



Fear not the simplicity - An experimental analysis of auctions for complements

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ABSTRACT

I evaluate the performance of four static sealed-bid package auctions in an experimental setting with complementarities. The valuation model comprises two items and three bidders: two 'local' bidders demand one item only, while the third (global) bidder only wants both. The rules I compare include the Vickrey and first-price auctions, the Nearest-Bid Rule and the Reference Rule. Auction-level tests find the first-price auction revenue dominant overall without losing efficiency, while the Vickrey auction performs worst; the other two rules rank intermediate. Bidder-level tests of the experimental data reject the competitive equilibrium bidding functions: overbidding is widespread in all four auctions, and bidders are averse to submitting boundary bids. In core-selecting auctions bidders do not revert to truth-telling rules of thumb. I also observe behavior consistent with collusive bidding in the Vickrey auction. Contrary to theoretical predictions, the Vickrey auction performs worst on efficiency, primarily for this reason. Overall, my results suggest that even in the presence of complementarities, the simple first-price rule may not perform as poorly as feared.

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1. Introduction

The growth in popularity of auctions has seen them applied to an ever wider range of markets, including markets where multiple different items are sold together as packages, and situations where bidder preferences exhibit complementarities. Practical examples of such markets are the auctions for mobile telephony spectrum, contracts for serving bus routes or airport take-off and landing slots, and many procurement applications, such as automotive components.² In all these cases, particular packages of items, sold or acquired together, are worth more than the simple sum of the values of individual items. For a simpler stylized example of such a situation, consider a seller offering a jacket and a pair of matching trousers. Some buyers may only want the jacket, others may only need the trousers, but some may want a complete suit, and thus prefer to buy both matching garments together. The fact that the two garments match creates additional value for the buyer who wants both - this is the complementarity. To deal with this increased complexity, a new class of mechanisms, called core-selecting auctions, have been developed and implemented, though our understanding of their incentive

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² On mobile spectrum, see [Danish Business Authority \(2012\)](https://www.danishbusinessauthority.com/), [ComReg \(2012\)](https://www.comreg.eu/) and [Ofcom \(2012\)](https://www.ofcom.gov.uk/). The auction of London bus routes is discussed in [Cantillon and Pesendorfer \(2006\)](https://www.cantillon.com/). An auction solution to allocating landing slots is discussed in [Federal Aviation Administration \(2008\)](https://www.federalaviationadministration.gov/).

properties is still incomplete. I conduct a bidding experiment to evaluate the performance of two static core-selecting auctions (the Nearest-Bid Rule and the Reference Rule) against two older alternatives (the Vickrey and first-price auctions).

The motivation for picking the Vickrey and first-price auctions is that they cover two extremes in terms of bidder incentives. In the Vickrey auction truthful bidding is a dominant strategy, while the first-price auction gives strong incentives for bidding below value. Both auctions also embody well-known theoretical weaknesses, which have limited their use in practice: the Vickrey auction may generate low revenue, and the first-price auction can be inefficient. A key motivation behind the use of core-selecting rules is that they should generate outcomes which are the “best of both worlds,” with efficiency better than in first-price, and revenue higher than in Vickrey auctions.³ To achieve this aim, the core-selecting rules partially de-couple bidders’ payments from their own bids (to encourage close to truthful bidding), while requiring that the payments lie in the core (thereby reducing the likelihood of low-revenue outcomes).

My main finding is the strong performance of the simplest of the four rules, the first-price auction: it is revenue-dominant without losing efficiency. I cannot reject revenue equivalence between the remaining three auctions. The Vickrey auction is least efficient, and no significant efficiency difference emerges between the first-price and the core-selecting rules.

At the bidder level, I test the experimental data against the Bayesian Nash equilibrium bidding functions for all four rules, as derived by [Ausubel and Baranov \(2010\)](#). The theory is not supported by my experiment, and overbidding is frequent in each auction. In the core-selecting auctions, when bidders’ behavior diverges from equilibrium, they do not revert to a truth-telling rule-of-thumb. Instead they attempt to game the rule to their advantage, albeit unsuccessfully. I also find evidence of attempted collusion in the Vickrey auction, which can explain the low revenue and efficiency of this auction. In the first-price auction when bidders deviate from theoretical equilibrium, they do so in predictable ways that do not undermine efficiency or revenue.

In my experiment, the first-price auction is very robust, and the attractive properties of the core-selecting rules are not fully borne out when bidders’ behavior deviates from expectation. Recently, many real-world package auctions have used complex core-selecting designs, without giving much attention to first-price rules. Against this backdrop, my results invite a re-consideration of the merits of the humble first-price package auction as a viable and easy to understand alternative, which warrants further research.

Recent experimental auction literature has focused on dynamic auctions, such as the combinatorial-clock, and simultaneous ascending auctions.⁴ This strand of research has been primarily concerned about efficiency properties of those auctions, and how bidders select packages in settings with complex valuation patterns. However, many practical implementations of such dynamic designs feature a one-shot static auction as their final phase. The final design is then hybrid auction, where the first stage is dynamic, and the second one static.

In Europe, the Danish, Irish and UK spectrum auctions in 2012 all used a Nearest-Bid or Vickrey-Nearest type rule to determine the prices and allocations of licenses, either for the allocation and preliminary pricing of generic spectrum lots, or in the final assignment of lots to particular frequency bands.⁵ Against this backdrop, my work is naturally seen as investigating how these static rules perform, in a context where a selection of packages has already been set. An explicit analysis of the interrelationship between the dynamic and sealed-bid phases of multi-stage auctions remains an open question for future research – the current single-stage analysis is not intended as a direct substitute.

The rest of the paper is structured as follows. The auction rules and valuation model are introduced in [Section 2](#), and the precise formulation of the hypotheses which I test are discussed in [Section 3](#). The experimental setup is presented in [Section 4](#), and [Section 5](#) performs a quality check of the data. Auction level results and hypothesis tests are presented in [Section 6](#), while bidder-level analysis is conducted in [Section 7](#). [Section 8](#) discusses the interpretation of the results, and [Section 9](#) concludes.

2. Auction setup and rule descriptions

My model consists of three bidders and two items, sold simultaneously. I label the items as ‘1’ and ‘2’, and assume that two of the bidders have a positive valuation on one item only. These are the ‘local’ bidders, and I label them as $L1$ and $L2$, corresponding to which item they value positively. The third bidder, G – the ‘global’ bidder – has a positive value only on the bundle of 1 and 2 together, and zero value on 1 and 2 individually. Each bidder is only permitted to bid on the bundle they value positively, so the auctioneer always receives three bids.

³ [Sun and Yang \(2006, 2009\)](#) have also proved that in the setting of my paper, there exists a dynamic incentive-compatible mechanism which finds the competitive equilibrium. In the present experiment, I only consider one-shot sealed-bid auctions, and thus do not include this mechanism in my comparison.

⁴ [Kagel et al. \(2010, 2014\)](#) are good examples of this, as is the earlier work by [Kazumori \(2005a\)](#).

⁵ For example, in the UK and Ireland, the allocation of generic spectrum lots to bidders was first carried out in the “Principal Stage”, which itself had two parts: firstly a dynamic ascending combinatorial clock phase, followed by a static sealed-bid supplementary phase, where bidders could submit bids beyond those recorded in the clock phase. Pricing at the end of the preliminary was carried out using the Vickrey-Nearest rule. After the end of the preliminary stage, bidders could further bid in an “Assignment Stage” to indicate their preferences over the particular frequencies at which their lots might be located. The Assignment Stage was also carried out as a single sealed-bid auction, using Vickrey-Nearest pricing.

Given other constraints on bidder behavior, such as reserve prices, the Vickrey prices used in final price calculations were strictly positive, so both Nearest-Bid and Vickrey-Nearest algorithms would have generated the same payments. For details, see [Danish Business Authority \(2012\)](#), [ComReg \(2012\)](#) and [Ofcom \(2012\)](#).

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