WHAT REALLY MATTERS IN AUCTION DESIGN

Paul Klemperer

Paul Klemperer is the Edgeworth Professor of Economics, Oxford University, England.
His e-mail address is <paul.klemperer@economics.ox.ac.uk>
and his website is <www.paulklemperer.org>
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Abstract: The most important issues in auction design are the traditional concerns of competition policy—preventing collusive, predatory, and entry-deterring behaviour. Ascending and uniform-price auctions are particularly vulnerable to these problems. The Anglo-Dutch auction—a hybrid of the sealed-bid and ascending auctions—may perform better. Effective antitrust is also critical. Notable fiascoes in auctioning mobile-phone licenses, TV franchises, companies, electricity, etc., and especially the European "third-generation" (UMTS) spectrum auctions, show that everything depends on the details of the context. Auction design is *not* "one size fits all".[94 words]

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Although some observers thought some of the behaviour described below warranted investigation, I do not intend to suggest that any of it violates any applicable rules or laws.

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Auctions have became enormously popular in recent years. Governments are now especially keen, using auctions to sell mobile-phone licenses, to operate decentralized electricity markets, and to privatize companies, etc. And the growth of e-commerce has led to many business-to-business auctions for goods whose trade was previously negotiated bilaterally.

Economists are proud of their role in pushing for auctions; for example, Coase (1959) was among the first to advocate auctioning radiospectrum. But many auctions—including some designed with the help of leading academic economists—have worked very badly.

For example, six European countries auctioned off spectrum licenses for "third-generation" mobile-phones in 2000. In Germany and the United Kingdom, the spectrum sold for over 600 euros per person ($80 billion in all, or over 2 percent of GDP). But in Austria, the Netherlands, Italy and Switzerland the revenues were just 100, 170, 240 and 20 euros per person respectively. To be sure, investors became more skeptical about the underlying value of the spectrum during 2000 (and they are even more skeptical today). But this is just a fraction of the story. The Netherlands auction was sandwiched between the U.K. and German auctions, and analysts and government officials predicted revenues in excess of 400 euros per person from the Italian and Swiss auctions just a few days before they began (Michelson, 2000; Roberts, 2000; Total Telecom, 2000). These other auctions were fiascoes primarily because they were poorly designed.

So what makes a successful auction?

What really matters in auction design are the same issues that any industry regulator would recognise as key concerns: discouraging collusive, entry-deterring and predatory behaviour. In short, good auction design is mostly good elementary economics.

By contrast most of the extensive auction literature (summarized in, e.g. Klemperer, 1999a, 2000a) is of second-order importance for *practical* auction design. The literature largely focuses on a fixed number of bidders who bid non-cooperatively, and it emphasises issues such as the effects of risk-aversion, correlation of information, budget-constraints, complementarities, etc. Auction theorists have made important progress on these topics which other economic theory has benefited from, and auction theory has also been fruitfully applied in political economy, finance, law and economics, labor economics, industrial organization, etc. often in contexts not usually though of as auctions (see Klemperer, 2001a). But most of this literature is of much less use for actually designing auctions.

This paper will list and give examples of some critical pitfalls in auction design, and discuss what to do about them. We show that ascending and uniform-price auctions are both very vulnerable to collusion, and very likely to deter entry into an auction. We consider including a

final sealed-bid stage into an otherwise-ascending auction to create an "Anglo-Dutch" auction, and emphasize the need for stronger antitrust policy in auction markets.

Collusion

A first major set of concerns for practical auction design involve the risk that participants may explicitly or tacitly collude to avoid bidding up prices. Consider a multi-unit (simultaneous) *ascending* auction. (This is just like the standard auction used, for example, to sell a painting in Sotheby's or Christies—the price starts low and competing bidders raise the price until no-one is prepared to bid any higher, and the final bidder then wins the prize at the final price he bid—except that several objects are sold at the same time, with the price rising on each of them independently, and none of the objects is finally sold until no-one wishes to bid again on any of the objects.) In such an auction, bidders can use the early stages when prices are still low to signal who should win which objects, and then tacitly agree to stop pushing prices up.

For example, in 1999 Germany sold ten blocks of spectrum by a simultaneous ascending auction with the rule that any new bid on a block had to exceed the previous high bid by at least 10 percent. Mannesman's first bids were 18.18 million deutschmarks per megahertz on blocks 1-5 and 20 million DM per MHz on blocks 6-10; the only other credible bidder—T-Mobil—bid even less in the first round. One of T-Mobil's managers then said. "There were no agreements with Mannesman. But [T-Mobil] interpreted Mannesman's first bid as an offer" (Stuewe, 1999, p.13). The point is that 18.18 plus a 10 percent raise equals approximately 20. It seems T-Mobil understood that if it bid 20 million DM per MHz on blocks 1-5, but did not bid again on blocks 6-10, the two companies would then live and let live with neither company challenging the other on the other's half. Exactly that happened. So the auction closed after just two rounds with each of the bidders acquiring half the blocks for the same low price (Jehiel and Moldovanu, 2001; Grimm et al, 2001).

Ascending auctions can also facilitate collusion by offering a mechanism for punishing rivals. The threat of punishment may be implicit; for example, it was clear to T-Mobil that Mannesman would retaliate with high bids on blocks 1-5 if T-Mobil continued bidding on blocks 6-10. But an ascending auction can also allow more explicit options for punishment.

In a multi-license U.S. spectrum auction in 1996-97, U.S. West was competing vigorously with McLeod for lot number 378—a license in Rochester, Minnesota. Although most bids in the auction had been in exact thousands of dollars, U.S. West bid $313,378 and $62,378 for two

licenses in Iowa in which it had earlier shown no interest, overbidding McLeod who had seemed to be the uncontested high-bidder for these licenses. McLeod got the point that it was being punished for competing in Rochester, and dropped out of that market. Since McLeod made subsequent higher bids on the Iowa licenses, the "punishment" bids cost U.S. West nothing (Cramton and Schwartz, 1999*)*.

A related phenomenon can arise in one special kind of sealed-bid auction, namely a *uniform-price* auction in which each bidder submits a sealed bid stating what price it would pay for different quantities of a homogenous good, e.g., electricity (that is, it submits a demand function), and then the good is sold at the single price determined by the lowest winning bid. In this format, bidders can submit bids that ensure that any deviation from a (tacit or explicit) collusive agreement is severely punished: each bidder bids very high prices for smaller quantities than its collusively agreed share. Then if any bidder attempts to obtain more than its agreed share (leaving other firms with less than their agreed shares), all bidders will have to pay these very high prices. However, if everyone sticks to their agreed shares then these very high prices will never need to be paid. So deviation from the collusive agreement is unprofitable.[1]

The electricity regulator in the United Kingdom believes the market in which distribution companies purchase electricity from generating companies has fallen prey to exactly this kind of "implicit collusion" (Office of Gas and Electricity Markets, 1999, pp. 173-4)). "Far from being the success story trumpeted around the world, the story of the U.K. generation market and the development of competition has been something of a disaster." (*Power U.K.*, issue 66, 31/8/1999, p 14. See also von der Fehr and Harbord, 1998; Newbery, 1998; Wolfram, 1998, 1999.) In addition, a frequently repeated auction market such as that for electricity is particularly vulnerable to collusion, because the repeated interaction among bidders expands the set of signalling and punishment strategies available to them, and allows them to learn to cooperate (Klemperer, 2002).

Much of the kind of behaviour discussed so far is hard to challenge legally. Indeed, trying to outlaw it all would require cumbersome rules that restrict bidders' flexibility and might generate inefficiencies, without being fully effective. It would be much better to solve these problems with better auction designs.

[1]Since, with many units, the lowest winning bid in a uniform-price auction is typically not importantly different from the highest losing bid, this auction is analogous to an ascending auction (in which every winner pays the runner-up's willingness-to-pay). The "threats" that support collusion in a uniform-price auction are likewise analogous to the implicit threats supporting collusion in an ascending auction. Collusion in a uniform-price auction is harder if supply is uncertain since this reduces the number of points on the bid schedule that are inframarginal and can be used as threats (Klemperer and Meyer, 1989; Back and Zender, 1993, 1999).

Entry Deterrence and Predation

The second major area of concern of practical auction design is to attract bidders, since an auction with too few bidders risks being unprofitable for the auctioneer (Bulow and Klemperer, 1996) and potentially inefficient. Ascending auctions are often particularly poor in this respect, since they can allow some bidders to deter the entry, or depress the bidding, of rivals.

In an ascending auction, there is a strong presumption that the firm which values winning the most will be the eventual winner, because even if it is outbid at an early stage, it can eventually top any opposition. As a result, other firms have little incentive to enter the bidding, and may not do so if they have even modest costs of bidding.

Consider, for example, Glaxo's 1995 takeover of the Wellcome drugs company. After Glaxo's first bid of 9 billion pounds, Zeneca expressed willingness to offer about 10 billion pounds if it could be sure of winning, while Roche considered an offer of 11 billion pounds. But certain synergies made Wellcome worth a little more to Glaxo than to the other firms, and the costs of bidding were tens of millions of pounds. Eventually, neither Roche nor Zeneca actually entered the bidding, and Wellcome was sold at the original bid of 9 billion pounds, literally a billion or two less than its shareholders might have received. Wellcome's own chief executive admitted "...there was money left on the table" (Wighton, 1995a, b).

While ascending auctions are particularly vulnerable to lack of entry, other auction forms can result in similar problems if the costs of entry and the asymmetries between bidders are too large.

The 1991 U.K. sale of TV franchises by a sealed-bid auction is a dramatic example. While the regions in the South and South East, South West, East, Wales and West, North East and Yorkshire all sold in the range 9.36 to 15.88 pounds per head of population, the only—and therefore winning—bid for the Midlands region was made by the incumbent firm and was just one-twentieth of one penny (!) per head of population. Much the same happened in Scotland, where the only bidder for the Central region generously bid one-seventh of one penny per capita. What had happened was that bidders were required to provide very detailed region-specific programming plans. In each of these two regions, the only bidder had figured out that no one else had developed such a plan.[2]

Another issue that can depress bidding in some ascending auctions is the "winner's curse." This applies when bidders have the same, or close to the same, actual value for a prize, but they

[2] *Important disclaimer* While I have advised the U.K. government on several auctions, I have never had anything to do with TV licenses!

have different information about that actual value (what auction theorists call the "common values" case). The winner's curse reflects the danger that the winner of an auction is likely to be the party who has most greatly overestimated the value of the prize. Knowing about the winner's curse will cause everyone to bid cautiously. But weaker firms must be especially cautious, since they must recognize that they are only likely to win when they have overestimated the value by even more than usual. Therefore, an advantaged firm can be less cautious, since beating very cautious opponents need not imply one has overestimated the prize's value. Because the winner's curse affects weak firms much more than strong ones, and because the effect is self-reinforcing, the advantaged bidder wins most of the time. And because its rivals bid extremely cautiously, it also generally pays a low price when it does win (Klemperer, 1998).

The bidding on the Los Angeles license in the 1995 U.S. auction for mobile-phone broadband licenses illustrates this problem. While the license's value was hard to estimate, it was probably worth similar amounts to several bidders. But Pacific Telephone, which already operated the local fixed-line telephone business in California, had distinct advantages from its database on potential local customers, its well-known brand-name, and its familiarity with doing business in California. The auction was an ascending auction. And the result was that the bidding stopped at a very low price. In the end, the Los Angeles license yielded only $26 per capita. In Chicago, by contrast, the main local fixed-line provider was ineligible to compete and it was not obvious who would win, so the auction yielded $31 per capita even though Chicago was thought less valuable than Los Angeles because of its lower household incomes, lower expected population growth, and more dispersed population (Klemperer, 1998; Bulow and Klemperer, 2000). For formal econometric evidence for the FCC auctions more broadly, see Klemperer and Pagnozzi (2002).

Of course, the "winner's curse" problem exacerbates the problem that weaker bidders may not bother to participate in an ascending auction. GTE and Bell Atlantic made deals that made them ineligible to bid for the Los Angeles license, and MCI failed to enter this auction at all. Similarly, takeover battles are essentially ascending auctions, and there is empirical evidence that a firm that makes a takeover bid has a lower risk of facing a rival bidder if the firm has a larger shareholding or "toehold" in the target company (Betton and Eckbo, 1995).

Because outcomes in an ascending auction can be dramatically influenced by a seemingly modest advantage, developing such an advantage can be an effective way to predate on rivals. An apparent example was the 1999 attempt by BSkyB (Rupert Murdoch's satellite television company) to acquire Manchester United (England's most successful soccer club). The problem was the advantage this would give BSkyB in the auction of football TV rights. Since Manchester

United receives 7 per cent of the Premier League's TV revenues, BSkyB would have received 7 per cent of the price of the league's broadcasting rights, whoever won them. So BSkyB would have had an incentive to bid more aggressively in an ascending auction to push up the price of the rights, and knowing this, other potential bidders would have faced a worse "winner's curse" and backed off. BSkyB might have ended up with a lock over the TV rights with damaging effects on the TV market more generally. Largely for this reason the U.K. Government blocked the acquisition.[3]

A strong bidder also has an incentive to create a reputation for aggressiveness that reinforces its advantage. For example, when Glaxo was bidding for Wellcome, it made it clear that it "would almost certainly top a rival bid" (Wighton, 1995b). Similarly, before bidding for the California phone license, Pacific Telephone announced in the *Wall Street Journal* that "if somebody takes California away from us, they'll never make any money" (Cauley and Carnevale, 1994, p.A4). Pacific Telephone also hired one of the world's most prominent auction theorists to give seminars to the rest of the industry to explain the winner's curse argument that justifies this statement, and reinforced the point in full page ads that in ran in the newspapers of the cities where their major competitors were headquartered (Koselka, 1995, p. 63). It also made organizational changes that demonstrated its commitment to winning the Los Angeles license.

Predation may be particularly easy in repeated ascending auctions, such as, for example, in a series of spectrum auctions. A bidder who buys assets that are complementary to assets for sale in a future auction, or simply bids very aggressively in early auctions, can develop a reputation for aggressiveness (Bikhchandani, 1988). Potential rivals in future auctions will both be less willing to participate, and bid less aggressively if they do participate (Klemperer, 2002).

Because an ascending auction often effectively blocks the entry of "weaker" bidders, it encourages "stronger" bidders to bid jointly or to collude; after all, they know that no one else can enter the auction to steal the collusive rents they create. In the disastrous November 2000 Swiss sale of four third-generation mobile-phone licenses, there was considerable initial interest from potential bidders. But weaker bidders were put off by the auction form—at least one company hired bidding consultants and then gave up after learning that the ascending-bidding rules would give the company very little chance against stronger rivals. Moreover, the government permitted last-minute joint-bidding agreements—essentially officially-sanctioned

[3]Although the term "toehold effect" coined by Bulow, Huang and Klemperer (1999), and Klemperer (1998) in the related context of takeover battles (see above) entered the popular press, and these papers were cited by the U.K. Monopolies and Mergers Commission (1999) report which effectively decided the issue, neither I nor my co-authors had any involvement in this case.

collusion. In the week before the auction, the field shrank from nine bidders to just four bidders for the four licenses! Since no bidder was allowed to take more than one license, the sale price was determined by the reserve price which was just one-thirtieth of the U.K. and German per capita revenues, and one-fiftieth of what the Swiss had once hoped for!

Other Pitfalls

Reserve Prices

Many of the disasters above were greatly aggravated by failure to set a proper reserve price (the minimum amount the winner is required to pay). Take the last example. It was ridiculous for the Swiss government to set its reserve at just one-thirtieth of the per-capita revenue raised by the German and U.K. governments for similar properties. Since the government's own spokesman predicted just five days prior to the auction that twenty times the reserve price would be raised, what was the government playing at?

Inadequate reserves also increase the incentives for predation and may encourage collusion that would not otherwise have been in all bidders' interests. A stronger bidder in an ascending auction has a choice between either tacitly colluding to end the auction quickly at a low price, or forcing the price up to drive out weaker bidders. The lower the reserve price at which the auction can be concluded, the more attractive is the first option—this factor may have been an important contributor to several of the fiascoes we have discussed.

Political Problems

Serious reserve prices are often opposed not only by industry groups, but also by government officials for whom the worst outcome is that the reserve price is not met so the object is not sold and the auction is seen as a "failure".

Standard (first-price) sealed-bid auctions—in which the bidders simultaneously make "best and final" offers, and the winner pays the price he bid—can sometimes be very embarrassing for bidders, as BSCH (Spain's biggest bank) found out when Brazil privatised the Sao Paulo state bank Banespa. When the bids were opened, BSCH's managers were horrified to learn that their bid of over 7 million Reals ($3.6 billion) was more than three times the runner-up's bid, and that they were therefore paying 5 billion Reals ($2.5 billion) more than was needed to win. In other auctions, meanwhile, losers who have just narrowly underbid the winners have found it equally hard to explain themselves to their bosses and shareholders. So firms, or at least their managers, can oppose first-price auctions.

On the other hand, a *second-price* sealed-bid auction—in which the winner pays the runner-up's bid—can be embarrassing for the auctioneer if the winner's actual bid is revealed to be far more than the runner-up's, even if the auction was ex-ante both efficient and revenue maximising. McMillan (1994) reports a second-price New Zealand auction in which the winner bid NZ $7 million but paid the runner-up's bid of NZ $5,000. Of course, New Zealand should have set a minimum reserve price that the winner had to pay, but even if that had been politically possible, the winner would probably have bid more than it had to pay, so this might have been an economically but not politically sensible auction.

Loopholes

In some cases, the auction rules may leave gaping loopholes for behavior to game the auction. In 2000, Turkey auctioned two telecom licenses sequentially, with an additional twist that set the reserve price for the second license equal to the selling price of the first. One firm then bid far more for the first license than it could possibly be worth if the firm had to compete in the telecom market with a rival holding the second license. But the firm had rightly figured that no rival would be willing to bid that high for the second license, which therefore remained unsold, leaving the firm without a rival operating the second license!

As another example, McMillan (1994) reports an Australian auction for satellite-television licenses in which two bidders each made large numbers of different sealed bids on the same objects and then, after considerable delays, defaulted on those bids they did not like after the fact—since the government had neglected to impose any penalties for default. More recently, the U.S. spectrum auctions have been plagued by bidders "winning" licenses and subsequently defaulting on their commitments, often after long delays. (India also recently fell into the same trap.) If default costs are small, then bidders are bidding for *options* on prizes rather than the prizes themselves. Furthermore, if smaller, underfinanced firms can avoid commitments through bankruptcy, then the auction favors these bidders over better-financed competitors.

Credibility of the Rules

It may not be credible for the auctioneer to punish a bidder violating the auction rules when just one bidder needs to be eliminated to end an auction, because excluding the offending bidder would end the auction immediately, and it might be hard to impose fines large enough to have a serious deterrent effect. Fines of hundreds of millions or even billions of dollars might have been required to deter improper behaviour in some of the European third-generation mobile-phone license auctions. In the Netherlands sale, for example, six bidders competed for five

licenses in an ascending auction in which bidders were permitted to win just one license each. One bidder, Telfort, sent a letter to another, Versatel, threatening legal action for damages if Versatel continued to bid! Telfort claimed that Versatel "believes that its bids will always be surpassed by [others'...so it] must be that Versatel is attempting to either raise its competitors' costs or to get access to their ... networks," but many observers felt Telfort's threats against Versatel were outrageous. However, the government took no action—not even an investigation. As a result, Versatel quit the auction and the sale raised less than 30 percent of what the Dutch government had forecast based on the results of the United Kingdom's similar auction just three months earlier.

Ascending auctions are particularly vulnerable to rule-breaking by the bidders since they necessarily pass through a stage where there is just one (or a few) excess bidders, and the ascending structure allows a cheat time to assess the success of its strategy (Klemperer, 2001b, 2002). Sealed-bid auctions, by contrast, may be more vulnerable to rule-changing by the auctioneer. For example, excuses for not accepting a winning bid can often be found if losing bidders are willing to bid higher. The famous RJR-Nabisco sale went through several supposedly final sealed-bid auctions (Burrough and Helyar, 1990). But if, after a sealed-bid auction, the auctioneer can re-open the auction to higher offers, the auction is really an ascending-bid auction and needs to be recognised as such. In fact, genuine sealed-bid auctions may be difficult to run in takeover battles, especially since a director who turns down a higher bid for his company after running a "sealed-bid auction" may be vulnerable to shareholder lawsuits.

Sealed-bid auctions can also be especially hard to commit to if the auctioneer has any association with a bidder as, for example, would have been the case in the U.K. football TV-rights auction discussed earlier if BSkyB (a bidder) had taken over Manchester United (an influential member of the football league which was the auctioneer).

Committing to future behaviour may be a particular problem for governments. For example, it may be difficult to auction a license if the regulatory regime may change, but binding future governments (or even the current government) to a particular regulatory regime may prove difficult.

The credibility of reserve prices is of special importance. If a reserve price is not a genuine commitment to not sell an object if it does not reach its reserve, then it has no meaning and bidders will treat it as such. For example, returning to the Turkish tale of woe, the government is now considering new arrangements to sell the second license, but at what cost to the credibility of its future auctions?[4]

[4]An auctioneer should make clear in advance what he would do if the reserve is not met. Re-auctioning with a lower reserve price after a delay to allow further entry might be sensible if there are high costs of entering the

Market Structure

In some auctions, for example of mobile-phone licenses, the structure of the industry that will be created cannot be ignored by the auction designer. It is tempting to simply "let the market decide" the industry structure by auctioning many small packages of spectrum, which individual firms can aggregate into larger licenses. But the auction's outcome is driven by bidders' profits, not by the welfare of consumers or society as a whole.

The most obvious possible distortion is that since firms' joint profits in the telecom market are generally greater the fewer competitors there are in the market, it is worth more to any group of firms to prevent entry of an additional firm than the additional firm is willing to pay to enter. So too few firms may win spectrum, and these winners may each win too much, exactly as a "hands-off" policy to merger control will tend to create an overly-concentrated industry. The Turkish fiasco discussed earlier was a spectacular example of how an auction can be biased towards generating monopoly.[5]

But this outcome is not the only socially suboptimal possibility. A firm with a large demand may prefer to reduce its demand to end the auction at a low price, rather than raise the price to drive out its rivals, even when the latter course would be socially more efficient (Ausubel and Cramton, 1998). There can also be too many winners if firms collude to divide the spoils at a low price. In the Austrian third-generation mobile spectrum sale, for example, six firms competed for twelve identical lots in an ascending auction and not surprisingly seemed to agree to divide the market so each firm won two lots each at not much more than the very low reserve-price. Perhaps six winners was the efficient outcome. But we certainly cannot tell from the behavior in the auction. (It was rumored that the bidding lasted only long enough to create some public perception of genuine competition and reduce the risk of the government changing the rules.)

So it may sometimes be wiser to predetermine the number of winners by auctioning off fewer, larger, licenses, but limiting bidders to one license apiece, rather than to auction many licenses and to allow bidders to buy as many as they wish.

When is Auction Design Less Important?

The fact that collusion and entry deterrence and, more generally, buyer market power is the key to auction problems suggests that auction design may not matter very much when there

auction. (Burguet and Sakovics, 1996; McAfee and McMillan, 1988).

[5]Similarly, the recent July 2001 Greek second-generation spectrum auction led to a more concentrated telecom market than seems likely to be socially efficient.

is a large number of potential bidders for whom entry to the auction is easy. For example, though much ink has been spilt on the subject of government security sales, auction design may not matter much for either price or efficiency in this case. Indeed the U.S. Treasury's recent experiments with different kinds of auctions yielded inconclusive results (Simon, 1994; Malvey, Archibald and Flynn, 1996; Nyborg and Sundaresan 1996; Reinhart and Belzar, 1996; Ausubel and Cramton 1998), and the broader empirical literature is also inconclusive. Of course, even small differences in auction performance can be significant when such large amounts of money are involved, and collusion has been an issue in some government-security sales, so further research is still warranted.[6]

Solutions

Making the Ascending-Price Auction More Robust

Much of our discussion has emphasized the vulnerability of ascending auctions to collusion and predatory behavior. However, ascending auctions have several virtues, as well. An ascending auction is particularly likely to allocate the prizes to the bidders who value them the most, since a bidder with a higher value always has the opportunity to rebid to top a lower-value bidder who may initially have bid more aggressively.[7] Moreover, if there are complementarities between the objects for sale, a multi-unit ascending auction makes it more likely that bidders will win efficient bundles than in a pure sealed-bid auction in which they can learn nothing about their opponents' intentions. Allowing bidders to learn about others' valuations during the auction can also make the bidders more comfortable with their own assessments and less cautious, and often raises the auctioneer's revenues if information is "affiliated" in the sense of Milgrom and Weber (1982).

A number of methods to make the ascending auction more robust are clear enough. For example, bidders can be forced to bid "round" numbers, the exact increments can be prespecified, and bids can be made anonymous. These steps make it harder to use bids to signal other buyers. Lots can be aggregated into larger packages to make it harder for bidders to divide the

[6] These views are personal; I have advised UK government agencies on the related issue of the sale of gold. See Klemperer (1999b) for more discussion.

[7] This applies in many "common-values" and "private-values" settings (Maskin, 1992), but is not necessarily the same as maximizing efficiency; when bidders are firms it ignores consumer welfare (which is likely to favour a more widely dispersed ownership than firms would choose) and, of course, it ignores government revenue. We assume governments (as well as other auctioneers) care about revenue because of the substantial deadweight losses (perhaps 33c per dollar raised) of raising government funds through alternative methods (Ballard et al., 1985). Resale is not a perfect substitute for an efficient initial allocation, because even costless resale cannot usually ensure an efficient outcome in the presence of incomplete information (Myerson and Satterthwaite, 1983; Cramton, Gibbons and Klemperer, 1987).

spoils, and keeping secret the number of bidders remaining in the auction also makes collusion harder (Cramton and Schwartz, 2000; Salant, 2000). Ausubel's (1998) suggested modification of the ascending auction mitigates the incentive of bidders to reduce their demands in order to end the auction quickly at a low price. Sometimes it is possible to pay bidders to enter an auction; for example, "white knights" can be offered options to enter a takeover battle against an advantaged bidder.

But while these measures can be useful, they do not eliminate the risks of collusion or of too few bidders. An alternative is to choose a different type of auction.

Using Sealed-Bid Auctions

In a standard sealed-bid auction (or "first-price" sealed-bid auction), each bidder simultaneously makes a single "best and final" offer, so collusion is much harder than in an ascending auction because firms are unable to retaliate against bidders who fail to cooperate with them. Tacit collusion is particularly difficult since firms are unable to use the bidding to signal. True, both signalling and retaliation are possible in a series of sealed-bid auctions, but collusion is still usually harder than in a series of ascending auctions.

From the perspective of encouraging more entry, the merit of a sealed-bid auction is that the outcome is much less certain than in an ascending auction. An advantaged bidder will probably win a sealed-bid auction, but it must make its single final offer in the face of uncertainty about its rivals' bids, and because it wants to get a bargain its sealed-bid will not be the maximum it could be pushed to in an ascending auction. So "weaker" bidders have at least some chance of victory, even when they would surely lose an ascending auction (Vickrey, 1961, Appendix III). It follows that potential entrants are likely to be more willing to enter a sealed-bid auction than an ascending auction.

A sealed-bid auction might even encourage bidders who enter only in order to resell, further increasing the competitiveness of the auction. Such bidders seem less likely to enter an ascending auction, since it is generally more difficult to profit from reselling to firms one has beaten in an ascending auction.

Because sealed-bid auctions are more attractive to entrants, they may also discourage consortia from forming. If the strong firms form a consortium, they may simply attract other firms into the bidding in the hope of beating the consortium. So strong firms are more likely to bid independently in a sealed-bid auction, making this a much more competitive auction.

Consistent with all this, there is some evidence from timber sales that sealed-bid auctions attract more bidders than ascending auctions do, and that this makes sealed-bid auctions

considerably more profitable for the seller, and this seems to be believed in this industry (Mead and Schneipp, 1989; Rothkopf and Engelbrecht-Wiggans, 1993), even though *conditional* on the number of bidders, sealed-bid auctions seem only slightly more profitable than ascending auctions (Hansen, 1986).

Furthermore, in the "common-values" case that bidders have similar actual values for a prize, the "winner's curse" problem for a weaker bidder is far less severe in a sealed-bid auction. Winning an ascending auction means the weaker bidder is paying a price his rival is unwilling to match—which should make the weaker bidder very nervous. But the weaker player has a chance of winning a sealed-bid auction at a price the stronger rival *would* be willing to match, but didn't. Since beating the stronger player isn't necessarily bad news in a sealed-bid auction, the weaker player can bid more aggressively. So auction prices will be higher, even for a given number of bidders (Klemperer, 1998; Bulow, Huang and Klemperer, 1999).[8]

But while sealed-bid auctions have many advantages, they are not without flaws. Mainly, by giving some chance of victory to weaker bidders, sealed-bid auctions are less likely than ascending auctions to lead to efficient outcomes. Moreover, in standard sealed-bid auctions in which winners pay their own bids, bidders need to have good information about the distribution of their rivals' values to bid intelligently (Persico, 2000). By contrast, in an ascending or uniform-price auction the best strategy of a bidder who knows his own value is just to bid up to that value, and winners' payments are determined by non-winners' bids. So "pay-your-bid" sealed-bid auctions may discourage potential bidders who have only small amounts to trade and for whom the costs of obtaining market information might not be worth paying. For example, in March 2001 the U.K. electricity regulator replaced the problematic uniform-price auction we described earlier by an exchange market followed by a "pay-your-bid" sealed-bid auction, which makes collusion harder because bids can no longer be used as costless threats. But a major concern is that the new trading arrangements may deter potential entrants from investing the sunk costs necessary to enter the electricity market (and the new arrangements may not fully resolve the collusion problem anyway since the market is so frequently repeated (Klemperer, 1999b)).

However, the entry problem in many-unit auctions is much less serious if small bidders can buy from larger intermediaries who can aggregate smaller bidders' demands and bid in their place as, for example, occurs in auctions of treasury bills. And the entry problem is also

[8] In Milgrom and Weber's (1982) model sealed-bid auctions are less profitable than ascending auctions if signals are "affiliated". But they assume symmetric bidders, and the effect does not seem large in practice (Riley and Li, 1997). Sealed-bid auctions are generally more profitable if bidders are risk-averse or budget-constrained (Klemperer, 2000a).

alleviated if smaller bidders are permitted to make "non-competitive bids", that is, to state demands for fixed quantities for which they pay the average winning price, as is also the case in some treasury bill auctions.

The Anglo-Dutch Auction

A solution to the dilemma of choosing between the ascending (often called "English") and sealed-bid (or "Dutch") forms is to combine the two in a hybrid, the "Anglo-Dutch", which often captures the best features of both, and was first described and proposed in Klemperer (1998).

For simplicity, assume a single object is to be auctioned. In an Anglo-Dutch auction the auctioneer begins by running an ascending auction in which price is raised continuously until all but two bidders have dropped out. The two remaining bidders are then each required to make a final sealed-bid offer that is not lower than the current asking price, and the winner pays his bid. The process is much like the way houses are often sold, although unlike in many house sales the procedure the auctioneer will follow in an Anglo-Dutch auction is clearly specified in advance.

Another auction with similar features—and probably similar motivations to the Anglo-Dutch—is W.R. Hambrecht's *OpenBook* auction for corporate bonds. The early bidding is public and ascending in style but bidders can make final sealed-bids in the last hour. Although all bidders are permitted to make final bids, higher bidders in the first stages are given an advantage that is evidently large enough to induce serious bidding early on (Hall, 2001, p.71).

The process also has some similarity to auctions on eBay (by far the world's most successful e-commerce auctioneer) which are ascending price, but with a fixed ending time so that many bidders often bid only in the last few seconds in essentially sealed-bid style. eBay attracts far more bidders than its rival, Yahoo, which runs a standard ascending auction with a traditional "going, going, gone" procedure that does not close the auction until there have been no bids for 10 minutes.

The main value of the Anglo-Dutch procedure arises when one bidder (for example, the incumbent operator of a license that is to be re-auctioned) is thought to be stronger than potential rivals. Potential rivals might be unwilling to enter a pure ascending-bid auction against the strong bidder, who would be perceived to be a sure winner. But the sealed bid at the final stage induces some uncertainty about which of the two finalists will win, and entrants are attracted by the knowledge that they have a chance to make it to this final stage. So the price may easily be higher even by the end of the first, ascending, stage of the Anglo-Dutch

auction, than if a pure ascending auction were used.

The Anglo-Dutch should capture the other advantages of the sealed-bid auction discussed in the previous section. Collusion will be discouraged because the final sealed-bid round allows firms to renege on any deals without fear of retaliation, and because the Anglo-Dutch auction eliminates the stage of the ascending auction when just one excess bidder remains and rules against collusion and predation may not be credible.

Consortium formation will also be discouraged. Imagine there are two strong bidders for an item. In an ascending auction they are unlikely to be challenged if they form a consortium so they have an incentive to do so. But in an Anglo-Dutch auction, forming the consortium would open up an opportunity for new entrants who would now have a chance to make it to the final sealed-bid stage. So the strong firms are much less likely to bid jointly.

But the Anglo-Dutch should also capture much of the benefit of an ascending auction. It will be more likely to sell to the highest valuer than a pure sealed-bid auction, both because it directly reduces the numbers allowed into the sealed-bid stage and also because the two finalists can learn something about each other's and the remaining bidders' perceptions of the object's value from behaviour during the ascending stage.

When the Anglo-Dutch auction is extended to contexts in which individual bidders are permitted to win multiple units and there are complementarities between the objects, the ascending stage makes it more likely that bidders will win efficient bundles than in a pure sealed-bid auction.

Finally, I conjecture that the ascending stages of the Anglo-Dutch auction may extract most of the information that would be revealed by a pure ascending auction, raising revenues if bidders' information is "affiliated", while the sealed-bid stage may do almost as well as a pure sealed-bid auction in capturing extra revenue due to the effects of bidders' risk-aversion, budget-constraints, and asymmetries. This suggests the Anglo-Dutch auction may outperform ascending and sealed-bid auctions even if it attracts no additional bidders.

In short, the Anglo-Dutch auction often combines the best of both the ascending and the sealed-bid worlds.

Antitrust

Effective antitrust is critical to fighting collusion and predation in auctions. But antitrust enforcement seems much lighter than in "ordinary" economic markets.

The U.S. Department of Justice has pursued some signalling cases, but the legal status of many of the kinds of behavior discussed in this article remains ambiguous, and collusion in

takeover battles for companies is legal in the United States.

European antitrust has been even weaker, as evidenced by T-Mobil's willingness to explicitly confirm the signalling behaviour described earlier. True, when apparently similar behavior was observed in the more recent German third-generation spectrum auction, firms refused to confirm officially that they were signalling to rivals to end the auction. Even so, the *Financial Times* reported: "One operator has privately admitted to altering the last digit of its bid in a semi-serious attempt to signal to other participants that it was willing to accept [fewer lots to end the auction]" (Roberts and Ward, 2000, p. 21). This kind of signalling behaviour could perhaps be challenged as an abuse of "joint dominance" under EC and UK law. But European regulators have showed no interest in pursuing such matters.

Firms are also permitted to make explicit statements about auctions that would surely be unacceptable if made about a "normal" economic market. For example, before the Austrian third-generation spectrum auction Telekom Austria, the largest incumbent and presumably the strongest among the six bidders, said it "would be satisfied with just 2 of the 12 blocks of frequency on offer" and "if the [5 other bidders] behaved similarly it should be possible to get the frequencies on sensible terms", but "it would bid for a 3rd block if one of its rivals did" (*Reuters*, 31/10/2000)). It seems inconceivable that a dominant firm in a "normal" market would be allowed to make the equivalent offer and threat that it "would be satisfied with a market share of just $\frac{1}{6}$" and "if the other five firms also stick to $\frac{1}{6}$ of the market each, it should be possible to sell at high prices", but "it would compete aggressively for a larger share, if any of its rivals aimed for more than $\frac{1}{6}$".[9]

Just as damaging has been the European authorities' acceptance of joint-bidding agreements that are, in effect, open collusion. Combinations that are arranged very close to the auction date (as in the example of Switzerland discussed earlier) should be particularly discouraged since they give no time for entrants to emerge to threaten the new coalition. One view is that auction participants should generally be restricted to entities that exist when the auction is first announced, although exceptions would clearly be necessary.

The antitrust agencies' response to predation in auction markets has also been feeble. Dominant bidders such as Glaxo and Pactel in the examples above are apparently allowed to make open threats that they will punish new entrants. For example, Glaxo's letting it be known that it "would almost certainly top a rival bid", would roughly translate to an incumbent firm

[9]Similarly, during the German third-generation spectrum auction, MobilCom told a newspaper that "should [Debitel] fail to secure a license [it could] become a 'virtual network operator' using MobilCom's network while saving on the cost of the license" (Benoit, 2000 p.28). This translates roughly to a firm in a "normal" market saying it "would supply a rival should it choose to exit the market", but Mobilcom's remarks went unpunished.

in a "normal" economic market saying it "would almost certainly undercut any new entrant's price".[10]

Regulators should take such threats seriously, and treat auction markets more like "ordinary" economic markets.

Tailoring Auction Design to the Context

Good auction design is *not* "one size fits all" and must be sensitive to the details of the context. A good example of this—and of our other principles—is afforded by the recent European third-generation mobile spectrum (UMTS) license auctions.

The U.K. which ran the first of these auctions originally planned to sell just *four* licenses.[11] In this case the presence of exactly four incumbent operators who had the advantages of existing brand-names and networks suggested that an ascending auction might deter new firms from bidding strongly in the auction, or even from entering at all. So the government planned an Anglo-Dutch auction. An ascending stage would have continued until just five bidders remained, after which the five survivors would have made sealed-bids (required to be no lower than the current price level) for the four licenses.[12] The design performed extremely well in laboratory experiments in both efficiency and revenue generation .

But, when it became possible to sell *five* licences, an ascending auction made more sense. Because no bidder was permitted to win more than one license, at least one license had to be sold to a new entrant and this would be a sufficient carrot to attract several new entrants.[13] Because licenses could not be divided, bidders could not collude to divide the market without resort to sidepayments. So the problems of collusion and entry deterrence were minimal, and

[10]Similarly, Pacific Telephone's remark that "if somebody takes California away from us, they'll never make any money" seems to correspond to threatening that "if anyone tries to compete with us, we'll cut the price until they lose money." And Pacific Telephone's hiring of an auction theorist to explain the winner's curse to competitors might correspond to hiring an industrial economist to explain the theory of the difficulties of entering new markets to potential entrants.

[11]I was the principal auction theorist advising the U.K. government's Radiocommunications Agency, which designed and ran the recent U.K. mobile-phone license auction. Ken Binmore had a leading role and supervised experiments testing the proposed designs. Other academic advisors included Tilman Borgers, Jeremy Bulow, Philippe Jehiel, and Joe Swierzbinski.

[12]It was proposed that all four winners would pay the fourth-highest sealed bid. Since the licenses were not quite identical, a final simultaneous ascending stage would have followed to allocate them more efficiently among the winners. The sealed-bid stage could be run without revealing the actual bids. See Klemperer (1998, 2001b, 2002), Radiocommunications Agency (1998a, b) and Binmore and Klemperer (2002), for more details.

[13]Because the U.K. ran the first third-generation auction it was particularly unclear which new entrant(s) might be successful, and this helped attract more entrants. Going to market first was a deliberate strategy of the auction team, and the sustained marketing campaign was also important. The U.K. auction attracted 13 bidders who then learnt about others' strengths, and none of the six subsequent auctions had more than 7 bidders.

a version of an ascending auction was therefore used for efficiency reasons. The auction was widely judged a success; nine new entrants bid strongly against the incumbents, creating intense competition and record-breaking revenues of £22.5 billion.

The Netherlands' sale came next. Their key blunder was to follow the actual British design when they had an equal number (five) of incumbents and licenses. It was not hard to predict (indeed the first draft of this paper, quoted in the Dutch press and Maasland, 2000 prior to the auction, *did* predict) that very few entrants would show up. Netherlands antitrust policy was as disfunctional as the auction design, allowing the strongest potential entrants to make deals with incumbent operators. In the end just one weak new entrant (Versatel) competed with the incumbents. As we have already discussed, with just one excess bidder in an ascending auction it was unsurprising when the weak bidder quit early amid allegations of predation, at less than 30 percent of the per-capita U.K. prices. Six months later, the Dutch parliament began an investigation into the auction process.

A version of the Anglo-Dutch design would probably have worked better in the Netherlands context. There are reasons to believe Versatel would have bid higher in the sealed-bid stage than the price at which it quit the ascending auction. And the fear of this would have made the incumbents bid higher. Furthermore, the "hope and dream" that a sealed-bid stage gives weaker bidders might have attracted more bidders and discouraged the formation of the joint-bidding consortia.

The Italian government thought it had learned from the Netherlands fiasco. It also chose roughly the U.K. design, but stipulated that if there were no more "serious" bidders (as defined by prequalification conditions) than licenses, then the number of licenses would be reduced. At first glance this seemed a clever way to avoid an uncompetitive auction but (as I and others argued) the approach was fundamentally flawed. First, it is "putting the cart before the horse" to create an unnecessarily concentrated mobile-phone market in order to make an auction look good. Second, our earlier discussion demonstrates that a rule that allows the possibility that there will be just one more bidder than license does *not* guarantee a competitive ascending auction! In the event, just six bidders competed for five licenses and the auction ended amid allegations of collusion after less than two days of bidding with per capita revenues below 40% of the U.K. level, about half the amount the government was expecting. Again, an Anglo-Dutch or pure sealed-bid design would probably have performed better.

Klemperer (2001b, 2002) discusses the 2000-2001 European spectrum auctions in much more detail.

Conclusion

Much of what we have said about auction design is no more than an application of standard antitrust theory. The key issues in both fields are collusion and entry. The signalling and punishment strategies that support collusion in auctions are familiar from "ordinary" industrial markets, as are firms' verbal encouragement to collude and the predatory threats they make. Our point that even modest bidding costs may be a serious deterrent to potential bidders is analogous to the industrial-organization point that the contestability of a market is non-robust to even small sunk costs of entry. We also argued that because an ascending auction is more likely than a sealed-bid auction to be won by the strongest firm, the ascending auction may therefore be less attractive to bidders and may therefore be less profitable than a sealed-bid auction; this is just an example of the standard industrial-organization argument that a market that is in principle more competitive (for example, "Bertrand" rather than "Cournot") is less attractive to enter, so may in fact be less competitive. A particular feature of auction markets is that "winner's curse" effects may mean that sealed-bid and Anglo-Dutch auctions not only attract more firms than ascending auctions, but may also lead to better outcomes for the auctioneer for a given number of firms. But there is no justification for the current feebleness of antitrust policy in auction markets: regulators should treat them much more like "ordinary" economic markets.

None of our examples of auction failures should be taken as an argument against auctions in general. Most auctions work extremely well. Occasionally—for example, when there are too few potential bidders, or large costs of supplying necessary information to bidders—a form of structured negotiations may be better, but an auction is usually more attractive to potential buyers who are crucial to a sale's success (Bulow and Klemperer, 1996). And even relatively unsuccessful auctions, such as the Netherlands and Italian spectrum auctions we discussed, were probably more successful than the "beauty contest" administrative hearings used to allocate third-generation spectrum in several other European countries. For example, the Spanish beauty contest yielded just 13 euros per head of population, but generated considerable political and legal controversy and a widespread perception that the outcome was both unfair and inefficient, all problems that are typical of such procedures (Binmore and Klemperer, 2002, Klemperer, 2000b), while the difficulties with the French beauty contest mean that France has not only missed its government's originally-planned date for allocation of the spectrum (already by six months at the time of writing) but also missed EU deadlines.

In conclusion, the most important features of an auction are its robustness against collusion and its attractiveness to potential bidders. Failure to attend to these issues can lead to disaster. And anyone setting up an auction would be foolish to blindly follow past successful designs;

auction design is *not* "one size fits all". While the sealed-bid auction performs well in some contexts, and the Anglo-Dutch auction is ideal in other contexts, the ascending auction has also frequently been used very successfully. In the practical design of auctions, local circumstances matter and the devil is in the details.

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