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Spectrum policy: what next?

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Spectrum Allocation, Spectrum Commons and Public Goods: the Role of the Market

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Abstract: The reallocation of radio spectrum to valuable new and emerging technologies and services is essential to achieving the next wave of productivity and consumer benefits driven by ICT. Currently spectrum is not allocated to the most valuable uses, particularly the large amount of spectrum held for government use, and command and control management cannot respond fully or quickly in reallocating spectrum. To achieve a more economically efficient allocation and the greatest overall benefit market mechanisms including trading and spectrum pricing must be introduced. Complementary reforms in areas other than spectrum management will be required, and the appropriate boundary between market and non-market allocation mechanisms need to be established. Setting clear principles regarding the market/non-market boundary will help in resisting the inevitable rent seeking by incumbents and potential entrants during the transition to market mechanisms. Countries that do not face up to these challenges and move quickly will see their citizens disadvantaged as spectrum becomes a key economic resource.

Key words: spectrum policy, auctions, trading, spectrum pricing, digital switchover, real options, public sector use and licence exempt use.

Radio spectrum is an increasingly valuable resource for wireless and mobile applications, yet historical allocations of spectrum and methods of allocation and reallocation are both inefficient and slow to adapt. Substantial spectrum resources are in effect hoarded by government, aviation and military users with little consideration of the opportunity cost to the wider economy. In considering how to reform spectrum management to ensure that spectrum is allocated to the most valuable uses market mechanisms such as auctions, trading and spectrum pricing should play a central role.

Yet progress internationally in moving from command and control to spectrum markets has been slow and partial, with limited application to government use including the military for example. The cost to welfare in terms of foregone services and productivity growth is likely to be very large, with ICT currently contributing around half of overall productivity growth in

the US and Europe, and growing scope for wireless to contribute to the networked economy.

This paper focuses on the potential role of spectrum markets, barriers to introducing market mechanisms and the optimal boundary between market and other allocation mechanisms. False arguments are often made for the continued use of administrative allocation processes and we distinguish between these and legitimate arguments. These issues have arisen, or are arising, in a number of countries in relation to the allocation of spectrum released by digital switchover in particular.

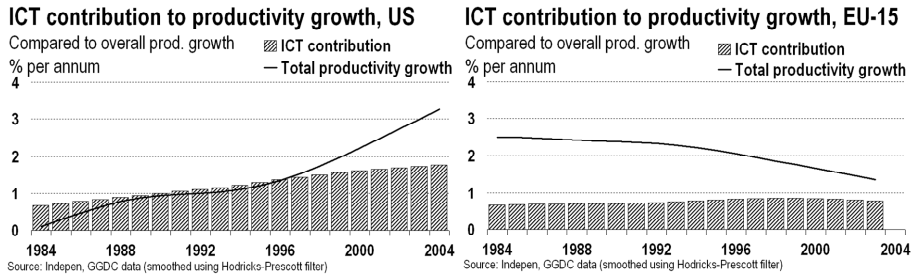
Digital switchover also illustrates path dependence between decisions, with early decisions resulting in irreversible commitments which can reduce flexibility to respond to future technological developments, particularly where early decisions involve public service broadcasting. We conclude that introducing market mechanisms on their own is not enough to deliver optimal outcomes. There needs to be parallel reform of other institutional arrangements including government funding of public sector users of spectrum in moving to markets. Where administrative decisions are required irreversibility needs to be explicitly taken into account.

■ Benefits of applying markets to radio spectrum

Radio spectrum is a scarce and essential input to the networked economy. It is therefore important to ensure that spectrum assignment and allocation adapt to changing demand and reflect the value of alternative uses and users. Radio spectrum policy should be seen in the broader context of Information and Communications Technology (ICT) which has made a substantial contribution to increased productivity growth in some regions, but not others, since the mid-1990s as can be seen in Figure 1 (WILLIAMSON, 2007).

Part of the explanation for these differences in the impact of ICT lies in the flexibility with which business and government processes can be adapted to make effective use of ICT. Labour and product market flexibility appear particularly important to facilitating the "creative destruction" required to utilise ICT effectively and efficiently, and to get a large payoff from investment in ICT (McMORROW & VEUGELERS, 2005).

Figure1 - ICT contribution to productivity growth



The capabilities of existing fixed and mobile access infrastructure may increasingly prove to be a constraint on the networked economy as distributed data access grows, and particularly if existing regulatory arrangements act as a constraint and/or provide investors with insufficient confidence to invest. Spectrum markets and pricing could therefore play a significant role in facilitating the reallocation of spectrum to meet such new demands.

The proponents of a market approach generally argue their position from first principles. It seems self evident to an economist that if users (and regulators) do not face any cost for the use of a resource such as spectrum then they have little, if any, incentive to adopt the economically efficient technology or to allocate spectrum to the highest value uses (FAULHABER, 2006).

An illustrative example of existing spectrum use that appears very inefficient when the value of spectrum in alternative uses is considered is aeronautical radar. Aeronautical radar in the UK involves a relatively old technology (magnetron radars), and more efficient alternative technologies are available such as the use of filter technology, different waveform techniques or a combination of the two [1].

There is evidence (INDEPEN & AEGIS, 2007) that over 270 MHz of spectrum – more than twice the amount released by digital switchover in the UK – could be released for mobile and WiMAX applications whilst maintaining aeronautical radar services. It appears this could be done at very modest cost relative to estimates of the value of such spectrum which is

[1] Whilst the use of ultra narrow band (continuous wave) transmissions would reduce requirements to only 10% of the amount of spectrum required by pulsed radars, this technology is not likely to be available for another 15 years.

estimated to be around £0.84m/MHz for the UK. Table 1 summarises the calculations.

Table 1 - Costs of reducing spectrum requirements for aeronautical radar by applying new waveforms and filters

	L Band (1.24-1.35 GHz)	*S-Band (2.7-3.1 GHz)*	*Ku-Band (15.4-15.7 GHz)*
Cost	£11.7m	£43.2-128.2m (*)	£0.8m
Spectrum released	70 MHz	200 MHz	200 MHz
Maximum annualised cost/MHz (assuming 10% discount rate & 15 year discount period)	£0.02m/MHz	£0.03-0.08m/MHz	£0.0005m/MHz

(*) The low end of the range is the cost for civil radars only. The high end includes military radars assuming the cost per radar is the same as for civil radars. Some NATS radars may already have this capability and so costs are overstated. Also costs of military radar conversion may be less than those for conversion of civil radars if there is less cost of downtime.

Source: INDEPEN & AEGIS (2007), based on analysis of radar technologies by QINETIQ et al (2004)

If these results apply in a relatively densely populated country with a sizeable aeronautical industry like the UK, we suspect similar gains could also be made elsewhere. Achieving such gains across countries would be necessary if the spectrum is to be released for services on an international basis.

However, in the absence of incentives to economise on spectrum in the aeronautical sector the status quo will tend to dominate administrative decisions, particularly in Europe where air traffic control is fragmented between national administrations. An illustration of the tendency to support the status quo is European opposition to proposals to allow the allocation of the 2.7-2.9 GHz band to advanced mobile services (OFCOM, 2007a).

A shift to greater reliance on market mechanisms including spectrum trading and/or spectrum fees reflecting the opportunity cost of spectrum in relation to aeronautical radar could result the reallocation of spectrum to a range of mobile applications with substantial benefits.

■ The implementation of spectrum markets is limited

The extent of application of market mechanisms to spectrum in practice is generally limited despite the potential benefits. While numerous countries have used auctions to assign licences for mobile and wireless access services, relatively few countries have gone beyond this to implement reforms to create spectrum access rights that can be freely traded and that allow change of use or technology (i.e. that are liberalised).

Trading and liberalisation policies have been implemented for some time and/or in numerous frequency bands in Australia, El Salvador, Guatemala, New Zealand, Norway, the UK and the US (ANALYSYS et al., 2004; WIK, 2005; OVUM, INDEPEN & AEGIS, 2006). In most cases implementation has been partial and limited to newly auctioned spectrum (e.g. New Zealand) or a limited number of frequency bands (e.g. New Zealand, Norway, the UK and the US), and to commercial users (e.g. the UK, US, New Zealand).

In the US by 2002 only 7% of the spectrum in the 300 MHz to 3 GHz range (i.e. the most valuable spectrum) was available for market allocation. In those countries where government users may enter markets they have generally not done so (e.g. Australia, El Salvador, Guatemala, and Norway). A possible reason for the lack of participation may be the way in which gains from spectrum sales would be treated in the overall budget process. Alternatively, resources that have an opportunity cost may receive less scrutiny than actual cash expenditure on spectrum. If the latter is the case spectrum pricing may be an important substitute or complement to trading, particularly in relation to government use.

Of course, to the extent that there is trading in proxies for spectrum, such as network capacity (for example, broadcast multiplex capacity) or buying and selling of companies to obtain access to spectrum, the extent of trading may be more extensive than it first appears.

However, if we take the example of the UK, where there has been a clear policy direction, changes have taken at least a decade to be implemented. Arguably the move towards market approaches started in 1994 with the release of a consultation paper by the government titled "The Future Management of Radio Spectrum" and this lead to new legislation (the Wireless Telegraphy Act 1998) allowing spectrum pricing and auctions in 1998.

In 2001 the Treasury and the Department of Trade and Industry commissioned an independent review of spectrum policy which advocated the broad application of market approaches to spectrum management (CAVE 2002). Spectrum trading was first introduced in December 2004 and is being incrementally extended each year, starting with bands used for private mobile communications and fixed wireless access. However, the OFCOM (2004) announcement did not propose the introduction of trading for 2G and 3G mobile spectrum until 2007. In 2004 the Treasury commissioned an independent audit of spectrum use by the public sector which has resulted in numerous specific actions, including the use of market mechanisms, aimed at improving the efficiency of spectrum use by the public sector (CAVE, 2005).

Why has it taken so long to achieve these changes? Is it just resistance by powerful incumbent interests or is developing new rights more complex than it first appears? In the remainder of this paper we seek to identify some of the real problems in moving to markets and the wider policy and institutional implications.

■ Distinguishing real versus false problems in moving to a market based approach

From a public policy perspective some of the claimed problems in developing market based approaches are real, and some are imagined or simply self serving. It is essential to distinguish between the two.

False arguments

Arguments that are sometimes made against the introduction of market based policies but that are not persuasive concern the claimed benefits from the services provided justifying "free" access to spectrum, and concerns about monopolisation and under use of spectrum if markets are applied (CAVE, 2006).

Contribution of spectrum using services to the economy

A frequent argument is that a particular sector makes a large contribution to GDP and employment, including indirect impacts on the economy, and

therefore deserves special access to spectrum such as spectrum reservations and access at low or no cost. An illustrative general example is the discussion of potential positive market externalities in relation to aviation in a report by the ATAG (2005).

Arguments regarding indirect economic or employment benefits, unless they relate to genuine (so called non-pecuniary) externalities such as pollution, are almost always spurious. Macroeconomic or second round effects normally represent a re-distribution of resources within the economy, without any net overall economic effect (BAUMOL & OATES, 1998; and BOARDMAN *et al*, 2006). In other words, the private valuation of spectrum expressed at auction, in trading and in response to spectrum pricing will reflect the social value.

External costs and benefits

Economic activity may also have negative or positive impacts on welfare and production that are not mediated by the market, for example, impacts via congestion, acoustic noise, radio interference and public service broadcasting, which is considered to have wider benefits in many countries. These are legitimate public policy concerns. However, the fact that an externality arises in relation to the production of outputs utilising spectrum as an input is not an argument for not relying on (or modifying) market instruments to manage spectrum inputs.

DIAMOND & MIRRLEES (1971) developed the general argument that in setting policy to maximise welfare in a second-best situation it is not desirable to tax (or subsidise) the use of inputs. Whilst it is in principle possible to address an externality by modifying the price of all inputs in an appropriate way, this is in practice infeasible given the information and practical constraints on achieving efficient outcomes via the modification of input prices (HOLTERMANN, 1976; HELFAND, 1999).

So what should be done? In sectors such as aviation that produce greenhouse gas emissions taxes or permits targeted directly at these emissions would be the appropriate response (INDEPEN & AEGIS, 2007). In such instances measures to address the externality need not accompany the introduction of spectrum markets or pricing, and should be separately considered on their merits. In the broadcasting sector a range of interventions targeted at the desired output (namely public service

broadcasting) are available, including direct funding (INDEPEN & AEGIS, 2005).

Monopolisation

Another strand of argument for intervention in the allocation of spectrum is that a market based approach would result in excessive market power in either the spectrum market or the final service market via monopolisation of the scarce spectrum input. A scarce input can lead to market power, but this problem is not unique to spectrum, for example, holdings of land by supermarkets in the UK have been investigated using general competition powers. Further, potential concerns over competition need not be a barrier to the introduction of market based approaches to spectrum allocation, provided they are explicitly addressed in policy design.

General competition law provisions might be judged adequate in addressing such concerns. If not, other interventions such as limitations on the amount of spectrum individual firms can acquire might be introduced at the time spectrum is auctioned. The availability of additional spectrum in future acquired via trading or auctions, or new technologies such as WiMAX and WiFi, may also disrupt any market power in, for example, the mobile market. Rather than concerns over market power impeding the introduction of spectrum markets, spectrum markets should be seen as reducing the potential for market abuse. For example, HAZLETT, IBARGUEN & LEIGHTON (2007) found that in Guatemala spectrum markets contributed to increased competition and lower prices.

Under-used spectrum

A further concern sometimes raised is that spectrum will be purchased and remain unused for speculative reasons, or to prevent access to spectrum by others. It is not uncommon for "use it or lose it" provisions to be advocated but they are rarely applied because of the problems in defining legitimate use. Though we note that in New Zealand the government has determined (based on a consultant's reports) that some of the cellular rights in the 800 and 900 MHz bands are underused by incumbents and that these underused rights should be sold at auction when the existing licences expire (Ministry of Economic Development, 2006).

Current non-use of at least part of a scarce resource is often optimal, either to allow for future growth, or because the optimal use is uncertain and

commitment to a particular use may involve the irreversible commitment of capital and other resources. An analogous example is the opportunity to develop vacant land, where valuable land can remain unused when real estate prices and the payoff from alternatives is uncertain (TITMAN, 1985). Less than full utilisation of a frequency band also makes spectrum re-planning easier. Use it or lose it provisions may therefore reduce the social value of spectrum. Fixed capital build out commitments or timing constraints with respect to usage in relation to spectrum allocations may also reduce the social value of spectrum, since flexibility itself has value (TRIGEORGIS, 1996).

A special case, however, are the legacy holdings of spectrum by government users including the military. There is no reason to presume that under use (or use) is optimal in this instance, and in the absence of opportunities to profit from trade or an explicit charge for spectrum government agencies could be expected to hold on to spectrum just in case, even where such holdings are inefficient.

Legitimate concerns

A number of legitimate public policy concerns arise in relation to moves to a more market based approach to spectrum allocation and reallocation, some of which may require complementary changes to institutional arrangements, whilst others may require a departure from a purely market based allocation of spectrum. We consider the question of whether spectrum should be reserved for "unlicensed" use as a public commons, the interaction with publicly funded outputs such as broadcasting and defence, and incumbency issues.

Spectrum commons

A number of economically valuable applications of spectrum involve use of a spectrum common, for example public WiFi, RFID and many consumer applications such as baby alarms and garage door openers. In these instances it may not be feasible for users to band together and pay for spectrum collectively due to the transaction costs involved. Given this, the reservation of spectrum for public commons must be decided administratively based on an assessment of the costs and benefits involved.

Estimates of the net economic benefits of collective use for a number of applications have been produced in a study by INDEPEN, AEGIS & OVUM (2007) for the UK regulator Ofcom. The results indicate that the net present value of these benefits over the next 20 years for the EU could be considerable (estimated by multiplying UK estimates by the ratio of EU to UK GDP):

- Home data networking: €36bn (this includes avoided costs of using wired systems and the benefits arising from the stimulus to broadband take-up).
- Public WiFi: €590bn (this includes the cost savings from not using cellular services for mobile internet access and the benefits from greater use of mobility services).
- Automotive radar: €220bn (this includes the benefits arising from reductions in the number of accidents).
- RFIDs: €200 bn (this includes the efficiency benefits to the retail sector alone).

The main challenge in undertaking any assessment of costs and benefits is that they occur in the future and so are necessarily uncertain. This means the likelihood of possible outcomes occurring needs to be assessed. This might be done with reference to analogous past situations and gathering views from industry participants and potential consumers.

Irreversibility and path dependence

Allocations of spectrum, in particular those for licence exempt use or public service broadcasting, may in effect be irreversible – at least for a very long time. Once a commons is created and used there is no straightforward way to release the spectrum for another use since use is unlicensed. An allocation for public service broadcasting involves the irreversible commitment of capital by consumers and a subsequent public switch-over problem if equipment is not forward compatible, for example, moving from MPEG-2 to MPEG-4 coding.

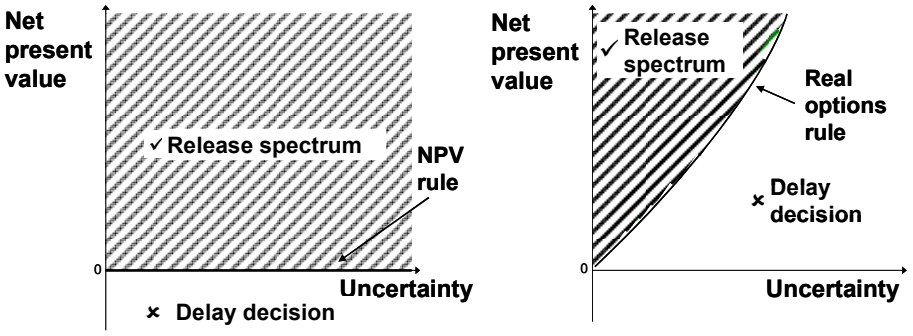
Consideration of irreversibility introduces path dependence into decisions and complicates the analysis of costs and benefits. It also implies that there should be no presumption of a "first mover" advantage since, should an irreversible decision prove mistaken it will be particularly costly. The standard (or static) net present value rule, under which the net present value

of benefits less costs is maximised, may not provide the optimal outcome in these circumstances.

An expanded NPV decision rule incorporating "real options" is required that explicitly takes into account uncertainty, irreversibility and flexibility in the timing of decisions (DIXIT & PINDYCK, 1994). Whilst real options techniques have been applied to a range of investment problems including spectrum use (HARMANTZIS et al., 2006), to date there has been very limited application in the policy context of spectrum allocation.

We have applied these ideas to the decision whether to release spectrum for licence exempt applications or not (QUOTIENT & INDEPEN, 2007). In figure 2 the left hand figure shows the result of applying the standard NPV calculation and the right hand figure shows (in stylised form) the results if the expanded NPV rule is applied. What these figures show is that where there are large uncertainties in the benefits to be had or to be forgone, it can be economically advantageous to wait before releasing or using spectrum and the optimal allocation at a point in time is likely to be smaller than a conventional net present value calculation would suggest. Hence, smaller more frequent releases of spectrum will be more appropriate than a single large release.

Figure 2 - Implications of "real options" for spectrum release



Public sector use

The public sector including defence is a large user of spectrum, in the UK accounting for over 40 per cent of the use of spectrum below 15GHz (OFCOM, 2007b). It is therefore important to introduce incentives for efficient use of spectrum in the public sector alongside a shift to market based incentives for private spectrum use. However, doing so may require additional measures since government users often face budgetary

constraints on their interest in and ability to use the gains from more efficient spectrum use for other purposes. These budget processes may also mean that public sector users are more responsive to the direct cost of purchasing spectrum or paying an annual charge for their spectrum holdings than the incentive provided by the "opportunity cost" of holding spectrum if trading is permitted. In addition, public sector users of spectrum may not be licensed in which case their rights of spectrum will need to be defined more precisely if they are to engage in market transactions and/or they are to receive protection from changes to rights made by their commercial spectrum neighbours.

International experience of applying financial incentives to government users of spectrum is limited. In the US, a number of bands have been identified for potential reallocation from government to non-government use. The costs of moving government users from these to other (less highly desired) bands are identified and the bands are auctioned but are only released to private sector bidders if the revenues raised exceed 110% of the cost of moving the government users. This mechanism for paying for moving costs gives government users an incentive to move and ensures the benefit to the private sector exceeds the economic costs of the reallocation.

In the UK, government users pay the same administratively determined spectrum prices for their spectrum access as commercial users. The recent Independent Audit of public sector spectrum holdings concluded that AIP is likely to remain a fundamental element in encouraging improved spectrum efficiency for public sector spectrum holdings (CAVE, 2005). Pricing has been introduced for defence, emergency services, science and commercial fixed and mobile use; and is planned for broadcast use and under consideration in relation to aeronautical and maritime use (which account for the remaining half of spectrum below 1 GHz not currently subject to spectrum pricing). Prices are set with reference to estimates of opportunity cost utilising the Indepen-Aegis methodology whereby the costs of providing a service are calculated assuming that less spectrum is available *via* an alternative technology or greater use of network infrastructure (INDEPEN & AEGIS, 2005).

Provided public agencies can keep some of the savings from economising on spectrum use for a period of time incentives to economise are introduced by spectrum pricing whether or not the agency receives an initial compensating adjustment to its budget. Spectrum pricing also has the advantage that not all of the issues related to the definition of rights, which may be required to implement trading, need be resolved.

Removal of implicit support for activities such as public service broadcasting via the free availability of spectrum may also require adjustment to existing funding arrangements and/or regulatory requirements if existing levels of public service broadcasting are to be maintained. Arguably explicit consideration of these issues and the clarity it brings is beneficial.

Incumbency issues

The introduction of explicit rights, allowing trading and potentially applying pricing to spectrum must all be considered against a backdrop of existing spectrum use and expectations. Whilst the reallocation of economic rents associated with past availability of spectrum may be irrelevant from an overall economic efficiency perspective, proposed reforms need to be carefully considered having regard to reasonable investor expectations and, if they are to be successful, the politics of reallocations of economic surplus.

Investment could be deterred if companies are not confident in the future continuation of their rights and so there could be a consequence for overall economic efficiency. This means the conditions for licence revocation and renewal must be made explicit in advance if spectrum markets are to work well. In addition, incumbents will incur real costs in clearing spectrum for new uses and these costs may need to be factored into policy decisions.

The most direct way of doing this is for new users to compensate incumbents for moving though if incumbents do not have time limited rights problems of hold-up will occur. To avoid these problems either rights must be time limited (CRAMTON *et al*., 1998) or the sum paid for moving incumbents needs to be agreed by an independent third party.

A degree of tolerance of prospective "windfalls" if rights are vested with existing users and become tradable might in some instances be preferable to the administrative and legal problems involved in reassignment. In particular, with hindsight digital switchover for broadcasting might have been made more clearly the responsibility of broadcasters if they had been granted existing spectrum and allowed to use surplus spectrum for additional channels and/or high definition TV (HDTV), or to sell the spectrum themselves, at switchover. The transition from analogue to digital mobile services was, for example, managed by the mobile operators themselves.

Finally, pure rent seeking, by incumbents or entrants, should be distinguished from legitimate concerns relating to the allocation or

reallocation of spectrum rights and resisted. HAHN & SINGER (2007) have argued that efforts to impose conditions on licences in the auction of 700MHz spectrum in the US amount to rent-seeking, and that giving the FCC discretion has inevitably resulted in rent seeking. Clarity over the limited range of legitimate grounds for intervention in a market allocation or inclusion of special conditions in spectrum licences will help in limiting the inevitable rent seeking associated with valuable rights and regulatory discretion.

■ Addressing all of these problems at once – allocating the Digital Dividend

All of the complexities discussed above arise in relation to the migration from analogue to digital TV and the associated release of spectrum for new users. We illustrate this using the UK as a case study. Here there are:

- Incumbent users whose interests need to be addressed, including existing broadcasters, programme making and special events users, radio astronomy and an aeronautical radar operated for commercial purposes.
- Potential new uses of the spectrum, including licence exempt as well as licensed use, that are argued to generate positive public benefits (e.g. public service broadcasting and rural broadband), uses that require a particular band plan (e.g. paired spectrum for two way mobile services) and publicly funded organisations (e.g. radio astronomy and the BBC).
- Spectrum reservations for six digital terrestrial TV mulitplexes, and the issue of whether these allocations should be made more flexible (e.g. tradable) arises.
- Complex migration issues. Current digital set top boxes use MPEG-2 compression, whereas other countries who waited have adopted MPEG-4 compression, allowing greater flexibility in the timing and allocation of spectrum for mobile TV and HDTV. Furthermore, a future switchover to MPEG-4 will be required in the UK.

A full market approach to reallocating this spectrum could involve either terminating all existing licences and then auctioning a clear block of spectrum (the big bang approach advocated by KWEREL & WILLIAMS, 2002, but not adopted so far by any government) or grandfathering tradable rights to the existing users and letting them manage the transition through

trading, private spectrum auctions and funding any consumer migration costs.

However, other policy measures that are beyond the scope of the regulator's activities may also be needed to ensure publicly funded bodies faced appropriate incentives to buy/sell spectrum and to address significant external costs/ benefits (e.g. funding or regulation targeted at these external effects). In addition the regulator must still decide whether licence exempt uses should be allocated spectrum administratively (i.e. using cost benefit analysis) or whether a private commons approach is preferable. If cost benefit analysis is applied then the benefits to all potential uses of spectrum need to be estimated - a considerable task.

What has happened so far in the UK is that the regulator, Ofcom, set out with the intention of using an auction (of technology and service neutral licences) to determine the allocation of the release spectrum recognising where there were material social benefits from particular uses that these might justify some sort of intervention in the market. The difficult question Ofcom has tried to answer is how big are the social benefits that derive from access to the UHF spectrum for each of the main potential uses of the spectrum?

Ofcom first estimated the private welfare benefits for each of the services (based on consumer market research and market modelling to estimate the sum of consumer and producer surplus) and then gave an indicative (judgemental) percentage for the uplift associated with wider social benefits. These benefits are judged to amount to 5-15% of the private benefits i.e. well within the range of errors on the private benefits. This might suggest that, with the possible exception of the licence exempt applications, an auction approach should be applied since private valuations will in a first approximation reflect the social value.

However, there is a further complication raised by the prospect of HDTV. Whilst HDTV may not have value *per se* in terms of public service broadcasting, the viability of the terrestrial public service broadcasting platform might be undermined over time if HDTV were not available on the platform (it is currently available on satellite and cable, and may in future be available over fibre access networks).

If provision of HDTV is important for the continued delivery of terrestrial public service broadcasting, then the question arises as to whether the main broadcasters could feasibly bid for it, given one broadcaster is publicly

funded and another is publicly owned, and whether these bids would take account of the public benefits from continued popularity of the terrestrial platform, given the other two main broadcasters are purely commercial organisations. If an auction is held the cost of spectrum access is not known in advance and there is a risk that public service broadcasters would be unsuccessful at auction, an outcome that might prove irreversible and lead to regret.

As a general matter Ofcom argues that reserving spectrum for a particular purpose that generates social value is not appropriate - rather changes should be made to financial and institutional frameworks to ensure that social value is taken into account (OFCOM, 2006). While this may be correct in principle, there is a significant practical issue to be addressed, namely will such financial and institutional frameworks be put in place in advance of the UHF spectrum auction?

There is also a longer term issue to consider in terms of the relationship between the delivery of public service broadcasting and the terrestrial broadcast platform. With growth in the availability and use of alternative platforms, the opportunity to consider terrestrial switch off and a further release of prime spectrum for mobile applications may arise in future.

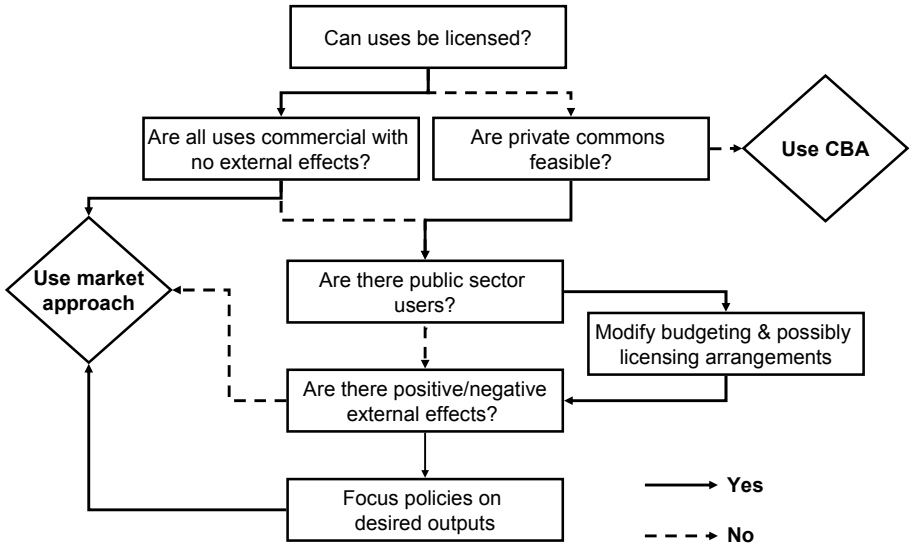
■ How should policy makers proceed?

Figure 3 summarises the decision process that is implied by the analysis given in this paper. To get to this stage, a process to achieve a degree of buy-in to application of a market based approach, as appropriate, is first required.

A key underlying decision is whether to rely on an administrative allocation supported by cost benefit analysis, or to rely on the market. In allocating spectrum released by digital switchover in the UK a combination of the two might ultimately be used, but the boundary between the two approaches must be clear. The extent of irreversibility involved in allocating spectrum for licence exempt or public service broadcasting use complicates decision making, since there is greater potential for regret in terms of the future scope to allocate spectrum in response to new applications (such as mobile TV). Clarity over the narrow range of circumstances in which departure from a market based approach to allocation, or imposition of

special license conditions would be justified, will also help in resisting rent seeking by incumbents and entrants.

Figure 3 - Decision process for deciding spectrum allocation policy



It is clear that the introduction of market approaches to spectrum management can be more complex than it first appears, requiring changes in policies aimed at specific spectrum uses and users. The simplest circumstances where market approaches can be applied are where current and expected future uses of spectrum are purely commercial and capable of being licensed. Even in these circumstances legacy issues need to be anticipated and managed.

Where users are in the public sector or uses generate significant external impacts it may also be necessary to adjust other policies that are outside the scope of the spectrum manager's remit. This emphasises the importance of wider government (and importantly Ministry of Finance) commitment to spectrum reform. If this commitment does not exist then continued intervention will be required such as spectrum reservations and/or the grant of "free" spectrum for public sector users and other uses generating wider public benefits. Judging the extent of these interventions is always problematic and means that over time these users have little incentive to change their spectrum use in response to technology and market changes. However, the potential prize in terms of productivity and new services is large, and considerable effort in addressing these more difficult policy areas is therefore likely to be justified.

References

ANALYSYS, DOTECON, HOGAN & HARTSON (2004): "Study on conditions and options in introducing secondary trading of radio spectrum in Europe". http://rspg.groups.eu.int/doc/documents/meeting/rspg4/rspg04_40_study_secondtrad_summary.pdf

ATAG (2005): "The economic and social benefits of air transport". http://www.atag.org/files/Soceconomic-121116A.pdf

BAUMOL W. & OATES W. (1988): *The theory of environmental policy*, Cambridge University Press.

BOARDMAN A., GREENBERG D., VINING A. & WEIMER D. (2006): *Cost-benefit analysis – concepts and practice*, Third Edition, Pearson Prentice Hall.

Cabinet Official Committee on UK Spectrum Strategy (UKSSC) in consultation with Ofcom(2006): "Independent Audit of Spectrum Holdings - Government Response and Action Plan", March. http://www.spectrumaudit.org.uk/220306.htm

CAVE M.:

- (2002): "Review of Radio Spectrum Management", March. http://www.ofcom.org.uk/static/archive/ra/spectrum-review/2002review/1_whole_job.pdf
- (2005): "Independent Audit of Spectrum Holdings", December. http://www.spectrumaudit.org.uk/pdf/caveaudit.pdf
- (2006): "New spectrum-using technologies and the future of spectrum management: a European policy perspective", in Ofcom, "Communications - the next decade", November. http://www.ofcom.org.uk/research/commsdecade/

CRAMTON P., KWEREL E. & WILLIAMS J. (1998): "Efficient Relocation of Incumbents", *Journal of Law and Economics*, 41, pp. 647-675. http://www.cramton.umd.edu/papers1995-1999/98jle-efficient-relocation.pdf

DIAMOND P. & MIRRLEES J. (1971): "Optimal taxation and public production 1: Production efficiency and 2: tax rules", *American Economic Review*, Volume 61.

DIXIT A. & PINDYCK R. (1994): *Investment under uncertainty*, Princeton.

FAULHABER G. (2006): "The future of wireless telecommunications: spectrum as a critical resource", *Information economics and policy*, Volume 18.

HAHN R. & SINGER H. (2007): "The political spectrum", AEI-Brookings Joint Centre Policy Matters June 07-19. http://www.aei-brookings.org/policy/page.php?id=292

HARMANTZIS F., TRIGEORGIS L. & TANGUTURI V. (2006): "Flexible investment decisions in the telecommunications industry; case applications using real options", September NET Institute Working Paper 06-06. http://www.netinst.org/Harmantzis-Trigeorgis.pdf

HAZLETT T., IBARGUEN G. & LEIGHTON W. (2007): "Property rights in radio spectrum in Guatemala and El Salvador: An experiment in liberalisation", Forthcoming in the *Review of Law and Economics* (Berkley). http://papers.ssrn.com/sol3/papers.cfm?abstract_id=889409

HELFAND G. (1999): "Controlling inputs to control pollution: when will it work?" *Association of Environmental and Resource Economists Newsletter*, November, Volume 19(2), p. 17. http://www.aere.org/newsletter/Newsletter_Nov99.pdf

HOLTERMANN S. (1976): "Alternative tax systems to correct for externalities, and the efficiency of paying compensation", *Economica*, February, Volume 43169.

INDEPEN & AEGIS (2005): "Study into the potential application of Administered Incentive Pricing to spectrum used for Terrestrial TV & Radio Broadcasting", October. http://www.ofcom.org.uk/consult/condocs/futurepricing/aipstudy.pdf

INDEPEN, AEGIS & OVUM (2007): "The economic value of licence exempt spectrum", January
http://www.ofcom.org.uk/research/technology/overview/ese/econassess/value.pdf

INDEPEN & AEGIS (2007): "Aeronautical and maritime spectrum pricing", April.
http://www.ofcom.org.uk/research/radiocomms/reports/spectrumaip/

INDUSTRY CANADA (2005): "Consultation on a Renewed Spectrum Policy Framework for Canada and Continued Advancements in Spectrum Management", May. www.spectrumreview.radio.gov.uk/newsite/report.htm

KWEREL E. & WILLIAMS J. (2002): "A Proposal for a Rapid Transition to Market Allocation of Spectrum", November, OPP Working Paper no. 38, FCC.
http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228552A1.pdf

MINISTRY OF ECONOMIC DEVELOPMENT (2006): "Renewal of cellular rights". http://www.med.govt.nz/templates/ContentTopicSummary____19223.aspx

MCMORROW D. & VEUGELERS R. (2005): "The Lisbon Strategy and the EU's structural productivity problem", DG Ecofin, February.
http://ec.europa.eu/economy_finance/publications/economic_papers/economicpapers221_en.htm

OFCOM:

- (2004): "A Statement on Spectrum Trading – implementation in 2004 and beyond". http://www.ofcom.org.uk/consult/condocs/spec_trad/statement/
- (2006): "Digital Dividend Review, A consultation", December.
http://www.ofcom.org.uk/consult/condocs/ddr/
- (2007a): WRC-07 agenda item 1.4., February.
http://www.ofcom.org.uk/consult/condocs/wrc07/statement/
- (2007b): "Spectrum Framework Review: The Public Sector", July.
http://www.ofcom.org.uk/consult/condocs/sfrps/

OVUM, INDEPEN & AEGIS (2006): "Spectrum Policy Review", CITB, Hong Kong. http://www.citb.gov.hk/ctb/eng/paper/pdf/SPR-Final_report.pdf

Qinetiq, University College London, University of Bath, & Rutherford Appleton Laboratory (2004): "Project AY4490 – A study into techniques for improving radar spectrum utilisation", April.
http://www.ofcom.org.uk/research/technology/spectrum_efficiency_scheme/ses2003-04/ay4490/

QUOTIENT & INDEPEN (2007): "Higher frequencies for licence exempt applications", May.
http://www.ofcom.org.uk/research/technology/overview/ese/higher/

TITMAN S. (1985): "Urban land prices under uncertainty", *American Economic Review*, 75(3).

TRIGEORGIS L. (1996): *Real options – managerial flexibility and strategy in resource allocation*, The MIT Press.

WIK (2005): "Towards more flexible spectrum regulation", Study for the Federal Network Agency, Germany.
http://www.bundesnetzagentur.de/media/archive/4745.pdf

WILLIAMSON B. (2007): "ICT, connectivity and productivity", in *The economic benefits of providing businesses with competitive electronic communications services*, BT, June.
http://www.btplc.com/Thegroup/Regulatoryinformation/Consultativeresponses/BTdiscussionpapers/Electronic/index.htm