SPECTRUM AUCTIONS VERSUS BEAUTY CONTESTS: COSTS AND BENEFITS

Andrea Prat (London School of Economics, Tilburg University and CEPR)

and

Tommaso Valletti (Imperial College, Politecnico di Torino and CEPR)

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1. Main Points

The purpose of this report is twofold. It summarises the main lessons learnt in the use and design of spectrum assignments. The report also compares the benefits and costs of licence assignment through auctions compared to beauty contests.

The report is structured as follows. After the Introduction (Section 2), Section 2 contains an overview of auction theory, stressing auction design, for one object and for multiple objects (Section 3). The goal is not to give a complete picture but rather to touch on the issues that in practice matter most for spectrum allocation. Then, the report examines the benefits and costs of auctions to allocate spectrum as compared with the traditional mechanism of competitive tender or, as commonly referred to, beauty contests (Section 4). Section 5 provides a critical examination of the outcomes of some recent large spectrum auctions for third-generation mobile services in several European countries. In Section 6 the possibility of an "aftermarket" for spectrum is discussed.

The main findings of this report are:

- Auctions employ a price mechanism to allocate spectrum and can be used to increase efficiency and revenue maximisation;
- Other objectives that governments may want to pursue can be accommodated in the auction design;
- There are several possible auction formats. The most widely used throughout the world is the Simultaneous Ascending Auction. While this mechanism has many advantages, it may also facilitate collusion and discourage bids on more than one license.
- Information asymmetry among buyers (winner’s curse) has negative consequences on revenue. Thus, the seller should specify the characteristics of the spectrum on sale, the terms of sale, and the rules governing the use of the licences as clearly as possible;
- Recent 3G auctions in Europe confirm that mechanism design is crucial. Flaws in the procedure can dissipate the benefits of using a market mechanism;
- Aftermarkets and more in general spectrum trading have the potential of further increasing efficiency and therefore should be promoted, unless there are serious market failures associated.

2. Introduction

Until the 1990s, mechanism design theorists examining the sale of public goods, composed of economists interested in comparing the properties of different mechanisms but only from an academic point of view, had little contact with public officials responsible for designing. These public officials designing mechanisms to sell public goods, used traditional methods (beauty contests, lotteries, and other administrative procedures) to allocate a whole range of public goods, including the spectrum (which was mainly used for terrestrial broadcasting and radio).[i]

However, the extraordinary technological progress in communication technology broadened the range of uses of the spectrum and increased the demand for new uses. In 1994, the Federal Communications Commission of the United States broke away with the past and decided to consult academic economists (to devise a new procedure to allocate spectrum licences.[ii] That was the beginning of a co-operation between mechanism design theorists and public officials. The theorists accepted to come out of their ivory tower and tackle the "dirty" details involved in the design of a real auction. The public officials were mostly receptive of the general principles that mechanism design had been elaborating in the previous decades.

By now, economists and public officials have a relatively long history of co-operation in designing spectrum allocation mechanisms, mostly in the US but also in several other countries. This survey purports to summarise the main lessons learnt from this collaboration.

Spectrum is a scarce resource. The development of new broadcasting and telecommunication technologies and services has been making increasing demands on attaining access to this scarce resource. For this reason greater emphasis has been given by policy makers to increasing efficiency in spectrum allocation and in spectrum usage. Countries are moving away from the notion that spectrum fees should only be aimed at recovering costs of spectrum management, laying more stress on market mechanisms as the best way to achieve efficient distribution of a scarce resource.

2. Auctions in Theory

Auction theory is by now a very developed field.[iii] This section provides a summary of the main results that are relevant to the design of spectrum auctions. The discussion starts with the case in which there is only one licence for sale. Then, it moves on to many objects, and it concludes by discussing other issues of importance, namely, common values, collusion, and risk aversion.

2.1 Allocating One Object

In this section we make the simplifying assumption that there is only one licence. In the language of auction theory, we say that there is a *seller* who wishes to allocate an *object* to one of n *buyers*.

Each buyer has a valuation for the object, which represents the maximum monetary amount that that particular buyer is willing to pay to secure the object. The valuation is not known by the seller and by the other buyers. Let v_i denote the valuation of bidder i.

For now we will assume that the goal of the seller is to allocate the object to the buyer with the highest valuation. We call this goal *efficiency*. More will be said about it later, and more will be said about the main other goal: *revenue maximisation*.

In the 1960s, the Nobel-prize winner James Vickrey identified a type of auction that always yields efficiency in this environment. This auction is called either *second-price sealed-bid auction* or *Vickrey auction*. All the buyers simultaneously submit a secret bid. The seller looks at the bids and selects the two highest bids. The object is allocated to the buyer with the highest bid, who however pays a price equal to the second-highest bid.

Result 1: The Vickrey auction achieves efficiency, in the sense that the object goes to the buyer with the highest valuation.

In a Vickrey auction, the best thing a buyer can do is to bid his valuation truthfully. This is true independently of what the other buyers are doing. This is immediately obvious. Suppose that buyer i has valuation v_i. He does not know what the other buyers will offer but he knows there are two cases: (a) someone offers more than v_i, or (b) all the other buyers offer less that v_i. In case (a), buyer i should not bid more than v_i because he only risks getting the object at a price above his valuation. In case (b), buyer i pays the second-highest bid and, therefore, he has no reason to go below v_i because this will not reduce the amount he pays but can jeopardise his chance of getting the object. As each buyer bids his valuation truthfully, the object goes to the buyer with the highest valuation and efficiency is achieved.

Example 1. There are two buyers with respective valuations: $v_1 = 3$ and $v_2 = 2$. If a Vickrey auction is used, buyer 1 bids 3, buyer 2 bids 2, the object goes to buyer 1 who pays 2.

The principle behind the Vickrey auction is that the winner should compensate society for the "damage" that he does by getting the object, since this precludes the next-best alternative use of the same object. As we shall see, this is an extremely general principle that underlies all of auction theory.

So far, we have assumed that the only concern of the seller is to allocate the object to the buyer with the highest valuation. However, the seller may have intrinsic preferences over who gets the object. For instance, the seller may prefer to give the object to a new entrant or to a national firm. Efficiency then needs to be redefined by taking these factors into account. The Vickrey auction as defined above does not guarantee efficiency anymore, as the following example illustrates:

Example 2. Valuations are as in example 1 except that buyer 2 is a new entrant and the seller deems that the benefit to consumers from having a new entrant rather than an incumbent is quantifiable as 1.5. Thus the total benefit to society of allocating the object to 2 is 3.5. However, a straightforward Vickrey auction still assigns the object to buyer 1 since the individual valuations of each buyer remain unchanged and do not reflect society's valuation.

However, this does not pose a great problem. A simple modification of the Vickrey auction restores efficiency. Each buyer is assigned a number that represents the social benefit if the object is allocated to him. His bid is computed as the sum of his actual bid plus the social benefit. In the case of example 2, this means that the bid of buyer 2 is augmented by 1.5. Then, it is easy to see that in equilibrium, buyer 1 still bids 3, buyer 2 still bids 2, but now the augmented bid of buyer 2 is now 3.5. The object goes to buyer 2 who pays the bid of buyer 1 minus the social benefit, that is 1.5.

More in general, let w_i be the social benefit of allocating the object to i. If b_i is the bid of i, the augmented bid of i is: $B_i = b_i + w_i$. Suppose that B_j is the highest augmented bid and B_k is the second-highest augmented bid. Then, the object goes to buyer j, who pays the second-highest augmented bid minus his social benefit: $B_k - w_j$. This modified Vickrey auction guarantees efficiency.

<u>Result 2</u>: If the concept of efficiency is extended to include social benefits, then a modified form of Vickrey auction still achieves efficiency.

Let us now revert to the simple model without social benefit (but everything we say in the rest of this section extends to the presence of social benefits). In practice, the Vickrey auction is not used often. The most common format is the *English auction*, which is used for instance by art houses like Sotheby's and Christie's. After the seller opens the auction, each buyer may submit a bid as long as this bid is higher than the current bid. When there are no more bids, the object is allocated to the buyer who made the current bid. Thus, while the Vickrey auction is a one-shot simultaneous mechanism, the English auction is a multi-stage ascending bid mechanism.

In this environment the English auction is equivalent to the Vickrey auction in the sense that the identity of the winner is the same and the price paid is the same. This is because each buyer will stay in the auction as long as the current bid is below his valuation. The current bid will go up until all buyers but one drop out. This happens when the current bid reaches the valuation of the buyer with the second-highest valuation. Thus, the winner is the buyer with the highest valuation and he pays the second-highest valuation (of course, if there is a minimum bid increment rule there may be a small discrepancy between the two auctions).

We conclude the section by looking at the other main goal, besides efficiency, that the seller may have, namely, *revenue maximisation*. A fundamental result in auction theory is *the Revenue Equivalence Theorem*.

<u>Result 3</u> (Revenue Equivalence Theorem): Suppose that the buyers have private valuations (as we have done so far), and that these valuations are drawn from the same distribution (that is, a priori the seller does not know which buyers have higher valuations). Suppose also that buyers are risk-neutral. Then any efficient auction mechanism yields the same expected revenue.

An important example is the first-price sealed bid auction, in which the object goes to the highest bidder but the winner pays his bid rather than the second highest bid. It is easy to see that in a first-price auction (with ex ante symmetric buyers), the object goes to the buyer with the highest valuation. Therefore, the Revenue Equivalence Theorem applies and the expected revenue is equal to the expected revenue of the Vickrey auction. However, the equilibrium bids in a first-price auction are not easy to compute, and in general buyers will bid less than their valuation.

Can a revenue-maximising seller "beat" the Revenue Equivalence Theorem by choosing an auction that is *not* efficient? The answer is yes and the most obvious example is the use of a *reserve price*. The seller (who uses a Vickrey auction) fixes a price r under which the object is not sold. This is clearly bad for efficiency because there is the risk that the object is not allocated at all. However, a reserve price can increase expected revenue. The idea is that, with positive probability, the seller will face a highly asymmetric situation: a buyer has a high valuation and all others have low valuations. In this case, the presence of a reserve price saves the seller from very low revenues. This of course has to be traded off with the probability that all buyers are below the reservation price. It can be shown that, in any Vickrey auction, the expected revenue is maximized by choosing a strictly positive reserve price. The price is decreasing in the number of buyers.

Result 4: The introduction of a (small) reserve price increases the expected revenue, but it is bad for efficiency.

Example 3. Suppose that v_1 and v_2 are uniformly distributed over the interval between 0 and 1. If no reserve price is set, the expected revenue is 1/3. If a reserve price r = 1/3 is set, then with probability 1/9 the object is not sold, with probability 4/9 the object is sold at 1/3, and with probability 4/9 the object is sold above the reserve price. It can be computed that this generates an expected revenue of 32/81, which is greater than the expected revenue without reserve price.

In the context of spectrum auctions, reserve prices have played a small role, probably because the number of buyers is typically large. However, they are becoming increasingly important, as shown by recent UMTS auctions in Austria, in the Netherlands and in Italy.

2.2 Multiple Objects

Suppose now that there is a set S of objects for sale. It is unimportant whether there are more buyers than objects. Each buyer has a valuation for each possible subset of objects. Hence we let $v_i(s)$ be the valuation of buyer i for subset s belonging to S. For instance, $v_i(1, 3) = 4$ says that buyer i has a valuation of 4 if he ends up with objects 1 and 3 (and *only* objects 1 and 3).

Valuations can display positive or negative complementarities. If $v_i(1, 3) > v_i(1) + v_i(3)$, there are positive complementarities. If $v_i(1, 3) < v_i(1) + v_i(3)$, there are negative complementarities. In spectrum auctions both cases are of practical relevance. An operator may need licences in two neighbouring regions or two licences in the same region in order to have a viable business, in which case we expect positive complementarities. Alternatively, an operator may face decreasing marginal revenues in the number of customers in which case we expect negative complementarities. As we will see, the existence and sign of complementarities play a big role in the choice of auction mechanism.

Efficiency now means that the objects are allocated in a way to maximize the total surplus, which is given by the sum of the valuations of all the buyers. An allocation A is a subdivision of S among the n buyers of the form $A=(A_1, A_2, ..., A_n)$. The efficient allocation satisfies:

$$A^* = \max_A \Sigma^n_{i=1} v_i(A_i).$$

There exists an extension of the Vickrey auction to multiple objects that achieves efficiency. It is called *generalised Vickrey auction* (or *Groves-Clark mechanism*, or *combinatorial auction*). As in the simple Vickrey auction that we saw before, bids are secret and simultaneous. Each buyer places a bid on each subset of S. For instance, if there are objects a, b, and c, each buyer bids on {a}, {b}, {c}, {a, b}, {a, c}, {b, c}, and {a, b, c} – a total of 7 numbers. The seller chooses the allocation that maximises the sum of bids for subsets belonging to that allocation. The amount that buyer i pays is determined by looking at the bids of other players. Let $b_{-i}(A)$ denote the total amount of bids from players different from i for allocation A. Then if A' is the winning allocation, the amount that i pays is:

$$p_i = \max_A b_{-i}(A) - b_{-i}(A').$$

Buyer i pays for the damage that he imposes on other buyers by changing – through his bid – the allocation. This is the same principle as paying the second highest bid. Indeed, if there is only one object, we have that $b_{-i}(A')=0$ and that $\max_A b_{-i}(A)$ is equal to the second highest bid, and hence the generalised Vickrey auction boils down to the simple Vickrey auction.

Result 5: The Vickrey auction can be extended to multiple objects.

It can be shown that in the generalised Vickrey auction it is a dominant strategy for buyers to bid their true valuation on every subset of objects. If every buyer bids truthfully, it is easy to see that the winning allocation will be the efficient allocation A*. The following examples illustrate these facts:

Example 4. There are two bidders (1 and 2) and two objects (a and b). The buyers' valuations are $v_1(a) = 3$, $v_1(b) = 2$, $v_1(a, b) = 4$, $v_2(a) = 1$, $v_2(b) = 4$, $v_2(a, b) = 5$ (the efficient allocation consists in giving a to 1 and b to 2: A* = ({a}, {b}). In equilibrium buyers bid truthfully: $b_1(a) = 3$, $b_1(b) = 2$, $b_1(a, b) = 4$, $b_2(a) = 1$, $b_2(b) = 4$, $b_2(a, b) = 5$. The allocation A* receives the highest total bid: 3 + 4 = 7. Thus, a goes to 1, who pays $\max_A b_2(A) - b_2(A^*) = 5 - 4 = 1$, and b goes to 2, who pays $\max_A b_1(A) - b_1(A^*) = 4 - 3 = 1$.

Example 5. There are two bidders (1 and 2) and two objects (a and b). The buyers' valuations are $v_1(a) = v_1(b) = 1$, $v_1(a, b) = 5$, $v_2(a) = v_2(b) = 3$, $v_2(a, b) = 3$ (the efficient allocation consists in giving both a and b to 1: A* = ({a, b},{})). In equilibrium buyers bid truthfully: $b_1(a) = b_1(b) = 1$, $b_1(a, b) = 5$, $b_2(a) = b_2(b) = 3$, $b_2(a, b) = 3$. The allocation A* receives the highest total bid: 5. Thus, both objects are allocated to 1, who pays $\max_A b_2(A) - b_2(A^*) = 3 - 0 = 3$.

The generalised Vickrey auction can be extended further to accommodate social welfare considerations. As in the one-object case, the seller assigns a social benefit to each buyer (except that now she must assign a number for each possible allocation). It is also possible to extend the mechanism to take care of externalities among buyers.

Given this strong efficiency property, it may then be surprising that the generalised Vickrey auction has never been in used in practice to sell spectrum. The reason is probably its complexity when the number of objects is high. The number of bids each buyer places is equal to the number of possible object combination. If the number of objects is m, the number of possible combinations is $2^m - 1$. This number becomes large very fast. With m = 20, it is over a million.

Auction designers have thus turned their attention away from one-shot mechanisms towards ascending mechanisms, with the idea that the latter are less computationally demanding because buyers only have to respond to the highest current bid rather than considering all possible combinations.

The most widespread design for spectrum sales is the *simultaneous ascending auction* (SAA), introduced by the FCC is 1994. The auction is structured in simultaneous rounds. In each round, each buyer can place a bid on one or more objects. There may be an upper limit on the number and type of object a buyer can place bids on (the *eligibility* rule), which is usually motivated by the desire to avoid excessive concentration. There may also be a lower limit (the *activity* rule), which has the objective to guarantee that the auction proceeds speedily. A buyer who violates the activity rule is eliminated from the auction. After bids are placed, the seller determines the current winners by looking at the highest bidder for each of the objects. The auction stops if, at some round, no new valid bids are received. In that case, the current highest bidder of each object is allocated the object and must pay his bid.

If there is only one object, the SAA is the same as the English auction. As we saw before, the English auction is equivalent to the Vickrey auction. However, if there is more than one object, the SAA is *not* equivalent to the generalized Vickrey auction.

Discrepancies between the SAA and the generalised Vickrey auction occur in the presence of *exposure risk*. There is exposure risk when some buyers have positive complementarities and others have negative complementarities.

Result 6: The SAA is not always efficient because of the exposure risk.

Example 5 revisited. Example 5 (where there are two bidders and two objects) is an instance of exposure risk, with buyer 1 displaying synergies between the two objects and buyer 2 displaying negative complementarities. If a SAA is used, the efficient allocation A* cannot be obtained. To see this, assume for contradiction that the auction closes with buyer 1 being the highest bidder on both objects. Given that the reservation value of buyer 2 is 3 for getting either object, buyer 1 must "beat" buyer 2 on both objects, paying at least 3 + 3 = 6. However, this is irrational for buyer 1 because he pays 6 while his valuation is 5. Indeed, it can be shown that in equilibrium each buyer gets one object, which is inefficient.

Not only does the exposure risk generate inefficiency in the SAA but it also reduces the expected revenue of the seller. An often cited example of how the exposure risk can hurt efficiency and revenues is the 1998 spectrum auction held in the Netherlands (DCS 1800 MHz). 18 licences were for sale. Six of them were grouped in lot A, six of them were grouped in lot B, and the remaining six were sold singularly but buyers could cumulate them. The outcome of the auction was that the prices per bandwidth on lot A and B were twice as high as on the small licences. This suggests that buyers had positive complementarities, they were interested in collecting several of the small licences but were deterred to do so by the risk of being left with only 1 or 2 small licences. One operator resold its only and almost worthless small licence after the auction, indicating that the auction format had not achieved efficient allocations in the first place.[iv]

In response to the exposure risk, the FCC has considered alternative auction formats. Following the advice of several leading auction theorists, it decided to adopt a *dynamic combinatorial auction* (DCA). The new format was first used in a FCC 700MHz spectrum auction held in September 2000. To date, no formal analysis of the auction result is available.[v]

The DCA is still an ascending bid auction. However, it differs from the SAA in that buyers are allowed *package bidding*, that is, they are allowed to make joint bids on more than one object. At each round a buyer can submit bids on single objects and on packages of objects. For instance, in example 5, a buyer can bid on {a}, {b}, or {a, b}. A bid on a package means that the bid is paid only if the buyer gets the *whole* package. A buyer can bid on many objects and many packages and these bids may be *nested* (for instance the buyer can bid on {a} and {a, b}). After bids are placed, the seller computes the allocation that would generate the highest revenue, analogously to the generalised Vickrey auction. The bids that compose the winning allocation are considered the current winning bids. But also the other bids stand. In the next round bidders must offer more than the current winning allocation but can do so by using the other standing bids. This point is illustrated through an example:

<u>Example 6</u>. Suppose there are two objects (a and b) and three buyers (1, 2, and 3). Suppose that buyer 1 has bid 10 for the package {a, b}, buyer 2 has bid 4 for {a}, and buyer 3 has bid 5 for {b}. The current winning allocation is to give both a and b to 1. In the next round, however, the bids of 2 and 3 still stand. For instance, supposing that the minimum increment is 1, if buyer 2 offers 6 for {a}, this is enough to beat the current winning bid because the allocation ({a} to 2, {b} to 3) collects a total of 11.

The main advantage of the DCA is that it eliminates the exposure risk. Indeed, if looking again at example 5, it can be seen that now buyer 1 can bid 4 on the package {a, b} and this beats the bids of buyer 2.

However, it has been pointed out that the DCA creates a problem that in some sense is the converse of exposure risk, which has been called the *threshold problem*. Small buyers who are interested in small lots may have an incentive to wait and see if other small buyers increase their offers, because that will help them beat the offers of large buyers interested in large lots. For instance, in example 6 if buyer 2 increases his offer by 2 then buyer 3 will get {b} without having to increase his bid. Likewise, if buyer 3 increases his offer by 2 then buyer 2 gets {a} without further expenses. Thus, the two buyers may be tempted to wait and see if the other buyer moves first. This strategic effect may induce inefficiency and lower revenues.

In conclusion, each of the three mechanisms that have been considered for multiple objects has a distinctive drawback. The generalised Vickrey auction may be too complicated, the SAA has the exposure risk, and the DCA has the threshold problem. The optimal choice will depend on the number of objects for sale and on the type of complementarities that the seller expects to exist.

2.3 Common Values

All the previous analysis assumed that the valuations of the buyers were private. Instead it may happen that the information that buyer i observes not only tells him something about his own valuation but also tells him something about the valuation of other buyers.

The classical example that is cited is an auction to exploit an oil field. The buyers have identical cost and revenue functions and hence they have the same valuation, which depends on how much oil there is and how hard it is to extract. Each buyer conducts an independent analysis and arrives at an estimate of the valuation. So, buyers are identical except for their estimate of the valuation. Now suppose that a Vickrey auction is held and each buyer bids his estimate. Clearly, estimates can be wrong either by overestimating or underestimating the resource available. The winner will be the buyer with the highest estimate, that is, the buyer who made the highest error in excess. Hence, that buyer will pay more than what the object is worth. In other words, winning is bad news to the winner. This general property of auctions with common values is known as the *winner's curse*.

However, buyers are assumed to be rational and therefore will take into account the fact that if they win it means that their estimate was too high. In equilibrium each buyer offers his expected valuation *conditional on the fact of having the highest estimate.* This means that all bids are revised downwards.

The Revenue Equivalence Theorem does not hold with common values. Instead, there is a strict ranking of auction mechanisms according to the expected revenue they generate: English auction, Vickrey auction, First-price sealed bid auction. The advantage of the English auction has to with the fact that it is ascending. Buyers observe other buyers dropping out of the auction and they are reassured that their estimates are not excessive if rivals stay in. Hence, they are less likely to be victims of the winner's curse and they are willing to be more bold in their bids.

The winner's curse is often cited as a reason to adopt an ascending auction format rather than the generalized Vickrey auction.

With common values, the seller is hurt by the extent of information asymmetry among buyers. If there is a policy that increases the information of all buyers, the seller should adopt it. Hence, the seller should specify the characteristics of the objects, the terms of sale, and the rules governing the use of the licences as clearly as possible.

While the presence of common values may change revenues, it does not in general affect efficiency. Buyers bid more cautiously but the ranking of buyers by valuation remains the same. The object still goes to the buyer with the highest valuation.

<u>Result 7</u>: The presence of common values decreases the expected revenue but does not – as a first approximation -- affect efficiency.

2.4 Collusion

Collusion among buyers may take many forms. It may entail explicit agreements before the auction (*bidding rings*) on how to bid during the auction. Perhaps more important in the case of spectrum auctions is *tacit collusion*. Buyers do not directly communicate but they have an implicit mutual understanding on how to keep prices down.

Example 7: Suppose there are two identical buyers and two identical objects and each buyer is willing to pay 10 for one object and 15 for two objects. Suppose a SAA is used. If buyers bid truthfully, each buyer will get one object and pay 5 (because 15 - 10 is the marginal benefit of having the second object). Now, suppose instead that buyers know each other's valuation and realise what the equilibrium is if they play truthful. Then, buyer 1 could offer 1 for object {a} and buyer 2 could offer 1 for object {b}. If buyer 1 increases the offer on object {b}, 2 can beat him on {b} and retaliate by raising the offer on {a}. The same holds for 2. Hence, buyers collude tacitly and keep prices at 1.

This type of tacit collusion goes away if the seller uses a one-shot format, such as the generalised Vickrey auction. It is the ascending nature of the SAA that allows for a credible threat of retaliation and hence for tacit collusion. Thus, the fear of tacit collusion goes in the opposite direction of common values, and tends to favour one-shot formats.

Result 8: One-shot mechanisms discourage tacit collusion.

2.5 Risk Aversion

So far, it has been assumed that buyers are risk-neutral. If they are risk-averse, the Revenue Equivalence Theorem does not hold anymore (even with private values). It can be proven that the first-price sealed bid auction yields higher expected revenue than the Vickrey auction and the English auction. Each buyer should be indifferent between the marginal benefit of increasing a bid (a higher probability of getting the good) and the marginal cost (less money with some probability). However, in a first-price auction bids are lower than in a Vickrey auction. Hence, the marginal cost is higher. That is why the introduction of risk aversion reduces bids in the second-price auction more than in the first-price auction.

Result 10: If buyers are risk averse, a second-price auction yields a higher expected revenue than a first-price auction.

To summarise, the extensions of the basic framework go in different directions. Common values militate in favour of the English auction. Collusion makes the use of one-shot mechanisms more attractive. Risk aversion favours first-price mechanisms. The optimal design should try to balance these different forces.

Hybrid formats are possible too. In the case of m identical licences and n buyers who can only acquire one licence each, one suggestion has been made to use an English auction to screen out all buyers but m + 1, and then running a first-price sealed bid auction among the m + 1 remaining buyers. This auction – called *Anglo-Dutch* -- should combine the benefits of the ascending format in reducing the winner's curse and the advantage of a one-shot format in avoiding collusion.[vi]

3. Auctions vs. Beauty Contests

In the previous sections, the multifaceted aspects of an auction have been shown. Despite the differences among the various formats that can be adopted, they all show at least one common feature: there is some price competition among bidders. This is the characteristic that distinguishes auctions from another common allocation mechanism, a beauty contest.

In a beauty contest (also known as comparative tender), a committee typically sets a number of criteria, possibly with different weightings. Candidates' offers are then evaluated by a jury that selects the plan that has the best "mix" of those criteria, usually the highest weighting. In the case of spectrum allocation for mobile services, criteria set out beforehand can include general criteria such as financial resources, reliability and investment in research, as well as more specific criteria such as the speed of network rollout, the requirement for geographic and/or population coverage, pricing, quality, technology and competitiveness.

It is important to stress that the difference between auctions and beauty contests is not as marked as it may seem at first sight. Auctions may still require participants to satisfy a certain set of technical and service parameters. Similarly, one of the criteria in a beauty contest can be a monetary one. The main difference between the two allocation methods arises from the emphasis they give to the price mechanism. In an auction, competitive bidding is pivotal, in a beauty contest it is not.

If there were no asymmetries of information between the Government and operators, an auction would not be needed at all. The Government would be able to identify the most capable operators and assign them a licence. It would also charge them exactly the price they are willing to pay, so that all the rent is given to taxpayers. However, this situation is very unlikely, hence an allocation mechanism has to induce operators to reveal their own private information. This is where beauty contests, in principle a very flexible way of allocating public goods such a s spectrum, fail.

Since asymmetric information is relevant in practice, operators must be given the right incentives to disclose the information that they possess. If there is no competitive price bidding, there is no particular reason as to why operators should tell the truth in their offers to the jury. Imagine a beauty contest selects the operators that offer the best business plan, defined in terms of quality of the services offered to customers. Imagine also that quality is objectively measurable. *Ex post*, i.e. once licences are assigned, market conditions will depend on all sort of contingencies, like the future state of technologies (both used by the licensee and by competitors), the disposable income of consumers, and so on. Clearly, the realisation of these variables may be very different from what an operator expected *ex ante*, i.e. before he offered his plan to the jury. Once an operator has secured a licence, then it is very difficult to enforce his original promises. The operator would have a strong case for renegotiating his plan, adapting it to the current market conditions. Anticipating this, the incentive to commit in a credible way to the original offer is blurred. The result is then that contestants will present unrealistic business plans, making the choice of the jury very difficult.

It is not claimed that unforeseen contingencies would be eliminated by an auction. They would exist in any case. However, by making the bidder financially responsible for what he offers, it gives a more stringent incentive to stick to what the bidder thinks will be realistic. The bidder will obviously make his own discounted calculations about the occurrence of future events. His bid represents a summary of his evaluation and does not require the Government to check *ex post* if all the promises are fulfilled.

It should be stressed again that the difference between auctions and beauty contests is about the emphasis they give to the price mechanism. In principle, if the Government could determine a set of objective parameters and be able to enforce the implementation of those parameters offered by the winning bids, at least up to the component not affected by the occurrence of unexpected events, then a beauty context would work well. However, this is not realistic, giving an advantage of auctions over beauty contests in terms of the incentives to reveal private information and achieve the aim of allocating a scarce resource to the people who value them most highly.

Another advantage of auctions over beauty contests is their objectivity and transparency. In the previous analysis, it was assumed that the set of criteria considered by the selecting committee in a beauty contest was objective. If this is not the case, then all sorts of additional problems may arise, since there would be an open door to favouritism and corruption. Even if the jury is not corrupt, different people may have different opinions about the optimal mix of parameters. Hence the composition of the jury affects the result and different juries may allocate licences to different operators. This makes legal challenges more likely, since losers may rightly feel discriminated if it is not clear on what basis the choice was actually done.

On the other hand, once an auction format is chosen, the winners do not depend on the identity of the auctioneer that runs it. The discretionary power of an auctioneer is much reduced compared to the power of a selecting committee. Winners would be those who make the highest bids, making a court appeal very unlikely. As a side result, also notice that the public acceptance of the assignment mechanism is easier with an auction. The public understands better why an object has been assigned to the bidder that offered the highest price than to the bidder that the jury selected. The downside of this is that an auction that does not go well would immediately attract the public attention. However, this is not a criticism against auctions, rather a warning that Governments should do their best to design properly the auction format.

There is also an equity argument in favour of auctions. If a beauty contest does not involve money, or sets an administrative fee that is considerably less than the market value of the spectrum, income which through an auction process would have accrued to the Government is left with the operators' shareholders. This does not in itself involve inefficiency, but many people would object to this on distributional grounds.

Auctions work on the assumption that the objects for sale are easy to define. In the case of the spectrum, although there are several open questions (transferability, interferences, etc.), the objects are relatively well defined. In other circumstances, it could be very difficult to specify all the characteristics of the objects. If that is the case, then the best procedure could be direct bargaining between the government and the buyers.

3.1 Common Criticisms to Auctions

Despite their good properties, both in terms of efficiency and revenue generation, auctions are sometimes criticised on several grounds. The objective of this section is to review such common objections and the grounds over which they are founded.

Objection 1: Firms pay "too" much in an auction. Behind this remark there could be two different stories. In the first one, firms are not profit maximisers in practice. Auctions would simply put pressure on bidders, until they pay exorbitant fees. This claim can be dismissed by noting that firms that make systematic losses cannot survive in the market place. Managers would not be able to bid any fee for a licence. They would first need the approval of major shareholders and then secure a line of credit from banks. Markets, both for capital and for managers, work reasonably well and there is no reason why the Government should replace them with its own judgement. A second story is related to the "winner's curse" phenomenon described in Section 3.3 in the context of common value auctions. As was argued there, the winner's curse would be taken into account by bidders, who would then make cautious offers, especially if the auction is run in a sealed-bid format. Hence, the possibility of being subject to the winner's curse may eventually lead participants to bid too little rather than too much.

Objection 2: Higher licence fees will mean higher prices to consumers. This criticism confuses he direction of causation: while it is true that *ex ante* operators do take into account their estimates on future prices and quantities in order to determine their willingness-to-pay for a licence; *ex post* licence fees do not affect consumer prices. To see why high licence fees do not raise prices, consider how a firm decides what to bid for a licence. It will know from the rules of the auction process how many competitors would be licensed and hence how many firms will be competing to provide service. By forming a conjecture about how the competitive process will play out, it can estimate what revenues over and above capital and operating costs it will earn. On this basis, it can calculate the maximum a licence would be worth to it and judge its bidding accordingly. Suppose that it has now been successful. It has paid for the licence, either up-front in full or through a binding commitment to pay in instalments. As far as the firm and its competitors are concerned, the licence fee is an irrevocable sunk cost. When deciding how to set prices, the firm rationally only takes account of its own forward-looking costs and revenues and the likely behaviour of other firms. Since the licence fee is a sunk cost for all firms, it falls out of the pricing equation for all of them. Hence the size of the licence fee does not affect prices.[vii, viii]

Objection 3: Higher licence fees will induce operators to collude more in the future. It is suggested that operators burdened by substantial sunk licence costs will feel themselves more vulnerable, hence more reluctant to engage in price wars and more inclined to act collusively. But this is open to the same objection as above. This does not mean that by adopting an auction mechanism, firms will not be able to collude. Rather the likelihood of collusion depends on the way competition law is enforced, something that has nothing to do with the size of licence fees. However, if firms differ in their innate ability to collude (imagine there are "fighters" and "non fighters"), then an auction may select those that will not fight in the future. In fact, these are the operators that in the future may be more willing to set high prices and extract rents from consumers, hence they can offer higher licence fees in the first place, win the licence and set collusive prices in the future. This may well be true, but it points to a weakness in the antitrust law rather than in the auction mechanism. If competition authorities are able to detect collusion, then this situation should not occur. If they were not able, it would be better to improve competition policy than to distort the allocation mechanism.

Objection 4: Large licence payments erode the finances of operators, requiring them to assume debts and reducing their credit rating. This criticism is founded in the presence of inefficient capital markets. However, the objection should be examined from a different point of view. It should be posited as follows: Is there a belief that capital markets are so inefficient and that Government has better information about the firms' prospects than potential lenders that the Government should use its own judgement in place of the judgement of commercial prospects implicit in firms' bids? This is seldom the case in general, and it is extremely difficult to support this assertion when applied to the telecommunications giants that are trying to acquire spectrum licences. In this context Governments should avoid interfering with capital markets. For instance, the temptation of relieving short-term financing problems by staging licence payments over various instalments should be resisted. If this happens, then the down payment is, in effect, merely the payment of an option, and the body issuing spectrum becomes effectively an issue of financial investment and may give rise to problems of moral hazard.[ix]

Objection 5: If operators spend large sums to get a licence, they will invest less in infrastructure. If capital markets are perfect, then this objection is answered in the same way as in objection 3. If they are imperfect, then it is answered as in objection 4. Also notice that if firms are financially constrained, then there is no reason for putting most of the money up front, given that without investments there will be limited services offered to consumers with associated reduced revenues.

Objection 6: Auctions put emphasis only on prices and do not take into account other objectives that the Government may want to pursue. This criticism is not a serious one. In general, there could be very legitimate objectives other than efficiency and revenues that the Government may seek (speed of network development and geographic coverage, requirements to interconnect, development of innovative technologies, etc.). If such objectives are deemed important, they should first be made explicit and then they could be easily built into the auction process by imposing appropriate rules and licence conditions (see the discussion in Section 3.1 on how to extend the Vickrey auction so that it can take care of social benefits). For example, if there is a desire to bring new entrants into the market, some licences can be reserved for them, or they might receive special benefits during the auction process (for example, by adding a notional monetary sum to their bids), or during the initial phases of competition (for example, by mandating roaming with 2G networks at conditions favourable to 3G new entrants). To give another example, imagine it is an objective of policy to ensure a fast network rollout, perhaps faster than a licensee would choose to go in its private interests. Then a licence could be allocated subject to rollout conditions. This would presumably reduce firms' willingness to pay, but the Government must have believed this to be worthwhile, as otherwise it should not have imposed the condition.

Objection 7: Auctions are just a way to maximise revenues for the Government. It is true that one of the objectives in an auction is to maximise revenues for the seller. However, if the Government really wanted to maximise revenues, then it should auction monopoly rights, rather than several licences for competing services. All the licences in an area would certainly have the highest value in the hands of a single operator, which could then have the full monopoly of the service. This is clearly undesirable, and this is why auctions are typically designed in a way such that any operator can control only a limited number of licences (one in many cases). Rather the purpose of an auction is to maximise the efficient use of scarce spectrum resources.

4. Auctions in Practice

Table 1 reports the progress of the roll out of 3G licences within Europe.[x] The table shows a mixed picture. Finland and Spain have already made their awards through beauty contests. In Spain, France Telecom has challenged the outcome in the Courts; this is a natural response by unsuccessful applicants to the discretionary and subjective nature of beauty contests. The success of the UK auction has elicited responses from both other Governments and bidders. In particular, France has adopted a hybrid system, in which licensees are chosen through a beauty contest but charged a high fee – about half that paid in the UK auctions. Italy has also adopted a hybrid system, selecting through a beauty contest the players that are admitted to an auction in a second stage.

Bidders have responded by quitting the contests or by forming alliances. Some companies held pre-auction contacts that have generated concerns. National competition authorities are currently investigating the possibility of improper behaviour both in Italy and in the

Netherlands. Fears of collusion have also dogged the Austrian auction for 3G mobile licences.[xi]

Since auction formats have differed in some important details, the following section describes the main results of the 4 major European auctions that have been completed so far, starting from the first one that was held in the UK.

4.2 United Kingdom

A long and open debate preceded the 3G mobile auction in the UK (see the web site of the Radiocommunications Agency at http://www.spectrumauctions.gov.uk/3gindex.htm). At first it was thought that there was sufficient bandwidth only for four licences. Given that there were four incumbents, the initial auction design tried to focus on how to encourage new entrants' participation. However, further technical studies showed that the same spectrum bands could accommodate up to 5 licence, albeit of different size, hence the auction design changed dramatically after this. The frequency capacities attached to each licence were fixed *ex ante* on the following terms (licences are valid for 20 years):

Licence A (Reserved for a new entrant)	2x15 MHz paired spectrum plus 5 MHz unpaired spectrum
Licence B	2x15 MHz paired spectrum
Licence C	2x10 MHz paired spectrum plus 5 MHz unpaired spectrum
Licence D	2x10 MHz paired spectrum plus 5 MHz unpaired spectrum
Licence E	2x10 MHz paired spectrum plus 5 MHz unpaired spectrum

By reserving the largest licence for a new entrant, the UK design tried to level the playing field among incumbents and new entrants. The auction format was studied and refined by two leading economists.[xii] The auction was a simultaneous ascending auction (SAA), in line with what the Federal Communications Commission had been experimenting with in the US. Some important details were introduced in the licence conditions in order to take account of some characteristics of the market for 3G services. For instance, some minimum coverage requirements were specified. Joint with the telecommunications regulator, OFTEL, the question of mandated roaming for entrants' on incumbents networks was also clarified, and the associated price following a rule denoted as "retail minus".

The auction attracted a total of 13 bidders, 9 new entrants besides the 4 incumbents. After 150 rounds conducted in 33 days, the auction ended with the following results:

Company	Round	Last offer (£ 000,000)	Licence	**Waivers**
BT3G	**149**	**4,030.100**	**C**	**0**
Orange	**148**	**4,095.000**	**E**	**0**
One2One	**146**	**4,003.600**	**D**	**0**
Vodafone	**143**	**5,964.000**	**B**	**0**
TIW	**131**	**4,384.700**	**A**	**0**
NTL Mobile	148	3,970.500	C	0
Telefonica	131	3,668.100	C	2
WorldCom	119	3,173.000	C	0
OneTel	97	2,180.800	E	3
Spectrum	95	2,100.000	D	1
Epsilon	94	2,072.200	C	3
3GUK	90	2,001.100	A	3
Crescent	90	1,819.400	C	3
Total		**22,477.400**		

The UK auction was perceived as a great success. The auction rules did not permit much strategic bidding (such as signalling), and most operators followed the natural strategy to bid the minimum increments in each round (5%) until they reached their reservation value, in which case they dropped out. It is also significant that a number of new entrants all exited at around £2 billion, giving a reasonable order of magnitude of the value of a licence for the least efficient operators. Stronger operators then struggled to get their licences and in the final rush prices increased considerably. It is also quite striking that most operators' had a clear strategy and they knew how much they were prepared to pay. Once such a value was reached, then there was no particular reason for waiting a little bit more, for instance by using a waiver. Finally, the 3 identical licences (C, D and E) virtually sold for the same price. Licence A was more expensive, but also the largest. The most expensive licence was B, the largest eventually available for incumbents. Vodafone systematically bid only on that licence, but even if its interest was clear from the beginning, it had to engage in a fierce battle to get it, in particular with BT, the other major incumbent.

4.2 The Netherlands

After the success of the UK auction, there were high expectations in Holland. Five licences, valid for 15 years, were put on sale as follows (see the site http://www.biedingenumts.nl/):

Licence A	2x15 MHz paired spectrum
Licence B	2x15 MHz paired spectrum
Licence C	2x10 MHz paired spectrum plus 5 MHz unpaired spectrum
Licence D	2x10 MHz paired spectrum plus 5 MHz unpaired spectrum
Licence E	2x10 MHz paired spectrum plus 5 MHz unpaired spectrum

The problem of auction design did not seem too complicated, since it could be thought that it was enough to mimic the UK experience. However, there was one crucial difference that made the situation in the Netherlands different from the UK. In Holland, there were 5 incumbent operators, and exactly 5 licences on sale. The Dutch designers did not try to encourage new entrants. Given incumbency's advantages, the interest of outsiders was not particularly high, since they probably felt that incumbents in the end would have obtained the licence anyway.[xiii]

Perhaps, there is also another motivation, which however is difficult to test. Operators felt they were going to pay a very high price if they had to compete as in the UK for every other European country holding an auction and started to form alliances or dropped off some markets, in an attempt to split the various markets among themselves.[xiv]

It is a fact that 8 operators applied to the Dutch regulator, but 2 of them pulled out of the auction, literally minutes before it began. Something similar happened in the German auction that was held in the same days. In the end, there was only one newcomer, VersaTel, to the Dutch market in the bidding, and it had been thought disadvantaged from the start.

The auction lasted 305 rounds (13 days) until VersaTel did not top any of the rivals' bids. Licences were assigned as follows:

Company	Last offer (Fl 000,000)	Licence
Libertel	1,573	A
KPN Mobile	1,567	B
Dutchtone	960	C
Telfort	947.6	D
3G Blue	870.5	E
Total	**5,918**	

As in the UK, larger licences sold for higher prices, and similar licences (A and B, or B, C and D) for similar prices. Total revenues were significantly short of the initial goal that the Dutch government had explicitly set at Fl 20billion.

4.3 Germany and Austria

The German auction introduced a totally different design. In place of predetermining the "right" number of licences (5 both in Holland and in the UK), the German regulatory agency adopted a more flexible design. Bidders did not submit bids for licences but for "blocks" of paired spectrum. The regulator put on sale a total of 12 blocks of spectrum, and a bidder would have obtained a licence only if it secured at least two blocks, but it could not acquire more than three blocks. The exact location of the blocks would be determined at the end of the auction, to ensure that a bidder would get adjacent blocks (licences would then last for 20 years).

This auction rule implies that the number of licences and their capacities are determined endogenously by the bidders. The number of 3G operators could then vary between 4 (if each got 3 blocks) and 6 (if each got only 2 blocks). The chosen auction format was then a SAA, as in the previous countries. To complete a brief description of the German set up, a second auction was going to be held immediately after the first one, to allocate some more unpaired spectrum that could not be easily accommodated in the first auction. Moreover, the second auction would have allocated eventual blocks unsold in the first auction (for instance, because the highest bid on a block failed to secure a second block, in which case the bidder would have paid nothing and the block re-auctioned).

The intentions of the German regulator were to introduce a flexible design, in agreement with general principles of competition policy that require fair and nondiscriminatory market solutions to the problem of finding an optimal market structure. By putting a higher number of "objects" on sale, more entrants presumably would also be attracted. Notwithstanding these laudable goals, some economists expressed doubts about the format chosen by the German regulator.[xv] Since a value of a licence depends, among other things, on the expected degree of competition in the 3G market, if a market is more concentrated, then firms would be more willing to pay for a licence. In this respect, the German design was biased in favour of a more concentrated market structure: a few operators would be prepared to pay a lot of money to get licences to operate in a market with a few competitors. If this turned out to be true, the Government would have cashed a lot of money, but consumers (future 3G users) would have been penalised by high prices for 3G services. This risk was exacerbated by the fact that there were 4 incumbents, and aggregation would have permitted to reduce the number of licensee down to the same number. It was not even sure that high revenues for the Government could be generated at all. In fact 12 consortia applied to participate to the contest, but 5 pulled out or made alliances before the auction began.

The actual auction was run within the framework described above. It lasted for 173 rounds (14 days) and, contrary to all negative expectations, it raised more than $45 billion, some $10 billion more than the amount raised in the UK. The details of the winners are the following (see the web site http://www.regtp.de):[xvi]

Company	Last offer (DM 000,000)	Blocks
E-Plus Hutchison	16,418.2	2
Group 3G	16,446	2
Mannesmann	16,473.8	2
MobilCom Multimedia	16,370	2
T-Mobil	16,582.2	2
VIAG Interkom	16,517	2
Total	**98,801.2**	

The outcome that some economists had predicted did not materialise and the German government arguably obtained the best of two worlds. High revenues and, at the same time, a high number of competitors. This does not imply that the considerations of economists should not be taken seriously or that this may not happen in similarly designed auctions. In fact, the major incumbents, T-Mobile and Mannesmann *did* try to aggregate a third licence, and it was their combined action that drove prices at high levels. To have an idea, the 7th bidder (Swisscom) exited the auction well before the end. Under different auction rules, at that point bidding would have stopped. However, bidding continued as incumbents tried to acquire additional capacity and to reduce the number of available licences (and of future competitors). This idea did not work in the end for various reasons. For instance, because the entrants were serious bidders, and because there was a potential co-ordination problem (to pull out a rival, a bidder had to raise the price, but remaining operators would benefit from the eventual reduced competition, hence it is not clear who will raise the price in the first place). The result was that the same number of firms (6) had to pay about $14 billion more that the amount they bid when Swisscom exited.

The auction format employed in Germany was put to a further test in Austria, where an almost identical mechanism was adopted. As in Germany, the Austrian auction was carried out in a SAA format in two stages. In Stage I of the auction, 12 frequency packages of 2x5 MHz each in the paired range were auctioned off. Each applicant had to acquire at least two – but no more than three – frequency packages. This means that 4 to 6 licenses could be acquired in this stage. The reserve price for each package was set at ATS 700 million. In Stage II, additional five packages of 5 MHz each in the unpaired range were auctioned off with a reserve price of ATS 350 million.

6 consortia participated to the auction. The bidding process lasted for 14 rounds (two days) and the licences were allocated as follows (see the web site of the Austrian telecommunications regulator http://umts.tkc.at/english):

Company	Last offer (ATS 000,000)	Blocks
Mobilkom	1,660	2
Connect	1,652	2
max.mobil	1,643	2
3G Mobile	1,616	2
Hutchison	1,563	2
Mannesmann 3G	1,557	2
Total	**9,691**	

Contrary to the German auction, operators did not engage into a fight to aggregate a third valuable block. The auction could have stopped only after two rounds, when each bidder had secured 2 blocks. This lead the regulator to call for a suspension of the auction to investigate into possible collusive behaviour. When the auction resumed, the 6 participants rather quickly found a way to get 2 packages each. The final total price was less than 8% above the initial reserve price.

It is instructive to follow the behaviour of the companies during the auction process. Mannesmann followed the most natural rule, bidding the minimum possible amount to be eligible for a licence. If some rival displaced Mannesman on one of its two blocks, next round Mannesmann would bid the minimum increment on the cheapest available block. On the other hand, Mobilkom participated more actively to the bidding process, and it engaged into a more strategic form of bidding. Mobilkom tried at first to aggregate 3 blocks of spectrum. Moreover, if one rival, say firm A, outbid Mobilkom on one of its blocks, then in the following round Mobilkom would "punish" firm A by outbidding one of firm A's blocks, despite the fact that in principle Mobilkom could also bid on other identical and cheaper blocks. However, this kind retaliation lasted only for a few rounds, after which Mobilkom gave up its attempt to secure a third block.

In the second auction, 5 additional tranches of unpaired spectrum were sold virtually at the reserve price. The second auction lasted 2 rounds. Mobilkom and max.mobil got two blocks each, and Hutchison one block, raising additional ATS 1,752 million.

4.4 Italy

Italy decided to award 5 licences (valid for 15 years) through a two-stage process, combining a pre-qualification beauty contest with a competitive auction, in a rather standard SAA format. As an important variant, it was decided that if less than 6 operators participated in the auction, then the number of licences would have been reduced accordingly. The base price for each of 5 identical licences was set at L4,000 billion. In addition, entrants could declare their interest for some additional spectrum (two packages in total), to be allocated in a second time at a starting price of L1,600 billion. In the (unlikely) case than 3 or more entrants would win the first auction and be interested in the additional spectrum, this would have been allocated via an auction as well.

It can be argued that the debate in Italy was not very clear and transparent. At first it was decided to have a beauty contest, with a nominal entry fee. A Government reshuffle in May 2000 then decided to abandon the original idea. Only at the end of June it was made clear that an auction was going to be adopted, and rules were made public at the beginning of August. This may explain why only 8 groups applied to join the contest, most having strong local attachments. Two of them were then excluded during the pre-qualification beauty contest. One failed to file documentation on time, another one could not prove to have a minimum telecommunications expertise as required by the regulator.

The auction lasted 10 rounds (2 days) and the licences were allocated as follows (see the web site of the Italian telecoms regulator http://umts.agcom.it/):

Company	Last offer (L 000,000,000)	Additional spectrum
Omnitel	**4,740**	
IPSE	**4,730**	**Declared interest**
Andala	**4,700**	**Declared interest**
Wind	**4,700**	
TIM	**4,680**	
Blu	4,490	
Total	**23,550**	**Additional L3,200 bn**

The initial reaction to the Italian auction was to declare it a failure. The amount raised was well below expectations (Italy represents the second European market for 2G services in terms of subscribers, after Germany). In particular, the behaviour of the loser, Blu, was questioned. It had appeared before the auction started that the consortium, backed among others by British Telecom and by the motorway group Autostrade, could not find internal agreements and, despite being an incumbent, its position seemed weak compared to the rivals. In a sense, the Italian situation resembled the Dutch case, with 5 licences and 6 participants, one of which was considerably weaker than the others. What caused outrage was that, had Blu not participated at all, the number of licences would have been reduced down to four, in which case revenues would have most probably been much higher. It was then felt that Blu made a generous present to the other operators, perhaps having agreed some kind of compensation from one or more of them. The Italian competition authority is currently investigating this allegation.

These criticisms are contentious, without evidence of dishonest dealing by Blu. The Italian auction is interesting in that it produced the rather remarkable result that one of the existing GSM incumbent operators did *not* receive a licence. This allocation would have almost certainly not been reached in a beauty contest, where it is common practice to award reasonably sound incumbents a licence. The Italian auction then reached efficiency via competitive bidding: Blu could not top the rivals' offers due to its inferior capabilities to survive in the market, on the other hand the remaining companies were willing to bid higher prices and in the end they won a licence. Since it has been argued before that the main objective of Governments should be to achieve efficiency, in this respect the Italian case should not be used against auctions. Clearly, there is also an interest to have revenues as a side-result of a well-designed mechanism. Solutions like the German auction, or a hybrid auction with final sealed-bid offers may ameliorate the situation. However, this is still an ongoing field of study and the European experiences will certainly be of great help to design better auction mechanisms.

5. Spectrum Trading

The huge sums that have been collected in the auctions held in Germany and in the United Kingdom imply that operators expect in the future to generate enough extra profits to cover what they bid for their licences. Another way of looking at the same problem, is to say that future competition will not be very intense and will not dissipate to zero super normal profits, otherwise operators would not have bid high sums in the first place. Where do such rents come from? Some come from very legitimate sources, such as product differentiation, innovative tariffs, higher efficiency compared to the rivals, and so on. Some other rents may arise from operators tacitly colluding with each other, which seemed to be a typical behaviour in the mobile telecommunications industry, at least in early days.[xvii]

In both cases, these rents are possible because it is expected that other operators will not be able to replicate what a licensee is doing, and eventually undercut him. This may happen because existing competing operators do not have enough capacity, or because an outside operator simply does not hold a licence to utilise a similar portion of spectrum. Whatever the reason may be, huge licence fees indicate that there is a rent associated with owning a portion of spectrum around 2 GHz. This simple consideration has important implications in terms of the policy towards spectrum management.

By adopting auctions, we have "discovered" that the opportunity cost of using certain frequencies for 3G services is pretty high. Perhaps if the service was also feasible using portions of neighbouring spectrum not originally allocated for 3G services, some operators would be willing to buy it. However, this may not happen for different reasons. One reason is a more technical one, i.e. that some bands are reserved and cannot be used to avoid interference problems. Another reason may be that a neighbouring band may be allocated for completely different purposes, using different technologies and supplying different services. Perhaps such neighbouring band may have been assigned to other firms using completely different methods, like a lottery or on a first-in-first-out basis, or may be in the hand of the military. Even if they wanted, neighbouring operators could not offer a 3G service if that was not permitted by their licence conditions.

The question arise as to why licences in different bands are allocated using different methods, and, perhaps more importantly, why licences often specify the use that could be done with a specific band. Here, we are making a distinction between spectrum *assignment* and spectrum *allocation*. Typically, spectrum is first allocated for a certain use, and then some mechanism is employed to assign licences.

From an economic point of view, there is no clear-cut difference between the two terms. Individuals or companies that have a need for spectrum are different economic agents with different willingness-to-pay. This abstract figure can encompass 3G operators with alternative business plans, or a company that uses the spectrum to provide digital TV, or a ship that needs spectrum for radar transmissions. Since the point about a market system is to create an environment in which scarce resources end up in the ownership of the agents that value them most highly, it is clear that in principle we should try to introduce the price mechanism in the most flexible way. This means that individuals or companies should get property rights and be allowed to decide about the use they intend to make of their spectrum band, as long as they pay for it. As a consequence, secondary markets should be encouraged, and spectrum owners should be allowed to offer the service they want by employing the technology they choose. Another consequence is that the number of licensees would not be pre-determined by the regulator, but it would arise endogenously from the working of the market place.

Spectrum trading has the potential to increase efficiency: if trade occurs, it signals that some gains are made by both parties, which is precisely what the market place does via a price mechanism. This position is clearly extreme, but it should provide the starting point for an efficient policy towards spectrum management. Spectrum trading should not be permitted only when it would lead to market failures; otherwise there is no reason for opposing it.

As it is often the case in economics, one should understand the trade-offs involved and then make a decision. As an example, consider the case for licence resale after initial rights are allocated via an auction. If the auction worked well in the first place, there should be no reason for reselling to occur later on. But perhaps the auction had not been designed properly, or a new entrant appears in the market "too late" to take part to the contest, or some firms, who did not win the licence, later become more efficient than the winners. In this case the ability to transfer the licence would clearly increase efficiency *ex post*. The downside is that secondary markets may decrease efficiency *ex ante*. For instance, the auction mechanism could have reserved a licence to new entrants, or introduced bidding credits for them, if it was believed that such entry was beneficial for society in terms of innovation capabilities, product variety and market competition (see Example 2 in Section 2.1). If a secondary market is allowed, then a new entrant may sell if its private value for the licence is below the private value of an incumbent that did not receive the licence. However the additional value to society created by the entrant would not be taken into account in his private decision and would then be lost. This could be a difficult trade-off to evaluate, but it is the only sensible framework to follow.

Another important "grey" area concerns the spectrum given to the military. Almost everywhere the spectrum is allocated and no fee is requested. This does not encourage at all an efficient use of the spectrum. Perhaps there is somebody else in the economy that may be prepared to pay a high price for the use the same band. Since spectrum is a scarce resource with alternative uses, we should ask again what society gains would be in the two situations. Security, national defence and so on have clearly a value, and the military could get some bidding credits accordingly. However they would still have to bid among potential rivals using their budget. If they are not prepared to do so, then an argument could be made on economic efficiency grounds that their spectrum should be returned.

Spectrum in also used in network industries, and this is why some interference with the market place may be needed, for instance by specifying the technology to be adopted. While in markets without network effects, it seems to be unambiguously desirable to allow multiple competing technological systems, this is less so in markets with network externalities: there are both advantages and disadvantages to having multiple systems rather than a single standard. The presence of (strong) network externalities typically leads to "tipping" markets, where the winning technology takes the whole market. The theoretical literature does not provide an unambiguous answer to the question of whether the prevailing technology will also be the best one.[xviii] Advocates of government intervention argue that imposing a single standard makes it possible to realise network externalities faster, and reduces the technological uncertainty among consumers. This is why GSM was adopted as a common 2G standard in Europe. Advocates of free markets point out that letting systems compete is the best guarantee to promote better technological systems (possibly a voluntary standard), and reduces the risk of being locked into an inferior technology promoted by the government (mandatory standard). For instance, because there was no mandatory standard in the US, it was this market that generated the new CDMA technology, which is the key building block for third generation mobile telecommunications. The dispute can be rephrased as follows: one side believes standards generate markets, while the other side believes that markets generate standards.

Interference between adjacent bands may be a serious problem (a negative externality); hence technical bodies are needed to avoid it and to harmonise the practices of the various states. Spectrum trading should also not be allowed when it is used by incumbent firms to damage potential rivals (spectrum hoarding). In this case antitrust policy should monitor that the transactions do not have negative anticompetive implications. In conclusion, a decentralised solution is the preferred allocation mechanism, with the regulator monitoring the proper working of competition rather than deciding who does what. Spectrum trading should be promoted as much as possible, unless there are clear and serious market failures associated to it.[xix]

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Country	Number (and type) of licences	Minimum Coverage Requirement	Licensing process + notes	Issue of Tender/timing	Licence Award
Austria	Complete, with 2 tranches of 2x5MHz awarded to six operators in first stage.	25% pop. by end 2003, 50% by end of 2005	1st stage auction completed, raising ATS9.69 billion. Winners are: Mobilkom, Mannesmann, max.mobile, Connect, Hutchison, 3G Mobile. Second stage completed, awarding an additional 1x5Mhz unpaired to Mobilkom, Hutchison and max.mobil, raising ATS1.75 billion.	Auction commenced 2.11.2000	Completed 3.11.2000
Belgium	4 National 2x15MHz per operator plus 5MHz unpaired. Duration 20 years	Subject to confirmation	Auction with EURO150m reserve price per licence	Auction start expected December 2000	Expected early 2001
Czech Republic	4 National licences (2x10MHz up to 15+5MHz) to be awarded to incumbent GSM operators and one new operator	Yes, TBA	Governmental decision on details of licensing process Nov 2000 (probably beauty contest)	Licensing process starts January 2001	Awards expected Q1 2001
Denmark	Probably 4 National	Yes, likely	Auction	Q1 2001	Q3 2001 likely
Finland	4 National awarded		Beauty contest. 15 applications received.	Complete	Completed March 1999
France	4 National	Yes, but not yet clearly defined; possibly according to pop. density	Beauty contest, with fixed cost at FFR32.5 billion per licence	14 criteria announced end June 2000. Bidding opens end Jan 2000.	June 2001
Germany	Complete, with 2 tranches of 2x5MHz awarded to six operators in first stage.	25% of pop till end of 2003, 50% till end of 2005. RegTP reserves the right to introduce 70% pop obligation at a later date.	1st stage auction completed (17.8.00), raising DM98.8 billion. Winners are: 4 incumbents (T-Mobil, Mannesmann, E-Plus, VIAG) + MobilCom and Group 3G. Second stage closed 18.8.00, awarding an additional 1x5Mhz unpaired to all except VIAG.	Auction commenced 31.7.2000	Completed 17.8.2000
Greece	Not yet confirmed		Full details not yet confirmed	Public enquiry opens Q1 2001	End Q1 2001
Hungary	4 licences expected		Full details not yet confirmed		Issue expected 2001-2002
Ireland	4 National		Beauty contest. 19 responses to consultation received by 15.9.00 deadline.	Contest begins mid-Nov 2000	End May 2001
Italy	5 National 2x10 + 5 MHz each. Additional spectrum (2x5 MHz) available for entrants.	Regional capitals within 2.5 years; provincial capitals within 5 years	Auction with prequalification. 8 applications received, but 2 then excluded from the auction. L23,550 billion raised. Winners are: 3 incumbents (TIM, Omnitel, Wind) + Andala and IPSE. Additional L3,200 billion raised from entrants.	Auction commenced 19.10.2000.	Completed 23.10.2000
Liechtenstein	1 National	-	Licence awarded to VIAG Intercom	Complete	Feb 2000
The Netherlands	5 National, licences valid until 2016: ▪ Three 2x10 + 5MHz ▪ Two 2x15MHz	Phased coverage I-III within defined timeframe (2003/5/7). 60% of pop. within 5 years	Auction completed after 305 rounds, raising Fl5.9 billion. Winners are incumbents: Libertel, KPN Mobile, Dutchtone, Telfort and 3G Blue consortium	Auction began 10.7.2000.	Completed 24.7.00
Norway	4 National		Applications received from seven bidders for beauty contest with NKr18 million per year plus one-off fixed charge per operator	Invitation to bid closed 4.8.2000	Q4 2000
Poland	5 licences, with one reserved for TPSA	-	Auction with a reserve price of 650 million euros	Deadline for applications to bid 1.12.2000	Regulators will select licensees by end 2000
Portugal	6 National	20% of pop. within 1	Beauty contest with Escudo 20billion fixed cost,	Bidding process	End 2000

		year of launch; 40% pop within 3 years, 60% within 5 years	based on technical ability. 6 participants.	opened 3.10.2000	
Slovenia	3 National		Auction	Not yet known	Late 2000
Spain	4 National licences awarded	All cities over 250,000 pop.	Beauty contest with fee of 150 mill euros. Winners are three incumbent GSM operators (Telefónica, Airtel, Retevisión) plus Xfera. Government is considering the introduction of a further 150 mill euros yearly fee.	Completed 13.3.2000	-
Sweden	4 National licences at 2x15MHz each plus additional 5MHz unpaired per operator. Regional licences may also be offered by regulator		2-stage beauty contest, based on business credentials plus coverage and roll-out commitments. SEK100,000 fixed fee per applicant. 10 applications received by 1st stage deadline.	16.4.2000	Awards anticipated end November 2000
Switzerland	4 National	50% of pop. by end 2004	Auction with qualification conditions. 10 applicants have submitted bids.	Auction starts 13.11.2000	End 2000
UK	5 National licences awarded. Largest licence reserved to entrants.	By 31.12.07: coverage of 80% of pop.	Auction completed, raising £22.5bn. Licences awarded to four incumbent GSM operators (Vodafone, BT 3G, Orange, one2one) plus new entrant TIW	Auction began March 2000	Completed 27.4.00

Table 1. IMT-2000 Licensing Conditions & Status (source: UMTS Forum, www.umts-forum.org/licensing.html updated from various web sites)

[i] A large part of this spectrum was provided to the military in the context of spectrum plans and without the use of a formal allocation procedure.

[ii] Mostly, Paul Milgrom and Robert Wilson of Stanford University.

[iii] A complete, yet accessible, survey of auction theory can be found in Klemperer (1999).

[iv] We are not saying that the structure of the licences was wrong in terms of coverage and bandwidth, but that the auction format did not allow for efficient aggregation. For a discussion of exposure risk in the 1998 Dutch auction, see van Damme (1999) and Milgrom (2000).

[v] See http://www.spectrum-exchange.com/files/da001486.doc for the details of the auction and http://www.fcc.gov/wtb/auctions/combin/combin.html for the FCC-sponsored conference on the use of dynamic combinatorial auctions held in May 2000.

[vi] See Klemperer (2000).

[vii] A variant that combines objections 1 and 2 is that even though firms should logically maximise their profits on the basis of the comparison of forward-looking costs and forward-looking revenues, managers in all the licensed firms will act 'as if' the licence fee were a forward-looking cost, and raise prices accordingly. The obvious flaw in this argument is that if all the licensees except one behaved in this way, the last licensee could increase its profits by undercutting the others and stealing their business.

[viii] Notice that operators do include licence fees as a cost, possibly depreciating the fees over time. However, this is an instance of an accounting cost that has no economic impact on pricing strategies. On the other hand, accounting practices are clearly important for tax purposes.

[ix] Moral hazard refers to the possibility of self-interest misbehaviour and its presence limits the contracts that can be written and enforced. To give a relevant example, in the US the Federal Communications Commission tried to give an advantage to small operators in the auction for block C of PCS services, by requiring an upfront payment of only 5% of the winning bids. The result was to encourage speculative bidding: many operators won a licence, waited a while to see that the spectrum price was falling, then declared bankruptcy. The FCC realised that it had acted inappropriately in place of capital markets and, after that failure, decided to require full upfront payments.

[x] There is a rather extensive literature on the FCC auctions in the United States; see McMillan (1995), McAfee and McMillan (1996), Cramton (1997), Cramton and Schwartz (2000).

[xi] The question is whether the companies colluded improperly during the auctions or before they took place. Some efforts to co-operate with other bidders were legitimate: companies formed consortia before each auction to bid for licences together. But if the different consortia talked to each other during the auctions, or set out to rig the auctions, they would have acted illegally.

[xii] Paul Klemperer of Oxford University and Ken Binmore of University College London.

[xiii] A licence is worth more to an incumbent than to an entrant because the incumbent will have more market power if its bid is successful. This creates a problem for efficiency. Moreover, the fact that entrants may not participate to the auction altogether creates a problem for revenue maximisation.

[xiv] While in the early days 2G licences were looked at as being purely national, UMTS can be used to transform EU markets into a wider economic space than at present.

[xv] Klemperer (2000), and especially Jehiel and Moldovanu (2000).

[xvi] The following auction (for the remaining bits of unpaired spectrum) lasted for a day and raised a further DM 0.5 billion.

[xvii] See Parker and Röller (1997) and Busse (2000) for the US; and Valletti and Cave (1998) for the UK.

[xviii] For an overview, see Katz and Shapiro (1994).

[xix] Flexible policies for spectrum management have already been in place for some time in Australia (http://www.sma.gov.au/index/default.htm) and New Zealand (see http://www.med.govt.nz/rsm/). The UK is also implementing a radical change since the introduction of the Wireless Telegraphy Act in 1998 (see http://www.radio.gov.uk/).