WHAT REALLY MATTERS IN AUCTION DESIGN

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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 (we discuss radiospectrum and football TV-rights auctions, electricity markets, and takeover battles), and the Anglo-Dutch auction—a hybrid of the sealed-bid and ascending auctions—may often perform better. However, everything depends on the details of the context; the circumstances of the recent U.K. mobile-phone license auction made an ascending format ideal. We also discuss the current 3G spectrum auctions in Germany, the Netherlands and Italy.

Auction design is a matter of "horses for courses", not "one size fits all".

JEL Nos D44 (Auctions) L41 (Antitrust) L96 (Telecommunications)

[1]Disclaimer: 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. The views expressed in this paper are mine alone.

The views expressed on past and future radiospectrum auctions in Germany, Holland, and the U.S.A., gold auctions, electricity markets, takeover battles, and football TV-rights auctions are also mine alone.

1. Introduction

Now that many economic markets—from electricity and financial markets to mobile-phone license auctions and business-to-business internet markets—are analysed as auctions, there is a danger that the lessons of traditional economics may sometimes be overlooked.

Most auction literature assumes a fixed number of bidders who behave non-cooperatively. For example, a typical survey (my own[1] is no exception) begins with the revenue-equivalence result and discusses the effects of risk-aversion, correlation of information, budget-constraints, asymmetries etc., with relatively little attention—reflecting the scant literature[2]—to collusion and entry deterrence. But while the thinness of the auction-theoretic literature on these latter topics may be defensible to the extent general economic principles apply, there is a real danger that they may be underemphasized in applications.

The most important issues in designing auction markets probably remain those with which industry regulators and competition authorities have traditionally been concerned—discouraging collusive, predatory and entry-deterring behaviour.[3]

2. Collusion

While explicit collusion can be a problem, a much bigger concern is "tacit" (and often legal) coordination among firms, just as this is probably

[1] Klemperer (1999a).

[2] The most important contributions to the economics literature on auctions are collected in Klemperer (2000).

[3] In addition to addressing these issues of conduct, regulators and competition authorities also analyse the merits of mergers or other changes to market structure. Issues of market structure are critical in the special case of designing auctions that create new markets. See [penultimate section].

the greater problem for competition policy given existing law. Multi-unit ascending and uniform-price auctions seem particularly vulnerable to tacit collusion.

In a multi-unit *ascending* auction, bidders can use the early stages when prices are still low to signal their views about who should win which objects, and then, when consensus has been reached, tacitly agree to stop pushing prices up.

For example, in a 1999 German spectrum auction of ten licences, Mannesmann bid a low price for half the licenses and a slightly lower price for the other half. Here is what one of T-Mobil's managers said. "There were no agreements with Mannesmann. But Mannesman's first bid was a clear offer." It seems T-Mobil understood that it could raise the bid on the other half of the licenses slightly, and that the two companies would then "live and let live" with neither company challenging the other on "the other's" half. Just that happened. The auction closed after just two rounds with each of the bidders having half the licenses for the same low price.[4]

Similarly, a 1997 U.S. spectrum auction that was expected to raise $1,800 million raised less than $14 million. While the enormous revenue shortfall was surely not all due to "collusion", Cramton and Schwartz (1999) explain how bidders used the final three digits of multi-million dollar bids to signal the i.d. numbers of the areas they coveted.[5]

[4]The auction was a simultaneous ascending auction in which any new bid on a license had to exceed the previous high bid by at least 10%. Mannesman's first bids were 18.18 million DM per MHz on licenses 1-5 and 20 million DM per MHz on licenses 6-10. The point, of course, is that 18.18 plus a 10% raise equals $19.998 \approx 20$ which is exactly what T-Mobil then bid on licenses 1-5 in round 2, after which no further bids were made.

The story in this paragraph is from Frankfurter Allgemeine Zeitung, 29/10/99, p.13, and Jehiel and Moldovanu (2000). It is my understanding that the bidders' behaviour was entirely legal.

[5]For example, in another auction U.S. West was competing fiercely with McLeod for

By contrast, bidders cannot easily achieve the same coordination in simultaneous conventional *first-price sealed-bid* auctions, in which each object is sold to the highest bidder at the price it bid for that object. In this case, there is neither the opportunity to signal, nor the ability to retaliate against a bidder who fails to cooperate; the low prices in the ascending auction are supported by the threat that if a bidder overbids a competitor anywhere, then the competitor will retaliate by overbidding the first bidder on markets where the first bidder has the high bids.

However, the problem of "implicit collusion" can arise in one special kind of sealed-bid auction, namely a *uniform-price* auction for multiple units of a homogeneous good (e.g. electricity). In a uniform-price auction the price for every unit is set only by the lowest winning bid, so the remainder of firms' bidding schedules can be used as costless threats that will determine prices only if another bidder deviates from an implicitly-agreed market division.[6] That is, bidders can tacitly agree to divide up the market at a very favourable

Rochester, MN (license 378). Although most bids were in exact $1,000s, U.S. West made bids such as $313,378 in Waterloo, IA, and $62,378 in Marshaltown, IA, where McLeod had the previous high-bids, together with other similar bids apparently intended to punish McLeod, after which McLeod stopped competing in Rochester. This story is from Cramton and Schwartz (1999). See also "Learning to Play the Game", The Economist, 17/5/97, p. 120.

Additional theoretical literature on the vulnerability of ascending auctions to collusion includes Robinson (1985) and Milgrom (1987) on the single-unit case, and Menezes (1996), Weber (1997), Engelbrecht-Wiggans and Kahn (1998), Ausubel and Schwartz (1999), Brusco and Lopomo (1999) and Cramton and Schwartz (2000) on the multi-unit case. See also Hendricks and Porter (1989).

[6] [Note Y] With many units, the lowest winning bid in a uniform-price auction is typically not importantly different from the runner-up's bid, so 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 those supporting collusion in an ascending auction.

Note that "collusion" in the uniform-price auction is supported even as a static "Nash equilibrium". See, especially, Wilson (1979), Anton and Yao (1992), and Back and Zender (1993). Implicit collusion 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. See, especially, Klemperer and Meyer (1989), Back and Zender (1993), and Nyborg (1997) and relatedly Back and Zender (1999), McAdams (1998), and Federico and Rahman (2000).

price for themselves by each bidding extremely aggressively for smaller quantities than "its share", thus deterring other bidders from bidding for more. The U.K. electricity regulator believes this market has fallen prey to exactly this kind of "collusion".[7]

Again, by contrast, "implicit collusion" is harder in a *discriminatory* auction in which every winner pays its actual bids for the quantity it wins,[8] so firms cannot use inframarginal bids as costless threats that support the collusive equilibrium. Partly for this reason the U.K. regulator has proposed a set of New Electricity Trading Arrangements (NETA) that will replace the uniform-price auction by an exchange market followed by a discriminatory auction.[9]

Furthermore, although it is easier for firms to collude in any auction that is repeated many times,[10] it remains true that repeated ascending and uniform-price auctions are generally more susceptible to collusion than are repeated sealed-bid and discriminatory auctions.

Although some of the "collusive" tactics described above may be illegal,

[7]See Office of Gas and Electricity Markets (1999), pages 173-4. In this market sellers bid supply schedules so "implicit collusion" leads to high prices.

A journalistic view is that "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. Despite decreasing levels of market concentration, as measured using the Hirschman/Herfindahl Index (HHI), and falling levels of input prices for generators, particularly coal, pool selling prices have failed to fall. The System Marginal Price (SMP) has actually risen in real terms since privatisation", according to Power U.K., issue 66, 31/8/99, p 14.

For academic analysis see von der Fehr and Harbord (1998), Newbery (1998), Wolfram (1998), and especially Wolfram (1999).

[8][Note Z] This is analogous to a first-price sealed-bid auction.

[9]Whether this change is enough to fully resolve the problem in a market that has relatively few bidders and is so frequently repeated is beyond the scope of this paper. See Klemperer (1999b).

[10]It is harder for bidders to collude if the repetition is finite, since collusion is no easier to sustain in the final auction than in a single auction, hence hard in the penultimate auction, etc.

or could be made illegal, it is much better to deal with these problems via auction design than by cumbersome rules that restrict bidders' flexibility, and may create inefficiencies, without being fully effective.

3. Entry Deterrence and Predation

Another key concern of competition policy is ensuring new entry is not too hard; an auction with too few bidders will both be unprofitable for the auctioneer[11] and potentially inefficient.

Ascending auctions may be particularly poor in this respect also. 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, and will, eventually top any opposition. So other firms have very little incentive to enter the bidding, and may not do so if they have any costs of bidding.

Consider, for example, Glaxo's 1995 takeover of the Wellcome drugs company (that created the world's largest drugs group). After Glaxo's first $9 billion bid, Wellcome solicited higher offers and received serious expressions of interest from two potential counterbidders: Zeneca was willing to offer about $10 billion if it could be sure of winning, while Roche considered an $11 billion offer.[12] The difficulty was that neither of the potential bidders wished to enter an auction that they expected to lose. The general percep-

[11] In a notorious German auction of three radiospectrum licenses (in which no bidder was allowed to win more than one license) exactly three bidders entered. So no bidder needed to exceed the (modest) reserve price that had been set.

More generally, Bulow and Klemperer (1996) stress the value of attracting additional bidders, relative to other concerns in auction design. For a theoretical application of this point see Gilbert and Klemperer (2000).

[12] See Financial Times 8/3/95 p. 26, 27, 32, for this story and the direct quotes. (To be precise, the potential bidders are described as 'understood to be Zeneca', 'thought to be Roche', etc.)

tion was that there were particular synergies that made Wellcome worth a little more to Glaxo than to any other potential bidder, and "Glaxo had let it be known that it would almost certainly top a rival bid".[13] Even though the costs of bidding were small compared with the stakes involved, they were non-trivial (tens of $ millions).[14] So neither counterbidder actually entered the bidding; Wellcome was sold at the original $9 billion bid price, and its shareholders received literally billions of pounds less than they might have.[15]

This kind of problem will arise whenever the auction form makes one firm the likely winner.[16] Potential opponents, who might sometimes have won, become no-shows. However, the problem is exarcabated, and can even drive out bidders with no costs of participating in the ascending auction, in "common-values" contexts in which bidders have the same (or close to the same) actual value but different information about that actual value.

The reason is the "winner's curse". When the prize has a similar value to everyone, every firm must bid cautiously to allow for the fact that it is most likely to win on those occasions when it has over-estimated the value of the prize. But beating an opponent with an advantage suggests one has over-estimated the value by even more, so one must bid even more cautiously. And if the weaker firms must be more cautious, the advantaged firm can be less cautious since beating very cautious opponents need not imply one

[13] Financial Times 8/3/95 p. 32.

[14] Glaxo's own fees were reported to be $30 million net of stamp duty.

The point that even modest entry fees have a serious deterrence effect is analogous to the competition-policy point that the contestability of a market is non-robust to even small sunk costs.

[15] The chairman and chief executive of Wellcome stated afterwards "...there was money left on the table." (Financial Times 8/3/95 p.32.) Note that for legal reasons Wellcome felt unable to pay other bidders' costs of bidding, and might also have been precluded from other sales mechanisms (such as a sealed-bid auction). See Klemperer (1998).

[16] In auction-theorists' language this is true in either "private-values" or "common-values" settings.

has overestimated the prize's value.[17] So in an ascending auction a bidder with even a small advantage is justified in taking the view that it should almost always be prepared to outbid its rivals, if necessary, since its rivals will be being very cautious anyway. Therefore rational rivals will bid very cautiously, if they bother to bid at all, since they know they can beat the advantaged bidder only if the advantaged bidder has extremely discouraging private information about the value of the prize. And because weak rivals will bid cautiously, if at all, the advantaged bidder not only wins most of the time, but also generally pays a low price when it does win.

The bidding on the Los Angeles license in the main (1995, broadband) U.S. auction for mobile-phone licenses illustrates this problem. While the license's value was hard to estimate, it was probably worth very similar amounts to several bidders, except that Pacific Telephone had small but distinct advantages from its database on potential local customers, its well-known brand-name, and its executives' familiarity with California.[18] The auction was an ascending auction.[19] The result was that although some other firms did enter the auction and made some bids,[20] the bidding stopped at a price that most commentators thought was very low relative to the prices

[17]That is, firms' bids are very strongly "strategic substitutes" in the terminology of Bulow, Geanakoplos and Klemperer (1985a,b). The point in this paragraph was first made by Bikhchandani (1988), and emphasised in these contexts by Klemperer (1998).

[18]Pacific Telephone was the "Baby Bell" which operated the wireline (fixed-line) telephone business in the area, and there might also have been other small economies of scope between the wireless and wireline businesses. Pacific Telephone also had no wireless properties prior to the auction, so had a strategic reason to enter the market as a hedge against its declining wireline business.

[19]More precisely, it was a simultaneous ascending auction, but this does not affect our argument.

[20]Some potential bidders seem to have been scared out of the bidding altogether. For example, GTE and Bell Atlantic made deals that made them ineligible to bid for the Los Angeles license, and MCI—one of the US's largest phone companies—also failed to enter the auction at all.

of other licenses where the auction was more symmetric.[21]

Because outcomes in an ascending auction can be dramatically influenced by apparently small advantages in valuation or in reputation for being a strong bidder, there is a strong incentive to invest in creating these advantages to deter the entry of potential rivals and to predate on actual rivals. Thus, for example, Glaxo made it very clear that it "would almost certainly top a rival bid",[22] and Pacific Telephone both said "if somebody takes California away from us, they'll never make any money"[23] and also hired one of the world's most prominent auction theorists to give seminars to the rest of the industry to explain the logic and implications of the "winner's curse" argument that justifies this statement.[24]

In another prominent example of apparent predation BSkyB (Rupert Murdoch's satellite television company) last year attempted to acquire Manchester United (England's most successful football club). The problem here was the potential effect on the auction of football TV rights. Since Manchester United receives 7 per cent of the Premier League's television revenues,

[21]The price for the single Los Angeles license was $26 per head of population. Compare this with Chicago where two licenses were sold for $31 per head of population. Yet most commentators thought LA's demographics were superior to Chicago's (Southern Californians are characterised as rich, loving new toys—as portable phones then were—and spending much of their time stuck on highways with little else to do than phone their friends), so that LA should have yielded the higher price.

A similar situation developed in New York and its license was also sold rather cheaply ($17 per head of population).

For econometric evidence of the effects described here, in the FCC auctions more broadly, see Klemperer and Pagnozzi (2001). See also Bulow and Klemperer (2000).

[22]Financial Times 8/3/95 p. 32.

[23]Wall Street Journal 31/10/94 p. A4.

[24]Note how anti-competitive the statements in this paragraph would seem in a normal competition-policy context in which dominant firms are threatened by new entry into their markets. The statement attributed to Glaxo would translate roughly to saying it "would almost certainly undercut any new entrant's price", while that attributed to Pacific Telephone would seem to correspond to threatening that "if anyone tries to compete with us, we'll cut the price until they lose money." Hiring an auction theorist to explain the winner's curse to competititors might correspond to hiring an industrial economist to explain the theory of the difficulties entering new markets to potential entrants.

BSkyB would then have received 7 per cent of the price of the league's broadcasting rights, whoever won those rights. 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 backed off. BSkyB might have effectively ended up with a lock over the TV rights with correspondingly deleterious effects on the pay TV (or even general TV) market more generally. Largely for this reason the U.K. Government blocked the acquisition.[25] Subsequently, however, and confirming this view of BSkyB's motive, BSkyB has taken smaller (mostly about 10 per cent) stakes in Manchester United, Manchester City, Chelsea, Leeds United and Sunderland thus obtaining a similar "toehold"[26] in the value of the league's television revenues while circumventing the competition watchdogs' restrictions on it owning too much of any one football club.[27] Meanwhile BSkyB's leading rivals have countered in similar style, with NTL, for example, taking partial stakes in Aston Villa, Leicester, Middlesborough, and Newcastle.[28]

These are all examples of ascending auctions. Although an advantaged

[25] [Note M] See U.K. Monopolies and Mergers Commission (1999). This report explicitly refers to Klemperer (1998) and Bulow, Huang and Klemperer (1999), etc., though none of these authors had any involvement in this case. The report also discusses difficulties with other auction forms in this context.

[26] The effect described here was named the "toehold effect" by Bulow, Huang and Klemperer (1999) who first pointed out its importance in the context of takeover battles in which one or more contestants had "toeholds" in the target company. In this context there is empirical evidence that 'greater toeholds increase the probability of a successful single-bid contest by lowering both the chance of entry by a rival bidder and target management resistance' (Betton and Eckbo, 1995).

[27] These stakes also gives BSkyB some rights over the clubs' internet broadcasting rights, which may increase the value of the main (live) rights to BSkyB, thus giving it a further advantage in the auction of the main rights.

[28] And the Premier League responded by changing the format of its June 2000 TV rights auction to a sealed-bid style auction which resolved some of the difficulties (see below), but not all of them. In particular, not only did the rules include some ascending aspects, but it is also not clear that the League could or would in every circumstance have stuck to the result of the auction in the face of a further bid (or threats) from a defeated bidder, so this was not a pure sealed-bid auction. A pure sealed-bid auction may not be possible in this context. (See note M.)

bidder is also more likely to win a sealed-bid auction, the outcome is much less certain because each bidder must make a single "best and final" offer in the face of uncertainty about its rivals' bids. Since it is restricted to a single bid in a sealed-bid auction, the advantaged firm cannot follow the strategy it would use in an ascending auction of starting low and bidding higher only if it has to; 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" firms have at least some chance of victory in a sealed-bid auction. It follows that potential entrants are likely to be more willing to enter a sealed-bid auction than an ascending auction.[29] Furthermore, since a "weaker" bidder can win in less extreme circumstances in a sealed-bid auction, it also faces a less severe "winner's curse", and so is also likely to bid more strongly having entered the sealed-bid auction than it would bid in an ascending auction.[30]

The logic is related to, but must be distinguished from, the standard competition-policy argument that a market that is in principle more competitive (for example, "Bertrand" rather than "Cournot") is less attractive to entry, so may be less competitive in fact. The difference here is that a sealed-bid auction may both attract more firms than an ascending auction, *and* lead to more satisfactory outcomes for a given number of firms. So in our context there is no trade-off between competitiveness ex-post, and attracting entry ex-ante. Of course, just as the less competitive (Cournot) market sacrifices some ex-post production efficiency, a sealed-bid auction is less likely to allocate the prize to the party who values it most among a given set of bidders. But neither short-run production efficiency nor efficient allocation

[29] These results all apply whether bidders have "private-values" or "common-values".

[30] This last result applies when there are some "common-values" components. For discussion of why the "winner's curse" is much less significant in asymmetric sealed-bid auctions then in asymmetric ascending auctions see Klemperer (1998), Section 6.1.

of the prize is the only objective. In particular, raising revenue should be an additional objective for a government, because of the substantial deadweight losses of raising government funds through alternative methods.[31,32]

4. Solving the Problems: the Anglo-Dutch Auction[33]

So ascending auctions can often support both collusive and predatory activity. But an ascending auction is also particularly likely to allocate the prizes to the bidders who value them the most.[34], [35] Furthermore, an ascending auction allows bidders to learn about others' valuations during the auction, which can both make the bidders more comfortable with their own assessments and often raises the auctioneer's revenues[36] if collusion and predation are absent.

So what should an auction designer do?

[31]Feldstein (1999) estimates that for the U.S. "a marginal increase in tax revenue achieved by a proportional rise in all personal income tax rates involves a deadweight loss of two dollars per incremental dollar of revenue", although this is substantially higher than others' previous estimates.

[32]Note that first-price sealed-bid and discriminatory auctions (which are in some ways analogous—see note Z) are not always more inviting to all kinds of new entry than are ascending and uniform-price auctions (which are analogous to each other—see note Y). For example, a bidder with inelastic demand for a small quantity can safely place a high bid in a uniform price auction in the knowledge that the price will be determined by others, but needs more information to make a sensible bid in a discriminatory price auction. Attractiveness to small bidders may not be important since they can buy from larger intermediaries who can aggregate smaller bidders' demands and bid in their places. However, our main, and robust, claim is just that attractiveness to entry is important. We do not claim that sealed-bid style auctions always dominate ascending style auctions in this respect.

[33]The Anglo-Dutch auction was first described and proposed in Klemperer (1998).

[34]At least among the bidders who show up. This is true even in many "common-values" settings. See Maskin (1992).

[35]This 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.

Allowing resale is not normally a substitute for an efficient initial allocation. See Myerson and Satterthwaite (1983) and Cramton, Gibbons, and Klemperer (1987).

[36]Milgrom and Weber (1982) show this is true if information is "affiliated".

One solution to the dilemma of choosing between the ascending and sealed-bid forms is to combine the two in a hybrid, the "Anglo-Dutch",[37] which often captures the best features of both.

For simplicity assume a single object is to be auctioned. Then in an Anglo-Dutch auction the auctioneer begins by running an ascending auction until just two bidders are willing to pay the current asking price. That is, the price is raised continuously until all but two bidders have dropped out. The two remaining bidders are then each required to make a "best and 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.

The main value of this procedure is 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. Absent the final sealed-bid, the potential rivals might be unwilling to enter against the strong bidder who would be perceived to be a sure winner. But the sealed-bid 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.

At the same time the Anglo-Dutch procedure will generally 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

[37] Ascending and sealed-bid auctions are sometimes called English and Dutch auctions, respectively. Hence the name "Anglo-Dutch".

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.

Another attractive feature of the Anglo-Dutch auction is that it eliminates the final stage of the ascending auction, when just one excess bidder remains, in which phase an ascending auction is particularly vulnerable to collusive and predatory behavior. Not only is the incentive for such behavior greater when just one bidder needs to be eliminated to end the auction but, more importantly, it may not be credible for the auctioneer to punish violations of the rules. We will see below that both the German and Dutch third-generation spectrum auctions suffered what many observers construed as violations of the rules when one excess bidder remained, but in neither case did the respective government take any strong action; excluding the offending bidders would simply have ended the auctions immediately, "cutting off the government's nose to spite its face."[38]

The Anglo-Dutch auction also reduces the incentives for firms to form consortia prior to the auction. Imagine, for example, that two firms seem clearly stronger than their rivals. Faced with an ascending auction these two firms have a powerful incentive to agree to bid jointly, in which case no other firm may bother to bid against them and their joint profits will then greatly exceed their profits if they had bid against each other. We will see below that the recent Netherlands spectrum auction suffered from a similar kind of joint bidding that resulted in very low revenue to the government.

[38] As we discuss below, the German case is actually more complicated, and the German auction might not have ended immediately had a bidder been excluded, since the number of winners was not pre-specified in that auction.

It may not have been possible for the governments to impose meaningfully large fines in the context of these multi-billion euro auctions.

But in an Anglo-Dutch auction, if the strong firms form a consortium they may simply attract other firms into the bidding in the hope of beating the consortium in the sealed-bid round. So the strong firms are more likely to bid independently in an Anglo-Dutch auction, making this a much more competitive auction.

Furthermore, the ascending stages of the Anglo-Dutch auction may extract most of the information that would be revealed by a pure ascending auction, and hence capture most of the consequent benefits of raising revenues[39] and making bidders more comfortable with their own assessments. At the same time the sealed-bid stage of the Anglo-Dutch may do almost as well as a pure sealed-bid auction in capturing extra revenue (relative to what would be expected from an ascending auction) due to the effects of bidders' risk-aversion, budget-constraints, and asymmetries. All these benefits of the Anglo-Dutch auction apply even if it attracts no additional firms into the bidding.[40]

The Anglo-Dutch auction can be extended to multi-object contexts, including contexts in which individual bidders are permitted to win multiple units. In these cases it has the additional advantage of making tacit collusion much harder than in a pure ascending auction;[41] because the sealed-bid stage allows firms to renege on any tacit deals without fear of retaliation,

[39] Milgrom and Weber (1982) shows the information revealed raises expected revenues if bidders' information is "affiliated".

[40] However, the effects in this paragraph are conjectures that need further research to confirm.

[41] In the single-indivisible-object case, tacit collusion is unlikely to be a problem since bidders cannot share the spoils without resort to side-payments.

they are unlikely to make such deals in the first place.[42],[43]

In short, the Anglo-Dutch auction often combines the best of both the ascending and the sealed-bid worlds.[44]

5. The U.K. and Netherlands Mobile-Phone License Auctions[45]

The U.K. (March-April 2000) and Netherlands (July 2000) third-generation mobile spectrum license auctions illustrate how good auction design is sensitive to the context:

The U.K. originally planned to auction just *four* third-generation licenses. In this case the presence of exactly four incumbent operators who might be thought to have advantages over other bidders[46] meant the designers were very concerned that an ascending auction might deter new firms from bidding

[42]Furthermore, if 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 in which they can learn nothing about their opponents' intentions.

[43]Obviously the auction designer's armoury has many other tools that fight collusion and predation, for example, reserve prices (possibly secret), policies about what information is released, etc.

[44]Many variants of the Anglo-Dutch auction are possible. With a single object for sale it may be desirable to move to the sealed-bid stage when there are still more than two bidders remaining. With multiple homogenous objects there is a choice between a discriminatory and a uniform price (but using the lowest-winner's price not the highest runner-up's price) sealed-bid stage. With N objects the ascending stage will typically continue until N+1 bidders remain, but the rule for moving to the sealed-bid stage is more complex if bidders are allowed to win multiple objects. If objects are heterogenous, the ascending stage for each object should probably be completed simultaneously and independently, as in a Simultaneous Ascending auction, prior to collecting the sealed bids for any object, and a rule for ordering the sealed bids for the different objects is required.

[45]I was the principal auction theorist advising the Radicommunications Agency which designed and ran the U.K. 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. The views expressed are mine alone.

[46]BT, One2One, Orange and Vodafone were the existing operators and were probably generally predicted to be the "strong" bidders, both because of their brand-name advantages over a new entrant, and because of their lower costs of building out a network.

strongly in the auction, or even from entering the auction at all.[47] So in this case the government proposed running an Anglo-Dutch auction. An ascending auction 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.[48] The design performed extremely well in laboratory experiments commissioned by the Radiocommunications Agency.[49]

However, when it became possible to auction *five* licences, a straightfoward ascending auction was no longer counterindicated, even though there were non-trivial entry costs and a limited number of potential bidders:[50] Be-

[47] [Note N] Efficiency was the main concern of the U.K. government. More precisely, in a written answer to a Parliamentary Question, Barbara Roche, then Minister for Small Firms, Trade and Industry, said "In offering through an auction licences to use specified frequencies for the delivery of UMTS, the Government's overall aim is to secure, for the long term benefit of UK consumers and the national economy, the timely and economically advantageous development and sustained provision of UMTS services in the UK.

Subject to this overall aim the Government's objectives are to (i) utilise the available UMTS spectrum with optimum efficiency; (ii) promote effective and sustainable competition for the provision of UMTS services; and (iii) subject to the above objectives, design an auction which is best judged to realise the full economic value to consumers, industry and the taxpayer of the spectrum." See Hansard, 18 May 1998.

[48] In this case it was proposed that all four winners would pay the fourth-highest sealed bid, and a final Simultaneous Ascending stage would have followed to allocate the four licenses more efficiently among the four winners. See Radiocommunications Agency (1998a, b) for more details.

[49] It performed well both in terms of efficiency (which was the main concern of the U.K. Government—see note N) and revenue generation (which was only a tertiary objective—see note N). The Anglo-Dutch design was also very successful in [confidential information censored while publication permission sought].

[50] Of course, predation and collusion are likely to be very hard when a commodity such as gold is offered to a potentially large number of bidders for whom entry to the auction is easy. In this case auction-design issues are likely to be of second-order importance to either price or efficiency. (Since I have been asked to serve on a National Audit Office Panel of Experts to review the sale of the U.K.'s gold stock-pile, it must be stressed that this view about gold is purely personal. And of course running an auction may be very important for transparency, and what is announced about the government's policies is certainly important to the market.)

Similarly, though much ink has been spilt on the subject, auction design may also not be critical for many government-security sales, (although collusion has arisen in some of these). For example, the U.S. Treasury's recent experiments with using uniform price auctions in place of discriminatory auctions yielded inconclusive results. See, for example, Simon (1994), Malvey, Archibald and Flynn (1996), Nyborg and Sundaresan (1996),

cause no bidder was permitted to win more than one license and licenses could not be divided, every bidder would end up either a winner of a single license, or a loser. So bidders could not collude to divide the market because there was no way to share the spoils without resort to sidepayments. Furthermore, with five licenses and only four incumbents, at least one license had to go to a new entrant and this would be a sufficient carrot to attract several new entrants.[51] So the problems of collusion and entry deterrence that this paper has emphasised were minimal in the U.K. context, and other considerations militated towards an ascending design.[52]

Therefore a version of an ascending auction was actually used, and it was widely judged to be a success; there were nine new entrants who bid strongly against the incumbents, creating intense competition and record-breaking ($22.5 billion) revenues.

On the other hand, the Netherlands plan to follow the actual British design was ill-conceived since there were *five* incumbent operators and *five* licenses in the Netherlands. The equal numbers of incumbents and licenses created exactly the situation in which this paper predicts that very few entrants will show up. (Indeed the first draft of this paper, written two months

Reinhart and Belzer (1996), and Ausubel and Cramton (1998). The broader empirical literature is also inconclusive. See Klemperer (2000b) for more discussion.

[51]Note that the simultaneous ascending design also guarantees that there are entrants available to threaten every incumbent until all the objects are finally allocated simultaneously.

[52]In particular, the five licenses were of unequal sizes. A sealed-bid component to the design might have introduced some inefficiency in the allocation of licenses among winners.

The ascending design chosen was a version of the one which was originally sketched by Vickrey (1976), and proposed and developed by McAfee, Milgrom and Wilson for the U.S. auctions. When each of an exogenously fixed number of bidders has a privately-known value for each of a collection of heterogenous objects, and (as in the U.K., but contrary to the U.S.) is restricted to buying at most a single license, the unique Nash equilibrium of the game induced by this design is efficient if bidding increments are arbitrarily small. (For more discussion of the U.S. sales see McMillan (1994), McAfee and McMillan (1996) and especially Milgrom (forthcoming).)

prior to the auction, *did* predict exactly this problem for the Netherlands.) Recognizing their weak positions, the potential new entrants made deals with incumbent operators, and Netherlands competition policy was as dysfunctional as the auction design, allowing firms such as Deutsche Telekom, DoCoMo and Hutchinson, who were all strong established players in other markets than the Netherlands, to partner with the local incumbents.[53] In the end there was just one relatively weak entrant (Versatel) to compete with the five incumbents for the five licenses. Versatel stopped bidding after receiving a letter from one of the incumbents (Telfort) threatening legal action if Versatel continued to bid.[54] Although Versatel complained to the government, the government took no action, perhaps because excluding Telfort would have ended the auction immediately, and it might have been hard to impose a meaningful fine. In the end, the auction raised less than one third of the per-capita revenue of the U.K. auction, that is, only $1.65 billion, rather than the almost $6 billion the Dutch government had forecast based on the U.K. experience.

6. Market Structure and the German and Italian Mobile-Phone License Auctions

[53] It would normally be better if combinations between potential entrants and incumbents had to wait until after the auction, just as the sale of Orange to France Telecom waited until after the U.K.'s auction. Similarly, the sale of part of Hutchinson's interest in its U.K. license after the auction to KPN and DoCoMo did not harm the British taxpayer, but allowing these firms to combine before the Netherlands auction hurt taxpayers there.

[54] Telfort's letter claimed that Versatel's weak financial and strategic position meant that the only reason that Versatel would continue to bid above the level the bidding would "soon reach" was that Versatel "believes that its bids will always be surpassed by bids of the other participants in the auction" so it "must be that Versatel is attempting to either raise its competitors' costs or to get access to their 2G or future 3G networks", and said such a bidding strategy "constitutes a tort towards Telfort, who will hold Versatel liable for all damages as a result of this".

Versatel argued that Telfort's letter violated the auction rule that "Prior to and in the course of the Auction Procedure, a Participant shall refrain from any conduct or from making any agreements that could hinder the competition to be created during the Auction Procedure."

In addition to addressing the problems of *conduct,* especially collusion and predation, competition authorities also analyse the merits of mergers and other changes to market *structure.*

Our paper has focused attention on conduct, taking structure as given, because in many auctions, such as those of oil, gold, financial instruments, etc., there is no issue about market structure. But is some contexts, in particular when auctioning licenses that create a new industry, the structure of the industry that will be created is crucial, and cannot be ignored by an auction designer any more than it can be ignored by an ordinary industry regulator.

The obvious example is the sale of third-generation mobile-phone licenses.[55] It may be 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 final consumers' (or social) welfare, so the outcome of such an auction will be distorted from the social viewpoint. The most obvious distortion is that since bidders' joint profits in the market being created will be maximised by a monopoly, too few firms will win spectrum, and these winners will each win too much (exactly as a "hands-off" policy to merger control will tend to create an overly-concentrated industry). In a multiunit ascending auction there is an offsetting effect, since firms know they can end the auction at a lower price if they reduce their own demands rather than let the price rise to drive out competitors.[56] So in this case it is

[55]Another example is that the most important issues in regulating the sale of U.K. football TV rights are: What packages are sold?, and How many packages is a single broadcaster allowed to win?

[56]See, especially, Ausubel and Cramton (1998).

in principle possible for too many firms to each win too little spectrum, and although this seems less likely, all that can definitely be said is that there is no presumption that the number of winners will be socially efficient.

Ignoring the issue of market structure was the most serious flaw in the design of the German (August 2000) third-generation mobile-phone license auction—though the outcome of the auction was very good, this was good luck not good design: Germany auctioned twelve blocks of spectrum from which bidders could create "licenses" of either two or three blocks, e.g., four firms could win large 3-block licenses or six firms could win smaller 2-block licenses. So the German government risked obtaining an overly concentrated mobile-phone market.[57] Since the bidding in the British auction had demonstrated that bidders believed that there was sufficient spectrum in Germany for six companies to operate there, the government should simply have auctioned six licenses.

In the event only seven bidders participated (entry was perhaps discouraged by the ascending design), and of these one (Debitel) looked quite weak. Debitel's resolve might have been further weakened by what looked like a collusive offer from a rival—MobilCom told a newspaper that it "would welcome customers from ...Debitel should [it] fail to secure a license [so Debitel could] become a 'virtual network operator' using MobilCom's network while saving on the cost of the license." As in the Netherlands case, the government did not attempt to punish MobilCom, perhaps because excluding it would have risked ending the auction almost immediately at an extremely low

[57] See Jehiel and Moldovanu (2000a) and the references therein for more discussion of this aspect of the German auction, and Jehiel and Moldovanu (2000b) for some more general analysis of license auctions and market structure.

price.[58] When Debitel dropped out at just over 60% of the per-capita revenue achieved by the UK auction there were then two natural outcomes, depending on the strategies followed by the two dominant incumbents (Deutsche Telekom and Vodafone-Mannesman, each of whom had about 40% of the existing German mobile market). *Either* these dominant firms could raise the price to force the weaker firms among the remaining six to quit, which would yield high revenue for the government but a concentrated industry. *Or* they could lead all six remaining firms to reduce their demands to two blocks each, thus ending the auction quickly and giving the government a lowish revenue but an unconcentrated industry.

Surprisingly, the dominant incumbents first pushed the prices up to almost UK levels, but then gave up and ended the auction before pushing any of the weaker firms out—it is hard to construct beliefs about opponents for which this is rational behaviour.[59] So the government ended up with both

[58]The price level at the time was about 3% of what the auction finally achieved.

Shares in Debitel rose 12 per cent in response to the remarks which, if taken literally, would be similar in effect to the offer of a side-payment for quitting the auction, and the German "telecommunications regulator launched a snap investigation into a possible collusion between the bidders", and "issued a stern warning against future breaches of strict anti-collusion rules". See Financial Times, 2/8/2000 p.28.

It might be hard for the government to impose fines large enough to have a serious deterrent effect.

[59]Deutsche Telekom's behaviour is reminiscent of the impatience of my father-in-law whom I have often observed join a queue for, e.g., sandwiches and then quit in frustration even after having got close to the front of the line. Rational behaviour generally involves sizing up the queue first, and then either quitting quickly (c.f. ending the auction quickly) or gritting one's teeth and waiting to the end (c.f. waiting for another firm to quit the auction). In fact my father-in-law's behaviour might be more rational than Deutsche Telekom's, since he might learn more about the queue's behavior. Deutsche Telekom learnt nothing new after Debitel quit (except that no-one else was quitting).

More technically inclined readers will recognise that the condition for Deutsche Telekom's behaviour to be rational (assuming it aimed to maximise expected profits) relates to decreasing hazard rates of the distribution of the weaker firms' quit points (though the different values of winning two and three blocks, budget constraints, etc., makes things a little more complex). The condition seems particularly implausible at the relevant price levels which were below those the same firms were prepared to pay in the U.K. auction.

The final digits of Vodafone-Mannesman's bids suggest that it was signalling Deutsche Telekom of its wish to end the auction much earlier.

high revenues (almost 98% of the UK revenues per capita) and an unconcentrated (six-firm) mobile-phone market![60]

The Italian (October 2000) auction was also flawed in failing to recognise the paramount importance of the final market structure. The key problem was the rule that if the number of bidders who satisfied various prequalification conditions was not more than the number of licenses on offer, then the number of licenses on offer would be reduced. The rule sounded attractive as a way to avoid an embarrassingly uncompetitive auction (the rule was perhaps inspired by the Netherlands' fiasco), but it is "putting the cart before the horse" to artificially create an unnecessarily concentrated mobile-phone market in order to make an auction look good.[61] A better approach, of course, is to increase the likely number of bidders by choosing an auction design that is more attractive to entry and by restricting joint bidding.[62]

Furthermore, as is clear from our earlier discussion, the Italian rule does *not* guarantee a competitive ascending auction. The rule allows the possibility that there will be just one more bidder than the number of licenses, and it was apparent from the Netherlands auction that if one of these bidders was weak (or was behaving weakly from collusive motives), then the revenues

[60]The problems we have emphasised were by no means the only flaws of the German auction design.

For example, a bidder might have stayed in the auction in the hope of being one of five winners, but suddenly found itself one of six winners, and been quite unhappy in this event, and even tried to default. (In fact, the bidding behaviour and other evidence suggests that all the winners were indeed happy to win.)

Furthermore, the possibility that the auction would end with a bidder being the high bidder on just a single block, in which case the rules called for the block to be re-auctioned, created both considerable uncertainty for bidders and the possibility of an inefficient allocation, since the price in the re-auction could be very different from that in the original auction. (Again, the government was lucky that this seemed not to create inefficiency in practise.)

[61]Furthermore if spectrum is withdrawn from the auction and it is not clear what will subsequently happen to it, this might lead to an inefficient auction outcome.

[62]The rule we are discussing may reduce the attractiveness of joint bidding, but joint bidding should be restricted directly.

from an ascending auction might be very poor in this case. In addition, as we have already argued, and the Netherlands and German auctions had demonstrated, an ascending auction is very vulnerable to collusive and predatory behavior when there is just one excess bidder. It seemed increasingly likely as the date of the auction approached that there would indeed be just one, or at most two, excess bidders.[63] In the end six bidders entered the auction to compete for five licenses and one, Blu, then quit after less than two days of bidding.[64] The final prices were only just above the starting price, resulting in per capita revenues of less than 40% of the U.K. level, or less than 14 billion Euros instead of the more than 25 billion Euros that the government had estimated.[65],[66],[67]

While the precise nature of the Italian disaster could not have been predicted, and while the Italian government might have been luckier,[68] it was

[63]By the time of the Italian auction, firms had learned who the likely winners were, at least in an ascending auction, so the number of plausible entrants had fallen from the 13 bidders who entered the U.K. auction to, perhaps, eight.

[64]Note that the government elimated two weak bidders prior to the auction (in a "beauty contest" phase). This was probably a mistake.

[65]One concern that has been expressed is that there might have been some implicit "collusion" between some firms by which Blu entered simply to avoid invoking the rule reducing the number of licenses, thus allowing every other bidder to win a cheap license. I have no reason to suppose that everything was not perfectly legal, but "Magistrates in Rome [have] opened an investigation into possible market rigging" and an Italian government undersecretary stated "Collusive behavior was recognised with [Blu] violating its obligation of confidentiality", see Independent, p.18, 25/10/00. Of course, illegal collusion is greatly facilitated by an ascending, rather than a sealed-bid, design so if this was a concern, this is a further argument against the ascending design used.

Blu was a joint venture between British Telecom and Italian-based firms whose main business was not in telecoms, and they were apparently unable to agree terms for competing seriously in the auction. See, for example, Financial Times p.27, 25/10/00.

[66]The Italian government had the advantage that it could use information from the U.K. and German auctions to set an appropriate reserve price to handle the unfortunate event that only a few bidders emerged, but the government did not seem to take full advantage of this.

[67]Another poor aspect of the auction design was the details of how new entrants could compete for extra spectrum.

[68]Contrast with the Netherlands where failure seemed very probable because the number of incumbent operators equalled the number of bidders (especially after a joint bidding agreement between Deutsche Telekom and Ben made all the incumbents seem strong). So

clear in advance that the design was not robust.

By contrast, an Anglo-Dutch design would probably have performed much better. Assuming the same entrants, the auction would have immediately moved to a "best and final" sealed-bid. The five strong bidders would have been unsure just how weak Blu was, so would have felt forced to make serious bids in case Blu did produce a good offer. Indeed Blu itself might have made a reasonable offer even if (as was the case) it didn't feel able to bid up to the level required to be a winner in the ascending auction. (And this possibility would have encouraged more aggressive bidding from the others.) As discussed above, the Anglo-Dutch format might also have attracted more entry, and so further increased the competitiveness of the auction.[69] Most likely the winners would have been the same firms, but the Italian government would have received revenues much closer to the U.K. levels, as it had originally predicted it would.

Revenues from European 3G Mobile Spectrum Auctions

		Euros per capita
UK	(March-April 2000)	630
Netherlands	(July 2000)	170
Germany	(August 2000)	615
Italy	(October 2000)	240[70]

in the Netherlands I predicted that failure was probable, and I very strongly criticised the design in print and in press interviews in advance of the auction. In Italy I was less sure of the outcome, and more cautious, though I wrote in a draft of this paper prior to this auction that a different auction design should have been chosen, and I also emphasised the advantages of including a sealed-bid component in the design in a speech in Rome three months prior to the auction.

[69]Deutsche Telekom (a winner in the U.K., Netherlands, and Germany) did not enter the Italian contest. Furthermore, the Italian government eliminated two potential bidders prior to the auction. Though they might have made little difference to an ascending auction, they might well have scared the stronger bidders into more aggressive bidding in a "sealed-bid" contest.

[70]This figure includes the expected revenue from additional spectrum that will be made available to the winners who are not incumbent operators. For spectrum sold so far the figure is 210.

Table 1

7. Conclusion

Auction design is a matter of "horses for courses", *not* "one size fits all". While the ascending auction is very risky in many contexts (and an Anglo-Dutch auction may perform better), it has also been used very successfully in other contexts, including the recent U.K. and some U.S. radiospectrum auctions.

The recent U.K., Netherlands, German and Italian examples show that auction design is very sensitive to the details of the environment. European governments would be foolish not to copy the U.K. in auctioning the radiospectrum, but they would be equally foolish to blindly follow the exact U.K. design without attention to their local circumstances.

In auction design, the devil is in the details.

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