Invited session for World Congress to be presented Friday 11th August.

**Why Every Economist Should Learn Some Auction Theory**

Paul Klemperer

This talk is largely based on

“Why Every Economist Should Learn Some Auction Theory”

but may also refer to

“What Really Matters in Auction Design”.

Both papers follow.
Why Every Economist Should Learn Some Auction Theory


Auction Theory Heineken. Refreshes the parts other economics beers cannot reach.

Disclaimer: We don’t contend that the following ideas are all as important as the one illustrated, merely that those who haven’t imbibed auction theory are missing out on a potent brew!

This is a preliminary draft of an Invited Symposium paper for the World Congress of the Econometric Society to be held in Seattle in August 2000. We discuss the strong connections between auction theory and “standard” economic theory, and argue that auction-theoretic tools and intuitions can provide useful arguments and insights in a broad range of mainstream economic settings that do not, at first sight, look like auctions. We also discuss some more obvious applications, especially to industrial organization.

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1 INTRODUCTION

2 USING AUCTION-THEORETIC TOOLS IN ECONOMICS: THE REVENUE EQUIVALENCE THEOREM

2.1 Comparing Litigation Systems

2.2 The War of Attrition

2.3 Other “All-pay” Applications

2.4 Solving for Equilibrium Behavior: Market Crashes and Trading ‘Frenzies’

3 TRANSLATING LOOSER ANALOGIES FROM AUCTIONS INTO ECONOMICS:

ASCENDING VS. SEALED-BID AUCTIONS

3.1 Internet Sales versus Dealer Sales

3.2 Anglo-Dutch Auctions and a Theory of Rationing

4 EXPLOITING DEEPER CONNECTIONS BETWEEN AUCTIONS AND ECONOMICS:

MARGINAL REVENUES

5 PRICE-SETTING OLIGOPOLIES

5.1 Marginal-Cost Pricing is NOT the Unique Bertrand Equilibrium

5.2 The Value of New Customers

5.3 Information Aggregation in Perfect Competition

6 AUCTION MARKETS

6.1 Electricity Markets

6.2 Treasury Auctions

6.3 Spectrum Auctions

6.4 Internet Markets

6.5 Applying Economics to Auction Design

7 CONCLUSION

Appendices

References
1 INTRODUCTION

Auction theory has attracted enormous attention in the last few years. It has been increasingly applied in practice, and this has itself generated a new burst of theory. It has also been extensively used, both experimentally and empirically, as a testing ground for game theory. Furthermore, by carefully analysing very simple trading models, auction theory is developing the fundamental building-blocks for our understanding of more complex environments. But some people still see auction theory as a rather specialized field, distinct from the main body of economic theory, and as an endeavour for management scientists and operations researchers rather than as a part of mainstream economics. This paper aims to counter that view.

This view may have arisen in part because auction theory was substantially developed by operational researchers, or in operations research journals, and using technical mathematical arguments rather than standard economic intuitions. But it need not have been this way. This paper argues that the connections between auction theory and “standard” economic theory run deeper than many people realize; that auction-theoretic tools provide useful arguments in a broad range of contexts; and that a good understanding of auction theory is valuable in developing intuitions and insights that can inform the analysis of many mainstream economic settings. In short, auction theory is central to economics.

We pursue this agenda in the context of some of the main themes of

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1See Klemperer (1999) for a review of auction theory; many of the most important contributions are collected in Klemperer (2000).

2Kagel (1995) and Laffont (1997) are excellent recent surveys of the experimental and empirical work, respectively. Section 6 of this paper discusses practical applications.

3The earliest studies appear in the operations research literature, for example, Friedman (1956). Myerson’s (1981) breakthrough article appeared in Mathematics of Operations Research, while Rothkopf’s (1969) and Wilson’s (1967, 1969) classic early papers appeared in Management Science. Ortega Reichert’s (1968) pathbreaking models of auctions, including a model of signalling that significantly predated Spence (1972), remain relatively little-known by economists, perhaps because they formed an operations research PhD thesis.
auction theory: the revenue equivalence theorem, marginal revenues, and ascending vs sealed-bid auctions. To show how auction-theoretic tools can be applied elsewhere in economics, Section 2 exploits the revenue equivalence theorem to analyze a wide range of applications that are not, at first sight, auctions. To illustrate how looser analogies can usefully be made between auction theory and economics, Section 3 applies some intuitions from the comparison of ascending and sealed-bid auctions to other economic questions. To demonstrate the deeper connections between auction theory and economics, Section 4 discusses and applies the close parallel between the optimal auction problem and that of the discriminating monopolist; both are about maximizing marginal revenues.

Examples we discuss include litigation systems, financial crashes, queues, rationing, wars of attrition, valuing new consumers and e-commerce. However auction-theoretic ways of thinking are also underutilised in more obvious areas of application, for instance, price-setting oligopolies which we discuss in Section 5. Few non-auction-theorists know, for example, that marginal-cost pricing is not always the only equilibrium when identical firms with constant marginal costs set prices, or know the interesting implications of this fact. Section 6 discusses some direct applications of auction theory to markets that are literally auction markets, including electricity markets, treasury auctions, spectrum auctions, and internet markets, and we conclude in Section 7.

2 USING AUCTION-THEORETIC TOOLS IN ECONOMICS: THE REVENUE EQUIVALENCE THEOREM

\[\text{4Of course, standard auction models form the basic building blocks of models in many contexts. See, for example, Stevens’ (1994, 2000) models of wage determination in oligopsonistic labor markets, and Bernheim and Whinston (1986), Feddersen and Pesendorfer (1996), Persico (2000) and many others’ political economy models, and many models in finance. [other examples]}\]
Auction theory’s most celebrated theorem, the Revenue Equivalence Theorem (RET) states conditions under which different auction forms yield the same expected revenue, and also allows revenue rankings of auctions to be developed when these conditions are violated. Our purpose here, however, is to apply it in contexts where the use of an auction model might not seem obvious.

**Revenue Equivalence Theorem (RET)** Assume each of a given number of risk-neutral potential buyers has a privately-known valuation independently drawn from a strictly-increasing atomless distribution, and that no buyer wants more than one of the k identical indivisible prizes.

Then any mechanism in which (i) the prizes always go to the k buyers with the highest valuations and (ii) any bidder with the lowest feasible valuation expects zero surplus, yields the same expected revenue (and results in each bidder making the same expected payment as a function of her valuation).

More general statements are possible but are not needed for the current purpose.

Our first example is very close to a pure auction:

### 2.1 Comparing Litigation Systems

In 1991 U.S. Vice President Dan Quayle suggested reforming the U.S. legal system in the hope, in particular, of reducing legal expenditures. One of his proposals was to augment the current rule according to which parties pay their own legal expenses, by a rule requiring the losing party to pay the winner an amount equal to the loser’s own expenses. Quayle’s intuition was

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5For example, Klemperer’s (1999) survey develops a series of revenue rankings starting from the Revenue Equivalence Theorem.

6See Klemperer (1999, Appendix A) for more general statements and an elementary proof. The theorem was first derived in an elementary form by Vickrey (1961, 1962) and subsequently extended to greater generality by Myerson (1981), Riley and Samuelson (1981) and others.
that if spending an extra $1 on a lawsuit might end up costing you $2, then less would be spent. Was he correct?  

A simple starting point is to assume each party has a privately-known value of winning the lawsuit relative to losing, independently drawn from a common, strictly-increasing, atomless distribution; that the parties independently and simultaneously choose how much money to spend on legal expenses; and that the party who spends the most money wins the “prize” (the lawsuit). It is not too hard to see that both the existing U.S. system and the Quayle system satisfy the assumptions of the RET, so the two systems result in the same expected total payments on lawyers. So Quayle was wrong (as usual); his argument is precisely offset by the fact that the value of winning the lawsuit is greater when you win your opponent’s expenses.

Ah, Quayle might say, but this calculation has taken as given the set of lawsuits that are contested. Introducing the Quayle scheme will change the

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7 This question was raised and analyzed (though not by invoking the RET) by Baye, Kovenock and de Vries (1997). The ideas in this section, except for the method of analysis, are drawn from them. See also Baye, Kovenock and de Vries (1998).

8 For example, a suit about which party has the right to a patent might fit this model. The results extend easily to common-value settings, e.g., contexts in which the issue is the amount of damages that should be transferred from one party to another.

9 American seminar audiences typically think this is a natural assumption, but non-Americans often regard it as unduly jaundiced.

We use it as a benchmark only, to develop insight and intuition. Similarly, lobbying contests and political campaigns are not always won by the biggest spender, construction contracts are not always won by the lowest price (quality and timing issues matter) and the lowest price does not win the whole market in any real “Bertrand” market, but making the extreme assumption is a common and useful starting point in each case.

The results extend somewhat to the case in which with probability \( (1-\lambda) \) the “most deserving” party wins, but with probability \( \lambda > 0 \) the biggest spender wins.

10 The fact that no single “auctioneer” collects the players’ payments as revenues, but that they are instead dissipated in legal expenses in competing for the single available prize (victory in the lawsuit), is of course irrelevant to the result.

11 Formally checking our claims requires checking that there are equilibria of the games that satisfy the RET’s assumptions. The assumption we made that the parties make a one-shot choice of legal expenses is not necessary but makes this checking relatively easy. (These equilibria need not always exist for the more general game analyzed in the Appendix.) See Baye, Kovenock, and de Vries (1997) for explicit solutions.

12 Some readers might argue they could have inferred the effectiveness of the proposal from the name of the proponent, without need of further analysis. In fact, however, this was one of Dan Quayle’s policy interventions that was not subject to immediate popular derision.
“bidding functions”, that is, change the amount any given party spends on litigation, so also change who decides to bring suits. Wrong again Dan! Although it’s correct the bidding functions change, the RET also tells us (in its parenthetical remark) that any given party’s expected payoffs from the lawsuit are unchanged, so the incentives to bring lawsuits are unchanged.

What about other systems, such as the typical European system in which the loser pays a fraction of the winner’s expenses? This is a trick question: it is no longer true that a party with the lowest possible valuation can spend nothing and lose nothing. Now this party always loses in equilibrium and must pay a fraction of the winner’s expenses, so makes negative expected surplus. That is, condition (ii) of the RET now fails. Thinking through the logic of the proof of the RET (every type’s surplus is determined by reference to the lowest-valuation type’s surplus\textsuperscript{12}) makes clear that all the players are worse off than under the previous systems. That is, legal bills are higher under the European rule. The reason is that the incentives to win are greater than in the U.S. system, and there is no offsetting effect. Here of course the issue of who brings lawsuits is important since low-valuation parties would do better not to contest suits in this kind of system; consistent with our theory there is empirical evidence (e.g. Hughes and Snyder (1995)) that the American system leads to more trials than, for example, the British system.

This last extension demonstrates that even where the RET in its simplest form fails, it is often possible to see how the result is modified. This is a particularly trivial example, but Appendix 1 shows how to use the RET to solve for the relative merits of a much broader class of systems of which those we have discussed are special cases. We also show there that a system that might be thought of as the exact opposite of Quayle’s system is optimal in this model. Of course, many factors are ignored (for example, asymmetries); the

\textsuperscript{12}See Klemperer (1999, Appendix A).
basic model should be regarded as no more than a starting point for analysis.

### 2.2 The War of Attrition

Consider a war of attrition in which $N$ players compete for a prize. For example, $N$ firms compete to be the unique survivor in a natural monopoly market, or $N$ firms each hold out for the industry to adopt the standard they prefer. Each player pays costs of 1 per unit time until she quits the game. When just one player remains, that player also stops paying costs and wins the prize. There is no discounting. The two-player case, where just one quit is needed to end the game, has been well analyzed.\(^\text{13}\) Does the many-player case yield anything of additional interest?

Assume players’ values of winning are independently drawn from a common, strictly-increasing, atomless distribution, and the game has an equilibrium satisfying the other conditions of the RET. Then the RET tells us that in expectation the total resources spent by the players in the war of attrition equal those paid by the players in any other mechanism satisfying the RET’s conditions—for example, a standard ascending auction in which the price rises continuously until just one player remains and (only) the winner pays the final price. This final price will equal the second-highest actual valuation, so the expected total resources dissipated in the war of attrition is the expectation of this quantity.

Now imagine the war of attrition has been under way long enough that just the two highest-valuation players remain. What are the expected re-

\(^{13}\)See, for example, Maynard Smith (1974) and Riley (1980) who discuss biological competition, Fudenberg and Tirole (1986) who discuss industrial competition, Abreu and Gul (2000), Kambe (1999), and others who analyse bargaining and Bliss and Nalebuff (1984) who give a variety of amusing examples.

Bliss and Nalebuff note that extending to $K + 1$ players competing for $K$ prizes does not change the analysis in any important way, since it remains true that just one quit is needed to end the game.

Another example analysed by Bulow and Klemperer (1999) is that of $N$ politicians each delaying in the hope of being able to avoid publicly supporting a necessary but unpopular policy that requires the support of $N - K$ to be adopted.
sources that will be dissipated by the remaining two players, starting from this time on? The RET tells us that they equal the auctioneer’s expected revenue if the war of attrition were halted at this point and the objects sold to the remaining players by an ascending auction, that is, the expected second-highest valuation of these two remaining players. This is the same quantity, on average, as before\(^{14}\) So the expected resources dissipated, and hence the total time taken until just two players remain, must be zero; all but the two highest-valuation players must have quit at once.

Of course this conclusion is, strictly speaking, impossible; the lowest-valuation players cannot identify who they are in zero time. However, the conclusion is correct in spirit, in that it is the limit point of the unique symmetric equilibria of a sequence of games which approach this game arbitrarily closely (and there is no symmetric equilibrium of the limit game).\(^{15}\) Here, therefore, the role of the RET is less to perform the ultimate analysis than it is to show that there is an interesting and simple result to be obtained.\(^{16}\)

\(^{14}\)Of course the expectation of the second-highest valuation of the last two players is computed when just these two players remain, rather than at the beginning of the war of attrition as before. But on average these two expectations must be the same, and the difference must be zero.

\(^{15}\)Bulow and Klemperer (1999) analyze games in which each player pays costs at rate 1 before quitting but must continue to pay costs even after quitting at rate \(c\) per unit time until the whole game ends. The limit \(c \to 0\) corresponds to the war of attrition discussed here. (The case \(c = 1\) corresponds, for example, to “standards battles” or political negotiations in which all players bear costs equally until all have agreed on the same standard or outcome; this game also has interesting properties—see Bulow and Klemperer.) Other series of games, for example games in which being \(k^{th}\) to last to quit earns a prize of \(\varepsilon^{k-1}\) times one’s valuation, with \(\varepsilon \to 0\), or games in which players can only quit at the discrete times \(0, \varepsilon, 2\varepsilon, \ldots\), with \(\varepsilon \to 0\), also yields the same outcome in the limit.

\(^{16}\)It was the RET that showed Bulow and Klemperer that there was an analysis worth doing. Many people, and some literature, had assumed the many-player case would look like the two-player case but with more-complicated expressions, although Fudenberg and Kreps (1987) and Haigh and Cannings (1989) observed a similar result to ours in games without any private information and in which all players’ values are equal.

However, an alternative way to see the result in our war of attrition is to imagine the converse but that a player is within \(\varepsilon\) of her planned quit time when \(n > 1\) other players remain. Then the player’s cost of waiting as planned is of order \(\varepsilon\), but her benefit is of order \(\varepsilon^n\) since only when all \(n\) other players are within \(\varepsilon\) of giving up will she ultimately win. So for small \(\varepsilon\) she will prefer to quit now rather than wait, but in this case she should of course have quit \(\varepsilon\) earlier, and so on. So only when \(n = 1\) is delay possible.
Of course by developing intuition about what the result must be, the RET also makes proving it much easier. Furthermore the RET was also useful in the actual analysis of the more complex games that Bulow and Klemperer (1999) used to approximate this game. In addition, anyone armed with a knowledge of the RET can simplify the analysis of the basic two-player war of attrition.

2.3 Other “All-pay” Applications

The preceding applications have both been variants of “all-pay” auctions. As another elementary example of this kind consider different queueing systems, for example for tickets to a sporting event. Under not unreasonable assumptions, a variety of different rules of queue management e.g. making the queue more or less comfortable, informing or not informing people whether the number queueing exceeds the number who will receive a ticket, etc., will make no difference to the social cost of the queueing mechanism. As in our litigation example (Section 2.1), we think of these results as a starting point for analysis rather than as final conclusions.\footnote{Holt and Sherman (1982) compute equilibrium behavior and hence obtain these results without using the RET.}

Many other issues such as lobbying battles, political campaigns,\footnote{See, especially, Persico (2000).} tournaments in firms, contributions to public goods,\footnote{Menezes, Monteiro and Temimi (2000) uses the RET in this context.} patent races and some kinds of price-setting oligopoly (see Section 5.2) can be modelled as all-pay auctions and may provide similar applications.

2.4 Solving for Equilibrium Behavior: Market Crashes and Trading ‘Frenzies’

The examples thus far have all proceeded by computing the expected total payments made by all players. But the RET also states that each
individual’s expected payment must be equal across mechanisms satisfying the assumptions. This fact can be used to infer what players’ equilibrium actions must be in games which would be too complex to solve by any direct method of computing optimal behavior.\textsuperscript{20}

Consider the following model. The aim is to represent, for example, a financial or housing market and show that trading “frenzies” and price “crashes” are the inevitable outcome of rational strategic behavior in a market that clears through a sequence of sales rather than through a Walrasian auctioneer. There are $N$ potential buyers, each of whom is interested in securing one of $K$ available units. Without fully modelling the selling side of the market, we assume it generates a single asking price at each instant of time according to some given function of buyer behavior to date. Each potential buyer observes all prices and all past offers to trade, and can accept the current asking price at any instant, in which case, supply permitting, the buyer trades at that price.

So traders have to decide both whether and when to offer to buy, all the while conditioning their strategies on the information that has been revealed in the market to date. Regarding the function generating the asking prices, we specify only that (i) if there is no demand at a price, then the next asking price is lower, and (ii) if demand exceeds remaining supply at any instant, then no trade actually takes place at that time but the next asking price is higher and only those who attempted to trade are allowed to bid subsequently.\textsuperscript{21} Note, however, that even if we did restrict attention to a specific

\textsuperscript{20}The same approach is also an economical method of computing equilibrium bids in many standard auctions. For example, in an ascending auction for a single unit, the expected payment of a bidder equals her probability of winning times the expected second-highest valuation among all the bidders conditional on her value being higher. So the RET implies that her equilibrium bid in a standard all-pay auction equals this quantity. Similarly, the RET implies that her equilibrium bid in a first-price sealed-bid auction equals the expected second-highest valuation among all the bidders conditional on her value being higher. See Klemperer (1999, Appendix A) for more details and discussion.

\textsuperscript{21}Additional technical assumptions are required to ensure that all units are sold in finite time. See Bulow and Klemperer (1994) for full details.
price-setting process, the direct approach of computing buyers’ optimal behavior using first-order conditions as a function of all prior behavior to solve a dynamic program would generally be completely intractable.

To use the RET we must first ensure that the appropriate assumptions are satisfied. We assume, of course, that buyers’ valuations are independently drawn from a common, strictly-increasing, atomless distribution, and that there is no discounting during the time the mechanism takes. And it is not too hard to check that the lowest-possible valuation buyer makes zero surplus and that the objects do eventually go to the highest-valuation bidders in equilibrium, because of our assumption that if demand ever exceeds remaining supply then no trade takes place and non-bidders are henceforth excluded. So the RET applies, and it also applies to any subgame of the whole game. (If, instead, excess demand resulted in random rationing the highest-valuation buyers might not win, violating the requirements of the RET, so even if we thought this was more natural it would make sense to begin with our assumption to be able to analyze and understand the process using the RET. The effects of the alternative assumption could then be analyzed with the benefit of the intuitions developed using the RET. Bulow and Klemperer (1994) proceed in exactly this way.)

Under our assumptions, then, starting from any point of the process, the remainder of the game is revenue equivalent to what would result if the game were halted at that point and the remaining $k$ objects were sold to the remaining buyers using a standard ascending auction (which sells all $k$ objects at the $(k+1)^{st}$ highest valuation among the remaining bidders). But it is easy to compute what the expected payment of any bidder would be in an ascending auction as a function of her signal and of the information revealed by the process to date about the remaining bidders’ valuations. So by the RET we know the expected payment of any buyer in the remainder
of our game, starting from any point of our game. But any potential buyer whose expected payment conditional on winning equals or exceeds the current asking price will attempt to buy at the current price. This allows us to completely characterize buyer behavior, so fully characterizes the price path for any given rule generating the asking prices.

It is now straightforward to show (see Bulow and Klemperer (1994)) that potential buyers are extremely sensitive to the new information that the price process reveals. So almost any seller behavior—for example, starting at a very high price and slowly lowering the price continuously until all the units are sold or there is excess demand—will result in “frenzies” of trading activity in which many buyers bid simultaneously, even though there is zero probability that two buyers have the same valuation. Furthermore these frenzies will sometimes lead to “crashes” in which it becomes common knowledge that the market price must fall a substantial distance before any further trade will take place. Bulow and Klemperer also show that natural

\[22\text{Specifically, if } k \text{ objects remain, the bidder’s expected payment conditional on winning will be the expected } (k + 1)^{\text{st}} \text{ highest valuation remaining conditional on the bidder having a valuation among the } k \text{ highest remaining, and conditional on all the information revealed to date. This is exactly the bidder’s expected payment conditional on winning an object in the ascending auction, since in both cases only winners pay and the probability of a bidder winning is the same.}

\[23\text{The marginal bidder, who is just indifferent about bidding now, will either win now or will never win an object. (If bidding now results in excess demand, this bidder will lose to inframarginal current bidders, since there is probability zero that two bidders have the same valuation.) So conditional on winning, this bidder’s actual payment is the current price. Inframarginal bidders, whose expected payment conditional on winning exceeds the current price, may eventually end up winning an object at above the current price.}

\[24\text{To see why a frenzy must arise if the price is lowered continuously, note that for it to be rational for any bidder to jump in and bid first, there must be positive probability that there will be a frenzy large enough to create excess demand immediately following the first bid. Otherwise the strategy of waiting to bid until another player has bid first would guarantee a lower price. For more general seller behavior, the point is that while buyers’ valuations may be very dispersed, higher-valuation buyers are all almost certainly inframarginal in terms of whether to buy and are therefore all solving virtually identical optimization problems of when to buy. So a small change in asking price, or a small change in market conditions (such as the information revealed by a single trade) at a given price, can make a large number of bidders change from being unwilling to trade to wanting to trade. The only selling process that can surely avoid a frenzy is a repeated Dutch auction.}

\[25\text{The price process is also extremely sensitive to bidder valuations; an arbitrarily small}
extensions to the model (e.g., “common values”, the possibility of resale, or an elastic supply of units) tend to accentuate frenzies and crashes. Frenzies and crashes arise precisely because bidders are rational and strategic; by contrast buyer irrationality might lead to “smoother” market behavior.

Of course our main point here is not the details of the process, but rather that the RET permits the solution and analysis of the dynamic price path of a market that would otherwise seem completely intractable to solve for.

3 TRANSLATING LOOSER ANALOGIES FROM AUCTIONS INTO ECONOMICS:
ASCENDING VS. SEALED-BID AUCTIONS

A major focus of auction theory has been contrasting the revenue and efficiency properties of “ascending” and “sealed-bid” auctions.26 Ideas and intuitions developed in these comparisons have wide applicability.

3.1 Internet sales versus dealer sales

There is massive interest in the implications of e-commerce and internet sales. For example, the advent of internet sales in the automobile industry as a partial replacement for traditional methods of selling through dealers has been widely welcomed in Europe;27 the organization of the European automobile market is currently a major policy concern both in official circles and the popular press, and the internet sales are seen as increasing “transparency”. But is transparency a good thing?

26By “sealed-bid” we mean standard first-price sealed-bid auctions. “Ascending” auctions have similar properties to second-price sealed-bid auctions. See Klemperer (1999) for an introduction to the different types of auctions.

27See, for example, “May the net be with you”, Financial Times, 21/10/99, p.22. In the U.K. Vauxhall began selling a limited number of special models over the internet late in 1999, while Ford began a pilot project in Finland.
Auction theory shows that internet sales need not be good for consumers. Clearly transparent prices benefit consumers if they reduce consumers’ search costs so that in effect there are more competitors for every consumer. And of course internet sales may also lower prices by cutting out the fixed costs of dealerships, albeit by also cutting out the additional services that dealers provide. But transparency also makes internet sales more like ascending auctions, by contrast with dealer sales that are more like (first-price) sealed-bid auctions, and we will show this is probably bad for consumers:

Transparent internet prices are readily observable by a firm’s competitors so lead, in effect, to an “ascending” auction; a firm knows if and when its offers are being beaten and can rapidly respond to its competitors’ offers if it wishes. So, viewing each car sale as a separate auction, the price any consumer faces falls until all but one firm quits bidding to sell to him. (The price is, of course, descending because firms are competing to sell, but the process corresponds exactly to the standard ascending auction among bidders competing to buy an object, and we therefore maintain the standard “ascending” terminology.)

On the other hand, shopping to buy a car from one of competing dealers is very like procuring in a (first-price) “sealed-bid” auction. It is typically impossible to credibly communicate one dealer’s offer to another. (Car dealers often deliberately make this hard by refusing to put an offer in writing.) So from the buyer’s perspective it is as if sellers were independently making sealed-bid offers in ignorance of the competition.

Of course, the analogies are imperfect, but they serve as a starting point.

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28There may be both a direct effect (that consumers can observe more firms), and an indirect effect (that new entry is facilitated). See Baye and Morgan (forthcoming) for more discussion. See also Kuhn and Vives (1994).

29This is not a good description of all automobile internet sites. Some U.S. sites merely list contact information without prices so behave more like traditional dealers.

30The analogies are less good for many other products. For lower-value products than cars, internet sales are less like an “ascending” auction since search costs will allow price dispersion, while traditional sales through posted prices in high-street stores are more like...
for analysis. So what does auction theory suggest?

Since, under the conditions of the revenue equivalence theorem, there is no difference between the auction forms for either consumer or producer welfare, we consider the implications of the most important violations of the conditions.

First, market demand is downward sloping, not inelastic.\textsuperscript{31} Hansen (1988) showed that this means consumers always prefer the sealed-bid setting, and firms may prefer it also; the sum of producer and consumer surpluses is always higher in a sealed-bid auction.\textsuperscript{32} The intuition is that in an “ascending” auction the sales price equals the runner-up’s cost, so is less reflective of the winner’s cost than is the sealed-bid price. So the sealed-bid auction is more productively efficient (the quantity traded better reflects the winner’s cost) and provides greater incentive for aggressive bidding (a more aggressive sealed bid not only increases the probability of winning, but also increases the quantity traded contingent on winning).\textsuperscript{33}

Second, we need to consider the possibilities for collusion, implicit or explicit. The general conclusion is that ascending auctions are more susceptible to collusion, and this is particularly the case when, as in our example, many auctions of different car models and different consumers are taking place simultaneously.\textsuperscript{34} As has been observed in the U.S. and German auctions of

\textsuperscript{31}For an individual consumer, demand might be inelastic for a single car up to a reservation price. From the point of view of the sellers who do not know the consumer’s reservation price, the expected market demand is downward sloping.

\textsuperscript{32}Of course, Hansen is maintaining the other important assumptions of the revenue equivalence theorem.

\textsuperscript{33}Because, of course, sealed-bid and ascending auctions correspond to first-price and second-price auctions, respectively.

radiospectrum, for example, bidders may be able to tacitly coordinate on dividing up the spoils in a simultaneous ascending auction. Bidders can use the early rounds when prices are still low\textsuperscript{35} to signal their views about who should win which objects, and then, when consensus has been reached, tacitly agree to stop pushing prices up; sale prices may therefore be well below what would have been achieved if each object had been sold in a single-object auction to the same group of bidders.\textsuperscript{36} The same coordination cannot readily be achieved in simultaneous sealed-bid auctions, where there is neither the opportunity to signal, nor the ability to retaliate against a bidder who fails to cooperate.\textsuperscript{37} The conclusion is less stark when there are many repetitions over time, but it probably remains true that coordination is easier in ascending auctions. Furthermore, as is already well understood in the industrial-organization literature,\textsuperscript{38} this conclusion is strengthened by the different observabilities of internet and dealer sale prices which make mutual understanding of firms’ strategies, including defections from “agreements”, far greater in the internet case. So selling over the internet probably makes it easier for firms to collude.

A third important issue is that bidders may be asymmetric. Then “ascending” auctions are generally more efficient (because the lowest-cost bid-

\textsuperscript{35} Bidders are competing to buy rather than sell spectrum, so prices are ascending rather than descending.

\textsuperscript{36} In a 1999 German spectrum auction 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.” 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 ‘their’ 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. See Jehiel and Moldovanu (2000).

In U.S. FCC auctions, bidders have used the final three digits of multi-million dollar bids to signal the market id codes of the areas they coveted, and a 1997 auction that was expected to raise $1,800 million raised less than $14 million. See Cramton and Schwartz (1999), and “Learning to Play the Game”, The Economist, 17/5/97, p. 120.

\textsuperscript{37} 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.

\textsuperscript{38} At least since Stigler (1964).
ders win\textsuperscript{39}, but sealed-bid auctions typically yield lower consumer prices (because they discriminate somewhat in favor of higher-cost bidders who have lower “virtual costs” when they have the same costs as those of stronger bidders\textsuperscript{40}). In this case economists generally favor ascending auctions, but competition-policy practitioners usually prefer sealed-bid auctions because most competition regimes concentrate on consumer welfare.

Furthermore, this analysis ignores the impact of auction type on new entry in the presence of asymmetries. Because an “ascending” auction is generally efficient, a potential competitor with even a slightly higher cost (or lower quality) than an incumbent will see no point in entering the auction. However, the same competitor might enter a sealed-bid auction which gives a weaker bidder a shot at winning. The extra competition may lower prices very substantially. Of course the entry of the weaker competitor may also slightly reduce efficiency, but if competition is desirable per se, or if competition itself improves efficiency, or if the objective is consumer welfare rather than efficiency, then the case for sealed-bid auctions is very strong.

Although there are other dimensions in which our setting fails the revenue equivalence assumptions, they seem less important.\textsuperscript{41} So the transparency...
induced between firms that makes internet sales more like ascending auctions than sealed-bid auctions is probably bad for consumers. While gains from lower consumer search costs and dealer costs could certainly reverse this conclusion, auction-theoretic considerations mount a strong case against “transparent” internet sales.

3.2 Anglo-Dutch auctions and a Theory of Rationing

The last disadvantage of ascending auctions discussed above—the dampening effect on entry—has been very important in practical auction contexts, for example, the U.S. radiospectrum auctions,42 and the July 2000 Netherlands spectrum auction.43 It was a prominent concern when the U.K. authorities designed an auction of four spectrum licenses for a market which was known to have exactly four strong bidders (and bidders could not be allowed to win more than one license each).44 In this case the design chosen was an “Anglo-Dutch” auction as first proposed in Klemperer (1998),45 in

42In the main (1995) auction of U.S. airwave licenses some large potential bidders such as MCI, the U.S.’s third-largest phone company, failed to enter at all. In addition many bidders were deterred from competing seriously for particular licenses such as the Los Angeles and New York licenses which were sold at prices that most commentateurs thought was very low. See Klemperer and Pagnozzi (2001) for econometric evidence of these kinds of problems in U.S spectrum auctions, Klemperer (1998) and Bulow and Klemperer (2000) for extensive discussion, and Bulow, Huang, and Klemperer (1999) for related modelling.

43The Netherlands third-generation mobile-phone license auction raised little more than one-quarter of the per-capita revenue raised by the equivalent U.K. auction, in large part because the ascending auction discouraged entry. See Klemperer (2000b).

44An auction of four UMTS licenses was planned for financial year 1998/99. The four strong bidders were the four companies who then operated mobile telephone services and therefore had clear advantages over any new entrant. See Klemperer (2000b).

45In an Anglo-Dutch auction for four licenses the price rises continuously until five bidders remain (the “English” stage), after which the five survivors make sealed-bids (required to be no lower than the current price level) and the four winners pay the fourth-highest bid (the “Dutch” stage). See Klemperer (1998, 2000b) and Radiocommunications Agency (1998 a,b) for more details and for variants on the basic design. (The Agency was advised by Binmore, Klemperer and others.) Weak bidders have an incentive to enter the auction because they have a chance of winning if they can survive to be among the five finalists. By attracting additional bidders the price even after the English stage, let alone after the final stage, might be higher than in a pure ascending auction. The design performed very successfully in laboratory testing not only in experiments commissioned by the Radiocom-
which some risk of an ex-post inefficient allocation was deliberately run in
order to increase the chance of attracting the additional bidders that were
necessary for a successful auction and reasonable revenues.\footnote{Note X}  

Translating this idea into a more traditional economics context suggests
a theory of why firms might ration their output at prices at which there is
excess demand as, for example, microprocessor manufacturers routinely do
after the introduction of a new chip.\footnote{Gilbert and Klemperer (2000)}  
Raising the price to clear the market
would correspond to running an ascending auction. It would be ex-post
efficient and ex-post profit maximizing, but would give poor incentives for
weaker potential customers who fear being priced out of the market to make
the investments necessary to enter the market (such as the product design
necessary to use the new chip). Committing to rationing at a fixed price
at which demand exceeds supply is ex-post inefficient,\footnote{We assume any resale is inefficient. But see Cramton, Gibbons and Klemperer (1987).}  
but may encourage
more entry into the market and so improve ex-ante profits. Details are in
Gilbert and Klemperer (2000). Again, this illustrates how an insight that is
routine in auction theory can help develop ideas in economics more broadly.\footnote{A similar point is that a patent race in which all parties can observe others’ progress is akin to an ascending auction. A weaker firm will not be willing to enter the race against a stronger rival who can always observe and overtake him. A race in which rivals’ progress cannot be monitored is more akin to a sealed-bid auction and may attract more entry. Of course there are even closer analogies to different kinds of all-pay auctions.}
4 EXPLOITING DEEPER CONNECTIONS BETWEEN AUCTIONS AND ECONOMICS: MARGINAL REVENUES

The previous sections showed how a variety of economic problems can be thought of in auction-theoretic terms, allowing us to use tools such as the revenue equilibrium theorem and intuitions such as those from the comparison of ascending and sealed-bid auctions. This section explains that the connections between auction theory and standard economic theory run much deeper.

Much of the analysis of optimal auctions can be phrased, like the analysis of monopoly, in terms of “marginal revenues.” Imagine a firm whose demand curve is constructed from an arbitrarily large number of bidders whose values are independently drawn from a bidder’s value distribution. When bidders have independent private values, a bidder’s “marginal revenue” is defined as the marginal revenue of this firm at the price that equals the bidder’s actual value. See Figure 1.\textsuperscript{50}

Although it had been hinted at before,\textsuperscript{51} the key point was first explicitly drawn out by Bulow and Roberts (1989) who showed that under the assumptions of the revenue equivalence theorem the expected revenue from an auction equals the expected marginal revenue of the winning bidder(s). The new results in the article were few—the paper largely mimicked Myerson (1981) while renaming Myerson’s concept of “virtual utility” as “marginal

\textsuperscript{50}The point of this construction is particularly clear when a seller faces a single bidder whose private value is distributed according to $F(v)$. Then setting a take-it-or-leave-it price of $v$ yields expected sales, or “demand”, $1 - F(v)$, expected revenue of $v(1 - F(v))$ and expected marginal revenue \( \frac{d(q_v)}{dq} = v - \frac{1 - F(v)}{F(v)} \). See Appendix B of Klemperer (1999).

\textsuperscript{51}For example, Mussa and Rosen’s (1978) analysis of monopoly and product quality contained expressions for “marginal revenue” that look like Myerson’s.
revenue but their contribution was nevertheless important. Once the
connection had been made it was possible to take ways of thinking that are
second-nature to economists from the standard theory of monopoly pricing
and apply them to auction theory.

For example, once the basic result above (that an auction’s expected
revenue equals the winning bidder’s expected marginal revenue) was seen,
Bulow and Klemperer (1996) were able to use a simple monopoly diagram
to derive it both more simply and under a broader class of assumptions then
had previously been done by Myerson or Bulow and Roberts. Bulow and
Klemperer also used standard monopoly intuition to derive additional results
in auction theory.

The main benefits from the marginal-revenue connection come from trans-
lating ideas from monopoly analysis into auction analysis, since most economists’
intuition for and understanding of monopoly is much more highly developed
than for auctions. But it is possible to go in the other direction too, from
auction theory to monopoly theory.

52Myerson’s results initially seemed unfamiliar to economists in part because his basic
analysis expressed virtual utilities as a function of bidders’ values, which correspond to
prices, and so computed revenues by integrating along the vertical axis, whereas we usually
solve monopoly problems by expressing marginal revenues as functions of quantities and
integrating along the horizontal axis of the standard (for monopoly) picture.

53Bulow and Roberts emphasize the close parallel between a monopolist third-
degree price-discriminating across markets with different demand curves, and an
auctioneer selling to bidders whose valuations are drawn from different distribu-
tions. For the monopolist auctioneer, \( \text{revenue} = \text{expected revenue} \) is maximised by selling to
the consumer bidder with the highest marginal revenue(s), not necessarily the high-
est value(s), subject to never selling to a consumer bidder with marginal revenue less
than the monopolist’s marginal cost auctioneer’s own valuation, assuming (i) resale can be prohibited,
(ii) credible commitment can be made to no future sales sticking to any reserve price, and (iii)
marginal revenue curves are all downward sloping
\( \text{higher ‘types’ of any bidder have higher marginal revenues than lower ‘types’ of the same bidder} \),
etc.

54See Appendix B of Klemperer (1999) for an exposition.
Consider, for example, the main result of Bulow and Klemperer (1996):

Proposition (Auction-Theoretic Version) An optimal auction of $K$ units to $Q$ bidders earns less profit than a simple ascending auction (without a reserve price) of $K$ units to $Q + K$ bidders, assuming (a) bidders are symmetric, (b) bidders are serious (that is, their lowest-possible valuations exceed the seller’s supply cost), and (c) bidders with higher valuations have higher marginal revenues.\footnote{See Bulow and Klemperer (1996) for a precise statement. We do not require bidders’ valuations to be private, but do place some restrictions on the class of possible mechanisms from which the “optimal” one is selected, if bidders are not risk-neutral or their signals are not independent. We assume bidders demand a single unit each.}


Application One application is to selling a firm (so $K = 1$). Since the seller can always resort to an ascending auction, attracting a single additional bidder is worth more than any amount of negotiating skill or bargaining power against an existing bidder or bidders, under reasonable assumptions. So there is little justification for, for example, accepting a “lock-up” bid for a company without fully exploring the interest of alternative possible purchasers.

The optimal auction translates, for large $Q$ and $K$, to the monopolist’s optimum. An ascending auction translates to the competitive outcome, in which price-taking firms make positive profits only because of the fixed supply of units. (An ascending auction yields the $K + 1st$ highest value among the bidders; in a perfectly-competitive market an inelastic supply of $K$ units is in equilibrium with demand at any price between the $K^{th}$ and $K + 1st$ highest value, but the distinction is unimportant for large $K$.) So one way of expressing the result in the market context is

Proposition (Monopoly-Theoretic Version) A perfectly-competitive industry with (fixed) capacity $K$ and $Q$ consumers would gain less by fully cartelis-
ing the industry (and charging the monopoly price) than it would gain by attracting $K$ new potential customers into the industry with no change in the intensity of competition, assuming (a') the $K$ new potential consumers have the same distribution of valuations as the existing consumers, (b') all consumers' valuations for the product exceed sellers' supply costs (up to sellers' capacity), and (c') the marginal-revenue curve constructed from the market-demand curve is downward sloping.$^{56}$

*Proof* No proof is required—the proposition is implied by the auction-theoretic version—but once we know the result we are looking for and the necessary assumptions, it is very simple to prove it directly using introductory undergraduate economics and we do this in a brief Appendix 2.

*Application* One application is that this provides conditions under which a joint-marketing agency does better to focus on actually marketing rather than (as some of the industrial organization literature suggests) on facilitating collusive practices.$^{57}$

5 APPLYING AUCTION THEORY TO PRICE-SETTING Oligopolies

We have stressed the applications of auction theory to contexts that might not be thought of as auctions, but even though price-setting oligopolies are obviously auctions, the insights that can be obtained by thinking of them in this way are often passed by.

5.1 Marginal-Cost Pricing is NOT the Unique Bertrand Equilibrium

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$^{56}$We are measuring capacity in units such that each consumer demands a single unit of output. Appendix 2 makes it clear how the result generalizes.

$^{57}$Of course the agency may wish to pursue both strategies in practice.
One of the most famous results in economics is the “Bertrand paradox” that with just two firms with constant and equal marginal costs in a homogeneous-products industry the unique equilibrium is for both firms to set price equal to marginal cost and firms earn zero profit. This “theorem” is widely quoted in standard texts. But it is false. There are other equilibria with large profits, for some standard demand curves, a fact that seems until recently to have been known only to a few auction theorists.\footnote{\textsuperscript{58}We assume firms can choose any prices. It is well known that if prices can only be quoted in whole pennies, there is an equilibrium with positive (but small) profits in which each firm charges one penny above cost. (With perfectly inelastic demand, there is also an equilibrium in which each firm charges two pennies above cost.)}

Auction theorists are familiar with the fact that a boundary-condition is necessary to solve a sealed-bid auction. Usually this is imposed by assuming no bidder can bid less than any bidder’s lowest-possible valuation, but there are generally a continuum of equilibria if arbitrarily negative bids are permitted.\footnote{\textsuperscript{59}For example, if each of two risk-neutral bidders’ private values is independently drawn from a uniform distribution on the open interval \((0, 1)\) then for any non-negative \(k\) there is an equilibrium in which a player with value \(v\) bids \(\frac{v}{2} - \frac{k}{p}\). If it is common knowledge that both bidders have value zero, there is an equilibrium in which each player bids below \(-p\) with probability \(\frac{k}{p}\), for any non-negative \(k\).} Exactly conversely, with perfectly-inelastic demand for one unit and, for example, two risk-neutral sellers with zero costs, it is a mixed-strategy equilibrium for each firm to bid above price \(p\) with probability \(\frac{k}{p}\), for any given \(k\). (Each firm therefore faces constant elasticity \(-1\) expected residual demand, and is therefore indifferent about mixing in this way; profits are \(k\) per firm.)

It is not hard to see that a similar construction is possible with downward-sloping demand, for example, standard constant-elasticity demand, provided that monopoly profits are unbounded. (See especially, Baye and Morgan (1997, 1999a)). One point of view is that the non-uniqueness of the “Bertrand paradox” equilibrium is a merely technical point since it requires “unreasonable” (even though often assumed\footnote{\textsuperscript{60}This demand can, for example, yield unique and finite-profit Cournot equilibrium.}) demand. However, the con-
struction immediately suggests another more important result: quite generally (including for demand which becomes zero at some finite choke price) there are very profitable mixed-strategy ε-equilibria to the Bertrand game, even though there are no pure-strategy ε-equilibria. That is, there are mixed strategies that are very different from marginal-cost pricing in which no player can gain more than a very small amount, ε, by deviating from the strategies.\footnote{Of course, the concept of mixed-strategy ε equilibrium used here is even more contentious than either mixed-strategy (Nash) equilibria or (pure-strategy) ε equilibrium. The best defense for it may be its practical usefulness.} (There are also “quantal response” equilibria with a similar flavor.) Experimental evidence suggests that these strategies may be empirically relevant. (See Baye and Morgan (1999b).)

5.2 The Value of New Consumers

The Revenue Equivalence Theorem (RET) can of course be applied to price-setting oligopolies.\footnote{As another example, Vives (1999) uses the Revenue Equivalence Theorem to compare price-setting oligopoly equilibria with incomplete and complete (or shared) information about firms’ constant marginal costs, and so shows information sharing is socially undesirable in this context.}

For example: what is the value of new consumers in a market with strong brand loyalty? If firms can price discriminate between new uncommitted consumers and old “locked-in” consumers, Bertrand competition for the former will mean their value is low, but what if price discrimination is impossible?

In particular, it is often argued that new youth smokers are very valuable to the tobacco industry because brand loyalty (as well as loyalty to the product) is very high (only about 10 per cent of smokers switch brands in any year), so price-cost margins on all consumers are very high. Is there any truth to this view?

The answer, of course, under appropriate assumptions, is that the RET implies that the ability to price discriminate is irrelevant to the value of the
new consumers. (See the discussion in Section 2.) With price discrimination, we can model the oligopolists as acting as monopolists against their old customers, and as being in an “ascending” price auction for the uncommitted consumers with the firm which is prepared to price the lowest selling to all these consumers at the cost of the runner-up firm. Alternatively, we can model the oligopolists as making sealed bids for the uncommitted consumers with the lowest bidder selling to these consumers at its asking price. The expected profits are the same under the RET assumptions. (See Section 3.1 for the effects of dropping these assumptions.) Absent price discrimination, a natural model is the latter one, but in addition each oligopolist must discount its price to its own locked-in customers down to the price it bids for the uncommitted consumers. The RET tells us that the total cost to the industry of these “discounts” to old consumers will on average precisely compensate the higher sale price achieved on new consumers. That is, the net value to the industry of the new consumers is exactly as if there was Bertrand competition for them, even when the inability to price discriminate prevents this.

So Bulow and Klemperer (1998) argue that the economic importance

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63 The price is descending because the oligopolists are competing to sell rather than buy, but it corresponds to an ascending auction in which firms are competing to buy, and we stick with this terminology as in Section 3.1.

64 Specifically let \( n \) “old” consumers be attached to each firm \( i \), and firms’ costs \( c_i \) be independently drawn from a common, strictly-increasing, atomless distribution. There are \( m \) “new” consumers who will buy from the cheapest firm. All consumers have reservation price \( r \).

Think of firms competing for the prize of selling to the new consumers, worth \( m(r - c_i) \) to firm \( i \). Firms set prices \( p_i = r - d_i \) to “new” consumers; equivalently they set “discounts” \( d_i \) to consumers’ reservation prices. If price discrimination is feasible, the winner pays \( md_i \) for the prize and all firms sell to their old consumers at \( r \). Absent price discrimination, the prices \( p_i \) apply to all firms’ sales, so relative to selling just to old consumers at price \( r \), the winner pays \( (m + n) d_i \) for the prize and the losers pay \( nd_i \) each.

For the usual reasons, the two sets of payment rules are revenue equivalent. For more discussion of this result, including its robustness to multi-period contexts, see Bulow and Klemperer (1998); if the total demand of new consumers is more elastic, their economic value will be somewhat less than our model suggests; for a fuller discussion of the effects of “brand loyalty” or “switching costs” in oligopoly see, especially, Klemperer (1987a, 1987b, 1995) and Beggs and Klemperer (1992).
to the tobacco companies of the youth market is actually very tiny, even though from an accounting perspective new consumers appear as valuable as any others.\textsuperscript{65}

Similarly the value of a free-trading market to firms each of which has a protected home market is independent of whether the firms can price discriminate between markets.\textsuperscript{66}

Section 3.1’s discussion of oligopolistic e-competition develops this kind of analysis further by considering implications of failures of the RET.

5.3 Information Aggregation in Perfect Competition

Although the examples above, and in Section 3, suggest auction theory has been underused in analyzing oligopolistic competition, it has been very important in influencing economists’ ideas about the limit as the number of firms becomes large.

An important strand of the auction literature has focused on the properties of pure-common-value auctions as the number of bidders becomes large, and asked: does the sale price converge to the true value, thus fully aggregating all of the economy’s information even though each bidder has only partial information? Wilson (1977) and Milgrom (1979) showed assumptions under which the answer is “yes” for a sealed-bid auction, and Milgrom (1981) obtained similar results for a second-price auction (or for a $(k + 1)^{th}$ price auction for $k$ objects).\textsuperscript{67} So these models justify some of our ideas about perfect competition.

\textsuperscript{65}If industry executives seem to value the youth segment, it is probably due more to concern for their own future jobs than concern for their shareholders.

\textsuperscript{66}See also Rosenthal (1980).

\textsuperscript{67}Matthews (1984), on the other hand, showed that the (first-price) sale price does not in general converge to the true value when each bidder can acquire information at a cost. Pesendorfer and Swinkels (1997) recently breathed new life into this literature, by showing convergence under weaker assumptions than previously if the number of objects for sale, as well as the number of bidders, becomes large. See also Pesendorfer and Swinkels (forthcoming), and see Swinkels (forthcoming) for related results about private-value auctions.
6 APPLYING AUCTION THEORY (AND ECONOMICS) TO AUCTION MARKETS

Finally, although it has not always been grasped by practitioners, some markets are literally auctions. The increasing recognition that many real markets are best understood through the lens of auction theory has stimulated a burst of new theorizing, and created the new subject of market design that stands in similar relation to auction theory as engineering does to physics.

We very briefly mention the most important auction markets.

6.1 Electricity Markets

It was not initially well-understood that deregulated electricity markets, such as in the U.K., are best described and analysed as auctions of infinitely-divisible quantities of homogeneous units. Although much of the early analysis of the U.K. market was based on Klemperer and Meyer (1989), which explicitly followed Wilson’s (1979) seminal contribution to multi-unit auctions, the Klemperer and Meyer model was not thought of as an ”auctions” paper and only recently received much attention among auction theorists. Indeed von der Fehr and Harbord (1993) were seen as rather novel in pointing out that the new electricity markets could be viewed as auctions. Now, however, it is uncontroversial that these markets are best understood through auction theory, and electricity market design has become the province of leading auction theorists, such as Wilson, who have been very

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68 especially on multi-unit auctions in which bidders are not restricted to winning a single unit each, since most markets are of this kind.

69 von der Fehr and Harbord (1998) provide a useful overview of electricity markets.

70 Klemperer and Meyer (1989) was couched as a traditional industrial organization study of the question of whether competition is more like Bertrand or Cournot, following Klemperer and Meyer (1986).
influential.\footnote{[note E] At the same time more standard auction markets may be falling a little out of favour. The New Electricity Trading Arrangements proposed for the U.K. will emphasize bilateral trading more and an auction pool less.}

6.2 Treasury Auctions

Treasury bill auctions, like electricity markets, trade a divisible homogeneous good, but the two settings present an interesting contrast.

Although treasury auctions have always been clearly understood to be “auctions”, auction theorists have never been as influential as they now are in energy markets. In part this is because the treasury auctions predated any relevant theory,\footnote{By contrast, the current U.K. government sales of gold are a new development, and the National Audit Office has now consulted auction theorists (including myself) about the sale method.} and the auctions seemed not to have serious problems. In part it may be because no clear view has emerged about the best form of auction to use. (Indeed one possibility is that the differences between the main types of auction may not be too important in this context.\footnote{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), Reinhart and Balzer (1996), andAusubel and Cramton (1998). The broader empirical literature is also inconclusive.}) This is in spite of the fact that the existing auction theory is probably even more relevant to treasury markets than to electricity markets where the very high frequency of repetition among market participants who have stable and predictable requirements makes the theory of collusion in repeated games also very relevant.\footnote{Another important non auction-theoretic issue is the nature of the game the major}
In a further interesting contrast the U.K. electricity market—the first major market in the world to be deregulated and run as an auction—was set up as a uniform price auction, but its perceived poor performance\textsuperscript{75} has led to a planned switch to an exchange market followed by a discriminatory auction.\textsuperscript{76} Meanwhile the vast majority of the world’s treasury bill markets have until recently been run as discriminatory auctions,\textsuperscript{77} but the U.S. switched to uniform price auctions in late 1998 and several other countries have been experimenting with these.\textsuperscript{78} A possible justification is that it seems less likely in a treasury market than in an electricity market that bidders in a uniform-price auction can successfully coordinate on submitting “implicitly collusive” bidding schedules.\textsuperscript{79} However, it seems there can be no general explanation for this difference.

\textsuperscript{75}See note E.

\textsuperscript{76}In a uniform price auction every bidder pays the same price, usually the lowest winning price or the highest losing price, for every unit. In a discriminatory auctions bidders pay the prices they actually bid (and a bidder may bid and pay different prices for the first unit won, the second unit won, etc.) When bidders each buy at most one unit each discriminatory auctions correspond to standard (first-price) sealed-bid auctions, while the uniform highest-losing price auction then corresponds to a second-price auction (the properties of which are similar to those of an ascending auction). See Klemperer (1999).

\textsuperscript{77}Of 42 countries surveyed by Bartolini and Cottarelli (1997), only Denmark and Nigeria used uniform price auctions.

\textsuperscript{78}The most prominent advocates of a switch to uniform price auctions were Merton Miller and Milton Friedman. Ausubel (1998) proposes a switch to an ascending-bid auction whose static representation is the Vickrey auction.

\textsuperscript{79}By “implicit collusion” we mean that bidders implicitly agree to divide up the market at a very favourable price for them (in a static Nash equilibrium) by each bidding extremely aggressively for smaller quantities than its equilibrium share so deterring other bidders from bidding for more.

The industry regulator believes the U.K. electricity market has fallen prey to exactly this problem. (See Office of Gas and Electricity Markets (1999), pages 173-4.) Treasury markets typically have a greater number of significant bidders (in the U.K. three companies have about two-thirds of the industry capacity, but most of the remaining capacity is gas or nuclear so these three players set the (uniform) market price a far higher proportion of the time, see Wolfram (1998) and Newbery (1998)), the bidders are less capacity constrained, the markets are less frequently repeated (the U.K. electricity market is currently run daily, but will be run half-hourly under the new trading arrangements) and new entry is typically easier, than in the electricity market.

Implicit collusion is harder in a discriminatory auction because bidders receive the price
conclusion that either form of auction is best either for all electricity markets or for all treasury markets.80

6.3 Spectrum Auctions

Academics were involved at all stages of the radiospectrum auctions from suggesting the original designs to advising bidders on their strategies. The original U.S. proponents of an auction format81 saw it as a complex environment that needed academic input, and a pattern of using academic consultants was set in the U.S. and spread to other countries. The dominant design has been the simultaneous ascending auction which was originally sketched by Vickrey (1976), and proposed and developed by McAfee, Milgrom and Wilson for the U.S. auctions.82 Although some problems have emerged, primarily its susceptibility to collusion and its inhospitality to entry, discussed in Section 3.2 above,83 it has generally been considered a success in most of

80 Other important issues include incentives for other forms of collusion, for entry (which may be best encouraged by either uniform or discriminatory auctions depending on the context), and (in the case of electricity) for vertical integration; the interaction with prior markets, and (in the case of treasury bills) with subsequent “when issued” markets; and maintaining the efficiency of the electricity market (Ausubel and Cramton (1996) show this objective has ambiguous implications). See Klemperer (1999b).

81 Evan Kwerel was especially important.


83 A third important problem with the early U.S. auctions (though one that had nothing to do with their basic design) is that they required little or no [be precise] payment up front so undercapitalized new firms could declare bankruptcy and default on their purchases.
its applications, and the U.S. experience directly led to similar auctions in other countries.\textsuperscript{84}

The possibility of complementarities between licenses was a large part of the motivation for the U.S. design, but it is unproven either that the design was especially helpful in allowing bidders to aggregate efficient packages, or that it would work well if complementarities were critical.\textsuperscript{85} Ironically, the simultaneous ascending auction is most attractive when each of an exogenously fixed number of bidders has a privately-known value for each of a collection of heterogenous objects, but (contrary to the U.S. case) is restricted to buying at most a single license. In this case entry is not an issue, collusion is very unlikely, and the unique Nash equilibrium of the game is efficient. For this reason a version of the simultaneous ascending auction was designed by Binmore and Klemperer for the U.K. auctions (in which each bidder was restricted to a single license) after concerns about entry had been laid to rest.\textsuperscript{86}

after the auction at very little cost to themselves. Uncapitalized entrants were in effect bidding for an option to purchase a license rather than for a license itself, and this gave them a large advantage over established firms who could not just declare bankruptcy if the purchase seemed unprofitable ex post. So entry was attracted, but of the wrong kind. See, for example, Board (1999) and Zheng (1999).

\textsuperscript{84}See Klemperer (2000b) for discussion of the recent European spectrum auctions. The U.S. spectrum auctions also focused theoretical attention on the difficulties when multiple heterogenous objects are being auctioned, but few general results have yet been obtained. Dasgupta and Maskin (1998) exhibit a form of ascending auction that achieves efficiency in a wide variety of multi-unit settings when each bidder’s signal is one-dimensional, but Jehiel and Moldovanu (1998) emphasize the general impossibility of achieving efficiency. (See also Perry and Reny 1998) and Ausubel (1997, forthcoming).\textsuperscript{85} Complementarities may not have been very large in the U.S. case. See Ausubel, Cramton, McAfee and McMillan (1997) for an estimate. See also Klemperer and Pagnozzi (2001) who show...\textsuperscript{86}See Section 3.2 (including note X) and especially Klemperer (2000b) for further discussion.
6.4 Internet Markets

Many other new auction markets are currently being created using the Internet, such as the online consumer auctions run by eBay, Amazon and others which have over 10 million customers, and the business-to-business autoparts auctions being planned by General Motors, Ford and Daimler-Chrysler which is expected to handle $250 million in transactions a year. Here too auction theorists have been in heavy demand, and there is considerable ongoing experimentation with different auctions forms.

6.5 Applying Economics to Auction Design

While many economic markets are now fruitfully analysed as auctions, the most significant problems in auction markets and auction design are probably those with which industry regulators and competition authorities have traditionally been concerned—discouraging collusive, predatory and entry-deterrent behaviour, and analysing the merits of mergers or other changes to market structure.

This contrasts with most of the auction literature which focuses on Nash-equilibria in one-shot games with a fixed number of bidders, and emphasises issues such as the effects of risk-aversion, correlation of information, budget-constraints, complementarities, asymmetries, etc. While these are also important topics—and auction theorists have made important progress on them which other economic theory can learn from—they are probably not as important.

Although the relative thinness of the auction-theoretic literature on collusion and entry deterrence may be defensible to the extent general economic principles apply, there is a real danger, illustrated by the examples discussed
above, that auction theorists will underemphasize these problems in applications. In particular, ascending, second-price, and uniform-price auction forms, while attractive in many auction theorists’ models, are more vulnerable to collusive and predatory behaviour than first-price and hybrid forms.\textsuperscript{87}

While auction theorists are justly proud of how much they can teach economics, they must not forget that the classical lessons of economics continue to apply.

7 CONCLUSION

Auction theory is a central part of economics. Situations that do not at first sight look like auctions can be recast to use auction-theoretic techniques, and insights and intuitions from auction theory can find fertile application in other contexts. Furthermore the design and analysis of many markets is best performed using the tools and methodology of auction theory.

\textsuperscript{87}Sections 6.2, 6.3, and 3.1 illustrate the problems with ascending auctions. Section 3.2 describes how the hybrid Anglo-Dutch auction form can overcome these problems. See Klemperer (2000b) for extensive discussion of these issues, and their application to recent mobile-phone license auctions.
Appendix 1. Comparing Litigation Systems

Assume that after transfers between the parties, the loser ends up paying fraction $\alpha \geq 0$ of his own expenses and fraction $\beta \leq 1$ of his opponent’s. (The winner pays the remainder.) So the American system is $\alpha = 1, \beta = 0$, the British system is $\alpha = \beta = 1$, the Netherlands system is roughly, $\alpha = 1, 0 < \beta < 1$, and Quayle’s is $\alpha = 2, \beta = 0$. It is also interesting to consider a “reverse-Quayle” rule $\alpha = 1, \beta < 0$ in which both parties pay their own expenses but the winner transfers an amount proportional to her own expenses to the loser. Let $L$ be the average legal expenses spent per player.

The following slight generalization of the RET is the key: assuming the conditions of the RET all hold except for assumption (ii) (that is, the expected surplus of a bidder with the lowest-feasible valuation, say $S$, may not be zero), it remains true that the expected surplus of any other types of bidder is a fixed amount above $S$. (See, for example, Klemperer (1999, Appendix A); the fixed amount depends on the distribution of the parties’ valuations, but unlike $S$ and $L$ does not depend on the mechanism $\{\alpha, \beta\}$.)

It follows that the average bidder surplus is $S$ plus a constant. But the average bidder surplus equals the average lawsuit winnings (expectation of {probability of winning}$ \times $ {valuation}) minus $L$, equals a constant minus $L$ by assumption (i) of the RET. So $S = K - L$ in which $K$ is a constant independent of $\alpha$ and $\beta$. But since the lowest-valuation type always loses in equilibrium (by assumption (i) of the RET) she bids zero so $S = -\beta L$ because in a one-shot game her opponent, on average, incurs expenses of $L$. Solving, $L = \frac{K}{1-\beta}$ and the surplus of any given party is a constant minus $\frac{\beta K}{1-\beta}$.

It follows that both expected total expenses and any party’s expected
payoff are invariant to $\alpha$, hence the remarks in the text about the Quayle proposal. But legal expenses are increasing in $\beta$, indeed become unbounded in the limit corresponding to the British system. So the optimal mechanism is the reverse-Quayle. The intuition is that it both increases the marginal cost of spending on a lawsuit and reduces the value of winning the suit. On the other hand, of course, bringing lawsuits becomes more attractive as $\beta$ falls.


The proof rests precisely on the assumptions (a'), (b'), and (c'). Without loss of generality let firms’ marginal costs be flat up to capacity, and consider what would be the marginal revenue curve for the market if the $K$ new consumers were attracted into it (see Figure 2).

A monopolist on this (expanded) market would earn area $A$ in profits, that is, the area between the marginal revenue and marginal cost curves up to the monopoly point, $M$. The perfectly competitive industry in the same (expanded) market would earn $\Pi^c = A - B$, that is, the integral of marginal revenue less marginal cost up to industry capacity, $K$. By assumption (a'), a monopolist (or fully cartelized industry) in the original market would earn $\Pi^M = \left(\frac{Q}{Q+K}\right)A$. Now the average marginal revenue up to quantity $Q + K$ equals the price at demand $Q + K$ (because total marginal revenue = price \times quantity), which exceeds marginal cost by assumption (b'), so

\[\text{If the industry cost curve is not flat up to the capacity, then use the argument in the text to prove the result for a cost curve that is flat and everywhere weakly above the actual cost curve. A fortiori, this proves the result for the actual curve, since a monopoly saves less from a lower cost curve than a competitive industry saves from the lower cost curve.}\]
\( B + C \leq A \). Furthermore, by assumption \((c')\), and elementary geometry,

\[
B \leq \left(\frac{K-M}{(Q+K)-M}\right) (B + C). \quad \text{So } B \leq \left(\frac{K-M}{Q+K-M}\right) A, \text{ and therefore } \Pi^c = A - B \\
\geq \left(\frac{Q}{Q+K-M}\right) A \geq \Pi^M, \text{ as required.} 
\]
Marginal revenue of bidder with value $v$ drawn from distribution $F(v)$ on $[\underline{v}, \bar{v}]$.

FIGURE 1

Construction of marginal revenue of bidder with value $\tilde{v}$.
FIGURE 2: Marginal Revenue if Demand is Expanded
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41


Pesendorfer, W. and Swinkels, J. M. (forthcoming)


Swinkels, J. M. (forthcoming) *Econometrica*


WHAT REALLY MATTERS
IN
AUCTION DESIGN
updated versions of this discussion paper will appear at
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PRELIMINARY DRAFT: PLEASE SEND COMMENTS

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 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 and
the Netherlands.

Auction design is a matter of “horses for courses”, not “one size fits all”.
1. Introduction
2. Collusion
3. Entry Deterrence and Predation
4. Solving the Problems: the Anglo-Dutch Auction
5. The U.K. and Netherlands Mobile-Phone License Auction
6. Market Structure and the German Mobile-Phone License Auction
7. Conclusion
References © Paul Klemperer, 2000
JEL Nos D44 (Auctions) L41 (Antitrust) L96 (Telecommunications)

1Disclaimer: I was the principal auction theorist advising the U.K. government’s Radiocom-
munications 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 aca-
demic 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 own¹ 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 literature²—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

¹Klemperer (1999).
²The most important contributions to the economics literature on auctions are collected in Klemperer (2000).
³In 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

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4The 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 ≈ 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.

5For 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. That is, bidders can tacitly agree to divide up the market at a very favourable

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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 Marshalltown, 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.


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,

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7See 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.


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

9Whether 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 (2000).

10It 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 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. The difficulty was that neither of the potential bidders wished to enter an auction that they expected to lose. The general perception was that there were particular synergies that made Wellcome worth a

\footnote{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.}

\footnote{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.)}
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 exacerbated, 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 has overestimated the prize’s value. 17 So in an ascending auction a bidder

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13 Financial Times 8/3/95 p. 32.
14 Glaxo’s own fees were reported to be £30 million net of stamp duty.
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.
17 That is, firms’ bids are very strongly “strategic substitutes” in the terminology of
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.\footnote{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.} The auction was an ascending auction.\footnote{More precisely, it was a simultaneous ascending auction, but this does not affect our argument.} The result was that although some other firms did enter the auction and made some bids,\footnote{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.} the bidding stopped at a price that most commentators thought was very low relative to the prices of other licenses where the auction was more symmetric.\footnote{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...}

Bulow, Geanakoplos and Klemperer (1985). The point in this paragraph was first made by Bikhchandani (1988), and emphasised in these contexts by Klemperer (1998).
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”, and Pacific Telephone both said “if somebody takes California away from us, they’ll never make any money” 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.

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, 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 advantage in the auction, and spent 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).

22Financial Times 8/3/95 p. 32.
24Note 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 competitors might correspond to hiring an industrial economist to explain the theory of the difficulties entering new markets to potential entrants.
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.\textsuperscript{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”\textsuperscript{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.\textsuperscript{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.\textsuperscript{28}

These are all examples of ascending auctions. Although an advantaged 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. 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.

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 of the prize is the only objective. In particular, raising revenue should be an additional objective for a government, because of the substantial deadweight

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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 than in asymmetric ascending auctions see Klemperer (1998), Section 6.1.
losses of raising government funds through alternative methods.\textsuperscript{31,32}

4. Solving the Problems: the Anglo-Dutch Auction\textsuperscript{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.\textsuperscript{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\textsuperscript{36} if collusion and predation are absent.

So what should an auction designer do?

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”\textsuperscript{37},

\textsuperscript{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.

\textsuperscript{32}Note that first-price sealed-bid and discriminatory auctions (which are in some ways analogous—see note \textsuperscript{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 \textsuperscript{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 \textit{not} claim that sealed-bid style auctions always dominate ascending style auctions in this respect.

\textsuperscript{33}The Anglo-Dutch auction was first described and proposed in Klemperer (1998).

\textsuperscript{34}At least among the bidders who show up. This is true even in many “common-values” settings. See Maskin (1992).

\textsuperscript{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 Cranton, Gibbons, and Klemperer (1987).

\textsuperscript{36}Milgrom and Weber (1982) show this is true if information is “affiliated”.

\textsuperscript{37}Ascending and sealed-bid auctions are sometimes called English and Dutch auctions, respectively. Hence the name “Anglo-Dutch”.
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 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.
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 collusion much harder than in a pure ascending auction;\textsuperscript{38} because the sealed-bid stage allows firms to reneg on any tacit deals without fear of retaliation, they are unlikely to make such deals in the first place.\textsuperscript{39, 40}

Analysis of other factors suggests that the Anglo-Dutch may have additional merits. In particular, the ascending stage 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\textsuperscript{41} and making bidders more comfortable with their own assessments. At the same time 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. These effects apply even if the Anglo-Dutch auction attracts no more bidders into the market.\textsuperscript{42}

In short, the Anglo-Dutch auction often combines the best of both the ascending and the sealed-bid worlds.\textsuperscript{43}

\textsuperscript{38}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.

\textsuperscript{39}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.

\textsuperscript{40}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.

\textsuperscript{41}Milgrom and Weber (1982) shows the information revealed raises expected revenues if bidders’ information is “affiliated”.

\textsuperscript{42}However, the effects in this paragraph are conjectures that need further research to confirm.

\textsuperscript{43}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
5. The U.K. and Netherlands Mobile-Phone License Auctions

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 meant the designers were very concerned that an ascending auction might deter new firms from bidding strongly in the auction, or even from entering the auction at all. 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. The design 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.

I was the principal auction theorist advising the Radiocommunications 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.

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.

[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.

In this case it was proposed that all four winners would pay the fourth-highest sealed
performed extremely well in laboratory experiments commissioned by the Radiocommunications Agency.\textsuperscript{48}

However, when it became possible to auction five licences, a straightforward ascending auction was no longer counterindicated, even though there were non-trivial entry costs and relatively few potential bidders:\textsuperscript{49} Because 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.\textsuperscript{50} So the problems of collusion and entry deterrence that this paper has emphasised were minimal in the U.K. context, and other considerations

\textsuperscript{48}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].

\textsuperscript{49}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), Reinhart and Belzer (1996), and Ausubel and Cramton (1998). The broader empirical literature is also inconclusive. See Klemperer (2000b) for more discussion.

\textsuperscript{50}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.
militated towards an ascending design.\footnote{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.}

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 ($34 billion) revenues.

However, given the importance of the relationship between the number of incumbents and the number of licenses, the Netherlands plan to follow the actual British design was ill-conceived since there were five incumbent operators and five licenses in the Netherlands. It was not hard to predict (indeed the first draft of this paper, written two months prior to the auction \textit{did} predict) that very few entrants would show up. Recognizing their weak positions, the potential new entrants made deals with incumbent operators, and Netherlands competition policy was as disfunctional 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.\footnote{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.} In the end there was just one relatively weak entrant (Versatel) to compete with the five incumbents for the five licenses. Not surprisingly, the auction finally raised less than one
third of the per-capita revenue of the U.K. auction, that is, only $2.5 billion, rather than the almost $8.5 billion the Dutch government had forecast based on the U.K. experience.

6. Market Structure and the German Mobile-Phone License Auction

In addition to addressing 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. In many auctions, such as those of oil, gold, financial instruments, etc., there is no issue about market structure. But when creating a new industry, its structure is crucial. For example, when auctioning radiospectrum for third generation mobile-phone services, auction designers must consider the competitiveness of the mobile-phone market that will be created by the auction.\(^{53}\) Simply “letting the market decide” will bias the auction’s result towards too few winners each of whom will win too much spectrum, since outcomes are driven by bidders’ profits, not by final-consumers’ surplus, and bidders’ joint profits are maximised by a monopoly over radiospectrum.\(^{54}\)

This is the critical defect of the planned German mobile-phone license auction in which the number of winners is endogenous. Germany plans to auction twelve blocks of spectrum from which bidders can create “licenses” of either two or three blocks (e.g. four firms could win large 3-block licenses

\(^{53}\)Similarly, the most important issues for the competition authorities in regulating the sale of football TV rights are: What packages are sold?, and How many packages is a single broadcaster allowed to win?

\(^{54}\)Though the “demand-reduction” effect emphasised by Ausubel and Cramton (1998) mitigates the bias.
or six firms could win smaller 2-block licenses), so the German government has risked obtaining an overly concentrated mobile-phone market.\footnote{See Jehiel and Moldovanu (2000a) and the references therein for more discussion of the German auction, and Jehiel and Moldovanu (2000b) for some more general analysis of license auctions and market structure.}

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, 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. and Netherlands 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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