**Unclassified** **DSTI/ICCP/TISP(2000)12/FINAL**

Organisation de Coopération et de Développement Economiques
Organisation for Economic Co-operation and Development **13-Dec-2001**

**English - Or. English**

**DIRECTORATE FOR SCIENCE, TECHNOLOGY AND INDUSTRY**
**COMMITTEE FOR INFORMATION, COMPUTER AND COMMUNICATIONS POLICY**

**DSTI/ICCP/TISP(2000)12/FINAL**
**Unclassified**

## Working Party on Telecommunication and Information Services Policies

# SPECTRUM ALLOCATION: AUCTIONS AND COMPARATIVE SELECTION PROCEDURES

**Economic Arguments**

**English - Or. English**

**JT00118426**

**Document complet disponible sur OLIS dans son format d'origine**
**Complete document available on OLIS in its original format**

## FOREWORD

The purpose of this report is to examine the pros and cons of the assignment of spectrum based on auctions and assignment based on a comparative selection process. The initial draft of the report was discussed in December 2000 by the Working Party on Telecommunications and Information Services Policy. The report, taking into account the views of the Working Party, was then submitted to the Committee for Information, Computer and Communication Policy in March 2001 where there was agreement that the report should be declassified through a written procedure.

The report is published on the responsibility of the Secretary-General of the OECD.

**TABLE OF CONTENTS**

## MAIN POINTS

The purpose of this report is to examine the pros and cons of the assignment of spectrum based on auctions and assignment based on a comparative selection (beauty contest). The paper also summarises the lessons learnt in the use and design of spectrum assignments and examines the theory underlying spectrum auctions. A number of OECD countries use a comparative selection procedure to allocate spectrum licences in some cases because they believe that the theoretical results of auctions may not hold true in reality or because they believe that a number of economic and/or social objectives cannot be fully incorporated into the auction model.

The report is structured as follows: after the Introduction (Section 1), Section 2 contains an overview of the pros and cons of auctions and comparative selection procedures. Section 3 provides a critical examination of the outcomes of some recent spectrum allocation for third-generation mobile services in several OECD countries. An Appendix contains an overview of auction theory.

The main findings of this report are:

- For the most part, economic and social objectives that governments may want to pursue when allocating spectrum can be accommodated equally in an auction and a comparative selection procedure.

- Auctions can increase the efficiency of spectrum use, when they are well designed, by using a price mechanism for the allocation of spectrum;

- When low licence fees are set, a comparative selection procedure can have a positive impact on the speed of network rollout and on the level of end user prices. This would depend on how sunk costs are treated.

- Firms are in a better position to evaluate the value of spectrum for the services they provide than governments. Although firms have greater knowledge of new markets and associated costs, the lessons of present 3G auctions is that in some cases firms, as well as governments, can err and can be subject to "exuberant expectations" as a result of the economic climate at the time.

- It is possible for auctions, when they are well designed, to maximise societal benefits of a scarce resource and ensure that economic rent is obtained by the public rather than shareholders.

- Correlated information among buyers in an auction (winner's curse) has negative consequences on revenue and can distort allocative efficiency. 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 and the rules accompanying the mechanism (such as special access and roaming) are crucial. Flaws in the procedure can dissipate the benefits of using a market mechanism.

- For licences allocated either by auction or a comparative selection procedure, the creation of conditions for competition is crucial in ensuring that users will benefit from price competition.

- Aftermarkets and more in general spectrum trading have the potential of further increasing efficiency and therefore should be promoted, but regulatory oversight is important to avoid any tendency towards the creation of oligopolistic markets.

## SECTION 1: INTRODUCTION

Technological change over the last several decades has led to significant growth in new communication services making demands on scarce radio-frequency spectrum resources. In the OECD the number of mobile operators increased from 35 in 1990 to 105 by 2000[1] and the number of subscribers increased from 10.5 million in 1990 to 359 million by the end of 1999, or on average 32 subscribers per 100 inhabitants for the OECD.[2] During 2000 a large number of OECD countries licensed 3rd generation cellular mobile services[3] and wireless in the local loop technologies (also known as fixed wireless access services). Growth in the demand for spectrum is expected to continue as new technologies develop in the telecommunications sector and with the demands from digital broadcasting technologies. In turn, these developments are leading OECD countries to focus more on the issue of allocation of these scarce radio-frequency resources. The allocation of 3rd generation licenses in 2000 focused policy attention on the mechanisms for spectrum allocation and led to a wider debate on the policy of spectrum allocation. In part this was due to the different results obtained by OECD countries in the licence revenues generated through auctions and through comparative tendering of licences.

In the early 1990s only two OECD countries (New Zealand and the United States) used an auction mechanism to allocate spectrum for telecommunication services. By 2000 12 countries used or were planning to use auctions to allocate 3G mobile licences. There is thus no consensus across the OECD on how best to allocate scarce spectrum resources. At the global level there is even less of a consensus on allocation methods. However, there has been agreement on some general principles that should apply to the allocation of scarce resources. For example, in the Reference Paper of the WTO agreement on basic telecommunications in referring to the allocation of frequencies notes that this should be carried out in an objective manner, under conditions of transparency and in a non-discriminatory way. To date there has been no attempt to amplify what is meant in this context by “objective”, “transparency”, and “non-discrimination”.

Early allocation of spectrum often took place without any formal allocation procedures, but rather through administrative measures. This was the case for allocating spectrum to the military and often true for the allocation of spectrum for broadcasting. Resort was also made to other methods such as lotteries and comparative selection procedures (commonly known as beauty contests).

Because spectrum is a scarce resource policy makers have in many countries been giving greater emphasis to increasing efficiency in spectrum allocation and in spectrum usage. As a result, countries began to move away from the notion that spectrum fees should only be aimed at recovering costs of spectrum management. More emphasis has been placed on market mechanisms as the best way to achieve efficient distribution of a scarce resource. The increased demand for spectrum has also has increased the value of this scarce resource to society.

The recent auctions for third generation mobile licences (3G), especially in Europe, the quite different results that occurred in these markets over a relatively short period of time, and the subsequent economic events which financially weakened telecommunication operators that had participated in these auctions, has led to a number of analysts refocusing attention on the auction mechanism.

In the European Union the licensing of 3G spectrum has so far led to a transfer of about Euro 130 billion[4] (USD 111 billion) from the private sector to governments. This amount is equivalent to over twice the total telecommunications investment in EU countries during 1999 or to about half the total EU telecommunications revenue (fixed and mobile) in 1999. This amount is only for licence acquisition, either through an auction or a comparative selection procedure, and does not include the investment costs.

## Common objectives in allocating spectrum

Countries in general have some common objectives in allocating spectrum irrespective of the method chosen. These include efficient allocation of spectrum and efficient use of the spectrum, transparency in the award of licences, non-discrimination in licence awards, and the creation of appropriate conditions for market competition. There may be other wider economic or social objectives as well. Some of these objectives are elaborated on below:

### *Efficient allocation*

The allocation process will be efficient if it allocates the licences to those companies who value them the most. The value of a licence to a firm is represented by the future returns that this firm expects to get if given the licence. These returns (profit) depend on several factors such as:

- The firm's own characteristics such as its cost, financial situation, ability to innovate and so on.

- The characteristics of competitors as this will be an important determinant of market shares and prices.

- The characteristics of the market such as user demand, and expectations for future service development.

- The performance of financial markets as it will affect the operators' financial situation and possibilities as operators rely heavily for their investments on such markets.

The firm has certain knowledge only for a few of these factors. This implies that there is uncertainty in terms of the value of the licence for any potential operator. Nevertheless, based on their knowledge of their own cost structure, expected user price structures and assessment of market demand, a firm is in a better position to assess the licence value than other parties, including governments. It is a legitimate assumption to believe that the "best" firms will place the highest value on a licence, where "best" refers to firms with the lowest costs, a great ability to innovate and remain competitive. Indeed, if potential market entrants share similar expectations over future demand, and the performance of markets over time, then differences in the value they place on spectrum reflect mainly differences in their own internal structural (*e.g.* cost and innovation) characteristics. Under such circumstances the potentially more competitive firms would place higher values on their licences.

***Efficient use of the spectrum***

Efficiency in the allocation of licences must be linked with efficiency in usage of the spectrum. Intuitively, a firm that made a competitive bid for spectrum through an auction procedure would tend to have a high incentive to use the spectrum efficiently. In turn this would mean that there is an incentive to build-out the network relatively rapidly. Other means are also available to ensure efficient use of spectrum. A market where competition was strong would provide appropriate incentives for efficient spectrum use, which in turn means that the number of licences issued for a particular service is important. Allowing the trading of spectrum resources can help improve efficient use. Imposing build-out requirements on licensees can speed up the development of services, but does not necessarily provide the right incentives to use spectrum efficiently.

***Market competition***

The creation of market competition is a goal that most OECD countries now have for their telecommunication sector. The number of licences made available can be a key factor in this regard. Governments need to make two decisions in this context. First, how many should be sold simultaneously. Second, should it be made clear to the industry that *a priori* no limitations will be placed on the number of licenses issued. In other words, as new technologies become available or as suitable spectrum is freed from other uses, it will be made available for new entrants. Such a policy provides an incentive for existing entrants to build-out their network rapidly and provide low prices. It also can impact on the price entrants are willing to pay for a licence in the case of an auction. Although in economic theory under certain conditions there need not be a clear relationship between the number of operators in a market and the intensity of competition, this condition holds where consumers can easily switch from one service provider to another, there is homogeneity in products offered, and if there is no tacit collusion in the market. Experience from second generation cellular markets (*e.g.* GSM) shows that a duopoly does not in fact generate much price competition.

If the creation of competition is an important criterion for a government then the choice of method used to allocate a licence can be important. An auction would normally allow for the most efficient firms to get a licence. Such operators would generally be in a position to offer the lowest prices. The identification of the most competitive suppliers is not a trivial task. Much of the information regarding an operator’s competitiveness is based on private information (*i.e.* known only to the operator), although this could be revealed through an efficient procedure in a comparative tender.

***Other potential objectives***

Countries have a number of other objectives, some of which differ. In the United States, for example, auctions had so-called spectrum ‘set-asides’ which were aimed at encouraging bidding for spectrum by small businesses, rural telephone companies, small businesses owned by minorities and/or women. Many countries have imposed geographic and population coverage requirements on 3G licenses (as they did for 2G licenses). Countries have also specified the speed in which networks are developed and service is made available. Social or other economic objectives can be inserted into licence conditions whatever the form used for the allocation of the licence. In an auction such objectives will be factored into the final price that a firm is willing to pay for a licence, but in a comparative selection procedure where a fixed fee is charged a firm has no flexibility and can only choose not to tender.

Generally OECD governments have not put revenue maximisation as an explicit objective, and certainly not a primary objective, in the allocation of spectrum. In reality, however, revenue maximisation has played a large part in a number of countries in the allocation of spectrum. This has been the case irrespective of whether spectrum has been auctioned or provided through a comparative selection procedure. It is unfortunate that this has taken place because it has tended to distort the primary objectives of efficient allocation of spectrum, rapid development of new services and affordable prices for end users. This has occurred not so much through the *method* used to allocate the licence but rather through the details attached to the method used: for example, limiting the number of licences, setting a 'high' entry price for a comparative selection procedure, or through the structure of an auction procedure.

The importance attached to revenue maximisation is evident from the fact that invariably governments judged the relative success of the allocation of 3G licences on the basis of revenue generated. It has been argued that the "auction revenue "dog" as the pursuit of dollars…has come to dominate long-standing traditional concerns for maximising the overall value to citizens of private sector use of their public resource."[5] Such comments are not aimed at criticising the method used to allocate spectrum but its design.

## SECTION 2: AUCTIONS VS. COMPARATIVE SELECTION PROCEDURES

There are some major differences between auctions and comparative selection procedures, but also some similarities. The first difference is that the decision on the price paid for spectrum, and therefore its economic value, is given by telecommunication operators through their bids. After all it is these operators who will exploit this spectrum to provide services to the public. It is also through these bids that firms determine who will get a licence in a transparent way. A comparative selection procedure leaves price decisions and allocation decisions to administrative fiat, that is, to a closed evaluation procedure that provides a subjective valuation of the spectrum to be allocated. In an auction there is price competition in that the players determine the price they pay for a licence.

A second important factor is that the allocation of spectrum through auctions is based on well established economic principles that have been tested in several areas. Comparative selection procedures are not based on such theoretical frameworks and by their nature involve a subjective evaluation of criteria. However, comparative selection procedures can be considered as fair because the same criteria are used to judge the merits of each submission. Usually a committee 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, competitiveness and public services.

It is important to stress that the difference between auctions and comparative selection procedures 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 comparative selection procedure can be a monetary one. When using a precise set of measurable and enforceable criteria with weighted valuation to each criterion, comparative selection procedures can deliver the right incentives to disclose private information and as such are very close to an auction. 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 comparative selection procedure 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 to occur, hence an allocation mechanism has to induce operators to reveal their own private information. This is where comparative selection procedures, in principle a very flexible way of allocating public goods such as 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 be forthcoming in their offers to the jury. For example, if a comparative selection procedure selects the operators that offer the best business plan, defined in terms of quality of the services offered to customers. *Ex post*, that is 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*, that is 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 by 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 enforce all the promises. In any case, even in the case of an auction, Government has to check *ex post* if conditions included in the authorisation (rate of coverage, quality of service, *etc*.) are fulfilled.

The financial difficulties that presently characterise the telecommunication industry, and the impact this is having on the ability of firms to rollout new infrastructure, are leading to a number of new policy discussions. For example, sharing in network infrastructure costs is being proposed by operators, and some regulators are sympathetic to this as long as they do not change underlying licence conditions. Sharing would involve sharing base stations, towers and antennae. Other operators are discussing the possibility of extending the licensing period, lengthening roll-out obligations, reducing licence conditions, and in some cases obtaining refunds for their bids. Regulators to a large extent have been wary of changing licensing conditions. It should be stressed that operator complaints are not limited to those markets where spectrum was auctioned. In one case, Spain, where spectrum was allocated through a comparative selection procedure and prices for licences were not considered generally high, the government has accepted to extend the deadline for the roll-out of networks because of problems linked to the availability of handsets and network equipment.

In the following sections some of the pros and cons of auctions and pros and cons of comparative selection procedures will be examined.

## Auctions: Pros and Cons

### *Pros*

#### *Revelation and use of information*

Licences for 3G have some uncertainty because of the new technology, new market and services. However, even given such an uncertain environment, operators have more information about themselves in terms of potential cost functions, price structures, potential returns to investment and innovative ability. Given this information they also have the capacity to judge the risks they are willing to assume. Incumbents, who have already been providing 2G services, have possibly better information about the 3G market and its potential.

Given that their future depends on their own internal predictions on profitability and market demand, operators have an incentive to ensure that their predictions about future demand and future opportunities are as accurate as possible. Their experience (once again, especially if they are incumbents) has provided them with knowledge about the type of technology that will be needed to satisfy consumers, its cost and skill requirements. Therefore, operators are more likely to have better estimates of the economic value they can create and the profits they can expect than governments.

An auction obliges the participants to reveal, via their bids, the future expected stream of profits. Their bids reflect this information. If well designed, the auction will give a clear ranking of operators, which should result in the most competitive suppliers obtaining a licence. They are therefore more likely to use the spectrum more efficiently. In terms of ensuring best use of scarce spectrum resources an auction also has the benefits of transferring rent from shareholders to the public (government).

*Equity and transparency*

Auctions rely on relatively simple and transparent rules that apply equally to all participants. As such they are fair and transparent. Given that bids are observable and verifiable by a court or any third party, the final allocation is less likely to be legally contested relative to a comparative selection procedure. In the case of 3G auctions there were cases in a number of countries where the auction ended very quickly and there was concern that collusion had taken place among bidders. However, investigation by competition authorities showed that no collusion had taken place.

*Avoiding corruption*

In an auction the final bids are all that matters for the final allocation of a licence. Since these bids are observable and verifiable, the scope for corruption in licence allocation is minimised since it would not affect the ranking of bids.

*Reliance on expertise*

Because operators determine the price and allocation of licences through bidding, the government does not need to rely on technical and financial experts to identify the most competent operators. Thus, an auction does not require any intermediate third party acting in between the government and the operators. This reduces the cost of allocating licences and eliminates possible “moral hazard” problems.[6]

Other Points

*Collusion*

It has been suggested that operators burdened by substantial sunk licence costs will feel more vulnerable, hence more reluctant to engage in price wars and more inclined to act collusively. The likelihood of collusion depends on the way competition law is enforced, which is not linked with the amount paid for licence fees. The number of licences issued will play an important role in the extent of price competition. Experience from 2G mobile markets has not shown any evidence that would link the degree of collusion to the methodology used to allocate licences.

*Revenue maximisation*

The value of a licence in an auction is decided by those who are most knowledgeable as regards the market for which the licence is issued and therefore have an economic interest to ensure that the price they pay reflects the market value of the licence. Thus, under an auction operators are more likely to pay what a licence is worth. As a result the government extracts most of the surplus rent which may be generated by

3G mobiles services. This is beneficial for the owners of the spectrum, that is society at large, and taxpayers, and for the government itself who can use the revenue for other objectives.

***Cons***

There are two major drawbacks of auctions. First, they may lead to high licence fees. This can hinder the rapid use of spectrum, the roll-out of new networks and services and the promotion of competition. Second, the success of auctions depends very much on their design, which can be a particularly complicated task. Some arguments why operators may pay too much for licences are discussed below, followed by a discussion of some of the possible drawbacks of high licence fees. Then the issue of auction design is briefly considered.

*Can operators pay too much for licences?*

Earlier it was argued that the licence bidders have the knowledge that would lead them to make an optimum bid. Theoretically, overbidding should not occur since firms are rational profit maximisers, they are well aware of the conditions of the licence and would not take a decision that puts them in financial jeopardy. Nevertheless, there are a number of arguments that could result in bids being "overpriced".

Most of the bidders for existing 3G licences have been incumbent second generation mobile cellular service providers. If an incumbent did not obtain a 3G licence it was generally assumed that the incumbent would over time cease operation as customers switched from 2G to 3G services. In effect, this meant that incumbents had to ensure that they obtained a licence for the future survival of the firm. A bid for survival could result in an overpriced licence. Such a consideration would result in bids being made which would be different than in a "stand-alone" situation. For example, bids for fixed wireless access did not in general reach the level of 3G bids because there are competitive alternatives to these services so that lack of success would not be crucial to a firm's future. For 3G some firms in Europe, which did not make submissions for licences, are now looking at upgrading existing GSM services using GPRS (General Radio Packet Services) or EDGE (Enhanced Data Rates for Global Evolution) technologies. It is difficult to say at this stage whether these technologies offer only an interim step or a more lasting solution to those operators without 3G licences.

In an auction, operators often pay whatever they bid[7]. The less they pay, the better. Still, the lower they bid the more likely they are to lose the auction. The extent to which operators want to increase their bids depends on the benefits accruing from owning a licence but also on the cost of not owning a licence. Because the spectrum is a scarce resource only a limited number of licences can be issued. If, as stated before, the alternative to owning a licence is to be out of business, the cost of losing can be quite high and operators have strong incentives to bid high.

Most European 3G licensing took place in 2000 during a period when there was a stock market boom which, in particular, led to high market capitalisation of telecommunication operators. In turn the euphoric market led to easy credit for potential 3G licensees. The dot.com economic bubble during this period seemed in particular to augur a bright future for any communication network endeavour. The value of a licence also depends on the stock markets' performance as it crucially affects the wealth of telecommunication firms. To determine their bids, the operators must rely on predictions. When expectations over future market performance are high, access to financial support is facilitated, and because of a high market valuation a firm may believe that it can "afford" to bid a high price, then economic circumstances can lead to high bids. Economic research on market overconfidence and its impact is, unfortunately, relatively new. Clearly, once there is a downturn in market conditions the price paid for spectrum, which may initially have looked reasonable, is viewed as high and as aggravating the financial strength of the buyer.

Auctions where high licence prices were paid, such as in the United Kingdom and Germany, took place in a period of overall economic optimism. But so did the auction in the Netherlands where prices (as measured by the amount paid per licence per capita) were much lower. More recent auctions that took place at the end of 2000, such as in Switzerland and Belgium, led to lower bids, and took place when the stock markets started to perform poorly.

The sudden collapse in market capitalisation and the high debts of companies accumulated by some companies in buying 3G licences, could lead to arguments that the auction system is at fault. But, many telecommunication operators that obtained 3G licences through comparative selection procedures also suffered from high debts and financial difficulties. It is true that the financial ability of operators would be eased if the terms and conditions of licences were different, for example, by allowing licences payments to be made over several years when revenue was being earned from new services, or to ease terms such as coverage or speed of build-out of networks. The latter point relates to the structure of the auction and is not a criticism of auctions as such.

Even if they have more information than government officials, operators still have to take a decision in a particularly uncertain environment. There is uncertainty about demand, uncertainty about the skills required to satisfy this demand, uncertainty about the economic value that will be created, uncertainty about the ability to retain some of this economic value, *etc*. Recently, delays in 3G rollout have been experienced because of problems in obtaining handsets, a factor that would have been hard to predict. Factors that slow down development of 3G infrastructures and services, and postpone future revenues may have a larger impact where auctions are used since upfront fees have already been paid.

Although economic theory does not factor in the possibility of too high prices, it nevertheless gives an argument for it: the winner's curse. The value of a licence to each operator does not only depend on its own characteristics, but also on characteristics that will affect all bidders (such as size of the future demand, the development of new technologies, *etc*.). Therefore, the values for all operators are correlated. When this is so, bidders suffer from the winner's curse: winning can be bad news as it means you might have over estimated the object's value. Even if bidders take into account this effect when calculating their offer and adjust their bids accordingly, it remains true that the winner is the one who has the highest value on average.

Several recent experimental studies performed by Kagel & others (see references) show that the winner's curse adverse effects might be more important than predicted by theorists. The experiments in Kagel and Levin (1986) showed that aggressive bidding resulted in negative profits. Kagel and Garvin (1994) show that inexperienced bidders in first-price common value auctions[8] suffer from the winner's curse, losing money on average. Similar results can be found in Kagel *et al*. (1989) where early auctions (in a context of repeated auctions) are characterised by high bankruptcy rates.

Overbidding is a phenomenon that also occurs in areas other than auctions. In take-over processes, it has been shown that bidders who own stakes of the target firm, have an incentive to bid aggressively. In particular, Burkart (1995) shows that bidders who own stakes of the target firm will overbid so as to sell their shares at a high price if they lose. In that context, high bids lower the probability of losing. In a context where there is a high cost of losing such as in an auction, overbidding could occur as noted above if the counterpart to winning a license is to be out of business.

*Consequences of high licence fees*

One proposition that has been put forward is that high licence fees lead to high debts, which reduce the possibility of making further investments, and increase the risk of financial instability. In turn this has negative impacts on the development of reliable, efficient and competitive services.

In the past year, 75% of European high-yield bond issues came from telecommunication firms. As a consequence of facing high debts, the credit rating of many telecommunication firms, including those that had won 3G licences, plummeted and their stock prices dropped. Moody's, a credit rating agency, reckons that the financial flexibility of some operators will be significantly weakened. This is likely to constrain the firms' investment possibilities. In retrospect, the high licence fees paid in some countries for 3G licences may be incompatible with the development of an efficient, reliable service at competitive price. However in other countries where 3G licences were issued through a comparative selection procedure at a relatively low fee compared to the auction fees paid in the United Kingdom or Germany, companies have delayed investment because of financial problems. The difficulties being faced by telecommunication operators, even in countries that have yet to allocate 3G licence fees, makes it difficult to conclude that the 3G auctions in themselves and high fees paid are the main problem underlying the present investment capability of operators.

However, with hindsight, more rational bids would have lessened their present financial difficulties, and better payment terms, which took into account revenue flows, would also facilitate development. Again it should be stressed that these difficulties should not be blamed on the auction process itself. The firms are to blame for what may, in present economic circumstances, be considered as irrational bidding in some countries, and governments with less concern for revenue maximisation and more concern for the development of the sector would have provided for better payment conditions for winning licence fees. It is important, however, for governments to avoid the temptation to try and reduce competition so as to guarantee that operators receive enough returns to remain in the market. Thus, where licences have yet to be issued or completely issued governments should try and ensure that the licensing process is complete to create favourable conditions for competition.

Overbidding in auctions may result in the lessening of potential competition. Trends in Europe toward reducing investment costs by sharing masts and other infrastructure need to be closely monitored by competition authorities to ensure that these trends do not reduce the overall level of competition and lead to collusion.

*High licence fees can impact negatively on universal coverage*

An argument that has been put forward is that high licence fees may weaken the firm's ability to raise more capital to invest, therefore slowing down investment. Further, if the investment possibilities of operators are constrained as a result of high debts, or if operators need immediate revenue inflow to remain in the market, they will postpone costly objectives such as universal coverage. This criticism is not specific to auctions since licence fees for comparative selection procedures can be high. The validity of the argument is also dependent on how payment for licence fees is required, that is, whether they are paid immediately or over time. However, a counter argument is that firms that have paid high licence fees have an incentive to roll-out their network rapidly in order to recover costs.

*High licence fees can discourage participation*

If there are expectations that the final price for a licence will be high, then the number of participants in an auction may be limited. This could occur if the auction is structured so that there is a minimum threshold bid (and this is too high), or if the government has “talked” the price up by indicating its expectations for the auction result. However, this critique can apply equally well to a comparative selection procedure where high announced entry prices led to fewer applications than the number of licences made available. Participation can also be reduced for the same reasons because potential bidders decide to merge in order to ensure that they can have stronger bids. The reduction in the number of participants can reduce the level of bids made and, therefore, the success of the auction, if revenue maximisation is used as the criterion to judge success. Again any criticism here is on the way in which auctions are managed rather than on the principle of auctions *per se*.

*Higher licence fees will mean higher prices to consumers*

When 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. If successful the firm will pay for the licence, either up-front in full or through a binding commitment to pay in instalments. In this context it can be argued that, 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, according to this argument, the size of the licence fee may not affect prices. It is possible that the calculations of a firm may result in overpayment of a licence resulting in financial distress or even bankruptcy. This would result in a one-time loss for investors and perhaps a change in ownership of the licenses and other assets, but would not harm consumers or the public interest.

If firms do not have to pay a licence fee for spectrum irrespective of whether it is through an auction or a comparative selection procedure will prices be lower for consumers? The market and the conditions of competition in the market will determine prices. If the market is not very competitive prices will remain high so administrative allocation of a licence with any fees does not necessarily guarantee lower prices. This premise can be illustrated by developments in the 2G cellular markets where countries which initially had a duopoly, had high prices and the best price performance was achieved in those countries that had more than three operators. In the case of 3G licences some countries that allocated licences with licence fees have only three operators while other countries that used an auction have five operators.

The assumption that licence fees are a sunk cost is, however, based on the argument that the market is sufficiently competitive, which is not always the case given that the number of licences issued is usually limited either by the government and/or by the availability of spectrum. In addition, since all firms with a licence face a similar level of licence fees the possibility exists that all firms shift the costs of the licence to users.[9,] In an oligopolistic market this may occur, but again this is not a criticism of auctions or comparative selection procedure, but depends on the number of licenses issued. From an accounting perspective licence fees are often capitalised and partially written-off over the years, depending on the relevant tax rates, as a cost.[10] While the concept of sunk costs has traditionally held sway in economic theory it has recently been questioned, and there is not unanimous agreement that the prices paid in auctions do not play a role in firm strategies especially with respect to their level of end user prices.

*Do licence fees favour wealthier companies?*

One argument that has been put forward is that auctions favour richer companies and therefore may lead to oligopolistic tendencies in the market. However firms with the know-how and technology would normally obtain support from financial markets. The danger in creating oligopolistic markets is probably greater when licences are administratively allocated since there is a tendency in that process to favour existing companies that are known to those allocating the licences rather than to allocate them to new entrants. The danger of oligopoly is also clearly linked to the number of licences given, which in turn would impact in an auction on the prices bid.

**The design of spectrum auctions**

The literature on auctions *per se* is far from being sufficient to characterise the best auction for licences.[11] The reason lies not only in the complexity of the environment (risk aversion, statistically dependent values *etc*.), but also on the fact that it is important to consider issues such as: discouraging collusion, entry deterrence, *etc*. In addition, market conditions differ from country to country so that auction design may have to take this into account. Using their experience, Klemperer (2001) and Cramton (1997) give some insights on auction design. Here is a summary of their observations:

The design of an auction is crucial for its success. However, this is a particularly difficult task. The auction must not only attain some of the objectives mentioned earlier, but must be easy to implement. There are several reasons why auction design is a complicated task:

- Each country may require a specific analysis and needs a different auction design.
- Several economic issues (other than the objectives themselves) need to be considered, each requiring substantial economic knowledge and experience. For instance, an auction can fail to achieve efficiency and to guarantee competition if it leads to collusion, deters entry and/or results in predatory behaviour. Because bids can be used as signals between operators, it is possible for anti-competitive behaviour to occur.
- The auction must reach all objectives by relying only on simple rules for implementation purposes.

Basically, governments face the problem of allocating several licences to more than one operator. Two major concerns came up: should open bidding be used and should licences be sold sequentially or simultaneously? Cramton (1997) puts forward the following arguments:

*(1) Open bidding versus single sealed-bid*

- Pros: An open auction releases more information and therefore allows bidders to condition their bids using more information; this is likely to promote efficiency. It also reduces the winner’s curse and therefore promotes competitive bidding.
- Cons: Because it allows bidders to use their bid as signals it favours collusion. Open bids can be used either to give information to other bidders or to punish deviation from a collusive agreement. If there are large differences among bidders (*e.g.* in terms of access to financial resources) an open auction will allow the richer bidder to win by simply increasing the price until the poorer bidder drops out. Along the same line, as cited by Klemperer (2001), an open auction can deter participation of bidders who believe that they are at a disadvantage as they

know they will be outbid at an early stage. Sealed bid auctions oblige financially rich bidders to evaluate more carefully their bid and the value of the licence since they have only one chance to bid and win. However, despite the fear of collusion, the open auction is believed to be better.

*(2) Simultaneous open bidding versus sequential auctions*

- Pros: To calculate their bids in a sequential auction, buyers have to guess the outcome of future auctions, which makes their task much more complicated. A simultaneous auction releases more information, and allows bidders to switch among licences given the flow of information. Bidders therefore have more flexibility and more information, which reduces the winner's curse.[12]

- Cons: Simultaneous auctions can facilitate collusion as bidders can increase the price on some licences to punish bidders deviating from collusive agreements or to signal which licence they want. Simultaneous auctions are more difficult to implement; sequential auctions have been extensively used in practice and are therefore less risky in terms of success.

In general, however, the greater flexibility and flow of information generated by simultaneous auctions are believed to outweigh its drawbacks.

In 1993, the United States Congress authorised the Federal Communications Commission (FCC) to use auctions to award the rights to use radio spectrum. The first auctions in the United States took place in July 1994. The FCC was also given a set of multiple goals to meet. After reviewing conventional auction designs, such as sequential or sealed bid auctions, the FCC developed a methodology for auctioning a large number of licenses at one time, referred to as a "simultaneous multiple-round auction". In addition to its auction design, the FCC added a combination of incentives and structured the auctions so as to put aside some licences to encourage participation by different types of new entrants, such as small and medium-sized enterprises, minority groups, *etc*.[13]

As argued by Melody (2001) the structure of competition in the bidding process is the most important element in the design process. Reducing barriers to entry is important if the goal is efficient spectrum allocation whereas if revenue maximisation is the goal then the creation of independence by bidders on the licence can achieve this.[14]

A particular problem in the case of the European Union countries was that the licence allocation took place over a relatively short period and the high final bids in the United Kingdom and Germany led to "irrational expectations" by governments in other countries in terms of the price they expected for licences, irrespective of whether they were using auctions or comparative selection procedures.

**Comparative selection procedures: pros and cons**

A comparative selection procedure can be structured in a number of ways. A common procedure is to set the licence price – an entry price – and set down as well other licence criteria. Potential licensees must submit in their applications their rollout plans, expected quality levels, technologies to be used, expected coverage of population and geographic area, *etc*. Each set of criteria is given a weight and the winners are those operators whose applications obtain the highest points. Instead of setting a licence fee, a minimum fee can be set and the amount offered for the licence becomes one of the criteria, but not necessarily the determining criteria, in choosing successful bidders.

***Pros***

*Equity*

It can be argued that there is equity in a comparative selection procedure in that all participants are required to submit the same information and the same criteria are used to judge and weigh the relative merits of a submission. The experts that review submissions are required to treat them in an objective and non-discriminatory manner. Nevertheless, it is evident that even if two bids were technically similar a judgement needs to be made as to which is relatively better. By definition this will need to be based on subjective criteria. This compromises equity.

*Fixed licence fee*

There are two main reasons why a government may charge a licence fee for users of spectrum. The first is to cover the costs of administration of spectrum. Traditionally spectrum fees were used to cover the costs of running the government agency that planned spectrum allocation, allocated spectrum and monitored spectrum use in order to prevent interference. The second reason is to increase efficient use of spectrum. In a comparative selection procedure the government can thus set a price, which is aimed at extracting economic rent from the operators and, as in an auction, induce the most efficient operators to apply for a licence. However, unlike an auction, governments need to decide what the appropriate level is for the licence fee. It is unlikely that the governments have access to the information which firms have to value the spectrum. The government's valuation of the licence fee thus has a degree of arbitrariness.

If the concept of *sunk costs* hold then the level of the licence fee should not pose a problem for firms (as long as this level is below the level that would have been bid in an auction). However, if licence costs impact on end user prices, and if the government's goal is to ensure affordable prices for 3G then the level of the licence fee is important. If there are other goals, such as rapid deployment of networks, or universal geographic coverage, then lower fees may also be important. Does this then mean that a comparative selection procedure is better since these social goals can be taken into account? The answer is no, as mentioned earlier, since such social goals can be introduced in an auction and their economic cost will be reflected in the amount that firms are ready to pay in an auction for a licence.

An auction also has the added advantage that the bids will normally reflect the economic conditions pertaining at the time and the access to capital and capitalisation value of the firm. Poor economic conditions will result in low bids. A comparative selection procedure is usually based on a pre-announced licence price which, politically, may be difficult to change to reflect the change in underlying economic conditions.

*Forecasts matter less*

The type of expertise required to guarantee the success of a comparative selection procedure is very different from the one needed for a successful auction. Because less emphasis is put on the price *per se*, forecasts over future markets' performances, future demand, *etc.*, are not so crucial. Instead, financial and technical experts determine the operators' ability to supply the market from their *current* financial situation and technology. These elements are not random, they are observable and even verifiable by a third party.

*Possibility to include social objectives*

Comparative selection procedures allow the government to favour specific entities if they wish or need to do so. It is not clear whether such considerations are worth considering. By maintaining a relatively low licence fee more onerous social objectives can be imposed on potential market entrants, but these can also be included in auctions where the bid price should take these into account.

***Cons***

*Revelation of information*

Most of the information needed to evaluate the operators is privately known. Even if the value of their stocks, accounts and the technology they use are perfectly observable, some information is not and can be manipulated.

By choosing a comparative selection procedure, the government does not give the appropriate incentives to firms to reveal and use their information. In particular, firms are asked to commit to some specific future actions (guarantee lowest prices, invest in infrastructure, *etc*.). First, it is not easy for the firms in such an uncertain environment to guarantee future prices, investments, *etc*. Second, the government might not be in a position to verify whether such commitments are respected and, if they are not, it might not be possible to penalise a firm who can claim they are doing their best given the circumstances. Therefore, because a comparative selection procedure relies on promises in an environment where one cannot guarantee that such promises will be enforced, it can lead the operators to make proposals that rely more on what the government wants to hear rather than on their true private information.

*Lack of transparency*

The final decision to provide a licence using a comparative selection procedure is based on evaluations taken in private meetings. The allocation does not depend on any observable and verifiable action such as bidding. The outcome is then more likely to be contested by losers. Justifying the decision is a complicated task as it often relies on many criteria some of which will invariably be subjective.

*Risk of corruption*

A comparative selection procedure introduces higher risks for potential corruption compared to an auction. Care must be taken to ensure that there is no collusion in the process prior to licence submissions. In addition, given that the selection committee is crucial in the decision making process, care must be taken that it is not subject to influence.

## SECTION 3: AUCTIONS IN PRACTICE

Table 1 shows the progress of the attribution of 3G licences within Europe and some other major OECD countries. The table shows a mixed picture. Finland and Spain have already made their awards through comparative selection procedures. 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 comparative selection procedures. 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 comparative selection procedure but charged a high fee – about half that paid in the UK auctions. Italy has also adopted a hybrid system, selecting through a comparative selection procedure 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 investigated the possibility of improper behaviour both in Italy and in the Netherlands. Fears of collusion also dogged the Austrian auction for 3G mobile licences.[15]

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

Judging the success of spectrum assignment is difficult. Spicer (1996) suggest that success should be judged on a set of goals: rapid licence assignment, rapid launch of service, participants' satisfaction appropriate compensation for public resources, and the creation of a dynamic wireless sector. He recognises that "success" would be attained if several, not necessarily all, of these characteristics were met.

### United Kingdom

A long and open debate preceded the 3G mobile auction in the United Kingdom (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 five licences, 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.[16] The auction was a simultaneous ascending auction (SAA), in line with what the Federal Communications Commission had been experimenting with in the United States. 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. In conjunction 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, nine new entrants besides the four 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 GBP 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.

**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 plus 5 MHz unpaired spectrum |
| Licence B | 2x15 MHz paired spectrum plus 5 MHz unpaired 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 Dutch auction design was based on the previous DCS-1800 auction. There was one crucial difference that made the situation in the Netherlands different from the United Kingdom. In Holland, there were five incumbent operators, and exactly five licences on sale. The Competition Authority and the independent telecommunication regulator saw the mobile market in the Netherlands as very competitive, with five operators active in the country already. The Government, following advice of the UMTS Forum, decided to offer five licences. Thus, unlike many other European countries it was not thought necessary that the number of UMTS licences should be greater than the existing number of cellular mobile licences. New entrants could in any case bid for the licences. 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.[17]

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 United Kingdom 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.[18]

Initially,10 operators applied to the Dutch regulator, but two then joined with an incumbent before the auction started and a further two pulled out of the auction, literally minutes before it began. Something similar happened in the German auction that was held around the same time. 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 (NLG 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 United Kingdom, larger licences sold for higher prices, and similar licences (A and B, or B, C and D) for similar prices. The Dutch government did not set a financial goal for the 3G auction and maximising profit was not a criteria, but total revenues were significantly short of expectations.

**Germany and Austria**

The German auction introduced a totally different design. In place of predetermining the “right” number of licences (five both in Holland and in the United Kingdom), 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 four (if each got three blocks) and six (if each got only two 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 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 would be 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 non-discriminatory 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.[19] 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 four 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 five 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 USD 45 billion, some USD 10 billion more than the amount raised in the United Kingdom. The details of the winners are the following (see the Web site http://www.regtp.de):[20]

| 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 both 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 (six) had to pay about USD 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 four to six licenses could be acquired in this stage. The reserve price for each package was set at ATS 700 million. In Stage II, five additional packages of 5 MHz each in the unpaired range were auctioned off with a reserve price of ATS 350 million. Six consortia participated in 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 in a fight to aggregate a third valuable block. The auction could have stopped after only two rounds, when each bidder had secured two blocks. This led the regulator to call for a suspension of the auction to investigate possible collusive behaviour. When the auction resumed, the six participants rather quickly found a way to get two 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 in the bidding process, and it engaged into a more strategic form of bidding. Mobilkom tried at first to aggregate three 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 of retaliation lasted only for a few rounds, after which Mobilkom gave up its attempt to secure a third block.

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

**Italy**

Italy decided to award five licences (valid for 15 years) through a two-stage process, combining a pre-qualification comparative selection procedure with a competitive auction, in a rather standard SAA format. As an important variant, it was decided that if fewer than six operators participated in the auction, then the number of licences would have been reduced accordingly. The base price for each of five identical licences was set at ITL 4 000 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 ITL 1 600 billion. In the (unlikely) case that three 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 comparative selection procedure, with a nominal entry fee. A Government reshuffle in May 2000 then decided to abandon the original idea. Only at the end of June was it 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 eight groups applied to join the contest, most having strong local attachments. Two of them were then excluded during the pre-qualification comparative selection procedure. 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 ten rounds (two days) and the licences were allocated as follows (see the Web site of the Italian telecoms regulator at http://umts.agcom.it/).

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 five licences and six 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 to four, in which case revenues would have most probably been much higher. The Italian competition authority is currently investigating whether there was any collusion or inappropriate behaviour.

| **Company** | **Last offer (ITL 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 ITL 3 200 bn |

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 comparative selection procedure, where it is common practice to award reasonably sound incumbents a licence. The Italian auction then reached efficiency via competitive bidding: Blu, an incumbent, 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.

## Table 1. IMT-2000 Licensing conditions and status

| Country | Number (and type) of licences | Minimum coverage requirement | Licensing process and notes | Issue of tender/timing | Licence award |
|---|---|---|---|---|---|
| Australia | No number of license set with 58 blocks available. | | Reserve price of AUD 1.08 billion (USD 504 million) set for spectrum. No bidder could acquire more than 25% of available spectrum and no more than 50% in regional Australia. 6 licences awarded Australia raised AUD 1.17 billion. | | |
| Austria | Complete, with 2 tranches of 2x5MHz awarded to six operators in first stage. | 25% pop. by end 2003, 50% by end of 2005 | Upward simultaneous multiple round format in two stages. 1st stage auction completed, raising ATS9.69 billion (706 million Euro). Winners are: Mobilkom, Mannesmann, max.mobile, Connect, Hutchison, 3G Mobile.<br>Second stage completed, awarding an additional 1x5Mhz unpaired to Mobilkom, Hutchison and max.mobil, raising ATS 1.75 billion. | Auction commenced 2.11.2000 | Completed 3.11.2000 |
| Belgium | Four national 2x15MHz per operator plus 5MHz unpaired. Duration 20 years | 30% pop. after 3 years, 40% after 4 years, 50% after 5 years | Auction with EUR 150 million reserve price per licence. Two licences sold at reserve price and 3rd at EUR 150.2 million. No applicant for 4th licence. | Auction in March 2001. Auction lasted one round and raised EUR 450.2 million | Expected two months after the start of the auction |
| Czech Republic | Four national licences (2x10MHz up to 15+5MHz) to be awarded to incumbent GSM operators and one new operator | Yes, TBA | Fixed price offer to three GSM incumbents, plus auction for 4th licence | Licensing process starts January 2001 | Awards expected Q1 2001 |
| Denmark | Four national | Licensees have to reach 80% coverage by end of 2008. Network sharing will be allowed once coverage requirements have been met and only for the remaining 20%. | Auction single round sealed bids. Minimum fee of DKK 500 million, 25% to be paid up front and the rest over a 10 year period. | | Set for 5.10.2001. |
| Finland | Four national awarded | | Comparative selection procedure.<br>15 applications received. | Complete | Completed March 1999 |

| Country | Number (and type) of licences | Minimum coverage requirement | Licensing process and notes | Issue of tender/timing | Licence award |
|---|---|---|---|---|---|
| France | Four national | Yes, but not yet clearly defined; possibly according to pop. density | Comparative selection procedure, with fixed cost at FRF 32.5 billion (EUR 4.95 billion) per licence | 14 criteria announced end June 2000. Bidding opened end January 2000, but only two submissions were made. | Two licences awarded 31.5.2001 (to France Telecom and SFR). A new tender will be held at an unspecified date for the two unallocated licences. |
| Germany | Complete, with two tranches of 2x5MHz awarded to six operators in first stage. | 25% of pop. till end of 2003, 50% till end of 2005.<br>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: four incumbents (T-Mobil, Mannesmann, E-Plus, VIAG) + MobilCom and Group 3G.<br>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 | | Auction | Auction start expected February 2001 | End Q1 2001 |
| Hungary | Four licences expected | | Full details not yet confirmed | | Issue expected 2001-2002 |
| Ireland | Four national with one licence reserved for a new entrant (this licence will also include spectrum in GSM bands). | | Comparative selection procedure.<br>19 responses to consultation received by 15.9.00 deadline. | Contest began mid-Nov 2000 | Q2 2001 likely |
| Italy | 5 National<br>2x10 + 5 MHz each.<br>Additional spectrum (2x5 MHz) available for entrants. | Regional capitals within 2.5 years; provincial capitals within 5 years | Auction with prequalification.<br>Eight applications received, butwothen excluded from the auction.<br>ITL 23 550 billion raised. Winners are: three incumbents (TIM, Omnitel, Wind) + Andala and IPSE. Additional ITL 3 200 billion raised from entrants. | Auction commenced 19.10.2000 | Completed 23.10.2000. Competition authority investigating alleged irregularities |

| Country | Number (and type) of licences | Minimum coverage requirement | Licensing process and notes | Issue of tender/timing | Licence award |
|---|---|---|---|---|---|
| Japan | 3 national licences awarded | Over 50% approx. in regional blocks within five years after initiating provision of services | Invited public comments concerning licensing method oi July 1998 and February 2000. Since all 20 carriers were opposed to using auctions, a comparative selection procedure was introduced in March 2000. | Initiation of licence submission: April 2000 | Three licences have been submitted. Licences have been awarded without employing the comparative selection procedure in July 2000. |
| Luxembourg | Four national | Not known | Comparative selection procedure | Deadline for bids Feb. 2001 | Q4 2001 likely |
| The Netherlands | Five national, licences valid until 2016:<br>Three 2x10 + 5MHz<br>Two 2x15MHz | 60% of pop. by the year 2007 | Auction completed after 305 rounds, raising NLG 5.9 billion. Winners are incumbents: Libertel, KPN Mobile, Dutchtone, Telfort and 3G Blue consortium | Auction began 10.7.2000 | Completed 24.7.2000 |
| Norway | Four national | | Comparative selection procedure with NOK 20 million per year plus NOK 100 million one-off fixed charge per operator.<br>Applications received from seven bidders. Winners are: Telenor, NetCom, Broadband Mobile, Tele2. | Invitation to bid closed 4.8.2000 | Completed 4.12.2000 |
| Poland | Five licences were initially offered, with one reserved for TPSA. Three licences awarded. | - | Auction with a reserve price of EUR 650 million. Only three bids received. Auction cancelled and three current operators' licence terms extended to add UMTS. 4th licence postponed to 2002. | Deadline for applications to bid 1.12.2000 | Auction cancelled 6.12.2000 |
| Portugal | Four national licences awarded | 20% of pop. within one year of launch; 40% pop. within three years, 60% within five years | Comparative selection procedure with PTE 20 billion fixed cost, based on technical ability.<br>Six participants. Winners: Telecel, Optimus, Telecommunicacoes Moveis, OniWay. | Bidding process opened 3.10.2000 | Completed 19.12.2000 |

| Country | Number (and type) of licences | Minimum coverage requirement | Licensing process and notes | Issue of tender/timing | Licence award |
|---|---|---|---|---|---|
| Spain | Four national licences awarded | All cities over 250,000 pop. | Comparative selection procedure with fee of EUR 150 million. Winners are three incumbent GSM operators (Telefónica, Airtel, Retevisión) plus Xfera. | Completed 13.3.2000 | Government raised annual 3G spectrum fee for each licence up to EUR 150 million for 2001 from EUR 5 million in 2000. |
| Sweden | Four national licences at 2x15MHz each plus additional 5MHz unpaired per operator<br>Regional licences may also be offered by regulator | | Two-stage comparative selection procedure, based on business credentials plus coverage and roll-out commitments. SEK 100 000 fixed fee per applicant.<br>Ten applications received by 1st stage deadline. Winners are: HI3G, Europolitan, Tele2, Orange Sverige Consortium. | 16.4.2000 | Completed 16.12.2000 |
| Switzerland | Four national | 50% of pop. by end 2004 | Auction with qualification conditions.<br>Ten applicants submitted applications but some then withdrew. Four participated to the auction. Winners are: Swisscom, dSpeed, Orange, Team 3G. Total sum raised CHF205 million. | The auction started on 13.11.2000 and was suspended after five of the ten candidates withdrew and two candidates merged. After investigating to ensure that there had been no collusion between parties the auction restarted on 6.12.2000 and terminated the same day. | Completed 6.12.2000 |

| Country | Number (and type) of licences | Minimum coverage requirement | Licensing process and notes | Issue of tender/timing | Licence award |
|---|---|---|---|---|---|
| UK | Five national licences awarded<br>Largest licence reserved to entrants | By 31.12.07: coverage of 80% of pop. | Auction completed, raising GBP 22.5 billion. Licences awarded to four incumbent GSM operators (Vodafone, BT 3G, Orange, one2one) plus new entrant TIW | Auction began March 2000 | Completed 27.4.2000 |

*Source:* OECD, UMTS Forum, www.umts-forum.org/licensing.html, updated from various websites.

**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 earn sufficient revenues, including a return on investment, to cover what they bid for their licences. This means that their evaluation of future revenue streams would, even in the face of competition from other licence holders, earn them a sufficient return. Product differentiation, innovative tariffs and higher efficiency compared to their rivals, are some of the factors that underlie their expectation for a better return than their competitors. The limitation to entry because of spectrum scarcity implies that new entrants will not be able to undermine economic rents earned in the sector. Some other rents may also 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.[21]

Economic 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, 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, it has been “discovered” that the opportunity cost of using certain frequencies for 3G services is relatively high. Perhaps if the service were 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 assigned to the military. Even if they wanted to, neighbouring operators could not offer a 3G service if that was not permitted by their licence conditions.

The question arises 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 made of 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 usage rights and be allowed to decide about the use they intend to make of their spectrum band, as long as they pay for it and respect some essential requirements. As a consequence, secondary markets should be encouraged, and spectrum users 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 economic 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 be promoted as much as possible, unless there are clear and serious market failures associated with it. However, care needs to be taken to ensure that trading does not lead to a consolidation in the market and creates oligopolies. Trading may therefore need to be subject to regulatory oversight to ensure that markets remain competitive and that licence conditions are met.

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 for 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). 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. Given that it is very unrealistic to suppose that public entities could bid on an equal footing with private companies for spectrum, it is the responsibility of the state to determine the costs and benefits of reserving a certain amount of spectrum for non-profit activities (security, defence, health, research, *etc.*).

Spectrum is 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.[22] 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 and became the leading mobile technology in the world. Advocates of free markets point out that letting systems compete offers a better chance to promote better technological systems (with network externalities it is not a guarantee), 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 United States, 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 anti competitive implications.

Secondary markets work when the objects for sale are easy to define. In the case of the spectrum, there are several open questions: transferability, interference, frequency bandwidth, usage of the frequency (broadcasting, telecom, *etc*.), degree of exclusivity in the exploitation of the spectrum, geographical coverage, restriction on the power, international harmonisation, *etc*. If the objects are not so well defined, it could be difficult to specify all the characteristics of the objects and a more direct intervention of the government may be needed.

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. Given the amount of externalities (positive and negative) in the many different uses of spectrum (commercial and non-commercial), spectrum trading should be promoted when possible taking care not to destroy the complex existing mechanism of allocating spectrum.[23]

# APPENDIX: AUCTION THEORY

## Concepts and definitions

### *Private, affiliated and common values*

*A priori*, the value of an object to a buyer can depend on:

- The information that the buyer possesses about the object. The word “information” has to be understood very broadly, as it can also refer to the buyer’s personal tastes, or characteristics.

- The information other buyers possess about that object. (The same applies for the word “information”.)

Additional variables that can affect the values of the object for each and everyone in the same way.

- In the case of licences, the following are examples for each category:

- The operator’s own cost and budget.

- Other operators’ costs and budgets.

- Consumers’ interest in using mobile telephones.

- Performance of the stock market.

Therefore, if we let $V_A$ denote the value of an object to buyer *A*, we have:

$$V_A = V(I_A, I_{B/A}, X)$$

where, $I_A$ denotes the information to buyer *A*, $I_{B/A}$ denotes the information to any other buyer except *A*, and *X* refers to any other variable that can affect the object’s value.

Bidders have private values when $V_A = I_A$. Consider for instance an auction of paintings. Consider moreover that none of the buyers is interested in resale markets. Then all that matters to any buyer is how much he likes the painting. This would be a case of private values. In such cases, the bidders know exactly what the object is worth to them[24].

Bidders have common value when $V_A = X$. The best example of common value is an auction for treasury bonds. The value of a Treasury bond never depends on the identity of the owner, and would be the same whoever holds it. In such cases, bidders do not know the value of the object. They form their bids using what we call “signals”.

Any situation where $V_A$ is of the form indicated above, is neither a private nor a common value case.

Finally, bidders’ values are affiliated when (very broadly) observing a large value for a buyer makes it more likely that other buyers also have large values[25].

Bidders for licences have values that are neither private nor common. Furthermore, their values are likely to be affiliated as they rely heavily on future market conditions, which would affect them in the same way.

***Risk aversion-risk neutrality***

Bidders are risk averse when the expectation of a gamble has more value to them than the gamble itself. For instance, the value they assign to a bond with a fixed return of 10% is higher than the value they would assign to a bond that generates a return of 0% with probability ½ and 20% with probability ½.

A bidder is risk neutral if he values equally the gamble and its expectation.

*Standard auctions*

*Open auctions:* The English auction: Bidders announce their bids openly in an ascending order. The auction stops when no one proposes a higher bid than the last announced. The winner is the last person to announce a price; he pays the price that he announced.

*Japanese version of the English auction:* The price raises slowly while bidders only signal if they are still in or whether they want to drop out. The auction stops when there is only one bidder remaining. He pays the price at which his last competitor dropped out.

*Dutch auction:* The auctioneer announces prices in a descending order. The auction stops when one bidder accepts to buy at the price announced. The winner pays the price at which he stopped the auctioneer.

*Sealed bid auctions:*

First-price sealed bid: Each bidder submits a bid in an envelope. The auctioneer examines all offers. The object goes to the highest bidder and he pays the amount he suggested. In Greece this method was used for the 2G licensing in 1992. However the second highest bidder, if this bid came within 10% of the highest bid, could match the highest bid and win the second licence. Otherwise there would be a second round of bidding by the participants.

Second-price sealed bid: Each bidder submits a bid in an envelope. The auctioneer examines all offers. The object goes to the highest bidder and he pays the second highest offer. New Zealand, in 1990, used this method to auction three cellular licences. One of the winners bid NZD 101 million, but only paid NZD 11 million.

### *Main results on the allocation of a single object*

The literature on mechanism design has mainly focused on two objectives: revenue maximisation and efficiency. This is mainly due to the fact that objectives other than profit maximisation and efficient allocations are difficult to model.

*Achieving efficiency*

The second-price sealed bid auction (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. 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.

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. This is an extremely general principle that underlies all of auction theory.

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.

The other main goal, besides efficiency, that the seller may have is *revenue maximisation*. A fundamental result in auction theory is *the Revenue Equivalence Theorem*.

### *The revenue equivalence theorem*[26]

If bidders are risk neutral, each has a privately known signal, and if signals are independent then all mechanisms such that:

1. The object always goes to the bidder with the highest signal.

2. The bidder with the lowest feasible signal expects zero surplus.

will yield the same revenue.

If signals are, in addition, identically distributed then, all the basic auctions cited above are equivalent in that they generate the same revenue for the seller. However, it should be noted that the theorem is true not only in a context of private values. It holds in more general common value models provided the signals are independent.

*Revenue maximisation*

If we have independent private values, risk neutrality, and if the function according to which signals are distributed displays a regularity condition[27], all standard auctions, with an optimal reserve price, maximise the seller's revenue.

*Note 1:* Under the hypothesis given above, both the second price sealed-bid auction and the English auction (with an optimal reserve price) maximise the seller's revenue. These auctions have a dominant strategy equilibrium: for each of these, buyers maximise their expected revenue by bidding their true values, *whatever the other players do*.

The existence of a dominant strategy equilibrium is interesting in that it is robust. Players need not know anything about the others (not even the number of competitors) to calculate their optimal bid.

*Note 2*: Discrepancy between efficiency and revenue maximisation.

Because revenue maximisation requires setting a reserve price, it may be inefficient. It is important to understand the source of inefficiency. If the object is sold, it will be to the one who values it the most (under the regularity condition). The outcome is inefficient only if the seller ends up keeping the object. Indeed, the optimal reserve price is such that there could be no sale agreement even though the object is of no value to the seller while all the buyers have positive values for it (basically, a reserve price allows the seller to get rid of reluctant buyers so as to get more revenue from eager buyers.)

***Risk aversion***

When bidders are risk averse, the revenue maximising auction becomes quite complex.[28] There are two sources of risk in an auction:

1. An auction is a gamble in that the bidders may win or lose. The difference between what they get in each of these events is one source of risk.

2. Conditional on winning (or even losing) the amount they must pay (or receive) can depend on their competitors' bids (as it does in a second price auction). Because they do not necessarily observe their opponent's bid their payment may be random. This is a second source of risk.

When bidders are risk averse, the following features can increase the seller's revenue:

3. Payments should never be random. (Using random payments only deters competition.)

4. Eager buyers (high bidders) should get compensated when losing by receiving a subsidy while reluctant buyers (low bidders) must be forced to pay a fee. The idea is that the seller provides insurance to high bidders by lowering their first source of risk. This induces them to bid higher. He pays for this via a punishment on low bidders. They face more risk, and are less competitive. What is won on high bidders more than compensates the loss on low bidders.

The complexity of the optimal auction with risk-averse bidders raises the issue of implementation. The features described above are never observed in practice for they would be difficult to implement and require too much information.

***Non-private values auctions: Winner's curse***

When the value of the object either does not depend on any of the bidder's characteristics (*e.g.* Treasury bond) or depends on his characteristics but also on other bidders' characteristics then the revenue equivalence theorem breaks down.

The English auction (even the Japanese version) releases information and performs better in terms of revenue maximisation than other mechanisms. More precisely the standard auction can now be ranked according to the revenue they generate as follows: English, Second price sealed-bid, First price sealed bid and Dutch (where the last two generate the same revenue).

*The winner's curse:* To evaluate their bids, buyers have to calculate estimates of the value of the object. Other things being equal, the buyer with the largest estimate will make the highest bid. Therefore, even if all buyers make unbiased estimates, given their information (or signal), the winner is the one who has over-estimated the object's value (on average). In other words, winning also means having the most favourable information regarding the object's value. Therefore, in some instances, the true value of the object may end up being lower than the estimate. This general property of auctions is known as the winner's curse.

Bidders, because they are rational, will take the winner's curse into account when they bid. In effect this means that all bids are revised downwards. Therefore, to increase his revenue the seller should weaken the winner's curse. By providing more information to all buyers the seller can reduce information asymmetry, increasing competition, and the value of bids.

In general, common value auctions (and more generally auctions with statistically dependent values) have received less attention than private value auctions. The main reason being that common values often lead to complex, non-tractable mathematical expressions.

*Multiple objects*

In the case where there are multiple objects for sale, a set S of objects, then each buyer has a valuation for each possible subset of objects. Hence if $v_i(s)$ is 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 in two neighbouring frequency bands) 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. The existence and sign of complementarities play a large role in the choice of an auction mechanism.

Efficiency now means that the objects are allocated in a way to maximise 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 in an independent private values contest and with no budget constraints or wealth effect. It is called *generalised Vickrey auction* (or *Groves-Clark mechanism*, or *combinatorial auction*). As in the simple Vickrey auction bids are secret and simultaneous, *i.e.* a one-shot sealed-bid auction. 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 seven 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, $b_{-i}(A')=0$ and that $\max_A b_{-i}(A)$ is equal to the second highest bid, and hence the generalised Vickrey auction is the same as the simple Vickrey auction.

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 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 he 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. One of the reasons 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 in 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 on which a buyer can place bids (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.

Discrepancies between the SAA and the generalised Vickrey auction occur in the presence of *exposure problems*. There is an exposure problem when some buyers have positive complementarities and others have negative complementarities. The SAA is not always efficient because of the exposure problem.

Not only does the exposure problem generate inefficiency in the SAA, but it also reduces the expected revenue of the seller. An often cited example of how the exposure problem can hurt efficiency and revenues is the 1998 spectrum auction held in the Netherlands (DCS 1800MHz). Eighteen 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 one or two small licences. One operator resold its only and almost worthless small licence after the auction. In this special case, the resale of the licence indicates that the auction format had not achieved efficient allocations in the first place.[29]

In response to the exposure problem, 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 will be used in a FCC 700MHz spectrum auction to be held in March 2001.[30] 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. 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. 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.

The main advantage of the DCA is that it eliminates the exposure problem. However, it has been pointed out that the DCA creates a problem that in some senses is the converse of the exposure problem, which has been called the *threshold problem*. This auction format can give rise to a free rider problem among bidders on the individual licences. 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. Thus, 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 problem, and the DCA has the threshold problem or free riding problem. The optimal choice will depend on the number of objects for sale, on the number of bidders and on the type of synergies (complementarities) that the seller expects to exist.

### *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.

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.

Under some assumptions, auctions may be perfect mechanisms to reach efficiency and maximise seller's revenues. The extensions of the basic framework go in different directions. If the goal is revenue maximisation, common values militate in favour of the English auction, collusion makes the use of one-shot mechanisms more attractive, while risk aversion favours first-price mechanisms. If instead the goal is efficiency, common values do not, as a first approximation, matter, and the effects of risk aversion and collusion are unclear. 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 run 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.[31]

## NOTES

1 The number of operators is in terms of 'equivalents' *i.e.* the number of equivalent national operators. If a country has 10 regions, each with three operators, the number of mobile equivalent operators for that country is three.

2 See *OECD Communications Outlook 2001*, Paris, 2001.

3 Also referred to as IMT-2000 (International Mobile Telecommunications) or Universal Mobile Telecommunications System (UMTS).

4 See Commission of the European Communities, *The Introduction of Third Generation Mobile Communications in the European Union: State of Play and the Way Forward*, Brussels, 6 March 2001.

5 See Prestowitz, Clyde, V., *Challenges to U.S. Spectrum Management: Easing Relocation and Fixing Auctions*, Economic Strategy Institute, Washington D.C., 2001.

6 Moral hazard refers to a situation where the government is not able to verify the experts' actions after they have been contracted (*e.g.* inability to verify whether the expert receives bribes, or inability to verify the amount of time dedicated to the evaluation of candidates).

7 Hong Kong is a special case where the four licences were sold at the fourth highest bid.

8 See Appendix for a definition of a common value auction.

9 An argument can be made 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 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.

10 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.

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

12 Sequential auctions of identical items led to the well known "declining price anomaly" (see for instance McAfee and Vincent (1993)). Prices of identical items follow a decreasing pattern. In simultaneous auctions, it has generally been observed that similar licences sell for (almost) the same prices, as they should. Therefore, there are adverse effects in sequential auction bidding which are not present in simultaneous bidding.

13 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).

14 Melody, ibid, page 8.

15 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.

16 Paul Klemperer of Oxford University and Ken Binmore of University College London.

17 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 in the auction altogether creates a problem for revenue maximisation.

18 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.

19 Klemperer (2000), and especially Jehiel and Moldovanu (2000).

20 The following auction (for the remaining bits of unpaired spectrum) lasted for a day and raised a further DEM 0.5 billion.

21 See Parker and Röller (1997) and Busse (2000) for the United States; and Valletti and Cave (1998) for the United Kingdom.

22 For an overview, see Katz and Shapiro (1994).

23 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 United Kingdom is also implementing a radical change since the introduction of the Wireless Telegraphy Act in 1998 (see http://www.radio.gov.uk/).

24 Private values can also include cases where $V_A=V(I_A,X)$, *i.e.* such that on average, values depend only on the buyer's own characteristics.

25 For a precise definition of affiliation see Milgrom and Weber (1982).

26 For a precise definition see Myerson (1981).

27 See Myerson (1981) or Klemperer (1999) for regularity conditions. These are satisfied by most distribution functions.

28 See Maskin and Riley (1984) for a detailed analysis.

29 This does not mean 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).

30 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.

31 See Klemperer (2000). The Anglo-Dutch auction is applicable to situations to multi-unit auctions only if each buyer can acquire at most one object. It is unclear whether the Anglo-Dutch auction is generalisable to situations in which package bidding is desirable.

## REFERENCES

Burkart, M., (1995), “Initial Shareholdings and Overbidding in Takeover Contests”, *Journal of Finance* 50(5), 1491-1515

Busse, M., 2000, “Multimarket Contact and Price Coordination in the Cellular Telephone Industry,” *Journal of Economics & Management Strategy* 9(3): 287-320.

Chowdry, B., and Nanda, V., (1993), “The Strategic Role of Debt in Takeover Contests”, *Journal of Financ*e 48(2), 731-745.

Cramton, P., 1997. “The FCC Spectrum Auction: An Early Assessment”, *Journal of Economics & Management Strategy* 6(3): 431-495.

Cramton, P. and J. Schwartz, 2000, “Collusive Bidding: Lessons from the FCC Spectrum Auctions,” *Journal of Regulatory Economics* 17(3): 229-252.

van Damme, Eric, 1999, “The Dutch DCS-1800 Auction,” in F. Patrone et al. (eds*.), Game Practice: Contributions from Applied Game Theory*, 53-73, Kluwer Academic Publisher.

Hazel, T. and R. Michaels, 1993, “The Cost of Rent-Seeking: Evidence from the Cellular Telephone License Lotteries,” *Southern Economic Journal* 59: 425-435.

Jehiel, P. and B. Moldovanu, 2000, “A Critique of the Planned Rules for the German UMTS/IMT-2000 Kagel, J.H., *et al*. (1989), “First Price Common Value Auctions: Bidder Behavior and the Winner’s Curse”, *Economic Inquiry* 27(2), 241-258

Kagel, J.H., and Gavin S., (1994), “Learning in Common Value Auctions: Some Initial Observations”, *Journal of Economic Behavior and Organization* 25(3), 351-372

Kagel, J.H., and Levin D., (1986), “Winner’s Curse and Public Information in Common Value Auctions”, *American Economic Review* 76(5), 894-920

Katz, M.L. and C. Shapiro, 1994, “Systems Competition and Network Effects*,” Journal of Economic Perspectives* 8(2): 93-115.

Klemperer, P., 1999, “Auction Theory: A Guide to the Literature,” *Journal of Economic Surveys* 13(3): 227-86.

Klemperer, P., 2000, “What Really Matters in Auction Design,” mimeo, Nuffield College, Oxford.

“Licence Auction”, mimeo, University of Mannheim.

Matthews, S. A., 1987, “Comparing Auctions for Risk-averse Buyers: A Buyer's Point of View,” *Econometrica* 55: 633-646.

Maskin, E. S., and Riley J. G., (1984), "Optimal Auctions with Risk-Averse Buyers", *Econometrica* 52: 1473-1518.

McAfee, P. and Vincent, D., (1993), "The declining price anomaly", *Journal of Economic Theory* 60: 191-212.

McAfee, R. P. and J. McMillan, 1996, "Analyzing the Airwaves Auction," *Journal of Economic Perspectives* 10: 159-176.

McMillan, J., 1995, "Why Auction the Spectrum?" *Telecommunications Policy* 19: 191-199.

Melody, W.H., "Spectrum Auctions and Efficient Resource Allocation: Learning from the 3G Experience in Europe", *Info*, Vol. 3 No. 1 February 2001.

Milgrom, P., 2000, "Putting Auction Theory to Work: The Simultaneous Ascending Auction," *Journal of Political Economy* 108(2): 116-26.

Milgrom, P.R., and Weber, R.J., (1982), "A Theory of Auctions and Competitive Bidding", *Econometrica* 50(5): 1089-1122

Myerson, R. B., (1981), "Optimal Auction Design", *Mathematics of Operations Research* 6(1): 58-73 available from http://www.nuff.ox.ac.uk/users/klemperer/papers.html.

.Parker, P.M. and L.-H. Röller, 1997, "Collusive Conduct in Duopolies: Multimarket Contact and Cross-Ownership in the Mobile Telephone Industry," *RAND Journal of Economics* 28(2): 304-322.

Spicer M., 1996, "International Survey of Spectrum Assignment for Cellular and PCS", Federal Communications Commission, US, September 1996.

Valletti, T.M. and M. Cave, 1998, "Competition in UK Mobile Communications", *Telecommunications Policy* 22(2): 109-131.