Auctions for Radio Spectrum (A)

LIANGLIANG JIANG[1]
MARK A. JAMISON

Basic Knowledge for Auctions

A spectrum auction is a process whereby governments use an auction system to sell the rights to broadcast over specific electromagnetic wavelengths.[2] Spectrum auctions were first applied in 1989 in New Zealand after being suggested in the academic literature for three decades. From July 1994 to February 2001, the United States conducted 33 spectrum auctions, and between 2000 and 2001, Europe launched third generation (3G) auctions.

Auctions answer the basic question, who should receive the license and at what price? The primary advantages of an auction are as follows:

a) Auctions tend to assign the spectrum to those best able to use it. (This is accomplished by competition among license applicants.)
b) The competition is not wasteful. (The competition leads to auction revenues, which can be used to offset distortionary taxations.)
c) An auction is a transparent means of assigning licenses. All parties can see who won the auction and why (Cramton, 2002).

Bidding behavior will depend on the mix of sources of uncertainty regarding the value of the item being sold. In a private valued situation, each bidder knows what the item is worth to him or her, but doesn't know its worth to others. In a common value situation, each bidder guesses the true value, in ignorance of the others' guesses. With hindsight, all would agree on the value.

First-Price Auctions and Second-Price Auctions[3]

First-Price Auction: A first-price auction is an auction in which the bidder who submitted the highest bid is awarded the object being sold and pays a price equal to the amount bid. Alternately, in a procurement auction, the winner is the bidder who submits the lowest bid and is paid an amount equal to his or her bid. In practice, first-price auctions are either sealed-bid, in which bidders submit bids simultaneously, or Dutch[4] in which the auction begins with a high asking price and is lowered until some bidder is willing to accept the price, or a predetermined reserved price is reached.

Information Asymmetry
In economics, information asymmetry occurs when one party to a transaction has more or better information than the other party. (It has also been called asymmetrical information.) Typically it is the seller that knows more about the product than the buyer. However, it is possible for the reverse to be true: for the buyer to know more than the seller, for example, about the value of the license to the buyer.

Efficiency implies a resource is employed in its highest valued use. Information asymmetry causes markets to become inefficient, since all the market participants do not have access to the information they need for their decision-making processes.

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Second-Price Auction: A second-price auction is an auction in which the bidder who submitted the highest bid is awarded the object being sold and pays a price equal to the second highest amount bid. Alternately, in a procurement auction, the winner is the bidder who submits the lowest bid and is paid an amount equal to the next lowest submitted bid. In practice, second-price auctions are either sealed-bid, in which bidders submit bids simultaneously, or English[5] auctions, in which bidders continue to raise each other's bids until only one bidder remains.

The theoretical nicety of second-price auctions, first pointed out by William Vickrey, is that bidding one's true value is an optimal strategy. In first-price auctions, however, bidders shade their bids below their true value to avoid paying a price equal to their valuation.

Ascending (English) Auction

Ascending auctions begin with low bids and bidders continue to raise their bids until the auction manager stops the bidding. One advantage of this type of auction is that it minimizes the probability that a bidder with lower valuations would outbid a bidder with higher valuations. On the other hand, ascending auctions are weak in encouraging entry and preventing collusion because they allow bidders to signal their willingness to collude and to punish non-cooperative behavior. Participation of potential entrants may be deterred, since a weaker player knows with certainty that a stronger rival can always top his bid.

Sealed-bid (Dutch) Auction

Sealed-bid auctions are suitable for preventing tacit collusion and encouraging entry. Entry is encouraged because "a stronger bidder does not know how much he needs to bid to win and doesn't want to bid too much because he wants to make a good profit when he does win. Therefore, the weaker bidder might win at a price that the stronger bidder would have been willing to bid, but didn't" (Klemperer, 2002, 831). However, this raises the danger of awarding the license to players with lower valuations, so sealed-bid auctions are more likely than ascending auctions to lead to inefficient outcomes.

Anglo-Dutch Auction

Combinations of the above two designs are called Anglo-Dutch auctions. "In the first stage, an ascending format guarantees a high degree of value efficiency, since strong bidders drive out the lowest valuations. The ascending auction continues until the number of active bidders is slightly higher than the number of available licenses. The remaining players then submit sealed bids. This second stage is intended to inject enough uncertainty into the game to make participation attractive and to deter collusion" (Illing and Klüh, 2004, 7).

"Paul Klemperer advocates an English design when new entry and competitive bidding can be guaranteed otherwise. He favors a Dutch design when encouraging entry is the main concern. In intermediate situations, a hybrid design might be the best solution (Illing and Klüh, 2004, 7).

Auctions and In-Market Competition

A license auction is, in effect, competition for the right to compete in the market for customers. Normally we would expect competition in the market to determine which firms survive and fail. However, when there is a limited resource such as radio spectrum that the government licenses to particular users, and when there is not an efficient secondary market for the licenses, then we need a mechanism to help identify which firms best promote efficient outcomes.

Whereas there is widespread progress in understanding the efficiency of different auction designs theoretically, it is very difficult to tell whether a real-world auction has led to efficient

outcomes. It is literally impossible to quantify the degree of efficiency, either ex ante or ex post. Therefore, it may be better to trust some basic empirical results of industrial organization and rely on a rule of thumb: namely, that we would consider an auction to be efficient when it has encouraged entry and has successfully prevented collusion. That is to say, more competition leads to more consumer benefit, which implies greater efficiency by most measures.

Auctions and Regulation

Economic regulation complicates auctions for a variety of reasons. First, regulation in practice does not necessarily advance the public interest as some would prefer. Furthermore, telecommunications is not a mature industry. Therefore, a primary challenge of economic regulation is to generate new competition and to deal with its consequences. Finally, the telecommunications industry operates in a highly dynamic environment in terms of technology and preferences. It is not a one-shot game, and all regulations are followed by unforeseen consequences in terms of the competitive behavior. We would expect telecommunications operators' views on post-auction regulation to affect their willingness to participate in auctions and how they bid once the auction begins.

Critiques of Auction Experiences

Auctions are theoretically the most efficient way to distribute scarce radio spectrum. They allocate it to the bidders with the highest prospective value and lead to government revenues that can replace distortionary taxes. However, practical application of auctions does not always ensure this outcome.

Cross-country learning applies to both government officials and service providers: governments learn about efficient auction techniques and identifying collusive behavior, and industry learns about avoiding competitive pressures.

Lastly, it is worthwhile noting that, auction design is not "one size fits all." For example, the ascending design that worked very well for the United Kingdom worked poorly in the Netherlands, Italy, and Switzerland because of problems with entry problems and because the operators learned how to avoid intense bidding competition from the United Kingdom experience, but not in the other countries. Other countries, such as Belgium and Greece, might have felt better if they had included a sealed-bid component in their auctions, as Denmark did. Exhibits 1 and 2 summarize the European experiences with 3G spectrum auctions.

Efficiency versus Value Maximization. The main goal for the European 3G auctions was economic efficiency, but putting licenses "in the hands of those who value them most" may not result in efficiency. Economic efficiency is measured as a weighted sum of firms' benefits and consumers' benefits (welfare). Thus, auctions that focus on firms' perceptions of benefits may neglect consumers to the extent that consumer benefits are not adequately reflected in the firms' valuation of potential profits. Hence some analysts argue that consumer benefits should be considered in the auction design stage. Unfortunately, at the auction design stage, government officials are generally uncertain about consumers' willingness to pay for services. Arguably the most effective way to take into account consumer welfare is to encourage competition. The most important variable for competition is *the number of licenses*.[6]

Value Maximization versus Revenue Maximization. Maximization of revenue was a secondary goal in the European 3G auctions. "Often this goal has been regarded as the main one by the media, by the public, and even by some academic commentators who tend to compare auction outcomes on the basis of the associated revenue. Generally speaking, the presence of asymmetries, heterogeneity among firms, externalities, and complementarities all hinder value maximization in an auction" (Ewerhart and

Moldovanu, 2003, 5-6).

Alternatives to Auctions

Before auctions were used to assign spectrum resources, governments often used comparative selection, or "beauty contests," in which the government awards spectrum to those with the most attractive proposals. (Comparative selections are still used in many countries.) Problems with comparative selection processes are that they are extremely slow, consume large amounts of time and resources, and lack transparency. For example, even with streamlined comparative hearings, it took the U.S. Federal Communications Commission (FCC) an average of two years to award thirty cellular licenses. In practice, comparative hearings in the United States became *de facto* auctions because the contestants in the selection process spent large amounts of money on attorney and consultant fees, and negotiated settlements with each other, such that the contestant who valued the license the most was the most likely to win.

Some governments experimented with lotteries, in which the government would randomly select the winner from a pool of qualified contestants. Several problems occurred. First, there was a strong incentive for large numbers of contestants to apply, which wasted government resources in creating and processing the applications. Also, the winners were rarely those best suited to provide the spectrum-based service.

As stated by Cramton (1998, 731), "Standard auctions at best ensure that the bidder with the highest private value wins, rather than the bidder that would maximize welfare. Private and social values can diverge in these auctions because the winners will be competing in a marketplace. One collection of winners may be more likely to exercise market power in the service market than an alternative collection of winners. For example, a new license might be worth more to an incumbent than a new entrant because the incumbent would be less likely to compete with its existing services than would the new entrant." Given this, some governments limit the amount of spectrum any one firm can hold in any geographic area. This will be discussed in detail later.

Exhibit 1. Summary Statistics on European 3G Auctions

Revenues from European 3G Mobile Spectrum Auctions, euros per capita

Year 2000	*Auction Type*	*Revenues*
Austria	"Variable-Prize" Ascending	100
Germany	"Variable-Prize" Ascending	615
Italy	Ascending	240
Netherlands	Ascending	170
Switzerland	Ascending	20
The U.K. Auction	Ascending	650
Year 2001		
Belgium	Ascending	45
Denmark	Sealed-bid auction	95
Greece	Ascending	45

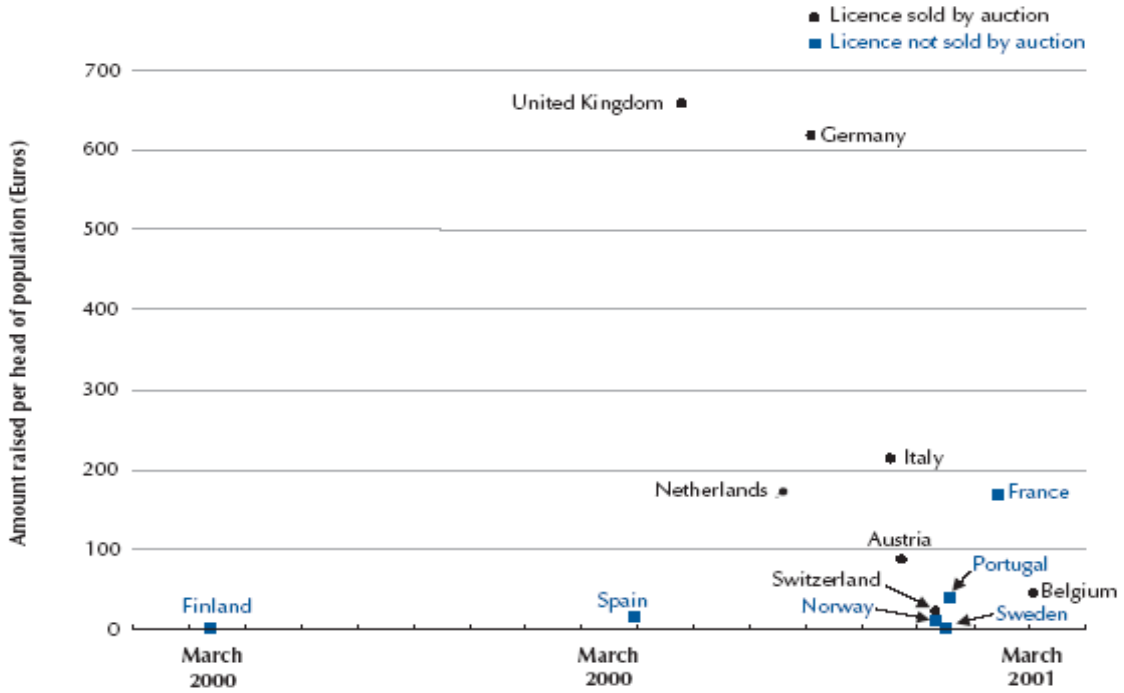
Costs of the Auction

Source: U.K. National Audit Office

Cost Element (£ million)	**Allocated Budget (£ million)**	**Outturn (£ million)**
External advisers	No specific budget	6.1
Staff costs (permanent)	0.9	1.1
Legal expenses: (Department of Trade and Industry)	0.3	0.3
Other running costs (including temporary staff)	0.5	0.6
Total	No overall budget	8.1

Cross-country Comparison of the 3G Spectrum Auction[7]

The auction of 3G spectrum in the United Kingdom raised higher proceeds on a per head basis than allocation of 3G Spectrum in other countries in the European Community.



Notes: 1. Countries not using auctions allocated licences through "beauty contests" in which officials assessed the standing and proposals of bidders. In Sweden and Finland bidders did not pay for the licences, in the other countries governments set a fee.

2. In France two of the four licences on offer went unsold. In Belgium three out of four licences were taken up.

Source: *The Strategis Group*

Exhibit 2.

Summaries of European 3G Auctions

The U.K. 3G Auction (March-April 2000)

Among the ascending auctions, the U.K. auction was widely considered to be successful in terms of revenue generation and advancing the competitive market structure. In contrast, the auctions in Italy, Netherlands, and Switzerland are considered to have failed, even though they used very similar auction design as the U.K.

The United Kingdom was the first country to run a 3G auction. The U.K. launched an ascending auction which made it possible to sell five licenses when there were four incumbent "2G" (second generation) mobile phone operators. Because no bidder was permitted to win more than one license and licenses could not be divided, "tacit" collusion would be very hard. Also, since the U.K. was the first in the world to auction the 3G spectrum so that it was unclear which new entrant might be successful, and this made it possible to persuade a large number to participate. As a result, nine new entrants bid strongly against the incumbents, creating intense competition and record-breaking revenues of 39 billion euros (Klemperer, 2002, 832-833).

The successful story from the U.K. "can be easily explained by the fact that the Telecommunication Agency in the U.K. allows more licenses than there actually were incumbents. This assures many potential entrants to participate, making arrangements to cooperate more difficult and risky. Participation was encouraged and, given a good chance of entry, collusion was effectively prevented: Everyone has to bid up to his or her true valuation. In contrast, the Netherlands, Italy, and Switzerland failed to convince entrants that they had a reasonable chance to win. Therefore, small companies entered joint-bidding agreements or attempted to close deals with powerful incumbents. As a result, bidders managed to coordinate on the low revenue equilibrium" (Klemperer, 2004).

The government emphasized early implementation of 3G in the U.K., thinking that it would be advantageous for operators and consumers alike. Winning the first licenses to be made available in a key European market might have been important to bidders because it could

- enable winners to approach equipment suppliers with realistic requirements before operators in other countries placed orders;
- allow the licensees to influence the shape of the products and to secure supplies; and
- provide licensees with a stronger basis on which to bid for licenses in other countries.[8]

The Netherlands Auction (July 2000)

The Netherlands followed the British design but with five licenses and five incumbent operators. Given this situation, it was surprising that few entrants participated in the ascending auction. However, some strong potential entrants made deals with incumbents, and Netherlands competition policy allowed firms such as Deutsche Telekom AG (DTAG), DoCoMo, and Hutchison, who were all strong established players in markets other than the Netherlands, to partner with the local incumbents. At the end, only one weak entrant (Versatel) competed with the incumbents but stopped after receiving a threatening letter from an incumbent (Telfort) who left signals of legal action for damages if Versatel continued to bid. Although Versatel complained to the government, the government took no action. "The result was that the auction raised less than 3 billion euros

rather than the almost 10 billion euros the Dutch government has forecast based on the U.K. experience" (Illing and Klüh, 2004, 100-101).

The German Auction (July-August 2000)

The Germans chose a more complex design: they auctioned 12 blocks of spectrum from which bidders could create licenses of either two or three blocks. For example, four firms could win large three-block licenses or six firms could win smaller two-block licenses. (A block refers to a frequency band.) As always, firms could win at most one license each. The 12 blocks were sold by a simultaneous ascending auction, much like the previously discussed auctions. "The point of the design was to let the number of winners be determined by the bidders who might have information unavailable to the government about, for example, the engineering advantages of large vs. small licenses" (Klemperer, 2004).

In Germany, "there were 7 bidders (including 4 GSM incumbents), after 6 other qualified bidders ultimately withdrew from the auction. The auction lasted for 3 weeks and 173 rounds of bidding, and resulted in 6 licenses being awarded (4 to the existing GSM operators). The licensed firms were the 4 incumbents and two new entrants (one of them already operating as a service provider). Each licensed firm acquired 2 blocks of paired spectrum, paying approximately 8.4 billion euros (or 4.2 billion euros per block)" (Ewerhart and Moldovanu, 2003, 8).

A most interesting outcome occurred "after one of the potential entrants, Debitel, left the auction after 125 rounds and after the price level reached 2.5 billion euros per block. Since six firms were left bidding for a maximum of six licenses, the auction could have stopped immediately. Instead, the remaining firms (and in particular, the two large incumbents) continued bidding in order to acquire more capacity. But no other firm was willing to quit, and bidding stopped in round 173. Compared to round 125, there was no change in the physical allocation, but firms were, collectively, 20 billion euros poorer" (Ewerhart and Moldovanu, 2003, 8).

The Italian Auction (October 2000)

The Italian government used roughly the same auction design as the U.K., with an additional rule that "if there were not more 'serious' bidders (as tested by various prequalification conditions) than licenses, then the number of licenses could (and probably would) be reduced." However, "firms had learned from previous auctions who were the strongest bidders, so weak bidders did not participate or they bid jointly." The result was that "only six bidders entered the auction to compete for five licenses and one potential entrant (Blu) quit after less than two days of bidding" (Klemperer, 2002, 834-835).

The Austrian Auction (November 2000)

Austria chose a very similar design to the German auction. "In Austria there were exactly six bidders (4 of them GSM incumbents) for a maximum of six licenses. Hence, in principle, the license auction could have ended immediately, at the reserve price. Nevertheless, the auction continued for another 16 rounds, before stopping with six licensed firms (four of them to the existing GSM operators), each paying on average about 118 million Euros per license" (Ewerhart and Moldovanu, 2003, 9).

The Swiss Auction (November-December 2000)

Switzerland copied the U.K. design and achieved the most embarrassing result of all of the auctions considered in this case. As stated by Klemperer (2002, 836), the Swiss ran an ascending auction for four licenses and attracted considerable initial interest from potential bidders. However, at least one company hired consultants and learned that the ascending-bidding rules would give the company very little chance against stronger rivals. Furthermore, the government permitted last-minute join-bidding agreements – essentially officially sanctioned collusion. So the field shrank from nine bidders to just four in the week before the auction was due to begin. The government postponed the auction for a month and tried to change the rules, but such change was furiously opposed by the remaining bidders. The bidders eventually paid the reserved price – one-thirtieth per capita of the U.K. and German prices, and one-fiftieth of what the government had once hoped for.

The Danish Auction (September 2001)

Denmark auctioned the same number of licenses (four) as it had incumbent operators, but the Danish were familiar with Klemperer's work. They followed his advice and "chose a sealed-bid auction to give weaker bidders a chance of winning, in the hope both of attracting new entrants and of scaring the incumbent operators into making higher bids." The auction was considered a "resounding success, attracting a serious bid from a new entrant and generating revenues of 95 euros per capita, or almost double most expectations" (Klemperer, 2002, 840-841).

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Endnotes

[1] The authors are Research Associate and Director, respectively, PURC, University of Florida, PO Box 117142, Gainesville, Florida 32611-7142, USA, http://www.purc.ufl.edu. The authors wish to thank Andrew Nahlik and Janice Hauge for their helpful comments and Patricia Casey for her editing work.

[2] http://www.nationmaster.com/encyclopedia/Spectrum-auction

[3] From GameTheory.net: http://www.gametheory.net/dictionary/Auctions/FirstPriceAuction.html.

[4] A Dutch auction is a type of first-price auction in which a "clock" initially indicates a price for the object for sale substantially higher than any bidder is likely to pay. Then, the clock gradually decreases the price until a "bidder buzzes in" or indicates his or her willingness to pay. The auction is then concluded and the winning bidder pays the amount reflected on the clock at the time he or she stopped the process by buzzing in. These auctions are named after a common market mechanism for selling flowers in Holland, but also reflect stores successively reducing prices on sale items.

[5] This form of English auction is a sequential second-price auction in which an auctioneer directs participants to beat the current, standing bid. New bids must increase the current bid by a predefined increment. The auction ends when no participant is willing to outbid the current standing bid. Then, the participant who placed the current bid is the winner and pays the amount bid.

[6] There are other regulatory instruments, such as mandatory roaming, mandatory site-sharing, and payment for license fees by installments that reduce fixed costs and/or financing costs for entrants, and hence encourage competition.

[7] National Audit Office. 2001. "The Auction of Radio Spectrum for the Third Generation of Mobile Telephones." Report by the Comptroller and Auditor General, HC 233, Session 2001-2002: 19 October, 2001, p. 19. London: The Stationery Office. http://www.nao.org.uk/intosai/wgap/0102233.pdf.

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