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## Introduction

Auction theory is one of economics' success stories. It is of both practical and theoretical importance: practical importance, because many of the world's most important markets are auction markets, and good auction theory has made the difference between successful auctions and disastrous ones; theoretical importance, because lessons from auction theory have led to important insights elsewhere in economics.

Auctions are not a new idea: the Babylonians auctioned wives, the ancient Greeks auctioned mine concessions and, in addition to their notorious slave auctions, the Romans auctioned everything from war booty to debtors' property. In the modern world, auctions are used to conduct a huge volume of economic transactions. Governments use them to sell treasury bills, foreign exchange, mineral rights including oil fields, and other assets such as firms to be privatized. Government contracts are typically awarded by procurement auctions, which are also often used by firms subcontracting work or buying services and raw materials. In these cases, of course, the auctioneer is seeking a low price rather than a high price. Houses, cars, agricultural produce and livestock, art and antiques are commonly sold by auction. Other economic transactions, for example takeover battles, are auctions by another name.

The range of items sold by auction has been greatly increased by e-commerce, and in the last decade or so there has also been an explosion of interest in using auctions to set up new markets, for example, for energy, transport, and pollution permits. Although many of these markets do not look like auctions to the layperson, they are best understood through auction theory. (For example, electricity markets are best described and analyzed as auctions of infinitely divisible quantities of identical goods.) The auctions of mobile phone licenses across the world are only the most famous of the new auction markets.

Not only are auctions an increasingly important part of the way the economy allocates resources, but also economists have increasingly realized the wider importance of auction theory: it has been the basis of much fundamental theoretical work not directly related to auctions. Many economic contexts that do not at first sight look like auctions can be re-cast to use auction-theoretic techniques, and a good understanding of auction theory is valuable in developing intuitions and insights that can inform the analysis of many mainstream economic questions.

This book considers the theory of auctions, practical auction design including case studies, and the application of auction theory to *other* areas of economics.

## A. AUCTION THEORY

Two basic designs of auction are most commonly used: the ascending auction, in which the price is raised successively until only one bidder remains and that bidder wins the object at the final price she bid; and the first-price sealed-bid auction, in which each bidder independently submits a single bid without seeing others' bids, the object is sold to the bidder who makes the highest bid, and the winner pays the amount she offered.

The key result in auction theory is the remarkable *Revenue Equivalence Theorem* which, subject to some reasonable-sounding conditions, tells us that the seller can expect equal profits on average from all the standard (and many non-standard) types of auctions, and that buyers are also indifferent among them all. William Vickrey's Nobel Prize was in large part awarded for his (1961, 1962) papers which developed some special cases of the theorem, and Riley and Samuelson (1981) and Myerson (1981) offer more general treatments.

Much of auction theory can be understood in terms of this theorem, and how its results are affected by relaxing its assumptions of a fixed number of "symmetric", risk-neutral bidders, who each want a single unit, have independent information, and bid independently. Myerson's (1981) paper shows how to derive optimal auctions (i.e., auctions that maximize the seller's expected revenue) when the assumption of symmetry fails. Maskin and Riley (1984) consider the case of risk-averse bidders, in which case the first-price sealed-bid auction is the most profitable of the standard auctions. Milgrom and Weber (1982a) analyzed auctions when the assumption of independent information is replaced by one of "affiliated" information, and showed that the most profitable standard auction is then the ascending auction. (Roughly, bidders' information is affiliated if when one bidder has more optimistic information about the value of the prize, it is more likely that other bidders' information will also be optimistic.) Models of auctions in which bidders bid for multiple units lead to less clear conclusions. For practical auction design, however, it is probably most important to remove the assumptions that the number of bidders is unaffected by the auction design, and that the bidders necessarily bid independently of each other; sealed-bid designs frequently (but not always) both attract a larger number of serious bidders and are better at discouraging collusion than are ascending designs (Klemperer, 1998, 1999b, 2000b).

Part A covers all these issues and a range of other topics including double auctions, royalties, incentive contracts, budget constraints, externalities between bidders, and the winner's curse. Appendices to chapter 1 contain technical details, some simple worked examples, and bibliogra-

phies. Exercises at first- and second-year graduate student level are at the end of this part; the solutions are at the end of the book.

## B. APPLICATIONS TO *OTHER* AREAS OF ECONOMICS

There are close connections between auction theory and other areas of economics.

By carefully analyzing very simple trading models, auction theory is developing the fundamental building blocks for our understanding of more complex environments. It has been important in developing our understanding of other methods of price formation, including posted prices and negotiations in which both the buyer and seller are actively involved in determining the price.

There are especially close connections between the theories of auctions and perfect competition. Wilson (1977), Milgrom (1979), and others have developed conditions under which the sale price of an object whose value is actually the same to all bidders converges to this value as the number of bidders increases, even though each individual bidder has only partial information about this value. The fact that an auction can thus fully aggregate all of the economy's information helps to support some of our ideas about perfect competition and rational expectations equilibrium.

There is also a close analogy between the theory of optimal auctions and that of monopoly pricing; the analysis of optimal auctions is "essentially equivalent to the analysis of standard monopoly third-degree price discrimination" (Bulow and Roberts, 1989). Thus insights can be translated from monopoly theory to auction theory and vice versa.

Because auctions are such simple and well-defined economic institutions, they have become an important testing ground for economic theory, and especially game theory. So auctions are also the basis of flourishing new empirical and experimental literatures.

More recently, auction-theoretic tools have been used to provide useful arguments in a broader range of contexts—including many that do not, at first sight, look like auctions—starting with models of oligopolistic pricing, running through non-price means of allocation such as queues, wars of attrition, lobbying contests, other kinds of tournaments, and rationing, and extending to models in finance, law and economics, labor economics, political economy, etc.

Part B discusses the connections between auctions and other areas of economics, emphasizing these broader uses of auction theory. It aims to demonstrate that auction theory should be a part of every economist's armory.

### C. PRACTICAL AUCTION DESIGN

Although there are now many extremely successful auction markets—and economists have much to be proud of in their role in developing them—there have also been some notable fiascos. Certain auctions of TV franchises, companies, electricity, mobile-phone licenses, etc., have failed badly—even comically—providing useful illustrations of what really matters in practical auction design.

The most important point is that everything depends on the context. Auction design is *not* “one size fits all”. A good auction needs to be tailored to the specific details of the situation, and must also reflect the wider economic circumstances.

Second, as stressed above, the critical issues are usually the bread-and-butter industrial-organization problems of encouraging entry and discouraging collusion. The more subtle points addressed by recent advanced auction theory are, more often than not, of lesser importance. So, for example, the Anglo-Dutch auction—a hybrid of the sealed-bid and ascending auctions—may often perform better than standard ascending auctions which are particularly vulnerable to collusive, predatory, and entry-detering behavior.

Finally, when advising governments, auction designers (and economic policy-makers more generally) need to be sensitive to the dangers posed by political and administrative pressures, and make their proposals robust to changes that are likely to be imposed.

Part C discusses all these issues, using numerous examples. Chapter 3 focuses on practical auction design, while chapter 4 takes a broader perspective on the policy-making process, but illustrates its points using examples of auctions.

### D. CASE STUDY

The 2000–2001 “3G” mobile-phone license auctions not only raised one hundred billion dollars and attracted intense media scrutiny, they also provide an excellent illustration of our points about practical design. Even though the licenses sold were very similar in each of the nine west European auctions, the different auction designs resulted in revenues that varied from less than 20 dollars per capita in Switzerland to almost 600 dollars per capita in the United Kingdom.

Part D describes and evaluates the 3G auctions as a case study for the earlier parts. I describe the design, and overall success, of each of the auctions (chapter 5); discuss the design *process*, and give fuller details of the successful UK auction which I helped design (chapter 6); and analyze why bidder strategies were a little different from those suggested by elementary theory (chap-

ter 7). Finally, I discuss the merits of running auctions versus the alternatives (chapter 8): although it is now fashionable to blame the 3G auctions for all the telecommunication industry's problems, there is absolutely no foundation for this. In spite of the design errors that were made, allocating the 3G licenses by auctions was clearly the correct policy.