Economic Analysis of the Radio Spectrum for Regulatory Purposes

Morten Falch
Reza Tadayoni

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Morten Falch, Ph.D. & Reza Tadayoni, Ph.D.

Center for Tele-Information, Technical University of Denmark

I. Introduction

The paper will present a study on the economic value of the spectrum and discuss how such a study can be used as a tool for regulation of the radio spectrum. In particular, the impact of various pricing strategies is analysed.

The organisation of the radio spectrum and its value has turned out to be of vital importance in recent years due to the rapid development of mobile communications and the recent 3G auctions. The focal point of regulation of scarce resources has, due to liberalisation of the telecommunications sector, changed from a matter of pure co-ordination and planning to be an important tool in creation of a competitive environment for various telecommunication services. Regulation of the spectrum has to a certain extend been subject to the same development.

Regulation of the spectrum scarcity is however not a purely technical matter. Economic considerations must be taken into account as well. A free market approach may be suitable for assigning frequency bands between operators within the same application, but is less suitable for allocation between various applications. Here regulatory intervention will be necessary to ensure efficient and harmonised patterns of usage across countries. In this respect an assessment of the economic value of various applications is an important input. This paper measures the economic value in terms of contribution to GDP. We use this approach, as it is very difficult to assess the user value as long as there is no market for trade in frequency licenses.

The economic value of the radio spectrum has been calculated for six different service applications (fixed links, Maritime and aeronautic applications, broadcasting services, mobile services, private mobile radio network services and military services). For each application the economic value is calculated for both use of the application and production of equipments related to each application. The paper draws on an extensive study of the economic value of the Danish radio spectrum prepared for the Danish Telecom Agency (Danish Telecom Agency, 2000).

II. Definition of exclusive rights to use of the radio spectrum and regulatory needs

Allocation and assignment of the radio spectrum resources have traditionally been seen mainly as a technical/administrative and not an economic issue. The purpose of regulation has been to optimize the allocation of spectrum resources in order to provide access to everybody – or at least as many users as possible – and to avoid interference between users.

However, the ongoing developments on the telecommunication market imply that there is a growing need to establish new and more market oriented procedures for managing spectrum resources. First, co-operation between the former telecommunication monopolies have been replaced by competition among a large number of rival operators. Second an increasing number of wireless applications are competing for the same frequencies.

Spectrum interference and scarcity of radio frequencies have traditionally been used as arguments for governmental intervention. With the deregulation of the telecom sector another argument has been that spectrum management could be used to promote competition in the sector. Hence, spectrum management should serve at least three different purposes:

1) Granting of exclusive rights
2) Ensuring effective use of a limited resource
3) Promoting competition

The question is whether the current institutional set-up is adequate both to ensure an efficient use of the spectrum with current technologies and to promote innovation of new technologies making the radio spectrum even more valuable.

Granting of exclusive rights is a fundamental precondition for ensuring effective use of the radio spectrum. Interference implies that some sort of co-ordination of spectrum use is needed. If not before, this became evident in the 1920's during the 'chaos in broadcasting' in America, where licences were granted to anyone who applied, and the licensees were free to decide on the power their stations wanted. It is however far from clear how this co-ordination should take place – in particular if the two other purposes are to be served also.

Ensuring effective use of the radio spectrum can be seen both from a technical and an economic viewpoint. From a technical viewpoint the objective will be to optimise the physical use in terms of number of users and the amount of radio signals. From an economic viewpoint the objective will be to give preference to the most valuable applications.

Promotion of competition implies that many operators will be allowed to provide the same services. In some countries (e.g. Denmark) it is a deliberate policy to emphasize more on competition than on efficiency. This implies that licenses will be given to more operators even if it leads to a less effective use of the spectrum.

A key issue is to define adequate property rights for the spectrum. Property rights can be used not only to ensure exclusive rights, but also to address the two other purposes. The question is here whether property rights can be defined in a way that all three purposes can be served by the market complemented by the general competition law or whether a sector specific regulation of the spectrum always will be necessary.

Defining property rights for the radio spectrum is a much more complicated issue than defining property right e.g. for use and ownership of land resources.

Considerations on property rights include:

- The size of the frequency blocks allocated per license
- Definition of the areas covered by each license
- Restrictions on transmission power
- Restrictions on applications of the radio spectrum
- How long time is a license awarded for?
- Limitations on transfer of and trade with licensees.

Licenses for use of the spectrum can be given for different types of slices with respect to frequencies included, areas covered and the time usage is allowed. As with land usage different applications can collide. Some slices may be unusable if not used in combination with other parts of the spectrum, and the needed shape of the slices depends on the type of applications that the spectrum is going to be used for. Establishment of a fixed radio link between two locations does not require a property right that goes much beyond the area between these two locations. On the other hand certain applications for satellite services demand a global right to a certain part of the spectrum.

As higher transmission power will increase interference in neighbouring areas, the allowed power of transmission is closely related to the definition of the areas, where transmission is allowed. Restrictions on transmission power will therefore enable issuing of more licenses.

Users have an interest in long term licenses as this enables them to plan their operation for a longer time horizon and to make long term investments in equipment. On the other hand this reduces flexibility of spectrum management, and complicates for instance allocation of additional spectrum resources to new users.

A key characteristic of a property right is whether it is transferable or even can be sold to a third party. Transfer of property rights limits the regulatory power of the issuing agency, but it makes the system more flexible. For instance new users can acquire spectrum resources directly from other users without involvement from any public regulator.

It can be useful to compare spectrum property rights with the property rights on real estate. In this case property rights are in principle infinite in time, and property rights can be sold on the market. If a certain piece of land is needed for a public purpose e.g. building of a public infrastructure, it may be possible expropriate the property, if it cannot be acquired on the free market. The property rights can also include certain restrictions on usage – e.g. various building regulations – in order to avoid interference with neighbouring properties and general public interests.

In spectrum management it is much more complicated to ensure a proper co-ordination so interference can be avoided:

- First interference between various users and applications depends on the power of transmissions and the types of applications. For instance analogue TV-broadcasting will not only prevent other broadcasters to use the same frequencies in a considerable geographical area. It will also prevent use of certain other frequencies for broadcasting purposes. The number of licenses that can be issued depends therefore on what they are going to be used for. This implies that restrictions on usage will enable more licenses to be issued and hence a more efficient use of the spectrum.

- Secondly there is the international dimension: It will be impossible to define property rights that will follow national borders, and international co-ordination is therefore needed.

- The third problem relates to the types of applications for the radio spectrum. A substantial part of the usage of the radio spectrum relates to different types of wireless infrastructures (mobile networks, broadcasting networks, networks for civic services etc.). Conflicting interests are therefore likely to arise between different types of infrastructure providers, who want access to the same parts of the spectrum resources. As noted above expropriation of land may be used if necessary for building public infrastructures, but how can the same approach be used to solve similar problems with regard to assignment of spectrum resources if both parties are infrastructure providers?

- A fourth problem relates to international harmonization. There are two aspects of international harmonization. First there is harmonization of cross-border services. If services are to be provided cross borders licenses covering more than one country is necessary. If licenses are to be obtained in every country it will be very complicated to provide truly international services covering a large number of countries. The second aspect is related to standardization of equipment and services. Standardization is more complicated if the same services are provided at different frequencies in different countries.

III. The Institutional Framework

As we have seen above, the regulatory response to these problems has been a rather detailed regulation, where Government agencies have been responsible for both defining the applications and assigning resources to particular users.

The response is however not based on technical and economic factors only. In addition to the above mentioned factors, the current institutional framework for spectrum management is a product of historical and political factors as well. The framework for spectrum management is developed over more than a century and the suggestions to a new spectrum policy needs to take this framework into account.

The first application of the radio spectrum as a transport medium for communication was wireless telegraphy. This service was an extension of fixed telegraphy and was therefore organised in the same way namely in state monopolies[1]. This historical starting point had

[1] Only domestic telegraphy was organized in state monopolies, while the market for international telegraphy was more liberal.

tremendous impact on how new wireless services were organised and regulated later on and how the radio spectrum was regulated nationally and internationally.

Another important factor was the close relation between spectrum management and regulation of broadcasting services. Here spectrum management was not only used as a tool for regulation of the transport infrastructure, but also as a tool for content regulation. Issuing of frequency licenses for broadcasting services was in many countries either given to public broadcasting companies or conditioned by fulfilment of certain public service obligations.

The current setup for spectrum management includes co-operation between national and international bodies established to cope with 'allocation policies'.

This process consists of three separate but not always distinct processes (Carter T. B., et al 1986):

Allocation: The division of the spectrum in blocks of frequencies to be used for specific services.

Allotment: The distribution of the spectrum rights within allocated bands to uses in various geographical areas.

Assignment: The choice among potential users of allocated and allotted channels or frequency bands.

The first two mainly deal with creation of optimisation from a planning point of view, while procedures for assignment also deal with issues related to market competition.

Allocation

The model has been to allocate frequencies between different types of applications. This allocation has mainly been done according to technical considerations on which frequencies that were the most suitable for a certain applications, and political priorities between different types of applications. However, market considerations play a role as well, as scarcity within a certain application may lead to allocation of additional resources. Allocations are first done at the international level, although the national regulators have some freedom in the detailed planning of frequency resources.

Allotment

Allotment includes allocation of frequencies between countries, and in particular in large countries allotment also includes allocation between states or provinces.

Assignment

Licenses are given to a specific application (e.g. broadcasting of a radio channel) and it is not allowed to use the frequency for other purposes. As licenses are issued to a well defined application they can take specifics of this application into consideration in the design of the licenses in terms of location, power of signals etc.

Assignment is within this model mainly been done either by issuing of licenses to selected public/semi-public institutions or according to the first come first served principle, and it is not possible to transfer a license to another user.

This principle works well if scarcity is limited and the users mainly are public utilities or other public companies. But in a liberalised market where access to radio frequencies is an important strategic resource, it is necessary to establish rules that can ensure equal access among competitors. This has led to development of a series of other assignment procedures, such as beauty contests or in some cases in the US by lotteries.

In a beauty contest companies are selected on basis of offerings covering a wide spectrum of qualitative and quantitative measures such as quality of service offerings, coverage, number of customers etc. (see e.g. S-H Yoo a.o., 2001) and license holders are mainly public utilities and other providers of public infrastructures.

Another alternative is auctions, where licenses are given to the companies with the highest bids. Auctions have been used in the US from the mid 90s, but were first introduced in New Zeeland (A. Grünwald, 2001). In Europe auctions have been used mainly in the recent assignments of UMTS licenses. The argument for auctions is that licenses will go to those who they represent the highest value, as they will come with the highest bids. Auctions create income to the public budgets and draw thereby money out of the telecom sector. This may be good for public budgets but have been a concern to the telecom sector. This problem became most evident during the UMTS auctions in UK and Germany (Harrington, 2000), but was raised by Eli Noam back in 1995 (Noam, 1995).

The institutional setup for frequency management has been criticised from the beginning. The argument against regulation has been that the market is there to allocate scarce resources and the scarcity by itself does not validate external regulations. Ronald Coase argued that the spectrum must be seen as another production factor and the value must be determined at the free market, while the interference problem must be solved by the regular private property right legislation (Coase 1959). Coase argued that by using this approach the frequencies will be allocated in the most efficient way and to the best-valued users.

Similar thoughts have been raised in the more recent discussion of spectrum policy in UK. The point of departure is here that ‘all spectrum users should face some form of price reflecting the opportunity costs of their spectrum use’ (Cave, 2001). The argument is that if there is scarcity of spectrum resources, there should be an incentive to make efficient use of the resources. If spectrum resources are given for free there is no incentive to minimize the amount of frequencies in use, or to return unused resources. The right pricing scheme will – at least in theory – ensure that frequencies are allocated to the most valuable applications.

A pricing scheme can be introduced through administrative pricing, where a regulator assesses the value of various parts of the spectrum and set the prices according to this value. Such a system is currently in use in UK. However, Oftel points out that also this system has certain limitations. The system does not tell if the same frequency could be used for a more valuable purpose, and even if an alternative application is recognised to be more valuable than the incumbent, the change of use is very slow. This can lead to a situation where scarcity rather is a result of inefficient allocation between applications rather than an actual scarcity of suitable spectrum resources (Oftel, 2001).

Spectrum auctions is one way to introduce more market based prices for spectrum resources, but auctions does not solve the allocation problem as licenses still are connected to a specific application.

A response to the allocation problem will be to issue licenses without restrictions on the type of applications the spectrum is used for and to establish a free market where spectrum licenses can be resold. Such a model is in line with Coase and is suggested in a recent study commissioned by Oftel (Valetti, 2001). In such a system no prior allocation of the spectrum between different types of applications is necessary. It is up to the licensees to decide how to use their own spectrum resource.

Within the EU there is a clear trend towards a more market oriented regime for spectrum management, but there is no general consensus on use of auctions. Several countries have preferred to use the beauty contest approach for assignment of UMTS licensees, and a free market for spectrum resources as proposed by Valetti has not been on the EU agenda at all. The EU is more concerned about harmonisation of both allocation and procedures for spectrum management (CEC, 2000). There is however a trade-off between harmonisation and flexibility of allocation. A free market based on issuing of tradable licenses without restrictions on usage cannot ensure a harmonised use of the spectrum.

The free market approach may be the best way to ensure that frequencies are assigned to those users who can make the most benefit out of the spectrum within a certain frequency band. It is however more doubtful whether the market approach can be used to obtain an efficient allocation of frequencies between different services. This approach does not per se solve the complications raised in section two, regarding interference problems that are too complicated to be solved by the market, reservation of resources for building of public radio based communication infrastructures and international harmonisation.

Without regulation, the industry will be left without any guidelines on which frequencies that may be available for provision of different types of services. This will complicate design and development of equipment, and slow down innovation of new services.

Two examples may illustrate the costs and benefits:

- In 1985 FCC increased the unlicensed use of spectrum band used by industrial, scientific and medical low-power applications. This led to more innovation and expansion of use (Noam, 1995).
- Agreement of a common European standard for 2G mobile telephony (GSM) has resulted in a coherent European network allowing national as well as international roaming and a high penetration of the service. At the same time the development in US has been hampered by competition between different incompatible standards.

The difference between the two examples is that in the first case interference problems are limited and the applications are not parts of a public service infrastructure. In the latter compatibility between networks is essential both for user value and competition.

The conclusion is therefore that some applications certainly will be able to benefit from a free market approach to spectrum management, but that others – in particular those related to provision of infrastructures to public services – benefit from a coordinated and harmonised use of spectrum resources.

The immediate consequence of this, is that substantial parts of the spectrum should be liberalised in the sense that restrictions on applications should be relaxed and the licenses should become tradable, while other parts of the spectrum should be reserved for specific infrastructure related services. However even in the latter case, a market based approach can be used in the assignment process.

Convergence and digitalisation are important technological trends that will change the scope for spectrum management. The same application is supplied via different types of technical platforms and it is possible to use the same platform for a wide range of services. It will be very difficult and also to a certain extend meaningless to maintain a strict regulation on to what applications a spectrum license is used for as long as they are provided on the same technical platform. Convergence may therefore pave the way towards a free market for spectrum licenses also within the area of public infrastructures.

By all means, it will take a while before a free market – if ever – will be established. In the meantime there will still be a need for deciding on allocation of frequencies among various applications. Therefore the allocation process and to a certain extent also assignment procedures can benefit from an analysis of the economic value of the various applications of the radio spectrum. Such an analysis is presented in sections V-VI below.

IV. Estimation of the Value of the Danish Radio Spectrum

The evaluation presented in this paper is prepared for the Danish Telecom Agency an is inspired by estimations on the value of the English radio spectrum prepared for OFTEL (NERA, 1995, 1997, Radio communications Agency, 2001). The data are collected in 1998-1999.

The evaluation distinguishes between following applications of the radio spectrum:

- Public mobile communication (GSM, NMT and similar)
- Radio and TV broadcasting
- Mobile Radio (PMR and TETRA)
- Fixed wireless services
- Maritime and aeronautic services
- Satellite communication

- Defence

Economic evaluation of the spectrum is relevant both in allocation and assignment of spectrum resources. In the assignment process the task is to ensure that the user, who gains the most benefit from use of a certain frequency resource, will get it. One way to achieve this goal will be to sell the spectrum to a price that reflects the marginal benefits, at this price supply will balance the demand as only the most efficient user is willing to pay the price.

In a free competitive market the correct prices will prevail more or less automatic, and no intervention from a regulatory agency is needed. It can therefore be argued that there is no need for an estimation of the market value beforehand.

However, in a situation where the vast majority of users have their licenses more or less for free, it can be difficult to introduce a free market for frequency resources from one day to another. An alternative approach would be gradually to raise the prices up to a level that reflects the economic value. This will enable the current users to adapt more easily to a liberalised market. An estimation of the user value of the spectrum can be used to define a target price for radio frequencies.

Valuation of the spectrum is also relevant for allocation of resources between different applications. Certain parts of the spectrum can be used for more than one type of application and if there is a scarcity of resources it can be necessary to give one application preference before another. Also this decision can be left to a market, but as long as part of the allocation is left to national and international agencies there is a need for prioritisation. In this situation it is important that purely technical considerations are supplemented with economic considerations in such a way that applications with a high value for the society are preferred to applications with a lower economic value.

An estimation of the economic value of different applications will in this situation act as a guideline for this prioritisation.

The exact definition of economic value should depend on which of these two purposes that should be served by the analysis. The value of the spectrum can be assessed from at least two different perspectives:

A micro perspective: The radio spectrum is seen as a raw material used as an input in the production. The economic value of this input can be estimated, as the price the operators using the spectrum are willing to pay for this input.

A macro perspective: The radio spectrum is seen as an economic sector, which contributes to GNP as any other sector. The economic value can be assessed by estimating the value of the economic activities using the radio spectrum as input in the production.

The first approach is the mostly relevant for pricing of assignment of frequencies to users, while the second approach is relevant mostly for allocation of spectrum resources between different types of applications. There are substantial difficulties in carrying out any of these approaches. For both approaches the major problem is that radio frequencies basically are treated as a free resource and therefore its value is not included in the costs of production.

Micro perspective

If the micro perspective is used, three different approached can be used for estimation of the economic value:

- The prices paid for a license
- The costs of using other inputs as alternatives to the radio spectrum
- The utility of the produced services

The first approach is only relevant if there already is a market for frequency resources. Today the license fee is in many countries related to the administrative costs of issuing the license and has no relation to the real value of the spectrum. There are still very few examples of a market based price for frequencies, and analyses of the operators' accounts will not be of any help for an estimation of the real value of the spectrum for the firm. On the other hand the user value will always be higher than the license fee (otherwise the users would never apply for a license).

If frequencies have been sold through auctions, prices will – at least in theory – reflect the user value. In Europe auctions have mainly been used for issuing of UMTS licenses. In particular the first auctions in UK and Germany were made on a market with very little information on the size of the size of the revenue that could be expected from UMTS. And the wide variations between countries in prices for similar frequencies can hardly been explained solely by differences in national markets.

For a number of applications of radio communication, wired services are an alternative, which will become attractive if the price of the spectrum increase beyond a certain level. In this case the alternative costs can be used as a proxy for the user value of the spectrum. However, this approach is less obvious for the host of services (e.g. civil aviation) where no alternative exists.

Finally the value can be estimated through analysis of the user value for a selection of users, either through interviews or analyses of financial company data.

Pricing of frequencies according to the user value is relevant only if scarcity occurs. Nothing is gained through saving of frequency resources unless they can be used for another purpose. Therefore pricing of frequencies in this case will imply a loss in welfare if some users for this reason will reduce their demand.

Macro perspective

The macro perspective measures the value of economic activities, which originates from the use of the radio spectrum. The idea is to estimate the macroeconomic impact of the use of the radio spectrum in terms of contribution to GDP. This can be done either for the whole radio spectrum or for each application. If such an analysis is used as guidance for spectrum allocation, applications with a large contribution to GDP will be preferred to applications with a smaller contribution.

There are several methodological problems related to the measurement of GDP impact:

First it can be questioned weather this measure really reflects the value of the spectrum. The radio spectrum is only one out of a number of production inputs. These inputs could be used for other productive purposes if the spectrum were not available. Therefore production using the radio spectrum displaces to a certain extent other economic activities (crowding out). An estimation based on the contribution to GDP will therefore tend to overestimate the value of the impact from use of the radio spectrum.

The value of this displacement should therefore be subtracted. The displacement effect could be estimated as the value of other the inputs to the production. If this is done the result will resemble the outcome of a user value analysis based on financial company data. However, the outcome of such an operation may be that the spectrum does not have any value at all, as the measured economic value of production more or less reflects the costs of production, and the costs for usage of the spectrum is in most cases close to zero. Also in this case the real problem is that it is difficult to estimate the real economic value of a resource not traded on a free market.

Second, it is difficult to separate spectrum related activities from other activities. Inclusion of all activities depending on the use of the spectrum will tend to exaggerate the economic value. For instance it will not be reasonable to include all activities related to civic aviation just because flight control heavily depends on radio communication. On the other hand a mere counting of activities strictly related to the transmission itself will clearly understate the importance of the radio spectrum.

The primary objective of estimation of the value of the radio spectrum presented in this paper is to provide guidance to allocation between various applications by comparing the economic value of these applications. For this purpose it is chosen to focus on the macro perspective. The reasons for this choice are:

1) It is very difficult to find applicable data for a micro oriented approach as long as there only are few examples on market based price setting.

2) It is most obvious to use a macro oriented approach if the purpose is to maximize benefits at the societal level.

We have therefore chosen not to consider the displacement effect. By all means the contribution to GDP is a fairly good indicator for the relative economic importance of the various applications, although there might be an overstatement of the overall impact on GDP.

The contribution from a specific application is estimated through an estimation of the costs related to use of radio-based systems. Only if use of radio based systems is the primary activity a sector is counted in full. This is the case only for wireless communication operators and broadcasting companies (excluding cable based activities).

GDP contribution coming from production of radio equipment and other types of input used in production of radio communication services can be counted in different ways:

- Domestic production of radio communications equipment used in domestic applications.

- The entire domestic production of radio communications equipment can be included.

- The value of equipment production can be completely excluded.

The first approach calculates the size of the demand and estimates thereafter how much this will contribute to GDP. Demand for imported equipment does not contribute to domestic production and it can therefore be argued that only domestic production should be included. This implies that the value of the national spectrum depends on the import share. A more globalised market for equipment production will therefore lead to a smaller contribution from equipment production and hence a lower value of the spectrum.

In a small open economy like the Danish, where 90% of the domestic production of telecom equipment is exported, it can be questioned whether there is any relationship between domestic demand and the value of equipment production at all. Therefore a pure Danish reallocation of spectrum resources will not affect the value of equipment production, but only the value of the services provided. From a national point of view, it can therefore be argued that equipment production is irrelevant as the value of this production more depends on global demand than on domestic demand. On the other hand the value of equipment production is a part of the economic activities initiated as a result of the use of the radio spectrum, and an international reallocation will affect the value of both service production and equipment production.

We have chosen to include the entire equipment production in the estimations. However, the calculations for the value of services and equipment productions are made separately, and the value of services excluding equipment production are depicted as well.

Broadcasting and public mobile phone services are the only applications, which it has been possible to identify as separate economic sectors. Broadcasting services are distributed not only by use of the radio spectrum, but also through fixed cable networks. 54% of the population are connected to a cable network, and the total contribution from broadcasting is therefore reduced by this share. Provision of TETRA is also becoming a business of its own, but this service is too new to be included in the calculation.

The values of other applications are estimated on the basis of the cost of the equipment and the number of people employed for each application. Only, people having radio communication as their primary activity are counted. These figures are estimated on basis of data collected from major users of each application.

The economic value of equipment production is calculated by use of national account data supplemented with financial data from major equipment suppliers.

The economic value of each application is depicted in table 1 below. The value is given as a percentage of GDP.

Table 1: Direct Contribution from the Radio Spectrum to Danish GDP (per Service Application in % of GDP).

Service Application	**Equipment**	**Services**	**Total**
Fixed Links	**0.01**	**0.01**	**0.02**
Maritime[2]	**0.01**	**0.02**	**0.03**
Broadcast	**0.09**	**0.19**	**0.28**
Mobile	**0.21**	**0.56**	**0.77**
PMR[3]	**0.03**	**0.03**	**0.06**
Defence	**0.00**[4]	**0.04**	**0.04**
Total	0.39	0.81	1.20

Source: DTA, 2000

It follows that the direct economic contribution from the radio spectrum constitutes 1.2% of GDP. About one third of the contribution comes from equipment production, while two thirds come from service provision. Similar results are obtained in the studies of the UK economy.

Mobile (including NMT 450, GSM 900 and GSM1800) is by far the most important application. Broadcast is second to mobile and together these two applications count for more than 85% of the economic value.

In a discussion on how allocation of frequencies between different service applications can be optimised, the economic value must be compared to the amount of frequency allocated for each application. It has not been possible to obtain data on the amount of allocated frequencies to all applications. 13% of the Danish spectrum resources is allocated to broadcasting, while 7% is allocated for current mobile communication. Additional 5% is

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[2] Include aeronautic services
[3] Private mobile networks
[4] It has not been possible to distinguish production of equipment for military purposes from other equipment.

allocated for UMTS. Table 2 compares the estimated values of the various applications with the allocations made in the British spectrum.

Table 2: GDP contribution and spectrum allocation by application

Service Application	Value (in % of total value)	Allocated spectrum resource (in % of spectrum allocated)[5]	Value/allocated spectrum ratio
Fixed Links	**1.7**	**5**	**0.3**
Maritime & Aeronautical	**2.6**	**30**	**0.1**
Broadcasting	**22.3**	**17**	**1.3**
Mobile	**55.0**	**15**	**3.7**
PMR[6]	**5.0**	**4**	**1.3**
Defence[7]	**3.2**	**28**	**0.1**
Other	**-**	**1**	**-**
Total	**100**	**100**	**1,00**

Sources: DTA, 2000 and Cave, 2001

It follows from that mobile communication and broadcasting not only are the major contributors to GDP, but also have the highest contribution per allocated frequency resource. The table include frequencies up to 3 GHz only. Frequencies above 3 GHz are mainly used for fixed links and defence. Minor shares go to broadcasting and civil and aeronautical applications. Thus this part of the spectrum is mainly used for applications which already have a low value/allocation ratio.

The immediate conclusion of this analysis is that an allocation of spectrum resources from applications with at value/allocation below 1.0 to applications with a value/application ratio at more than 1.0 would enable a larger positive impact on GDP from the radio spectrum. I.e. more resources should be given to mobile, PMR and broadcasting at the expense of all other applications. As follows from below, there are however a number of considerations which must be taken into account before such a conclusion can be made.

[5] Allocation in the UK spectrum (300-3,000 MHz)
[6] Ecluding emergency services
[7] Including emergency services

V. Allocation of Spectrum to Broadcasting Services

In spite of the high economic value of broadcasting services, the Danish debate on reallocation of frequencies has focussed on the possibility of allocating resources from broadcast to mobile services and PMR. The reasons for this are that the market for these services are rapidly expanding and that digitalisation, and use of satellite and cable-TV offer alternatives to use of traditional analogue terrestrial broadcasting networks. Furthermore broadcast occupies frequency resources that it might be possible to reallocate in such a way that there would be more room for mobile services.

This section discusses the technical opportunities for such a reallocation estimates the economic impact.

International agreements allocate part of the VHF band in Europe for FM radio broadcasting (87.5 – 108 MHz), while terrestrial TV broadcasting uses part of the VHF and the UHF band.

Terrestrial broadcasting of digital radio (T-DAB-T and S.DAB) has been allocated a part of the VHF band around 200 MHz and part of the UHF band around 1.5 GHz. No new frequencies have been allocated for terrestrial broadcasting of digital TV (DVB-T). It has been decided internationally to reuse the frequencies currently allocated for analogue TV to this purpose.

Table 3 outlines the frequency resources allocated for broadcasting purposes.

Table 3 Overview of the allocated frequencies for Radio and TV

	Application	Frequency band	Bandwidth
LF	**AM radio**	**148.5-255 kHz**	**0.1065 KHz**
MF	**AM radio**	**562.5-1606.5 kHz**	**1.044 MHz**
VHF	**tv-kanal 2-4**	**47-68 MHz**	**21 MHz**
VHF	**FM radio**	**87.5 - 108 MHz**	**20.5 MHz**
VHF	**tv-kanal 5-12**	**174 - 223 MHz**	**49 MHz**
UHF	**tv-kanal 21 – 60**	**470 - 790 MHz**	**320 MHz**
Total			411.7 MHz

Source: Frequency allocation table from Danish telecom agency

It is, however, far from all these resources that can be used in Denmark. Frequencies must be used in a way that they do not interfere with similar services in neighboring countries – a problem that requires detailed international co-ordination. Signals from different applications have different levels of sensitivity and frequency channels, that can not be used for analogue TV due to interference with other TV signals, may be used for other applications like PMR, TETRA or even digital TV.

Radio space for mobile services is allocated in four different areas of the spectrum: Around 450 MHz (NMT450), around 900 MHz (NMT900 and GSM-900), around 1800 (DSC-1800) and 1900-2170 (UMTS). In the near future the NMT networks will be closed down and the frequencies will be transferred to GSM and TETRA. An overview of the assigned frequencies is depicted in the annex.

It follows that frequencies used for broadcasting and frequencies used for are heavily intertwined, although there is no direct overlap between them (see also Figure 1). It is technically possible to use the frequencies in the UHF band allocated for TV (470-790 MHz), for public mobile communication.

Although it is not possible to transfer the broadcasting frequencies to the public mobile communication in the short term, it is important to make prioritization between different uses because:

1) reallocation of broadcast frequencies to public mobile will be possible in the long term,
2) reallocation can include other services. E.g. PMR and TETRA can operate both on frequencies currently allocated to broadcasting and frequencies used for public mobile services.

If terrestrial broadcasting frequencies are used for other purposes, broadcasting services can be distributed via other infrastructures like satellite and cable networks. This will cost 50-100 mill. € per year to implement this solution in Denmark.

In addition to this, the solution will cause losses due to lack of portable and mobile reception. The solution will also have severe consequences for local and regional TV stations as households will have less incentive to maintain their UHF/VHF antennas.

Digitalisation of broadcasting services also plays a role. It has been agreed that public broadcasting companies should provide digital services, and that analogue services should be discontinued, when it can be expected that digital services are accessible for the vast majority of the population. But broadcasting companies and the Government are both hesitant to invest in a digital terrestrial broadcasting network.

The estimation of the economic value of different spectrum applications indicates that a reallocation of frequencies from broadcast to mobile will have a positive impact. This follows from the fact that although more resources are allocated to broadcast than to mobile, the contribution to GDP is larger from mobile than for broadcast. The economic impact of reallocation of frequency resources corresponding to one analogue TV-channel (112 MHz) from broadcast to mobile applications has been calculated under various economic assumptions on the marginal value of spectrum resources. All results indicate that such a reallocation would give a positive contribution to the economic activity. Unfortunately the results very much depend on the assumptions made, as the positive contribution to GDP ranges from 200 to 600 mill. USD.

V. Conclusion

The data presented in sections IV-V document that the radio spectrum constitutes a substantial natural resource with a growing economic value. When scarcity appears, as it is the case in certain frequency bands, methodologies to make a proper allocation between applications, allotment between regions and assignment between users must be developed. So far such methodologies have focussed on the technical limitations. The data presented is a first step towards establishment of procedures that include economic considerations as well.

The data measure the economic value per service application and can provide some guidelines at the macro level that can be used as an input in the discussion for allocation of frequencies between different service applications. The data should however be used in combination with other types of input.

First of all technical considerations must be included as well. 1 MHz is not just 1 MHz but the technical characteristics and hence the economic value for different applications depends very much on the position in the radio spectrum. Some parts of the spectrum are well suited for broadcasting, while others are better suited for point-to-point communication. Some frequencies are well suited for communication over long distances while other are better for short distances.

Second, there are substantial methodological problems related to the measuring of the economic value. The data presented in this paper measure the economic value as the contribution to GDP. The major reason for this decision was that reliable data was available.

Third, the method does not provide any guidance in judgement of spectrum scarcity. The high value of the existing mobile applications does not necessarily prove that more spectrum will lead to an even higher value.

Fourth, the economic evaluation does not take into consideration if alternatives to use of the radio spectrum are available (e.g. wired solutions).

Finally, other than economic considerations are relevant in the allocation between applications for instance safety obtained through use of PMR services for police, fire brigades a.o.

The data indicate that priority should be given to mobile services and that a reallocation of frequency resources from broadcasting will increase the economic value of the spectrum, but more studies on the economic impact of scarcity of frequencies for mobile services must be made before precise recommendations can be given. Other service applications could also be included in such a reorganisation. Some applications with very modest contributions to GDP occupy substantial frequency resources. Quite often these applications have been developed and allocated resources long time ago before a situation with severe scarcity of frequencies arised. One example of this is radio links used for fixed link services.

During the past decade the telecom market has developed from a market dominated by semi public operators enjoying monopoly rights to a liberalised market with competition in most market segments. Spectrum management however has not been through a similar development. Although auctions and spectrum pricing have been used in a few cases, the institutional framework is basically the same.

Allocation of frequencies between different applications is mainly treated as a purely technical matter on how to allocate as many resources as possible without spectrum interference among users.

This paper suggests a more market oriented approach towards spectrum management. This is certainly not a new idea, but was suggested by Coase back in the 1950s, but this advice has not yet been followed in the design of the overall institutional framework for spectrum management.

Still there are a number of technical arguments against a free market approach. These include:

- Interference among users depends on transmission power and the type of applications. Restrictions on these parameters will therefore enable a better utilisation of resources.
- Radio waves does not follow international borders and licenses must therefore be international co-ordinated.
- The radio spectrum provides resources for a wide range of infrastructures with conflicting interests that not easily can be solved at the market.
- International harmonisation of frequency plans benefit usability of cross-border service such as mobile telephony, and contribute to common industry standards for new equipment and services.

This is not to say that it will be impossible to develop a free market for spectrum resources. A free market approach may be suitable for assigning frequency bands between operators within the same application. Regulators can sell licenses at the market and users may be allowed to buy and sell licenses from each other. A relaxation of current restrictions may in certain frequency bands lead to a more efficient use from a technical as well as an economic point view. But as long as restrictions on how the various bits of the spectrum is used persist, it will be necessary for a regulator to decide on allocation of resources between different applications and regulatory intervention will be necessary also to ensure efficient and harmonised patterns of usage across countries.

In the long term convergence will make it more difficult and somewhat meaningless to maintain a strict regulation on to what applications a certain spectrum license is used for. Convergence may therefore pave the way towards a free market for spectrum licenses also for allocation, but until then a prioritisation among applications must be made.

In this respect an assessment of the economic value of various applications is an important input. This paper measures the economic value in terms of contribution to GDP, and illustrates how this can be used as guidance in the allocation process.

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Annex: Overview of frequencies assigned for public mobile services in Denmark

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Application	Operator/ID	Frequency band (MHz)	Assignment (MHz)	Bandwidth (MHz)
NMT 450	**TDK**	**453-457.5/463-467.5**	2x4.5	**9**
NMT 900	**TDK**	**890-895.8/935-940.8**	2x5.8	**11.6**
GSM 900	**TDK/ GSM1**	**896-904.8/941-949.8**	2x8.8	**17.2**
	Sonofon/ GSM2	**905-913.8/950-958.8**	2x8.8	**17.2**
	Telia/ GSM3	**880.2-880.8/925.2-925.8 and 886.4-889.8/ 931.4-934.8 and 890.0-890.8/935.0-935.8 and 892.8-893.4/937.8-938.4 and 893.6-894.6/938.6-939.6**	2x7.4	**14.8**
	Orange/ GSM4	**881.0-881.6/926.0-926.6 and 882.8-886.2/927.8-931.2 and 891.0-891.8/936.0-936.8 and 892.0-892.6/937.0-937.6 and 894.8-895.8/939.8-940.8**	2x7.4	**14.8**
DCS 1800	**TDK/ DCS1**	**1731.6-1746/1826.6-1841**	2x14.4	**28.8**
	TDK/ DCS6	**1717.4–1729.4/1812.4 –1824.4**	2x12.2	**24.4**
	Sonofon/ DCS2	**1710-1717.2/1805-1812.2**	2x7.2	**14.4**
	Sonofon/ DCS5	**1717.4–1729.4/1812.4–1824.4**	2x12.2	**24.4**
	Telia/ DCS3	**1746-1760.4/1841-1855.4**	2x14.4	**28.8**
	Orange/ DCS4	**1760.4-1774.8/1855.4-1869.8**	2x14.4	**28.8**
UMTS	**HI3G / I**	**1920-1935/2110-2125 and 1915-1920**	2x15 + 5	**35**
	TDC/ II	**1935-1950/2125-2140 and 1900-1905**	2x15 + 5	**35**
	Telia/ III	**1950-1965/2140-2155 and 1905-1910**	2x15 + 5	**35**
	Orange/ IIII	**1965-1980/2155-2170 and 1910-1915**	2x15 + 5	**35**
I alt				**374.2**

Sources: NMT, GSM, DCS 1800 and UMTS licenses issued by Danish Telecom Agency.