

Managing the Radio Spectrum: Framework for Reform in Developing Countries

Björn Wellenius

Isabel Neto

The World Bank
Global Information and Communication Technologies Department
Policy Division
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Abstract

Bringing management of the radio spectrum closer to markets is long overdue. The radio spectrum is a major component of the infrastructure that underpins the information society. Spectrum management, however, has not kept up with major changes in technology, business practice, and economic policy that have taken place worldwide during the last two decades. For many years traditional government administration of the spectrum worked reasonably well, but more recently it has led to growing technical and economic inefficiencies as well as obstacles to technological innovation. Two alternative approaches to spectrum management are being tried in several countries, one driven by the market (tradable spectrum rights) and another driven by technology innovation (spectrum commons). This paper discusses the basic features, advantages and limitations, scope of

application, and requirements for implementation of these three approaches. The paper then discusses how these approaches can be made to work under conditions that typically prevail in developing countries, including weak rule of law, limited markets, and constrained fiscal space. Although spectrum reform strategies for individual countries must be developed case by case, several broadly applicable strategic options are outlined. The paper proposes a phased approach to addressing spectrum reform in a country. It ends by discussing aspects of institutional design, managing the transition, and addressing high-level changes such as the transition to digital television, the path to third-generation mobile services, launching of wireless fixed broadband services, and releasing military spectrum. The paper is extensively annotated and referenced.

This paper—a product of the Policy Division, Global Information and Communication Technologies Department—is part of a larger effort in the department to promote access to information and communication technologies in developing countries. Policy Research Working Papers are also posted on the Web at <http://econ.worldbank.org>. The authors may be contacted at ineto@worldbank.org and welkenius@attglobal.net.

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1 Introduction

Moving management of the radio spectrum closer to markets is long overdue. The radio spectrum is a key component of the telecommunications infrastructure that underpins the information society. Spectrum management, however, has not kept up with major changes in technology, business practice, and economic policy during the last two decades. Traditional spectrum management practice is predicated on the spectrum being a limited resource that must be apportioned among uses and users by government administration. For many years this model worked well, but more recently the spectrum has come under pressure from rapid demand growth for wireless services and changing patterns of spectrum use. This has led to growing technical and economic inefficiencies, as well as obstacles to technological innovation. Two alternative approaches are being tried, one driven by the market (tradable spectrum rights) and another driven by technology innovation (spectrum commons). Wholesale replacement of current practice is unlikely, but the balance between administration, tradable rights, and commons is clearly shifting. Although the debate on spectrum management reform is mainly taking place in high-income countries, it is deeply relevant to developing countries as well (Wellenius and Neto 2005). Indeed, to the extent that developing countries have less investment in wireless infrastructure than do many developed countries, adoption of more efficient spectrum management regimes may be easier and have larger payoffs (in relative terms) than in developed countries.

Developing countries comprise, by definition, all countries with low or middle average per capita incomes. These are about 150 countries in all continents, accounting for 85 percent of the world's population and about one-half of its GDP at purchasing power parity or 30 percent at current exchange rates (The Economist 2006). Despite the common label, this is a very heterogeneous group. *Per capita* annual incomes range from about \$100 in Ethiopia to nearly \$10,000 in Argentina, and sizes go from 1.3 billion in China to a few thousand in some Pacific islands. There is also major variation within individual countries. Modern economic sectors (including telecommunications in some countries) may perform to world standards yet coexist with a subsistence agricultural economy. Prosperous groups live next to large segments of the population in abject poverty.

Communication and information services in the developing world have experienced explosive growth. Between 1980 and 2005 the number of phones (fixed and mobile) multiplied 30-fold (while population grew by one-half and real GDP more than doubled) and their share in the world's stock of phones more than tripled to about 60 percent. This largely resulted from economic and sectoral reforms, starting in the late 1980s and gradually extending to most developing countries, which led to private-led, increasingly competitive telecommunications markets. Yet about one-half of all developing countries still have closed or only modestly open

markets. Moreover, significant differences remain among and within developing countries. Fast growth in large emerging markets, notably China, India, and Brazil, masks slower development in other economies. Progress has been made reaching out to rural areas and the urban poor, but in many countries these groups still lag in relative terms. More advanced communication and information services have become available through the Internet, but are only reaching the better-off population groups (Wellenius 2006).

In most developing countries, the radio frequency spectrum is managed along the lines of traditional government administration. Some spectrum authorities have become very competent, and a few now play lead roles developing regulatory capacity in their regions. But in most countries spectrum management performs rather poorly. One or more of the following deficiencies are commonly found:

- Many countries fail to make detailed country-specific allocations in their national frequency plans, creating uncertainty for users and investors.
- Spectrum needed to provide new services (e.g., mobile, fixed wireless) is typically made available initially to only one operator, and gradually to a few more, resulting in artificial scarcity and high spectrum prices.¹
- Spectrum occupied in the cities is often under-utilized in rural areas.
- Spectrum allocation and use may be different across countries, and cross-border interference may arise.
- Large spectrum parcels are in the hands of public sector entities, including the military,² and used only sparsely.
- Day-to-day administration is constrained by incomplete records of existing authorizations, limited capability to monitor and enforce compliance,³ slow processing of new applications, and shortage of skilled staff and data processing facilities.
- Unpredictability of the spectrum regime adds to regulatory risk and discourages investment.⁴
- Unclear rules and lack of transparency create opportunity for political interference and corruption.
- While the primary objective of government administration should be to protect spectrum users from harmful interference by one another, in practice spectrum management is often viewed as a source of revenue for the government.

¹These policies seek to protect incumbents from competition and raise windfall revenues for the treasury. Artificial scarcity and high cost of spectrum, however, discourages investment and propagates throughout the economy. The result is slow growth and innovation as well as high prices of intermediate and final information and communication services.

²This is especially the case in central and eastern Europe, a legacy of the former Soviet Union.

³The ITU has recommended formulas for monitoring spectrum efficiencies of assigned spectrum (recommendations SM 1046-1). But geographical, traffic, and network differences make it difficult to measure spectrum efficiencies even across the same city or region.

⁴For example, a key feature of telecommunications reform in Ghana in 1996 was the issuing of a license for a second national operator that would compete head-on in all market segments with the incumbent that was being privatized. Ten years later, however, the second operator had barely one percent of the market. Inability of the spectrum authorities to make the 900 MHz band available to the new entrant as had been promised was reportedly one of the main reasons for this failure.

Efforts to improve spectrum management have mainly focused on day-to-day administration. For example, large investments are made in monitoring facilities that often go beyond critical needs and exceed the authorities' human resources and enforcement capabilities. In the absence of spectrum policy changes and constrained by institutional capacities, these efforts tend to have limited impact. But a growing number of developing countries are trying to do more. Auctions are now routinely used in many countries to assign spectrum when demand exceeds supply.⁵ Spectrum refarming is making space for broadband wireless services using third-generation mobile technology. Some spectrum is being released or reallocated for unlicensed use.⁶

Limited improvements of an essentially outdated model are unlikely to suffice. Further change in the spectrum management regime will largely be driven by current domestic issues, new technologies with potential to accelerate progress toward priority development objectives, and awareness of growing experience in other countries. Current high-visibility issues include moving toward third-generation mobile services, facilitating the deployment of broadband wireless technologies, planning the transition to digital television broadcasting, and recovering military spectrum for commercial use. But the scope of spectrum reform is broader, and solutions need to be designed that transcend particular applications.

What can developing countries do about the opportunities and challenges of spectrum reform? In particular, how would the various approaches to spectrum management fare in poor countries with weak governance, incomplete infrastructure networks, large rural populations with minimal service, fast growth, and persistence of legacy equipment? How can countries make the transition from often poorly run government administration of the spectrum to a regime increasingly driven by markets and technology? How much effort should be invested in improving government administration of the spectrum? Would it not be better to improve administration rather than introduce new management models? What agencies could deal with harmful interference and resolve disputes? Is there danger that spectrum will be cornered by a few influential players? Who would pay for the cost of spectrum regulation as larger segments are released for unlicensed use? How can treasuries be weaned from the large rents they have grown accustomed to exact from spectrum licensees? How can spectrum policies be integrated with telecommunications and broadcasting reforms and with economic policy generally? Some of these questions can be answered only in a particular country context and go beyond the scope of what can be achieved by a desk exercise.

This paper sets out to build a framework to analyze these questions in individual countries. Chapter 2 examines the main features, advantages, limitations, and scope for improving traditional government administration of the spectrum. Chapters 3 and 4 discuss the potential for introducing tradable spectrum rights and spectrum commons regimes in the context of government administration. Chapter 5 brings all this together by proposing a framework for the design of spectrum reform in a particular developing country: comparison of the three

⁵Auctions are prescribed by law as the standard process to grant new spectrum authorizations in Mexico, Guatemala, Peru, and other countries, when a request for radio authorization is contested by others interested in the same frequencies.

⁶This is allowing initial deployment of new wireless technologies, such as Internet hot spots in cities and novel entrepreneurial initiatives in rural areas.

approaches to spectrum management, how to make these approaches work in developing countries, striking a balance among approaches and over time, institutional considerations, and managing the transition. Chapter 6 offers concluding comments.

2 Improving Traditional Government Administration

Traditional spectrum management is predicated on the spectrum being a limited resource that must be apportioned among uses and users by the government. The primary objective of government administration is to protect spectrum users from harmful interference by one another. Additional objectives are to achieve economic and technical efficiency of spectrum use, safeguard public services, and balance certainty to attract investment with flexibility to take advantage of change.⁷

2.1 Basic Features

Government administration of the radio spectrum comprises a tiered structure of regulation at the international and national levels. The international framework is set out primarily in a treaty developed, signed, and ratified by the member states of the International Telecommunication Union (ITU), a specialized United Nations agency. World and regional radio conferences convened by the ITU every three or four years establish regulations, agreements, and plans for the global use of the radio spectrum. This includes an international table of frequencies that allocates the spectrum among classes of radio services.⁸ A wide range of regulatory, operational, and technical provisions ensure that radio services are compatible with one another and free from interference among countries. Individual countries also undertake additional commitments in the context of regional and sub-regional telecommunications organizations,⁹ other international organizations,¹⁰ and bilateral or multilateral agreements.

Individual countries manage the national use of the spectrum reflecting these broad international commitments and extending them to the retail level in more detail.¹¹ Each country estab-

⁷There are several ways to evaluate spectrum efficiency. Economic efficiency involves ensuring that the spectrum is allocated and assigned to uses and users that derive the highest economic value. Technical efficiency means achieving the most intensive use possible of the available spectrum within acceptable interference limits. It also seeks to promote the development and use of spectrum-saving technologies (Lie 2004).

⁸About 40 different types of fixed, mobile, and satellite services are currently defined. Many bands are shared among primary and secondary classes of users, the former having priority in case of conflicting uses resulting in harmful interference. Some 30 notes add detail by regions.

⁹Such as the Comisión Inter-Americana de Telecomunicaciones (CITEL) and the European Conference of Posts and Telecommunications Administrations (CEPT).

¹⁰Such as the World Trade Organization, International Maritime Organization, International Civil Aviation Organization, and the World Meteorological Organization.

¹¹The national plans are usually far more detailed than the ITU's because there will be different types of service under each major radio service heading. For example, there are many mobile services, both private and public, ranging from car security locking devices, to shared trunked radio systems used by transportation companies, to public service cellular mobile systems.

lishes a national table of frequency allocations that sets out what radio services can use which frequency bands and under what conditions, and coordinates these allocations with neighboring countries.¹² Rules are set for each band, specifying eligibility and service restrictions, power limits, build-out requirements, fees, and other conditions of use. Frequencies are assigned to individual users on exclusive or shared basis for particular services and technologies, and authorizations are issued for radio equipment and operators. Compliance of spectrum users with allocations, rules, and authorizations is monitored and enforced.

2.2 Advantages and Limitations

A major advantage of government administration of the radio spectrum is that it is well established. It has been in place worldwide for over 100 years, originating in the early days of radio communication.¹³ A wealth of experience has built up, mainly in high-income countries but more recently also in middle-income and low-income countries. Good practices are well documented. For example, an online spectrum management toolkit developed by infoDev, a multi-donor grant facility administered by the World Bank, in cooperation with the ITU, contains an annotated selection of over 200 reference documents mainly reflecting modern government administration of the radio spectrum. Specialized software, equipment, and technical assistance are readily available.

Government administration, where well implemented, has proven to be effective in coordinating use of the spectrum to prevent harmful interference, at both national and international levels (Analysys et al. 2004). Authorizations to use the spectrum typically specify what transmission equipment may be used, its location, bandwidth, modulation type, and maximum power radiated.¹⁴ By setting conditions for all users this way, the levels of interference can be modeled through engineering analysis and maintained at acceptable levels within the geographical and frequency boundaries of each authorization.

Government administration has also been used successfully to manage spectrum used by the government for purposes such as defense, public safety, and aeronautical and maritime communications.¹⁵ And it did well managing spectrum used for public telecommunications services while these were provided by a small number of companies and both services and technology changed fairly slowly.¹⁶

In the last ten years, however, government administration has had increasing difficulty responding to fast growth of spectrum demand, new technologies, and changing markets. Convergence among telecommunications, media, and computing is breaking down the traditional

¹²Coordination with neighboring countries mainly seeks to prevent cross-border interference in compliance with international commitments, as well as facilitate services that span several countries such as mobile roaming.

¹³All countries have some form of government administration of the spectrum at the national level set in the context of ITU and other international commitments.

¹⁴Emissions of a radio transmitter are authorized at specific frequencies and bandwidths. Limits are set for out-of-band and spurious emissions.

¹⁵In developing countries, spectrum management is often also seen as a way to ensure national sovereignty.

¹⁶In such situations, the spectrum authority could reasonably have as good an understanding of the best use of spectrum as the market itself and hence could sensibly control all aspects of spectrum use (Ofcom 2005b).

association of spectrum to specific applications, such as the distinction between broadcasting and telecommunications spectrum, and is changing the demand for spectrum among services, such as between fixed and mobile voice communication. This results in major technical and economic inefficiencies, excessive regulatory burden on all parties, and obstacles to technological innovation (Wellenius and Neto 2005). Beyond deficient implementation, the growing inadequacy of spectrum management can be traced ultimately to three limitations that are inherent to the administration regime itself:

- The mandate of government administration of the radio spectrum is by now too broad. When the government was the main spectrum user, and public services were operated mostly by state enterprises, it made sense that it was also the government who managed the spectrum. But by now responsibility for the provision of telecommunications, broadcasting, and information services lies primarily in the hands of private companies operating in increasingly competitive markets. Yet the spectrum authority still makes decisions that constrain or pre-empt business choices. The authority constantly second-guesses markets and technology trends which it cannot possibly know as well as the immediate users, and incurs risks on behalf of the users that accrue the costs and benefits. And by controlling access to the spectrum, the authority plays a major role in determining the structure and level of competition of downstream markets.¹⁷ The result is growing economic inefficiency of spectrum allocation and assignment.
- Slow response to changing circumstances undermines efficiency and discourages entrepreneurship and innovation. Spectrum allocations and assignments are tied to the life cycle of individual authorizations.¹⁸ Neither the users nor the authorities are free to move spectrum quickly to higher-value uses to offset initial allocation or assignment inefficiencies or changing circumstances. Changes of existing spectrum authorizations are exceptional and tend to be slow and costly. New authorizations are subject to elaborate technical and economic analyses by the authority and require disclosure of proprietary business information by prospective users. Rules designed to protect users from interference now restrict new entry, limit competition, and delay the introduction of new technologies with improved interference management capabilities.
- Spectrum administration imposes large costs on both the authorities and the users. The technical, economic, legal, and administrative complexity of the functions of the spectrum authority is compounded by several factors: fast growth of the number of spectrum users, increasing need to revisit past decisions that have become outdated in the wake of market and technology changes, and added complexity brought about by attempts to adapt the spectrum regime to cope with situations it was not designed to handle. In addition, the unrealized benefits and opportunity costs of not authorizing new services quickly cannot be ignored.

¹⁷For example, the authorities determine the number of radio licenses that are made available for mobile services, mainly in terms of their assessment of how many competitors the market may sustain. This decision is sometimes distorted by pressures from incumbents to slow the pace of competition, or by the treasuries seeking windfall revenues by restricting the number of licenses to command higher sales prices.

¹⁸Radio licenses typically have a duration of 5–20 years and may be renewable.

2.3 Improving Traditional Practice

Traditional government administration practice can be improved at the margin to mitigate some of its shortfalls. This includes releasing spectrum held back by the authorities, allowing greater flexibility of spectrum use, separating spectrum and operating authorizations, reallocating spectrum to improve current use, using auctions to assign scarce spectrum, introducing other market tools, and bringing market disciplines to public sector spectrum use. Moreover, in many countries traditional spectrum administration is poorly implemented and there is ample opportunity to make it work better.

Release spectrum held back by the authorities. In most countries, substantial spectrum remains reserved for indeterminate later use. An alternative is to make all spectrum available immediately, without restrictions on use or technology beyond those strictly necessary to comply with international commitments. This may go a long way toward alleviating spectrum shortages to expand current services, introduce new services, and enhance sustainable competition in downstream services.¹⁹ Reallocating spectrum to new uses in the future, when the need arises, is possible under government administration (see below) but facilitated if by then a spectrum rights market is in place (see next chapter).

Allow greater flexibility of spectrum use. Most authorizations to use the radio spectrum are tied to specific services and technologies. This discourages innovation and stifles investment in more spectrally efficient systems. Some operators have pointed out that the real issue with access to spectrum by current users is not scarcity but rigidity. Removing restrictions on the technologies that may be used in the assigned frequencies would go a long way toward developing new services.²⁰ Others have argued for allowing operators to use their spectrum to provide a wider range of services than originally envisaged. World and regional frequency allocation tables allow individual countries considerable liberty to decide how each band will be used.

Separate spectrum and services authorizations. In many cases the spectrum authorizations are packaged together with authorizations to provide specific services. Restrictions on the services thus translate into rigidities in the use of the spectrum assigned to them. Decoupling both authorizations enables the spectrum authority to remove technological and service limitations on the use of assigned frequencies. Decoupling will also reduce demand for spectrum, since not all operators (e.g., cable, Internet service providers) want spectrum.

Reallocate spectrum in current use. Existing allocations of the radio spectrum at the national level need to be changed from time to time. This may be necessary to realign the national table

¹⁹The example of Guatemala illustrates how putting new spectrum on the market can increase competition and reduce prices in mobile services even in a small lower-middle income country. This was achieved by combining the release of spectrum with setting up a regime of tradable spectrum rights. But practical problems have included spectrum hoarding and retrieving spectrum to reallocate for license-exempt use. The literature on the Guatemala case does not examine these issues.

²⁰For example, a major provider of mobile services is prepared to invest in third generation systems using its large spectrum holdings in the 900 MHz band, but these are authorized for older GSM operation only. The alternative proposed by the authorities, namely to deploy 3G in the newly available 2.1 GHz band, would require higher capital expenditure and undermine the corporate strategy based on full use of its current business assets, of which spectrum is a major component.

of frequencies with changes in the international table, use underutilized frequencies to relieve congestion in adjacent bands, allow flexible or shared use of bands currently assigned to individual users, make spectrum available for new services or more spectrum-efficient new technologies, or other reasons (Cramton et al. 1998). The costs incurred by current users required to move to other frequencies may be absorbed by the users themselves, paid wholly or partly by the new users of the spectrum being vacated, or other ways.

Use auctions to assign scarce spectrum. If not already in place, auctions should be adopted as the standard procedure to assign frequencies for which demand exceeds supply. This is by now established practice under government administration in many countries. Auctions can direct the spectrum to high-value use, increase process transparency, and reduce opportunity for corruption. When well designed and executed, spectrum auctions can succeed even in the most challenging of circumstances.²¹ Auctions generally must be tailored to specific circumstances, as there are important tradeoffs among design features.²² Some approaches (e.g., auctions that also consider the promised service price in comparing bids, as has been done in Morocco, or bidding service coverage instead of license price, as in Chile) could be particularly appropriate for developing countries. A successful auction requires a clear understanding by participants of the rights and obligations of the winner, as well as precise rules on how the auction will be conducted and awarded. Auctions are also the preferred way to initially place new or recovered spectrum in the market under a spectrum rights regime.

Introduce other market tools. Other opportunities can be found to introduce market mechanisms in the context of spectrum administration. In Brazil, for example, several occupants of the 1.9 GHz band were given five years' notice to vacate their frequencies so other current users could move in, thereby freeing spectrum for IMT-2000 third-generation mobile services.²³ The process was accelerated by encouraging the parties to negotiate compensation for early departure of current occupants.

Bring market discipline to public sector spectrum use. Under government administration, large parts of the spectrum have been set aside for use by the public sector (e.g., government departments, state-owned enterprises, military). There is no economic reason why the public sector should not treat the radio spectrum as any other factor of production, including paying for its use at market-related prices.²⁴ Subjecting public spectrum use to market discipline can result in widespread efficiency gains within and beyond the public sector. This can start by putting together an inventory of public sector spectrum holdings, estimating their value, and incorpo-

²¹The example of Nigeria's GSM license auction of 2001 illustrates this and emphasizes the value of auctions to achieve transparency of award. See Lee 2003.

²²Multiple radio licenses may be auctioned simultaneously or in sequence, bids may be visible to all participants or made through sealed tender, and there may be minimum or reserve prices.

²³International Mobile Telecommunications 2000 (IMT-2000) is the global standard for third generation wireless communications defined by ITU recommendations. By linking diverse terrestrial and satellite networks, IMT-2000 will exploit the potential synergy between digital mobile telecommunications technologies and systems for fixed and mobile wireless access systems. See <http://www.itu.int/home/imt.html>.

²⁴As it does for, say, equipment (including radio), utilities, fuel, and labor. Nor why the rights and obligations attached to public sector spectrum holdings should not be spelled out and enforced like those of private sector users.

Box 2.1 Bringing Market Discipline to Public Sector Use of the Radio Spectrum

- Inventory of public sector spectrum holdings
- Valuation of holdings
- Incorporation of spectrum valuation in public sector expenditure and investment decisions
- Application of administrative incentive prices based on opportunity cost
- Development of opportunities and incentives to lease or share spectrum with private sector
- Full participation of public sector bodies in spectrum market

Source: Cave 2006

rating spectrum value in budget and investment decisions.²⁵ One step up, administrative incentive prices can be applied to spectrum use to promote more efficient use. Eventually public sector bodies could participate fully in spectrum markets, once these are established (Box 2.1).

Administrative incentive pricing has been introduced recently by some authorities to promote more efficient use of the spectrum within the framework of traditional government administration. Pricing the use of spectrum at levels that somehow reflect the economic value of specific frequencies can induce users to adopt spectrum-saving new technologies and return unused spectrum. It can also signal the cost of reserving large parts of the spectrum for government use, including the military, or for uncertain future commercial applications at the expense of meeting immediate spectrum demand. Administrative incentive prices can be set in terms of the opportunity cost of the specific frequencies or by reference to prices observed in market transactions in the same or related frequencies (Ofcom 2005a).²⁶

2.4 Scope of Application

Despite these partial improvements, the trend is toward introducing market-oriented alternative solutions (Wellenius and Neto 2005). Wholesale replacement of government administration is, however, unlikely in the foreseeable future. Governments will continue playing important roles managing parts of the spectrum and discharging government responsibilities:

- Manage spectrum use as necessary to accomplish compelling public interest objectives. For example, public safety and critical infrastructure may require dedicated spectrum at particular times to ensure priority access for emergency communications. Radio

²⁵In the absence of a market mechanism, taking the opportunity cost of spectrum into account in investment decisions is consistent with calculating economic (as distinct from private) returns of public sector projects. This includes pricing resources so as to reflect real scarcities for the economy as a whole rather than the prices actually paid for them. See, for example, Belli et al. 2001.

²⁶The opportunity cost of a particular frequency can be calculated as the increase in cost which would occur in producing the same service with another input, such as a different frequency or non-radio technologies. In imperfectly competitive markets, observed market prices may include excess profits from exclusivity or market power.

astronomy may need to have protected spectrum bands, due to its highly sensitive applications and the fact that its benefits accrue to society as a whole and only over the long run. Global harmonization of satellite frequency bands is unlikely to be sustainable without government intervention. Broadcasters traditionally are subject to rules that represent their unique history and services. Rural interests have special needs that may be costly to meet, and there is strong support for public policy that will address these needs. Such public service objectives should, however, be carefully defined, and the amount of spectrum subject to government administration should be limited to the minimum amount necessary to ensure that those objectives are achieved. Many spectrum users will claim that they warrant special consideration and exemption from market discipline. It is critical to distinguish between special interest and the public interest (FCC 2002).

- Manage spectrum allocated to government uses. This may include spectrum that is shared between government and other users. Nonetheless, market practices can lead to better administration. For example, wider use of administrative incentive pricing of spectrum use can promote efficiency, spectrum-saving technologies, and returning unused spectrum. The prices at which other parts of the spectrum are traded in secondary markets can provide useful indication of the opportunity cost of the spectrum that remains subject to government administration.
- Maintain the legal and regulatory framework for overall spectrum management. The government must set the boundaries among different approaches to spectrum management, and revise these from time to time. In the absence of effective general competition law, the spectrum authority may have to take responsibility for promoting and enforcing fair competition in spectrum markets as these develop. And it may bear ultimate responsibility for resolving spectrum-related disputes. Although generally commons use comes with no guarantees for interference-free operation, there is still a role for the government in setting the conditions for band use, equipment type acceptance, enforcement and dispute resolution.
- Attend to international relations. This includes keeping abreast, preparing for, and participating in radio conferences and study groups of the ITU and other international and regional organizations. It also includes coordinating and cooperating in areas with cross-border implications, such as the use of satellites and of terrestrial radio communications that takes place close to the country borders. Finally, it includes ongoing activities such as registration of spectrum use, processing of frequency coordination requests, and following technological and regulatory developments elsewhere to assess their potential impact on the country's use of the spectrum.

2.5 Building Blocks

Setting up or improving government administration of the radio spectrum relies primarily on four building blocks: allocation, rules, authorization, and enforcement.

Allocation. Developing a national frequency allocation table lies at the core of planning spectrum use. The national table is established within the framework of the ITU radio regulations and made consistent with international allocations for the region where the country is

located.²⁷ Subsets of international service categories are often added,²⁸ and, conversely, international allocations for several services may be restricted at the national level to a single service.²⁹ Further sub-allocations or designations of use are often made in order to group like technologies or users in the same frequency bands.³⁰ National allocations are revised from time to time, for example, to reflect changes in international allocations, reallocate spectrum to higher-value uses,³¹ or make spectrum available for spectrum-saving new technologies.

Rules. Detailed regulations and procedures provide the primary day-to-day tools of spectrum management. These rules are promulgated by the spectrum authority within the framework set out in legislation.³² The rules constitute the basis for the conduct of radio services, allow spectrum users to understand how their operations are governed, establish how users and the spectrum authority relate to one another, and set out the steps to appeal decisions and amend the rules themselves.³³ Lack of explicit, clear, and stable spectrum rules discourages the development of radio services and places investments at risk of arbitrary decisions of the authority.

Rules on technical standards provide the basis for preventing interference and ensuring equipment performance. They comprise documents that specify the standards, the processes to obtain approvals and permits, and the processes for testing and certifying radio equipment to determine compliance with standards or manufacturers' specifications. Technical standards also allow the authorities and users to limit interference between radio equipment and other equipment, such as industrial machinery and power networks. Technical standards are established mainly for radio equipment and spectrum use. Radiation standards are usually set by the health authorities, but the spectrum manager plays a role in ascertaining compliance. Environment, construction, land use, and other standards may also apply to spectrum management (Box 2.2).

Rules on spectrum pricing, in addition to creating incentives for efficient spectrum use, establish the basis for recovering the cost of spectrum management. Often governments also use spectrum charges as a source of public revenue. Cost recovery pricing aims at meeting the costs incurred in managing the spectrum from fees levied on spectrum users.³⁴ Some of these

²⁷The ITU allocation table often contains more radio services than are relevant in the particular country, and related provisions need not apply.

²⁸For example, paging, two-way radio dispatch service, cellular mobile telephone service, and trunked mobile radio service may be separated out at the national level under the broader international category of mobile services.

²⁹For example, a band allocated to the mobile or land service may nationally be designated only for cellular mobile telephone service, excluding other services.

³⁰Greater technical efficiency of the spectrum can be obtained when uses with similar parameters (e.g., high-power applications such as radar) are grouped in the same frequency bands.

³¹Such as from analog to digital television and radio broadcasting, discussed elsewhere in this paper. Or to meet excess demand in some bands (e.g., mobile) by reallocating underutilized neighboring frequencies (e.g., earlier reserved for services that did not develop as expected).

³²Legislation includes clear allocation of institutional responsibilities for spectrum management.

³³Rules cover matters such as obtaining and renewing radio licenses, technical standards, equipment authorization, and operational requirements.

³⁴The costs of running a spectrum authority mainly include skilled labor, information technology resources, technical monitoring equipment, membership and expenses to participate in ITU and other international organizations, and inputs such as office space, utilities, and supplies. In principle spectrum management costs should be recovered from users in both the private and public sectors.

Box 2.2 Technical Standards for Spectrum Management

- Radio equipment standards establish the minimum acceptable technical specifications and performance characteristics of radio equipment. National spectrum authorities may adopt radio equipment standards developed in other countries or by international standards organizations.
- Spectrum use standards state the minimum technical requirements for efficient use of specified frequency bands. They are utilized in the design, specification, and evaluation of technical applications for new radio facilities or modification to existing radio systems.
- Radiation standards address concerns that radio transmissions may be harmful to health or a concern of public safety.
- Other standards relating to the environment, construction, and land use may apply to spectrum management

Source: infoDev 2006

costs can be attributed directly to individual users, and recovered from them, while other costs (often a large part) are shared among groups of users or are overheads.³⁵ Allocating such shared and common costs can be difficult and largely arbitrary, and arguably they are attributable to a government function rather than to individual spectrum users and should therefore be recovered from general government revenue. Ways to deal with cost allocation vary from the use of detailed costing models to simple rules of thumb.

Authorization. Authorization is the process by which users gain access to the spectrum. This mainly involves assigning frequencies to individual users and approving radio equipment:

- Frequencies are assigned to individual users for exclusive or shared use. When enough spectrum is available to meet demand, assignment is conducted on a first-come, first-served basis. When demand exceeds supply, the trend is to use auctions to assign scarce frequencies among competing users.³⁶
- Radio equipment is tested and certified for compliance with technical standards or manufacturers' specifications. This ensures compatibility with other equipment, consistency with provisions to contain interference, and consumer protection. Testing and certification is performed by the spectrum authorities themselves or, increasingly, by recognized private facilities. Self-certification by manufacturers may also be accepted in well-disciplined markets. Bilateral or regional mutual recognition agreements reduce the need for national testing and certification, facilitate equipment trade among countries, and reduce the cost of equipment supply.

³⁵Directly attributable costs include, for example, the expenses incurred in issuing and maintaining individual radio licenses, testing specific equipment for approval, and enforcing violations.

³⁶The most common modality is to award the frequencies to the bidder offering the highest price, which can be specified in the bidding documents as payable in full up front, through revenue or profit sharing (e.g., royalties), or a combination of both. Alternatively, the frequencies can be awarded by some other quantifiable metric, such as population coverage, roll-out time, or end user charges (for example, of mobile phone service). Not all countries use auctions.

Enforcement. Spectrum users must comply with the terms of authorization and the applicable rules and regulations. Spectrum managers are particularly concerned with interference problems affecting public safety and security services such as emergency services (ambulance, fire, police) and navigational services (air, maritime), as well as commercial bands where spectrum holders have often invested and incurred large sunk costs and expect protection for these investments. The spectrum authority needs a framework and process for responding and dealing with complaints from the public and users and for settling disputes. The powers, duties, and obligations of the spectrum manager and protection of rights for the public under circumstances where inspection of property is necessary must be established by law. Penalties, remedies, and alternative dispute mechanisms help ensure rapid resolution.

2.6 Implementation

Implementing the building blocks of spectrum administration requires support in terms of data, analysis, administration, monitoring, and international affairs. Typically about one-third of all personnel employed in regulating telecommunications and broadcasting is occupied in government administration of the spectrum.³⁷

Detailed knowledge of current use across the entire spectrum is required for effective planning. In addition to the basic data on frequency, users, and location, a national register contains information on the functions performed by the equipment, detailed technical characteristics, and costs of system implementation. A single national frequency register database should be created if one does not already exist.

Spectrum allocation and assignment under traditional administration regimes is based on detailed spectrum engineering analyses undertaken by the spectrum authority. This includes using computer models of radio propagation patterns to ensure compatibility among uses and equipment, examine the likelihood of interference among users, and assess potential health and safety hazards. Comprehensive national records of individual spectrum assignments and use are maintained as needed for these engineering analyses as well as for administrative purposes.

Spectrum use is monitored to obtain technical and operational information on current use as well as to detect illegal or wrongful use of frequencies or equipment. Monitoring is needed for effective spectrum allocation and assignment, to resolve interference problems, and to verify and enforce compliance with regulations and the conditions of authorization. Measurements typically include frequency, power, and emission spectrum of transmitters.³⁸ The trend is to focus monitoring on areas of known problems and congestion rather than continuous

³⁷For example, of the total 1,100 staff employed by Agencia Nacional de Telecomunicacoes (ANATEL, the telecommunications regulatory authority of Brazil), about 600 work in spectrum management, including about 400 staff occupied in spectrum monitoring at headquarters and each of the 23 states. One-hundred and twenty staff of a total of 300 employed by the Office of the Telecommunications Authority of Hong Kong works on spectrum planning, frequency allocation, assignment, and licensing. The radio authority of Ukraine employs about 200 people.

³⁸Equipment mainly comprises radio receivers, spectrum analyzers, direction finders, and antennas.

monitoring of all spectrum. Priority is given to monitoring frequency bands that affect essential services and where commercial activity is concentrated.³⁹ Monitoring facilities include fixed, remote, unmanned, and mobile equipment.

3 Establishing Tradable Spectrum Rights

Like traditional government administration, the tradable spectrum rights approach to management of the radio spectrum (a) is based on the premise that the spectrum is an inherently scarce resource that must be apportioned among competing uses and users and (b) focuses on protecting users from harmful interference. But responsibility for apportioning spectrum among uses and users is primarily delegated to the market rather than kept in the hands of the spectrum authority.

3.1 Basic Features

At the core of this approach lies a set of exclusive and transferable rights to use specified parts of the spectrum in given geographical areas at given times, governed primarily by technical rules to protect against harmful interference and by trade rules to protect against anti-competitive behavior. These rights are initially assigned to individual owners by the spectrum authority. Other prospective users of these frequencies must obtain the owners' approval and agree on terms and conditions. Owners may reconfigure (aggregate, divide) and trade their spectrum rights without limitation as to uses and technologies other than as needed to comply with technical and trade rules. The tradable spectrum rights approach thus comprises two distinct processes: changing ownership of spectrum rights originally assigned by the authorities (spectrum trading), and changing the uses and technologies to which these rights were allocated (spectrum liberalization).

Experience with applying the spectrum rights approach is limited but growing quickly. Many countries have, for a long time, permitted indirect trading of spectrum rights without changes in use through transfer of corporate ownership, usually subject to approval by the spectrum authority.⁴⁰ Particular forms of direct spectrum trading, with various degrees of liberalization, have been in place for several years in Australia, Guatemala, New Zealand, and the US (see Box 3.1). While all these applications of the tradable spectrum rights approach have improved spectrum management considerably, and yield important lessons, arguably none of them realize the potential of full-fledged spectrum markets. Following extensive consultations, regulatory measures were adopted in the UK that introduced a

³⁹Priority public services include air and maritime navigation, fire, safety, ambulance, and police. Much of the commercial activity prone to interference is in the VHF and UHF bands.

⁴⁰The sale by Bell South of its Latin American mobile operations to Telefónica in 2004 resulted in most of the spectrum rights being transferred. European buyers of 3G licenses in the early 2000s created wholly-owned subsidiaries as holding vehicles for the usage rights, and these companies can then be bought and sold.

Box 3.1 Experiences in Spectrum Trading

Australia: Trading of spectrum and equipment licenses with partial liberalization of use was introduced in the late 1990s. This enabled, for example, rolling out a broadband two-way wireless service in the 28–31 KHz band, aggregating private mobile radio licenses to form a national network, buying spectrum in the 2.4 GHz band from a pay TV broadcasting company and using it to provide high-speed Internet service, and providing additional spectrum on a short-term basis for coverage of the Sydney Olympics (ITU 2004a).

Guatemala: Telecommunications sector reforms in 1996 maintained state ownership of the spectrum but privatized the right to use it. Some 5,000 titles granting rights of use for 15 years were auctioned, thereafter freely traded, and are renewable. Over one-fourth of all titles have been exchanged, mainly in the FM radio broadcasting bands. Titles are also leased or used as collateral for loans (Ibarguen 2003).

New Zealand: Two types of tradable spectrum rights were introduced in 1989. Management rights grant exclusive right to the management of a nationwide band of frequencies for up to 20 years and issue (typically local) sub-licenses. Tradable license rights afford the holders the right to use spectrum within the band specified within a defined area. The range of uses to which spectrum can be put is unlimited, other than by interference constraints. Telstra, an original holder of GSM spectrum, sold its license to Bellsouth (now Vodafone) in a private deal. Similarly, the original purchasers of New Zealand's 28 GHz LMDS spectrum sold on their rights. Many smaller trades have involved license rights in the AM and FM radio broadcasting bands (van Caspel 2002).

USA: Measures introduced since passage of the new telecommunications act in 1996 seek to encourage spectrum trade in several bands, providing for reconfiguration as well as leasing. Around 1,000 assignments to use spectrum are traded annually, many through private organizations (band managers) authorized to grant usage rights and define interference limits. Trade with change in use was pioneered in 1991 when the Federal Communications Commission indirectly enabled Nextel to launch a national mobile network by aggregating local specialized mobile radio licenses, but authorization to change use resulted only after years of litigation [(Ref)].

Source: Authors' compilation

broader form of spectrum trading and liberalization from 2005 (Ofcom 2005b). The European Commission has concluded consultations on spectrum trading and is taking steps toward implementation (EU 2005).

Trading of spectrum rights can take several forms. In a *sale*, ownership of the spectrum right is permanently transferred to another party. *Buy-back* involves the sale of a spectrum right to another party with an agreement to buy it back at a given date. *Leasing* transfers the right to exploit spectrum to another party for a defined period, but ownership and some control of the spectrum right remains with the original owner. *Mortgage* uses the spectrum right as collateral for a loan, and the right is transferred only in case of default. *Options* establish a right to buy, or an obligation to sell, spectrum rights under specified conditions (e.g., a fixed price) by

a fixed date. *Futures* are contracts to buy or sell spectrum at a later date under given terms and conditions.

It is believed that once the basic framework for spectrum rights is in place, the development of specific trading mechanisms can be left largely to the market. *Bilateral negotiation* among individual buyers and sellers approaching each other can be an effective mechanism in many cases. Where there are a substantial number of sellers or buyers for one transaction, *auctions* are likely to be more effective and can be structured in various ways. *Brokers* can offer a central point through which numerous small buyers and sellers can find one another at low cost.⁴¹ In large enough markets, price information generated by spectrum sold in an *exchange* could facilitate trading through enhanced transparency, encouraging buyers and sellers to come to the market. Several spectrum trading mechanisms can be used and may coexist.

3.2 Advantages and Limitations

Introducing a tradable spectrum rights regime for managing the radio spectrum in the context of government administration can result in substantial gains in economic efficiency. The gains are greatest when spectrum rights are clearly defined, there are a sufficiently large number of buyers and sellers to create the competition and choice necessary for an efficient market, and spectrum trading and liberalization of spectrum use are both possible. This ensures that spectrum users face the opportunity cost of using spectrum throughout the lives of their rights of use. Current and prospective users, as well as equipment suppliers, can monitor opportunities for better spectrum use. When alternatives arise that would lead to higher returns, there is the possibility and incentive to change use, acquire, or dispose of spectrum.⁴² Trading and liberalization provides a decentralized market mechanism to revise and update initial spectrum allocations and assignments.⁴³ This mechanism can respond faster than government administration to changes in technology and demand. The impact of spectrum trade and liberalization will be greatest when initial allocations and assignments were inefficient, or when technology and demand have subsequently changed substantially.⁴⁴ In turn, efficiency gains in spectrum use will lead to increased competition in downstream markets.⁴⁵ Transparent spectrum costs also will help policy makers assess the opportunity cost of spectrum reserved for public services.

The spectrum rights approach, however, is not equally well suited to manage all parts of the spectrum nor in all country conditions. The main limitations that may arise relate to insuffi-

⁴¹For example, law firms in New Zealand have acted as brokers for spectrum trades.

⁴²For example, an incumbent user could invest in new technologies that use spectrum more efficiently thus freeing up some of spectrum (e.g., guard bands) for other uses or for sale.

⁴³Spectrum trading may allow a licensee to tailor its spectrum holdings precisely to its requirements, for example, by selling or leasing a sub-block of spectrum or its use in a particular geographical area where it is not needed.

⁴⁴Auctions to assign spectrum for new services, such as mobile, arguably place the new spectrum in hands of whoever can do the best with it. But whether the outcome is optimal in the long run depends, among other factors, on the ability to predict the future accurately. The same applies for the amount of spectrum initially allocated for mobile service. Scarce allocations for mobile are close to underutilized allocations for certain fixed services.

⁴⁵Cost reductions by existing or new operators can be passed on to consumers. Easier access to spectrum through markets rather than regulatory decisions can lower barriers to entry and expansion.

cient liquidity, lack of individual spectrum rights, high transaction costs and inefficiencies, international constraints, market failures, and conflict with public policy.

Insufficient liquidity. Relatively few buyers, sellers, or available frequencies. Markets require choice among competing price offers and substitutable goods, in this case frequencies and authorized transmission zones. When this condition is not met, increasing spectrum demand and supply should be a policy objective.

Lack of individual rights. Spectrum trading and liberalization can be applied only if individual spectrum users have specific spectrum rights. The industrial, scientific, and medical (ISM) radio bands were originally reserved internationally for non-commercial purposes in these fields. In recent years they have also been used for license-exempt communications applications with built-in tolerance for error, such as wireless local area networks. Short-range low-power devices, such as cordless phones, wireless microphones, medical implants, and remote controls, also generally do not require individual user licenses.⁴⁶ Amateur radio operators require operator licenses awarded on the basis of skill and knowledge tests but are not assigned individual frequencies.⁴⁷ In all these cases users have no spectrum rights that might be traded.⁴⁸

High transaction costs and inefficiencies. Efficient trades materialize only if transaction costs (incurred by buyers and sellers to find each other and agree on a trade) are low relative to the value of the trade.⁴⁹ Measures to reduce transaction costs can be taken by the spectrum authority⁵⁰ or may develop in the market.⁵¹ In some cases, however, it may not be possible to reduce transaction costs, and the spectrum rights approach would not work well. For example, where there are many small spectrum users it may be impractical to bring them all together in a trade, or the effort may be frustrated by some users attempting to get a free ride.⁵² Spectrum hold-up,

⁴⁶Although users are not licensed, the equipment sold for these purposes is typically subject to type approval that ensures compliance with technical standards designed to contain interference.

⁴⁷Citizens' band (CB) is another use of the spectrum for which users have no individual spectrum rights.

⁴⁸This could be remedied by assigning rights just like initial property would be assigned, but this is not necessarily desirable.

⁴⁹Reflecting high transaction costs, buyers will reduce their willingness to pay and sellers will not be exposed to the full opportunity cost of their spectrum. Likewise, sellers will increase their minimum price to reflect transaction costs, and buyers will find the cost of spectrum higher than warranted by its real scarcity in the economy.

⁵⁰Transaction costs may be affected by the way spectrum rights of exiting users are defined. For example, trading would be discouraged if rights required prior regulatory approval in a way that places onerous or non-transparent criteria on whether unacceptable interference may result (Ercolo 2004). At a different level, the spectrum authority can facilitate spectrum trading by maintaining and publishing up-to-date records of current spectrum holdings.

⁵¹For example, spectrum brokers help bring together buyers and sellers for which the cost of individually identifying trade opportunities might be excessive.

⁵²This would be the case if one wanted to use the market to determine whether a particular band should be assigned to a single user or allocated for unlicensed use as a commons. The commons users typically would be numerous and anonymous, and although conceivably as a group they might be willing to pay more than an individual user for the spectrum, in practice it would be difficult to pull them all together into a trade. Moreover, since commoners do not have individual usage rights, some of them could refuse to pay their share of the price, on the expectation that they could get a free ride—once the band becomes (or remains) available as a commons they could use it at no cost. Theoretical approaches to solving free-rider problems are complex and generally impractical to apply.

i.e., when a spectrum rights owner blocks another user from assembling spectrum across a contiguous area, could also be an issue.

International constraints. Spectrum use can be traded and liberalized only to the extent that this is consistent with international treaties and agreements to which the country is a party. Spectrum rights for satellite and terrestrial broadcasting are established largely through global and regional mechanisms.⁵³ Regional harmonization, such as across the EU, promote rapid deployment of new services but limit the pace at which spectrum can be reallocated among technologies and uses.⁵⁴ Frequencies and standards used for radio navigation and maritime services are agreed internationally and used worldwide, reflecting the global nature and public safety requirements of these services. Although international commitments evolve with time reflecting new technologies and business models, they do so rather slowly, and individual countries are not free to walk away unilaterally. The nature of international constraints varies from country to country. New Zealand is roughly 1,500 km from its nearest neighbor—little coordination is required. In contrast, Germany must coordinate with about dozen countries that are within 150 km of its borders. Similarly, most of the land area of China and India lies far from the border.⁵⁵ In contrast, essentially all of the land area of Togo and Benin lies close to the border. Thus, India and China can have spectrum policies that are far more self-contained and autonomous than can Togo or Benin.

Market failures. Spectrum markets will yield economically efficient results only if the price paid for spectrum reflects its value to society at large. This will not be the case if there are significant external costs or benefits associated with using the spectrum, parties engage in anti-competitive behavior, spectrum trade results in increased harmful interference, or benefits from standardization are lost.

- Some downstream uses of spectrum, such as national defense, emergency services, public broadcasting, and radio astronomy, have important social benefits that are not reflected in the private valuation of spectrum. Protection from interference can be critical for life or safety. And changes in spectrum use may also bear consequences for users. For example, the shift from analog to digital television broadcasting is expected to free large amounts of spectrum in demand for other uses and allow broadcasters to offer better services at lower costs, but imposes on consumers a high aggregate cost of replacing receivers. In principle, public sector support (e.g., subsidies) could bridge the differences between social and private valuations, so all spectrum would be subject to market discipline.⁵⁶ In general, however, the spectrum rights approach would not be

⁵³Satellite broadcasting rights are provided on an international basis through the ITU and cannot be transferred for use on an alternative satellite at a different orbital slot. Some spectrum rights are thus not only bound by international treaty but also inseparable from specific investments. The spectrum used for terrestrial broadcasting has been divided at the international level into channels, which are subsequently allotted through regional agreements to each country, ensuring that the available spectrum is reused as much as possible across the region.

⁵⁴In the EU, harmonization directives on GSM and UMTS have constrained the reallocation of spectrum from underutilized public access mobile radio and paging services to cellular services in great demand.

⁵⁵Far in radio terms generally means more than about 150 km.

⁵⁶For example, a subsidy for public broadcasting can seek to place it on equal footing with commercial broadcasting as regards the ability to compete for spectrum in the market.

appropriate to allocate and assign spectrum to activities where the private and public valuations are likely to be very different.⁵⁷

- Spectrum trading may be abused by parties engaging in anti-competitive behavior. Spectrum could be acquired to block rivals from offering competing services, or to build up or maintain downstream market power in the supply of services to end users.⁵⁸ Spectrum trading could thus result in economically inefficient outcomes. Liberalizing spectrum use can reduce the risk of such outcomes. If change in use is possible, spectrum can be acquired outside traditional allocations, and preemptive purchasing of spectrum then becomes impractical as a tool to fend off competition.⁵⁹
- Harmful interference may increase when spectrum is traded, especially if it is also liberalized.⁶⁰ Where reconfiguration and change of use is possible, rules may be needed to define and enforce rights and obligations to protection from interference for all parties. Where uses cannot be accommodated without causing intolerable interference, rules may be needed to bar such situations from arising or provide the parties incentives to resolve the problem among themselves.
- As more spectrum decisions are left to the market, some of the benefits from standardization may be lost.⁶¹ Coordination of spectrum use and equipment for specific services within and among countries results in economies of scale of equipment supply, roll-out of new technology, and mobility of end users.⁶² Traditionally this has been achieved

⁵⁷Nonetheless, measures should be taken to promote economic efficiency even in cases where the spectrum is not traded. Administrative incentive pricing of spectrum reserved for public use, including defense, may be a second-best solution where spectrum trading is not a practical choice.

⁵⁸Monopoly rents may make it worthwhile for incumbents to buy spectrum they do not need rather than allow new entrants and face competition. The value of spectrum to the incumbent may be higher than to a competitor. This risk decreases once several competitors are in place, or if spectrum liberalization allows new entrants to obtain spectrum from different sources (Ofcom 2005b).

⁵⁹Spectrum trading can be applied only if individual spectrum users have specific spectrum rights which are generally known. Among the first countries that permitted spectrum trading, it was more common for license transfers to occur between competitors in the same industry rather than between firms in unrelated industries. The former type of trade is much more likely to raise concerns about excessive market consolidation, which may be perceived differently by the government and the public than by the firms involved in the transaction. This puts a premium on ensuring outsider access to complete information about the economic consequences of the trade, which may discourage or encumber the trade, and it also requires monitoring of the results of the transaction. (Source: Robert Horvitz, communication to the authors, 2006.)

⁶⁰For example, simple ownership change of spectrum rights associated with fixed links (e.g., point-to-point microwave) can lead to interference to other users when a station is moved even a short distance. Changes in the use of high-value spectrum, for example, from fixed microwave links to mobile, satellite, or broadcasting uses, may call for elaborate engineering assessments to ensure it does not result in harmful interference, especially if the spectrum is shared with other services.

⁶¹For example, the harmonization of the GSM standard at European level is widely credited for fast development and growth of second-generation mobile phone service in Europe and subsequent adoption in other parts of the world (GSM Europe 2004). Arguably, licensing in the US of several mutually incompatible technologies resulted in slower service growth and loss of competitive position of US manufacturers relative to European rivals (Telefonica 2004). On the other hand, the competitive market in the United States was essential to the commercialization of CDMA technology for mobile phone service. That technology was then adopted universally for 3G wireless—the entire world benefits today from the innovations created under the policy in the United States.

⁶²Such as mobile roaming.

through government and inter-governmental allocations and rules, with mixed results. As a tradable spectrum rights regime is introduced, the scope of government intervention needs to be reassessed.⁶³

Conflicts with public policy. The application of the tradable spectrum rights approach to spectrum management must be consistent with broader public policy. The transition to a tradable spectrum rights regime, however, may result in windfalls for existing users that are deemed unacceptable, temporary loss of fiscal revenue, difficulty enforcing existing non-spectrum obligations, weakening of industrial policy, and constraints on the evolution of spectrum management practice itself.

- Windfall gains and losses are likely to occur when a tradable spectrum rights regime is introduced in a government administration environment by assigning rights to current users. Operators that had obtained authorizations to use the radio spectrum at little or no cost (for example, on a first-come-first-served basis) can now trade or capitalize these rights at market prices, resulting in large windfall profits.⁶⁴ Making new spectrum available or allowing flexibility of use can undermine the market value of licenses bought by incumbents at high prices, for example, in auctions for a restricted number of mobile operating licenses. Such one-off gains and losses resulting from changes in the rules of the game may be politically unacceptable, have anti-competitive effects, or be deemed to undermine the overall investment climate.⁶⁵
- Delegating decisions on spectrum uses and prices to the market reduces the opportunity for governments to extract large revenues from spectrum licensing and use. Market approaches to the spectrum limit the scope for discretionary intervention by government, which may be resisted in some circles. Many governments are accustomed to taxing spectrum use heavily as a continuous source of general revenue. Policies that limit the pace at which new licenses are placed on the market have been driven by the prospects of large one-off fiscal benefits. Weaning treasuries away from these practices may require finding alternative sources of government funding during the transition.⁶⁶
- Non-spectrum obligations of spectrum authorizations may need revision. For example, if population coverage obligations of a mobile phone company have not yet been fully met, they may have to be passed on to new owners if the spectrum rights are traded. Customers need to be protected from losing service when a provider sells spectrum to a

⁶³Where the political mechanisms for regional coordination exist (notably in the European Union, but also in weaker forms in other regions), questions arise as to what extent should regional decisions and guidelines be used to create and enforce a formal context for standardization among member countries.

⁶⁴In China the Peoples Liberation Army controlled large parts of the radio spectrum that eventually became suitable for commercial use (e.g., the 800 MHz mobile telephone band). From the late 1970s, the PLA used these assets to invest heavily in new telecommunications operating companies (Mulvenon and Bickford 1999).

⁶⁵Changes in the value of spectrum resulting from business developments not anticipated by the parties, such as lower than expected demand, the appearance of a competing product, or changing cost structures brought about by new technologies, are not windfalls but normal consequences of business.

⁶⁶In principle, spectrum trading and liberalization is not inconsistent with taxing spectrum use. Moreover, fiscal revenues in the long run are likely to rise due to faster growth, reflecting efficiency gains from improved spectrum management in the sectors that use spectrum as well as throughout the economy. In addition, governments could introduce other taxes on spectrum users that could compensate for losses of spectrum licensing and use revenues. Such taxes could be designed in ways that do not distort allocation decisions.

different business.⁶⁷ This can limit the extent to which the spectrum rights may be reconfigured (e.g., divided on geographical basis) or given a different use (e.g., fixed wireless).

- Industrial policies to build up domestic manufacture of telecommunications equipment may require reserving parts of the spectrum for specific technologies or limiting what parts of the spectrum may be used to provide given services. The potential benefits of indigenous industrial development are traded off against possibly inefficient use of the spectrum in the longer run.
- Tradable spectrum rights may make it difficult to change the boundaries between administration, rights, and commons approaches to spectrum management. Such changes are likely to be necessary from time to time.⁶⁸ There is an inevitable tension between retaining authority to reclaim spectrum and creating uncertainty for users.

3.3 Scope of Application

Whether a country is capable of addressing effectively the potential limitations of spectrum trade and liberalization discussed above is a matter to be assessed case by case. Table 3.1 summarizes these limitations and suggests which ones are in principle within the reach of country authorities or the industry to address. Pre-eminent in this class are the risks of anti-competitive behavior and increased interference. In principle these fall within the province of sectoral and general competition authorities. But the ability to mitigate these risks and deal with related problems when they materialize is likely to be the main regulatory concern when introducing the tradable spectrum rights approach. Also, conflicts with broader public policy can, in principle, be addressed with other government agencies or by escalating the issues to higher levels of government.

The powerful arguments in favor of spectrum trade and liberalization apply to all uses across the radio spectrum. But in practice the limitations discussed above mean that this approach is better suited to some spectrum uses than others. Decisions on which parts of the spectrum can be opened to trade or liberalized must be based on the analysis of the conditions prevailing in the particular country. Table 3.2 suggests a format for reviewing country conditions.⁶⁹ For illustration, the last column summarizes the conclusions reached by one major regional study comprising developed as well as middle-income developing economies. The broad finding in this case is that spectrum trade and liberalization are likely to be applicable mainly to broadcasting, fixed terrestrial links and access networks, mobile services, and satellite communication. In a more limited way, they may also provide incentives for more efficient use of spectrum reserved to special users groups, especially military and other government uses.

⁶⁷For example, Telstra in Australia is closing its CDMA operations, and a mobile virtual network operator attached to it is debating what to do next. It is important to ensure that changes in spectrum holdings do not hurt customers, especially if the new spectrum owners do not provide the same services as the older spectrum owner.

⁶⁸For example, in Guatemala the regulatory authority has had difficulty buying back spectrum rights bands now needed for unlicensed use in keeping with new international recommendations to enable development of wireless broadband service using WiFi and WiMax technologies.

⁶⁹The blank columns on risks and limitations reflect the view that these can only be assessed meaningfully in individual country situations. There are few generic answers that can be applied across the board. The last column summarizes the result of the analysis done in Europe, including transition economies that recently joined the EU.

Table 3.1 Limitations on Spectrum Trading and Liberalization		
Factors	Problems	Problems are within reach of users or authorities
Individual spectrum rights	Individual spectrum rights do not exist or cannot be created.	
Transaction costs	High transaction costs cannot be effectively reduced.	
International commitments	Proposed changes of ownership, use, configuration, or technology are constrained by international commitments.	
Market failures <ul style="list-style-type: none"> • Externalities • Anti-competitive behavior • Interference • Standardization 	Major differences exist between private and social valuations of spectrum. Sector or competition authorities are not equipped to handle anti-competitive behavior. There is widespread potential of increased harmful interference. Major adverse effects on services are expected from reduced global or regional standardization or harmonization.	✓ ✓ ✓
Public policy <ul style="list-style-type: none"> • Fiscal impact • Windfalls • Service obligations • Industrial policy 	Fiscal losses are critical. Large windfall profits or losses are likely to occur and are politically unacceptable. The objectives of non-spectrum obligations of existing licenses have not yet been reached and remain important. Industrial development policies require some restrictions on spectrum use or technology.	✓ ✓ ✓ ✓

Table 3.2 Scope for Spectrum Trade and Liberalization: Suggested Format for Country Analysis and Conclusions of a Major Regional Study								
Spectrum uses	Summary description	Nr of users	Typical bands	Risks and limitations				Trade and liberalization are generally applicable^a
				Rights and trans. costs	International commitments	Market failures	Policy conflict	
Aeronautical	Radio services for aircraft. Includes aeronautical navigation, traffic control, communication (including satellite), global positioning.	+++	Numerous narrow bands up to 16 GHz					
Amateur radio, CB	Amateur radio: experimentation, community support, leisure. Citizen band radio: short-range personal and business communication.	+++	Numerous narrow bands up to 259 GHz					
Broadcasting—satellite	Downlink radio and TV broadcasting from satellites to community or individual receivers. Associated uplinks to feed programs.	+	12 GHz. Up-links 14 and 17 GHz					✓
Broadcasting—terrestrial	Radio and TV broadcasting to the general public, either commercial or as a public service.	+	Radio 0.5–26 and 88–108 MHz. Analog and digital TV 470–854 MHz					✓
Fixed links	Terrestrial point-to-point links (e.g., microwave), generally part of networks for corporate or public communication services (e.g., between mobile base stations)	++	Throughout spectrum, usually shared					✓
Fixed wireless access	Systems to connect commercial or residential locations to public networks. Includes wireless local loop, broadband Internet access.	+++	2.5, 10, 26, 28 GHz					✓
ISM and short-range	ISM: Industrial, scientific, and medical non-commercial uses. Also wireless local area networks, cordless phones, alarms, medical implants, and other short-range devices.	+++	0.9, 2.5, 5 GHz					

continued

Table 3.2 *Continued*

Spectrum uses	Summary description	Nr of users	Typical bands	Risks and limitations				Trade and liberalization are generally applicable^a
				Rights and trans. costs	International commitments	Market failures	Policy conflict	
Land mobile—private mobile radio	PMR: two-way mobile radio systems used by individuals (e.g., walkie talkies), or organizations (e.g., security patrols), or vehicle fleets (e.g., taxis, delivery vans).	+++	5 or 10 MHz-wide bands throughout 30–900 MHz spectrum					✓
Land mobile—public mobile radio	Mobile voice and data services for public use. Includes mobile public telephone, short text messaging, Internet services. Also paging services and public access mobile radio (PAMR) networks.	+	Standardized bands 0.4–2.7 GHz					✓
Maritime	Radio services for ships. Includes maritime navigation (radar), communication, electronic positioning, port traffic control, coastal surveillance, distress, weather.	+++	Standardized bands up to 9.3 GHz					
Radio navigation	Systems for navigation, including satellite services, meteorology (e.g., storm detection), global positioning, as well as aeronautical and maritime (above).	++	Numerous bands up to 265 GHz					
Satellite—fixed and mobile	Up- and down-link communication between satellites and earth stations (fixed or mobile). Includes land services (e.g., VSAT), aeronautical, and maritime (not broadcasting)	+	Many bands 2.5–31 GHz, mostly shared					✓
Scientific	Space research and operations, radio astronomy, meteorology, earth exploration satellites, standard frequency and time signals.	++	Numerous bands up to 275 GHz					

continued

Table 3.2 Continued								
Spectrum uses	Summary description	Nr of users	Typical bands	Risks and limitations				Trade and liberalization are generally applicable^a
				Rights and trans. costs	International commitments	Market failures	Policy conflict	
Reserved user groups								
Military	Support for strategic planning, conduct of operations, and a large variety of military applications. In many countries, defense and security is the largest spectrum user.	++	Across the spectrum					
Public safety	Safety services to the public. Includes fire, police, and ambulance services, and emergency coordination also with other bodies.	++	Several bands 56–395 MHz					
Public transport	Systems used for the operation of public transport services, such as railways, buses, trams, underground, road and traffic control.	++	Several bands 6–78 GHz					
<i>Source:</i> developed from Analysys et al. 2004. +++Many user rights, often in the thousands ++Moderate number of users rights, often in the hundreds +Few user rights, typically less than 10 ^a European Union, 2004								

3.4 Building Blocks

Management of the spectrum in terms of tradable spectrum rights has three main building blocks: defining spectrum rights and obligations, managing interference, and safeguarding fair competition. These building blocks are essential irrespective of whether the tradable spectrum rights approach is established as a greenfield project, such as during the early stages of privatization and liberalization of the telecommunications market overall,⁷⁰ or introduced in the context of fairly developed government administration spectrum practice. In the former case it is easier to move quickly toward the full potential, simplicity, and benefits of the rights approach, whereas in the latter case more compromises may be needed and progress may be slower. Specific choices must be tailored to the country's circumstances.

Defining spectrum rights. For a spectrum market to work well, it is essential that buyers and sellers have legal certainty about the rights that are traded. These rights, including any associated obligations, largely define how any particular part of the spectrum may be used and thus have a big impact on its value.

Spectrum rights are defined primarily in terms of four parameters: spectrum endowment, geographical coverage, duration and time of use, and protection from interference.⁷¹ These parameters apply irrespective of how the rights are initially granted and whether and how they are subsequently traded, but the way they are specified varies with the approach to spectrum management under which they apply. New rights, such as granted when spectrum is released to the market for the first time or following recovery from existing users, can be defined from the outset in ways that are suitable for trading. Existing rights granted through traditional spectrum administration, however, need to be clarified, especially with respect to protection from interference, before they can be effectively traded. Existing rights often are tied to additional obligations, which also need to be clarified.

- *Spectrum endowment* defines the spectral domain within which the rights apply. This has traditionally been stated in terms of individual frequencies or bands of spectrum comprised between two given frequencies.⁷² The practice has been carried over to the spectrum rights approach.⁷³ Where permitted, rights holders may reconfigure (divide or aggregate) their spectrum endowments.⁷⁴ Combined with trading (e.g., sale, lease) and change of use, reconfiguration can improve the efficiency of spectrum allocation and assignment over time, but increases the risk of interference and spectrum fragmentation. The trend is toward leaving it up to spectrum rights owners to decide how they reconfig-

⁷⁰As was the case in Guatemala (Ibarguen 2004).

⁷¹Additional parameters have been proposed by various sources, reflecting different conceptions of what the rights should entail. See, for example, Aegis 2006.

⁷²Trade and reconfiguration can increase efficiency of allocation and assignment over time, as well as improve the efficiency of initial assignments.

⁷³Alternative ways of specifying spectrum endowment have been proposed but so far not adopted in practice.

⁷⁴New spectrum, or spectrum recovered from other users, could be released in large blocks leaving it to the market to determine the extent to which disaggregation is efficient—provided there are no related competition issues either in the spectrum market or downstream services. Besides dividing and aggregating spectrum by frequency, reconfiguration can also be done by geographical coverage, time of use, or other characteristics such as coding technique.

ure their spectrum, subject to rules on interference that apply independently of technology used or service provided.⁷⁵

- *Geographical coverage* specifies the spatial domain within which the spectrum rights may be used. Rights may apply, for example, throughout the country, within given regions, or in specific locations. Spectrum is often used more intensely in some parts of the country than others. Where allowed, reconfiguring national rights by geographical coverage frees unused spectrum for different applications. Provisions to limit geographical coverage designed to prevent harmful interference can be relaxed in areas where spectrum is used lightly.⁷⁶
- *Duration and time of use* specifies the time domain of the spectrum rights. Clarity about expiration and renewal of rights is a key factor determining the value of spectrum and the willingness of rights holders to invest in its use. Under traditional administration, rights are generally granted for finite periods so the authorities can eventually reallocate and reassign spectrum in response to changing circumstances.⁷⁷ Under the rights regime, flexibility is achieved faster through the market by spectrum trade, reconfiguration, and change of use.⁷⁸ The trend is for the authority to issue rights in perpetuity but retain the possibility of reclaiming spectrum at market value under exceptional circumstances spelled out in the rights and subject to a process that ensures transparency and fairness.⁷⁹
- *Protection from interference* establishes the right to receive signals without harmful interference from other spectrum users, and the obligation not to cause harmful interference. The risk of interference is not materially affected by spectrum trade alone,⁸⁰ but may increase when spectrum rights are reconfigured or use is changed. The trend is to specify, as part of defining spectrum rights, the maximum acceptable levels of signal strength caused by the rights user outside the authorized frequencies and geographical areas. The primary responsibility for resolving interference problems is placed on the spectrum users themselves. Resolving interference problems when they occur can be facilitated by incorporating in the spectrum rights an obligation to negotiate interference management arrangements with other spectrum users and establishing clear rules for handling unresolved disputes. An alternative approach would be to define spectrum rights in terms of maximum transmitter contributions to interference within and outside

⁷⁵A variant, pioneered in Australia, comprises defining the smallest parcels into which the spectrum may be divided and traded. Another variant, used in New Zealand, is to grant rights to manage (e.g., reconfigure and trade) large parcels of spectrum for use by others. The combination of reconfiguring, change of use, and leasing would enable owners of spectrum use rights to become *de facto* rights managers even if rights managers are not explicitly created.

⁷⁶This facilitates extending services to unserved or underserved areas, notably provincial and rural areas in poor countries.

⁷⁷Duration varies between long periods (e.g., 20 years) with possible but uncertain renewal, to one year with expectation of automatic renewal except in specific circumstances. Some authorizations have been issued for perpetuity but with the option of the authority to recall them on short notice.

⁷⁸Except in the case of market failures.

⁷⁹Exceptional circumstances may include market failures, national emergencies, broadly recognized need to free spectrum for unlicensed use, or changes in international or regional commitments.

⁸⁰Pure change of ownership does not change interference, but even small changes in usage, such as relocation of a transmitting station (for example, a microwave terminal), can alter significantly the interference pattern.

authorized frequencies and geographical areas, giving the rights holders flexibility of services and technologies to avoid harmful interference without the need to negotiate with one another (Kwerel and Williams 2006). Interference management is further discussed below.

Additional obligations are often attached to spectrum rights granted in the context of traditional spectrum administration. This typically includes restrictions on type of service and technology, or downstream service obligations (e.g., roll-out, coverage). Such additional obligations limit the scope for spectrum trade and liberalization.⁸¹ Legal certainty is needed over whether and how these additional obligations will be transferred in the event of a trade.⁸² Whenever possible, the additional obligations could be dropped before trade is introduced.⁸³ New rights, such as granted for spectrum newly released or recovered from previous users, should not be burdened with additional obligations that would distort the emerging spectrum market.⁸⁴

Managing interference. The prevailing view on the critical issue of preventing and managing interference under the spectrum rights approach is along the following lines. The holder of spectrum rights has (a) the right to receive signals within a specified zone without interference by others above a certain level, and (b) the right to transmit signals in a specific bandwidth either on a mobile, itinerant, or nomadic basis or within a specific area, and (c) the obligation not to cause harmful interference to other stations operating in conformance to their authorization above that level.⁸⁵ Defining spectrum rights only by frequency, space, and time does not afford protection against interference. Interference thresholds must be specified as integral part of spectrum rights. In order for rights to be tradable with possible reconfiguration and changes of use, interference thresholds must apply irrespective of the technology used or the service provided.⁸⁶ Defining interference thresholds can be a difficult task.

Several options for ensuring acceptable interference levels in a spectrum rights context can be considered. Interference issues can be primarily managed by the spectrum authority, as under

⁸¹By impeding access to parts of the spectrum or distorting the costs of deploying particular technologies or services.

⁸²If the additional obligations remain with the original rights holder, the incumbent may be placed at a competitive disadvantage relative to new users of its spectrum. If reconfiguration and change of use is allowed together with trade, it may be difficult to ensure that the obligations are honored.

⁸³This may be the case when the obligations have already been met, for example the timetable to roll out a new mobile network.

⁸⁴The main argument for additional obligations is for supporting public policy objectives. In general these objectives can best be met by using other policy instruments, such as subsidies, rather than by distorting spectrum markets.

⁸⁵While the concept of permissible levels of interference exists in a transnational setting, and negotiations between states normally produce context-specific definitions of permissible interference, intra-national regulations still tend to equate detectable interference with harmful interference even when the economic damage is negligible. This implies that *any* interference is harmful. However, the concept of an interference protection mask has gained popularity among regulators recently as a way to specify the conditions under which authorized signals may overlap, while avoiding disputes over whether harm has been caused. (Source: Robert Horvitz, communication to the authors, 2006.)

⁸⁶The usual tools to achieve interference protection under government administration of the spectrum are technology- and service-specific and not suitable for trading (other than pure change of ownership). Some technologies will be better off than others at given levels of interference threshold.

government administration, including examining proposals for change of use on a case-by-case basis, establishing interference limits, and resolving disputes. Alternatively, interference management may be largely delegated to the users themselves.⁸⁷ This reduces the workload of the regulatory authority, facilitates moving away from entrenched administration attitudes and practices, and reduces the risk of capture by incumbent users. The spectrum authority might nonetheless retain ultimate responsibility for enforcement, manage interference issues among users subject to different spectrum management regimes,⁸⁸ and manage spectrum that remains under government administration.

Whichever way the responsibility for interference management is apportioned between the users and the spectrum authority, default interference levels must be set as the starting point for technical planning by users as well as for negotiating and resolving disputes. Options for defining interference thresholds include use of existing thresholds for individual bands under government administration, definition of new technology-neutral thresholds, and a combination of both.⁸⁹

Enforcing fair competition. Anti-competitive behavior in the spectrum market can arise as users defend or try to create positions of market power in the provision of downstream services. This may occur through concentration of spectrum holdings currently in use to provide a particular service, or through incumbents buying up spectrum that would be needed by potential competitors.⁹⁰

Some measures to reduce the risk of anti-competitive behavior in spectrum markets are within the province of spectrum policy itself. Anti-competitive trades can occur only when spectrum for a particular use is scarce. As much spectrum as possible should be placed in the market, without technology or service restrictions. Any such restrictions on spectrum currently in use should be removed. Operating licenses for particular services should not be tied to specific spectrum frequencies.⁹¹ More generally, policies that encourage widespread competition in downstream services reduce the incentive for anti-competitive behavior in the spectrum market.

⁸⁷All countries where the tradable spectrum rights approach has been introduced devolve substantial responsibilities for interference management to users. There is evidence that spectrum users can cooperate to manage interference adequately, provided they have commercial incentives to do so.

⁸⁸Delegating responsibility for resolving interference issues to the spectrum users is unlikely to work well in cases of interference between a rights holder and unlicensed users (e.g., of an adjacent band), or when spectrum is shared among many users (Analysys et al. 2004).

⁸⁹The UK has put in place a form of defining interference thresholds that start from existing levels of protection from interference under traditional government administration of the spectrum and moves towards technology- and service-neutral new thresholds as the opportunity arises. This approach provides both flexibility of use and a high level of protection against actual interference. See Ofcom 2005b, 2006.

⁹⁰Holding unused spectrum (hoarding, warehousing) may be for a legitimate business purpose. This includes providing for future capacity expansion or broadening of services, aggregating spectrum on geographical or frequency basis for subsequent provision of new services, and as investment for sale when it has appreciated.

⁹¹Operating licenses to provide high-value services, such as mobile phones, are often tied to specific spectrum assignments to be used with specific technologies. Mobile operators typically are not allowed to use other bands. This creates a entry barrier to the downstream market.

Remaining risks of anti-competitive behavior in the spectrum market can be handled by applying general competition law. General competition law can be used to address abuse of market power through spectrum trading once it has occurred.⁹² As a body of experience builds up applying competition law *ex-post* to specific cases of spectrum trading, it will also provide *ex-ante* guidance to parties involved in potential trades with competition implications. Attempts to apply general competition law *ex-ante* are less likely to work. There are no simple objective criteria that can routinely distinguish spectrum trades that are anti-competitive from those that reflect legitimate business strategies.⁹³ Case-by-case examination would be needed, and the authorities would find it difficult to predict whether a particular spectrum transaction would in the future result in adverse effects on downstream competition.⁹⁴

Some anti-competitive spectrum trades may fall under merger control rules. Large spectrum trades are often accompanied by the change in ownership of related assets (e.g., network infrastructure, customer base). Merger regulations can be applied to determine whether the transfer of spectrum involved in such a transaction is likely to adversely affect the existing level of competition, for example, by constraining or eliminating a competitor. In such cases, mergers may be approved subject to specified changes in the spectrum holdings.⁹⁵

Where effective general competition law and merger controls are not in place, the primary tools for containing anti-competitive spectrum trade will be accelerating spectrum trade and liberalization as well as competition in the provision of downstream services. In addition, rules for fair competition can to some extent be incorporated in sector-specific legal and regulatory frameworks or built into the spectrum rights themselves. Imposing some conditions on spectrum trading, such as transparency and non-discrimination, can reduce the risk of deals that preserve market power, albeit at the expense of some of the efficiency gains from trading.⁹⁶

⁹²Competition law prohibits the abuse of market power, not the existence of market power itself.

⁹³A variety of screening criteria have been proposed. Examples include the amount of spectrum transferred, the parties' spectrum holdings after the transfer, and the parties' downstream market shares before and after the transfer. Arguably none of these criteria, alone or combined, provide an effective basis for allowing or prohibiting spectrum transactions. Likewise, restrictions on spectrum use, such as "use it or lose it," cannot discriminate effectively between keeping spectrum idle to constrain competition or for legitimate business purposes. Moreover, "use it or lose it" rules cannot be enforced objectively and undermine the potential efficiency gains from trading.

⁹⁴Assessing the future impact of a particular spectrum trade on competition is likely to be highly subjective and speculative. Whether a particular transaction will hurt competition depends, among other factors, on the technology used, the ability to use existing or new equipment in other frequencies, whether spectrum is being traded in alternative bands, the extent to which spectrum use has been liberalized, and benefits from following international standards.

⁹⁵The sale of Bell South mobile operations in Latin America to Telefónica in 2004 was subject to approval in several countries where the competition authorities were able to require some of the combined spectrum to be returned to the authorities for reassignment to existing or new competitors. In contrast in Peru, where Telefónica already had market power in fixed voice, cable, and Internet, there were no applicable merger or competition controls that could be used to similar effect.

⁹⁶Selling spectrum only to weak competitors or with market conditions attached can help entrench market power. Prescribing how spectrum should be traded, however, can reduce the efficiency gains from trading as it limits the options open to potential trading partners.

3.5 Implementation

Rapid deployment of the rights regime throughout the applicable spectrum extends the opportunities of trading and liberalization to all users in all bands, and allows migration among all bands to overcome quickly artificial scarcities resulting from traditional spectrum management practice, but possible speed of implementation may depend on market maturity.

Whenever possible, rights should be assigned for spectrum that is not in current use.⁹⁷ This gives the spectrum authority a free hand in designing the new rights without the complication of amending or coexisting with old licenses, and the new rights holders are free from interference from legacy uses. Unassigned and returned spectrum are prime candidates. Mandatory clearance of occupied bands before issuing new rights may be possible, without major disruption or undermining credibility of the regulatory regime, when existing licenses expire, there is alternative spectrum to which users can migrate, or users are willing to move on a voluntary basis. An alternative is to let the market determine the timetable for clearance. For example, new tradable rights can be granted for occupied frequencies, encumbered by the incumbent users' rights until the latter expire by a fixed date. The parties can negotiate earlier clearance.

The main tool to handle existing users is converting the current licenses to new tradable rights. This allows quick deployment of the spectrum rights regime, avoids disruption and uncertainty, and enhances the value of spectrum to current users. Many existing licenses can be converted into tradable rights through a class authorization, which keeps processing costs down, but some licenses may need to be handled case-by-case.⁹⁸ Converting existing licenses to tradable rights can be quite complex, including introducing measures to contain and manage interference and resolving what to do with additional obligations (e.g., roll-out, coverage) attached to the existing licenses.

4 Developing a Spectrum Commons

In contrast with the traditional government administration and the spectrum rights regime, both predicated on individual licenses conveying rights to use specific frequencies in a defined area, the commons approach is based on an open sharing of spectrum among users without guarantees of interference-free operation. Spectrum frequencies are not assigned to specific users, neither by a regulatory authority nor by the market, and it is generally left to the users and their equipment to avoid interfering with one another.

4.1 Basic Features

Under the spectrum commons approach, spectrum is available to all users that comply with a few established technical standards.⁹⁹ These standards are designed to mitigate potential

⁹⁷This may raise concerns about hoarding, windfalls, and other potential problems. An alternative may be to release spectrum only in response to demand.

⁹⁸While allowing trading is easy, liberalization (providing flexibility of use) is more difficult. Ofcom found that class authorization could be applied only to few licenses.

⁹⁹Technical restrictions may apply to transmitted power (generally much lower than allowed under government administration or spectrum rights), system range (distance covered), or protocols.

interference from building up for the commons as a whole. Usage rights can be flexible, with minimal or no restrictions placed on the type of service for which the spectrum can be used. Because the regulator has limited information about the deployment of spectrum commons equipment, it is impractical to investigate or manage interference among users. Users of such equipment are aware that there may be heavy spectrum sharing at certain locations and the ability of the equipment to withstand interference depends on its technology, design, and quality. The spectrum authority generally abstains from regulating equipment quality except for compliance with the basic technical rules, often by reference to agreed minimum international standards.¹⁰⁰

Besides the need to reform spectrum management resulting from the limitations of government administration, the major driver for the development of a spectrum commons is technological innovation. Radio technologies now coming to market or under development avoid causing insurmountable interference among users even when transmitting at the same time, in the same place, and on the same parts of the spectrum.¹⁰¹ These technologies result in more efficient use and easier sharing of the spectrum, and may eventually render spectrum scarcity obsolete—all this at declining costs (Wellenius and Neto 2005).

Several specific commons models are being tried or proposed:

- The license-exempt model allows using designated bands without individual authorization, which facilitates entry and encourages experimentation with new technologies and business models.¹⁰² License-exempt use, however, does not mean unregulated. The authorization for use of these bands is accompanied by some technical limitations, both to contain interference among commoners and to protect other users of these bands.¹⁰³

¹⁰⁰The commons model has in the past been referred to as relying on community-based arrangements and compared to grazing lands that are used in common by herdsmen in a community, or to public parks or hunting lands that can be accessed by anyone. Some have even argued that access to spectrum on an unlicensed basis is a human right, and that issuing licenses should be an exception, not the rule. This argument was put forth by the Open Spectrum UK group in its comments to Ofcom's Spectrum Framework Review (see <http://www.ofcom.org.uk/consult/condocs/sfr/responses/openspectrum.pdf>): "Article 10 of the European Declaration of Human Rights asserts that everyone has the right 'to receive and impart information and ideas without interference by public authority.' Licensing is an 'interference by public authority' and as such it is permitted by the EDHR only for 'broadcasting, television or cinema enterprises' or when 'prescribed by law and . . . necessary in a democratic society . . . [for] public safety, for the prevention of disorder,' etc. When licensing cannot be justified by any of these exceptions, it must be considered a violation of human rights."

¹⁰¹These technologies are based on advanced digital signal processing (compression, multiplex, spread spectrum applied to the design of new types of radio equipment (smart radios and antennas, software-defined radios, cognitive radios, multiple-input multiple-output networks, and mesh, ad-hoc, or viral networks).

¹⁰²Deregulating spectrum access by promoting license exemption (for example for the use of WLAN technologies) can offer significant advantages for users, in particular the cost savings and convenience resulting from the possibility of using radio equipment without the need to apply for a license. It also benefits innovation, as it gives entrepreneurs the grounds to experiment with new technologies or business models (Neto 2004).

¹⁰³See, for example, ITU-R Resolution 229, adopted at the World Radio Conference in 2003 (WRC-03), on the "Use of the bands 5150–5250MHz, 5250–5350MHz and 5470–5725MHz by the mobile service for the implementation of wireless access systems including radio local area networks." This resolution created the first globally-harmonized bands for unlicensed WLANs as a primary allocation. But to protect existing co-primary users in these bands, including radar systems, WLANs are required to have interference-mitigation capabilities and built-in protocols.

- Another model is the private commons, where only qualified users have access to the band, which they share. Amateur radio, for example, is a service where many individually authorized users share designated spectrum bands without individual frequency assignments.¹⁰⁴
- The more general open wireless networks model involves managing the use of spectrum as public property by opening up the bands to users of equipment that can find, aggregate, and use vacant spectrum (Benkler 1998). Arguably this is akin to the Internet regulatory model, in which a decentralized commons structure is possible because the network's intelligence lies in the decentralized nodes, i.e., the users' computers (Hatfield 2005).¹⁰⁵

Spectrum rights (discussed in chapter 3) can be designed so as to approximate some of the benefits of the commons model. A variant of the exclusive rights approach would subject rights holders to government-mandated easements. Easements would, for example, allow other users to transmit on the same frequencies without the rights holders' authorization, provided they do not interfere with its services (Faulhaber et al. 2002).¹⁰⁶ This variant addresses the high transaction costs that otherwise would be incurred by users of several new technologies now coming to market that have considerable spectrum-saving potential and network development advantages but need broad access to the spectrum.¹⁰⁷ Easements could also address high transaction costs for users that need immediate but short-term access to certain portions of the spectrum (e.g., public safety agencies) or global access to spectrum under harmonized rules (e.g., satellite operators) (FCC 2002).¹⁰⁸

¹⁰⁴Amateur radio is a hobby enjoyed by about three million people worldwide. They use internationally allocated bands to experiment and communicate using voice, data, or video technologies. Amateur radio operators are licensed and given unique identification call signs by their governments upon passing tests on related technical and regulatory subjects. Amateur radio operation is subject to regulations in each country. Enforcement of regulations and management of interference are largely achieved through voluntary adherence to codes of behavior.

¹⁰⁵Benkler (1998) argues that this means regulating wireless communications as the Internet, with minimal standard protocols and limited governmentally-imposed rules of the road. In the Internet domain, a decentralized commons structure is possible because the network's intelligence lies in the decentralized nodes, i.e., the computers (Hatfield 2005). In the spectrum domain the nodes would be the radio receivers—hence the potential for smart and cognizant radios. It can be argued, however, that in the Internet domain management models started with the commons approach, but that there is now the need to introduce some intellectual property and administrative (ICANN) governance functions. The challenge faced in Internet governance, as in the spectrum domain, is to find the right balance between the different models.

¹⁰⁶The FCC recently published two decisions which give interference rights to unlicensed users and non-exclusive use rights to licensed users in different bands (FCC 2003b).

¹⁰⁷Examples are technologies that require simultaneous low-power use of a wide spectrum range (e.g., ultra-wide band technologies) and short term access to individual frequencies over a wide spectrum (e.g., software-defined radios).

¹⁰⁸Engineers are concerned that there are more serious limitations for radio devices to recognize the radio environment in which they operate (which would be a precondition for designing an underlay approach). Ways out may include requiring existing users to broadcast characteristic signatures that would make it easier to detect their presence. More thinking in this area needs to be done and it will likely not be sufficient to just declare that devices may use any frequency as long as they do not interfere.

Different forms of spectrum commons are already in place in several countries, usually in the bands allocated to industrial, scientific, and medical devices.¹⁰⁹ By late 2004, at least 55 countries had allocated spectrum for license-exempt use (ITU 2004). Bands that were regarded as of little use are now considered to be potentially valuable, and their use is encouraging technology innovation as well as more intensive band utilization (Weiser and Hatfield 2005).

There are numerous consultations underway around the world about extending the commons approach to additional services.¹¹⁰ The trend is for license-exempt use to grow. Several countries have also permitted the use of some new technologies, such as ultra-wide band, to operate across bands in which exclusive user authorizations are in use, acknowledging that spectrum sharing is possible. The US is also furthering this idea by discussing the concept of allowing any transmission whose interference does not surpass a certain level to exploit already-assigned frequencies (FCC 2003a).¹¹¹

4.2 Advantages and Limitations

The argument for a spectrum commons is mainly that it may constitute one of the answers to the current debate about how to manage and use the radio spectrum more efficiently. Because under the commons approach no spectrum is exclusively held, and the permitted signal range is relatively short, a very high density of users can be accommodated, and users have practical incentives to adopt spectrum-efficient technologies that use whatever spectrum is available (FCC 2002). Devices that better tolerate interference will win more buyers and gradually displace less resilient equipment from the market. New wireless systems also may be the technology of choice in parts of developing countries where the spectrum is not very congested and the risk of interference is low, and also because of lower costs and minimum investment requirements.

Innovation is not only the driver of a spectrum commons, it may also be its product. Opening bands to commons use, with low entry barriers and without authorization conditions that freeze the characteristics of radio equipment, opens up grounds for innovation. This allows users to experiment with new technologies, potentially respond rapidly to changing demand patterns, and adapt technologies to local needs.¹¹² Success, however, depends among other fac-

¹⁰⁹The Consumer Electronics Association in the U.S. estimates that there are around 350 million license-exempt devices in use in applications such as cordless telephones, garage door openers, remote-control toys, baby monitors, home security systems, and automobile keyless entry systems (Hatfield 2005).

¹¹⁰A report issued in early 2006 gave numerous examples from 16 European countries. Since 1997 Denmark has been gradually introducing license exemption in the maritime mobile service. Sweden plans to exempt the use of VHF by private boats in 2006. Estonia is considering the exemption of satellite news gathering equipment. Hungary already exempts amateur radio use from licensing, and the Netherlands plans to do the same from 2007 (CEPT 2006).

¹¹¹This concept is referred to as *interference temperature*. A different type of co-existence is cognitive radio. A cognitive radio looks for momentarily unused parts of the spectrum, makes use of the spectrum and then vacates it before the license holder wishes to use it. In a recent statement the UK regulator, Ofcom, declared that it sees many technical and commercial problems with cognitive radio which might result in interference, and so does not propose to make it license exempt. Ofcom, however, mentions that, under trading, it would allow license holders to agree cognitive access with third parties if they wish to do so (Ofcom 2005b).

¹¹²There is anecdotal evidence and a swelling conceptual debate linking the speed of innovation on the Internet to the availability of an open access platform (Bar et al. 2000; Lemley and Lessig 2001).

tors on avoiding unnecessary technical restrictions on equipment.¹¹³ Equipment manufacturers and users should determine product features and functions, rather than the regulator second-guessing the market.

Simplified, license-exempt access to commons bands also lowers barriers to entry, enhances competition, may result in lower capital requirements,¹¹⁴ and reduces time for deployment. The regulatory and financial burden on all players is reduced, as users do not need to go through the formal process of obtaining exclusive authorizations and paying the corresponding fees, and as new technologies provide more cost-effective alternative means to contain interference. The risk of regulatory capture and corruption in the assignment of authorizations is also reduced.¹¹⁵ Moreover, exclusive-use licensing is poorly suited to authorize these new technologies, and thereby delays the benefits they can bring (Ikeda 2003, Benkler 2002, Reed 2005). Lower barriers to entry may facilitate a more participatory and community-based utilization of the spectrum by non-commercial entities—for example by NGOs, local governments and civil society.

The main concern about the commons approach is the risk that the commons will be overused and degraded by interference. Despite technology evolution, there is a limit to the number of devices that can coexist. Some technical parameters will be needed to keep interference at manageable levels in high-occupancy areas. Even so, if spectrum remains in short supply, the commons could have too many users and overall performance could decline.¹¹⁶ Possible strategies of dealing with this issue will be discussed below. Associated risks include deliberate abuse and intentional harmful interference.¹¹⁷

An additional concern for governments when looking at license-exempt bands is the loss of fiscal revenue. In most countries, the fees charged for spectrum authorization and use represent a significant source of revenue for the national treasury and also of the spectrum authority's operating budget. License-exempt use of the spectrum arguably increases consumer welfare

¹¹³The success of a radio commons depends to a large degree on the reasonableness of the criteria for “type acceptance” of the equipment. It is unfortunately easy to move rigid, restrictive conditions found in licenses to the type acceptance process, so that there is hardly any gain from de-licensing. Many members of the European Union, for example, require license exempt WLANs in the 2.4 and 5GHz bands to use only the “integral antenna” supplied with the transceiver at the time of purchase—eliminating the possibility of choosing an antenna better suited to the specific link requirements and less likely to cause or be affected by interference.

¹¹⁴Capital costs can be distributed among users (e.g., through mesh networks) rather than being concentrated in traditional supply infrastructures.

¹¹⁵For cases which have been found to be problematic, see, for example, “Majority of Corruption Cases in China Linked to Licensing: Official,” People’s Daily, 30 August 2003 at http://english.people.com.cn/200308/30/eng20030830_123408.shtml, or “Ministerio Público investiga a CANARA y Oficina de Control de Radio,” Informa-Tico.com, 9 June 2005—at <http://www.informa-tico.com/php/expat.php?id=06-06-0501237&ed=53&fecha=06-06-05&foro=40>.

¹¹⁶As earlier with fishing in international waters, overgrazing of public pastures, and other situations, this has been labeled “the tragedy of the commons”.

¹¹⁷We can draw a parallel between these and Internet spam. While unlicensed spectrum provides huge cost savings to the user, it has the side effect that denial of service attacks are trivially simple. By just turning on a high powered access point, cordless phone, video transmitter, or other 2.4GHz device, a malicious person could cause significant problems on the network. Many network devices are vulnerable to other forms of denial of service attacks as well.

and economic productivity, but it also reduces opportunity to levy fees. While deregulated spectrum is generally seen as being of an unprotected nature, some level of regulatory enforcement may be needed to prevent excessive interference and free rider problems (Hatfield 2005), and therefore there are some associated regulatory costs that must be recovered.

Other transition issues include legacy equipment, irreversibility of deregulation, and related loss of government control. Whereas new devices may behave nicely in a coexistence scenario, traditional technology does not, and there may be situations where legacy equipment and commons equipment coexist in the same or adjacent frequency bands. For example, short-range low-power devices for mass market commons use (such as wireless routers for residential use) invariably have limited receiver performance, rendering them susceptible to interference from generally higher-power older devices operating in adjacent licensed bands. From a spectrum management point of view, the process of opening a band to commons use would be very difficult to reverse. The same could be said for changes in regulation for the spectrum rights approach, given that there are sunk costs associated with network build out. But, in the case of the commons bands, there is the additional complexity that there is no record of who is using the bands and with what equipment, and therefore it is a challenge to discontinue use other than by the slow process of waiting for the equipment in use to reach the end of their lives (RA 2002). When considering which bands to make available for commons use, the difficulties involved in subsequent re-allocation of the spectrum must be taken into account.

4.3 Scope of Application

The commons approach to spectrum management is more appropriate for certain uses than other. Despite arguments about the ability of spectrum commons to alleviate congestion, congestion across key parts of the spectrum is likely to continue for the foreseeable future. Whereas there are mechanisms to reduce the possibility of congestion in license-exempt bands (e.g., power limits, operating protocols) some argue that the license-exempt approach should be restricted to bands and applications where congestion is unlikely (Cave and Webb 2004). Commons approaches would therefore have advantages for short range communication, in relatively closed spaces (such as offices, hotels, or airports), or where communication density and spectrum use are low. This is likely to be the case, for example, in the rural areas of developing countries.

Moreover, there are some indications that a commons regime may not be as attractive to investors as an exclusive rights system (FCC 2003a) for applications that require fixed investments for network build-out, or whose users require higher reliability and quality of service. In these circumstances operating companies might have trouble attracting capital because of the lack of assurances against future interference or sustainable throughput. Box 4.1 gives an example.

4.4 Building Blocks

One or more of the following four building blocks need to be put in place in order to implement a commons approach to spectrum management: rules for access and use, mechanisms to

Box 4.1 Tanzania: Commercial Services vs. Unlicensed Spectrum Use

An example from Tanzania highlights the possible inadequacy of unlicensed bands when providing commercial services. In contrast to projects devoted to ubiquitous access, commercial wireless deployments focus on delivering services to organizations, typically those with critical international communications needs. Technical solutions must therefore provide solid, 99.5% availability Internet and data connectivity.

CyberTwiga, one of the first Internet service providers in Africa, was founded in 1995. Commercial services, limited to dial-up email traffic carried over a 9.6 Kb/s SITA link (costing over \$4000 per month), began in mid-1996. Frustrated by erratic performance of the local telephone connections used to reach its customers, and buoyed by a successful deployment of a three-node point-to-multipoint (PMP) network for the Tanzania Harbours authority, CyberTwiga negotiated with a local cellular company to place a PMP base station on their central mast. Connecting a handful of corporations to this proprietary 2.4 GHz wireless local access network system in late 1998, CyberTwiga validated the market and its technical capacity to provide wireless services.

As competitors haphazardly deployed unlicensed 2.4 GHz networks, however, two facts emerged: a healthy market for wireless services existed, but a rising radio noise floor in the 2.4 GHz band would undermine network quality. CyberTwiga's chose to merge with the cellular carrier, in mid-2000, including plans for a nationwide wireless network built on the existing cellular infrastructure (towers and transmission links) and exclusive radio spectrum allocation.

Source: Adapted from Limehouse 2006, p. 230

implement rules, measures to enforce compliance with rules, and dispute resolution mechanisms. It is not enough to declare bands open for commons use. License-exempt does not mean unregulated, but the debate over which rules and regulations are needed is open and at early stages. In some countries, the regulatory regime will require exempting some uses or equipment from authorization. In others it will require removing unnecessary restrictions, and setting technical standards to promote and ensure successful spectrum sharing.

Rules for access and use. Given that spectrum is a perfectly renewable and non-exhaustible resource, the only characteristic of the spectrum that could lead to overuse and decline of a spectrum commons is the potential for interference and abuse. Each individual user of the spectrum has an incentive to use more and more power or bandwidth, because the user will receive all the benefits, while bearing few of the costs.

Some rules need to be established to reduce the likelihood of interference and prevent overuse and decline. Although users of commons spectrum have no assurance against interference from other such users, a successful spectrum commons will not be unregulated (Ofcom 2005b). Usage will be restricted by the spectrum authority setting technical parameters to reduce the probability of interference and avoid congestion. Users of commons must comply with

specified technical standards¹¹⁸ and, in some cases, specialized requirements and protocols.¹¹⁹ Over time, rules may need tightening (e.g., if congestion grows) or relaxing (e.g., if new spectrum is available).

For each modality of commons use allowed, technical parameters must be set. This applies to both license-exempt bands and arrangements where license-exempt users coexist with individual spectrum assignments. Arguably, it is both easier and more important to define parameters for the latter. The objective of setting up these parameters is to prevent or minimize interference between two devices potentially using different technologies. In license-exempt bands the parameters may need to be defined in a very general way, because less is known about the technology being used. In bands where license-exempt and individual rights coexist, one of the users' technology is known, and therefore parameters may be easier to set up. It is also more important to get it right, given that, although commons users will generally have no guarantees of interference-free operation, individually authorized users do, and the spectrum authority needs to ensure compliance.¹²⁰

Different rules, for example, on maximum power levels, may be needed for urban and rural areas, as congestion and interference are less likely in the latter, and higher power levels may enable innovative solutions for rural coverage. This may be especially the case in developing countries.¹²¹

Mechanisms to implement rules. Mechanisms are needed to make the rules work and encourage compliance.¹²² While the existence of rules does not ensure that they will be followed, the literature cites many examples of commons that have been employed successfully for centuries (Hardin 1991, Ostrom 1998). Analyzing which mechanisms ensure compliance can help prevent overuse and abuse.

Three types of non-public regulation mechanisms have been proposed to help prevent overuse and decline of the commons, by minimizing or eliminating deviations from the rules: social norms, market solutions, and system architecture (Weiser and Hatfield 2005):

- Social norms may have a significant impact on good behavior in spectrum use. Game theory proposes an explanation: where interaction with other spectrum users is on a regular basis, users will tend to respect collaboration and social norms that address and prevent counterproductive behavior, for fear of retaliation. When distance between users is large, however, or identification of offenders is difficult, social norms are likely to have minimal impact.
- Certification-type solutions could be developed as private sector initiatives. This could be similar to limiting e-mail spam through the use of filtering programs or by black-

¹¹⁸E.g., maximum power restrictions.

¹¹⁹E.g., do not transmit on a particular channel if you detect that it is already in use.

¹²⁰Having said this, efforts to protect the incumbent user from interference should be reasonable and based on likely conditions—i.e., while it is important to protect incumbents, these tend to consider worst case scenarios.

¹²¹Power levels are otherwise limited because of the health risks caused by electromagnetic radiation.

¹²²Tragedy-of-the-commons type concerns are not merely theoretical. Experience with the citizen's band (CB) radio demonstrated how interference caused by unauthorized uses (such as power amplifiers) can undermine a previously popular use of spectrum.

listing Internet service providers that violate codes of practice. Spectrum equivalents are at early stages of development, but could include software that enables different access points to communicate with one another and choose non-conflicting frequencies or adjust their power levels to reduce coverage overlap. Another example is an initiative to develop a scheme for certification of service providers and users, which would in practice amount to transfer the regulatory burden toward equipment certification. Where distance and large numbers are present, or where parties are not easily identified, this approach may not work, as bad actors are not interested in cooperating with a collective solution.

- System architecture can be designed to embed rules of good behavior and limit interference. Equipment certification would ensure that the equipment performs in accordance with these rules.¹²³ The weakness of this approach is that non-compliant equipment can always be designed or modified to circumvent those rules, and it would be impractical to keep such equipment out of the market.¹²⁴ Moreover, limiting equipment supply to follow pre-defined rules embedded in this manner would outright contradict one of the original advantages of spectrum commons, namely, to promote innovation.

Measures to enforce compliance with rules. Whether government or public law and enforcement need to step in to resolve interference and non-compliance problems is a matter under debate. Some authors propose that the mechanisms described above (social norms, market solutions, system architecture), however important, will likely not be sufficient, and public sector intervention will also be needed (Weiser and Hatfield 2005). Others argue that, based on the experience of managing other resources under a commons regime, the success of the management system partly depends on limited law enforcement, with responsibility depending on users and user-managed dispute resolution systems, so as to empower them to solve eventual problems (Buck 2002).

There is a distinction between the situation where interference arises because rules are being violated or because of congestion—i.e., even though the defined technical rules are being followed by users, interference still emerges. If in the former case there may be an enforcement role for the public sector, in the latter the public sector may need to step in to change the established rules, or allocate more spectrum to commons use.

Public intervention would involve either the courts of law to adjudicate tort actions to monitor the use of spectrum commons, or the spectrum authority to develop reactive enforcement measures to non-compliance of established rules for commons management.¹²⁵ In a technologically

¹²³Some of these rules can be very basic, such as power limits. More sophisticated solutions could involve, for example, designing user equipment to gain credits for good behavior, and only be able to transmit when it has a certain number of credits available to spend (Sin 2003).

¹²⁴A related example comes from the history of amateur radio. Power amplifiers sold for licensed amateur radio operation in the 28.0–29.7 MHz band were being used in the adjoining 27 MHz unlicensed CB band at a power level far in excess of that authorized for CB. Equipment manufacturers responded by installing in the amplifiers a patch that prevented them from being tuned as low as 27 MHz. On submitting proof of their license, amateurs received a free kit to remove the patch.

¹²⁵Tort is the legal term that refers to civil wrongs as distinct from criminal wrongs. Common tort actions are negligence, nuisance, and trespass.

Box 4.2 General Principles for Successful Commons Management

1. Clearly defined boundaries—Individuals or households who have the right to withdraw resource units from the commons must be clearly defined, as must the boundaries of the commons itself.
2. Congruence between appropriation and provision rules and local conditions—Appropriation rules restricting time, place, technology, or quantity of resource units are related to local conditions and to provision rules requiring labor, material, or money.
3. Collective-choice arrangements—Most individuals affected by the operational rules can participate in modifying the rules.
4. Monitoring—Monitors, who actively audit the commons conditions and the behavior of the users, are accountable to the users or are users themselves.
5. Graduated sanctions—Users who violate operational rules are likely to be assessed graduated sanctions, depending on the seriousness and context of the offense, by other users, by officials accountable to these users, or by both.
6. Conflict resolution mechanisms—Users and their officials have rapid access to low-cost local arenas to resolve conflicts among users or between users and officials.
7. Minimal recognition of rights to organize—The rights of users to devise their own institutions are not challenged by external governmental authorities.
8. For commons that are parts of larger systems (nested enterprises)—Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises.

Source: Ostrom 1990

dynamic environment, monitoring and testing for compliance could prove a challenge, as rules may not cover all potentially harmful behavior, and the monitoring equipment itself may not be adapted to measure and identify more complex offending behavior (Weiser and Hatfield 2005).

Collective choice arrangements would be an alternative to public sector intervention. Principles drawn from successful commons management in other fields (see Box 4.2) could be applied to the management of a spectrum commons (Buck 2002). These principles seek to empower users, as opposed to public sector entities, as the main actors in ensuring well-functioning of the commons. The public sector's role could therefore be limited to co-managing the commons with the users: "The state . . . assigns and protects group rights, enforces restrictions on group membership, and protects boundaries from incursions by outsiders. That is, the state governs relationships between common property regimes, provides external legitimacy for the group of resource users within regimes, but does not support any particular form of governance within regimes" (Swallow and Bromley 1994). Applied to managing a spectrum commons, this would translate to the spectrum authority being responsible for establishing some basic boundaries and formulating principles for membership of localized spectrum management groups. "For most spectrum uses (i.e., all those frequencies which are not capable of long distance transmission), the local spectrum management group would be the primary source of authority and governance" (Buck 2002). In practice, in developing countries with weak governance, commons arrangements should be decentralized as much as possible.

Dispute resolution mechanisms. Whether government or privately managed, formal or informal, dispute resolution mechanisms need to be in place to deal with interference issues, when they arise. Disputes may arise between two commons users or between a commons user and a user with individual authorization (e.g., under government administration or rights regimes).

Legal action for those who do not follow commons rules should be kept at a minimum. Management should be decentralized as much as possible and in the users' domain. Setting up mediating facilities between users could assist user communities of commons and minimize the cost of dispute resolution. These facilities could also make available basic monitoring equipment such as spectrum analyzers and direction finding devices. Individual users or small operators may have limited access to monitoring equipment that could assist users in identifying sources of interference and of tracing rogue operators. Legal action should be available, however, as a last resort.

In contrast, when a commons user is causing insurmountable interference to a user with individual authorization, the spectrum authority generally has the responsibility to ensure interference protection for the latter. In this case, the individually authorized user should have legal recourse. And all users, whatever the spectrum management regime they are subjected to, should be able to appeal from any decision of the spectrum authority concerning them.

4.5 Implementation

In some respects the transition toward a commons spectrum management regime may be easier than the transition to a tradable rights approach, as it does not involve defining an initial distribution of rights. Nevertheless, a few elements need to be in place, as implied above.

Effectively setting up a spectrum commons approach will require:

- Identifying bands to be allocated for commons use. The likelihood of interference in the commons decreases as more spectrum is allocated. Also, not all bands have the same value or propagation characteristics.¹²⁶ In order to benefit from economies of scale and standards from different parts of the world, developing countries would gain from harmonizing the bands available for commons use.
- Vacating the identified bands and compensating existing users, if appropriate. This is no different from vacating other bands, and has been discussed before (see chapter 2).
- Making any necessary changes in the regulatory and authorizations regime.¹²⁷ Revisions may be needed over time. Sunset clauses would facilitate further revisions later on. Removing bands from commons use, however, would be complicated as the users that need to be displaced are anonymous.
- Defining operating rules to ensure well-functioning of the bands and containing the risk of interference. The authority needs to define some basic rules (e.g., power limits).

¹²⁶Factors influencing whether harmful interference occurs include power, frequency of transmission, equipment compliance with national or international standards, and type of use (Ofcom 2005b).

¹²⁷Many countries use class licenses or general authorizations to comply with their national legislation which may require all spectrum use to be licensed or authorized. In any case, while the effect of a class license is to obviate the need for an individual license, a class license is not the same as no license at all. Class licenses can have a license fee, and can also be amended or revoked.

Different rules may be needed for urban vs. rural areas, especially in developing countries, as congestion is less likely in the latter, and higher power levels may enable innovative solutions for rural coverage.

- Making sure the appropriate institutions are in place to deal with interference and non-compliance and to handle dispute resolution. Management of the commons bands in developing countries should be decentralized as much as possible. The institutions will need to understand the concept of a commons and be willing to relent control. This may require capacity building. Regulators could support user groups that manage the commons bands. This could be done by making available resources such as toolkits for starting a wireless community and providing access to mediating and monitoring equipment. Provisions for legal recourse and appeal also need to be understood and set up.

5 Pulling It All Together: Elements of Spectrum Reform

There is ample opportunity to improve spectrum management in many developing countries. In addition to its inherent limitations, government administration of the spectrum is often poorly implemented. Moreover, both the tradable rights and the commons approach to spectrum management have considerable potential to increase spectrum efficiency, respond to changes in demand and technology, reduce the regulatory burden on users and authorities, limit opportunity for arbitrary intervention and corruption, and improve the investment climate.

Going forward, the right balance among approaches to spectrum management must be found that is best suited to each particular country. This will have to be determined on a case-by-case basis. Nevertheless, some initial guidance can be derived from the features and requirements of each approach examined in terms of the conditions typically prevailing in developing countries. This chapter provides a framework in which to think about the solutions that are best suited for a given country, and proposes a general way to go about it.

5.1 Comparison of the Three Approaches

The three approaches to spectrum management differ considerably, particularly in terms of the balance of rights and responsibilities between government and spectrum users, the extent to which user incentives are aligned with broader public policy, and the constraints and risks of implementation. Table 5.1 summarizes the main features, advantages, and limitations of each approach. Table 5.2 summarizes the scope of application of each approach and under what conditions they are likely to be most effective. A detailed discussion was presented in chapters 2–4 of this paper.

Five categories of building blocks are required to implement any of the three approaches to spectrum management. These blocks deal with allocation, rules, authorization, and enforcement regarding interference and fair competition. Table 5.3 summarizes the scope of each class of building block and its main functions under each approach to spectrum management. Building blocks were discussed in chapters 2–4.

Table 5.1 Summary of Spectrum Management Approaches: Main Features, Advantages, and Limitations			
	Improved Administration	Tradable Rights	Commons
Features	<ul style="list-style-type: none"> • government allocates spectrum among types of uses and establishes conditions of use • within each band, government assigns frequencies to individual users for exclusive or shared use • detailed technical and operating rules and standards prevent harmful interference 	<ul style="list-style-type: none"> • government grants exclusive and transferable rights to individual users to use specific frequencies • rights holders may sell, lease, divide, or aggregate spectrum • rules and rights of use prevent harmful interference 	<ul style="list-style-type: none"> • spectrum is made available to all users • users are subject to minimal technical standards to limit interference • flexible usage rights with little or no restriction on use or technology • no guarantee of interference-free operation
Advantages	<ul style="list-style-type: none"> • mature practice, ample experience on which to draw • proven effective in preventing harmful interference • scope for some improvement over traditional practices 	<ul style="list-style-type: none"> • can correct for inefficient initial assignment and allocation • creates incentives for efficient use • accelerates response to changing technology and demand • enhances transparency and reduces opportunities for corruption • reduces regulatory burden 	<ul style="list-style-type: none"> • encourages use of spectrum-efficient technologies • lowers entry barriers, enhances competition, facilitates innovation • reduces some forms of anticompetitive behavior • reduces regulatory burden
Limitations	<ul style="list-style-type: none"> • increasingly unable to respond to demand growth, changing uses, and new technology • inflexibility and shortages slow down services competition, innovation, and growth • can result in major economic and technical inefficiencies • limited scope for improvement • excessive regulatory burden 	<ul style="list-style-type: none"> • few spectrum buyers and sellers can impede effective market development • high transaction costs can discourage spectrum trades • international agreements limit scope for liberalizing spectrum use • risk of market failures, mainly interference and anticompetitive trading • potential conflict with public policies, mainly fiscal, windfalls, service obligations, industrial 	<ul style="list-style-type: none"> • risk that commons will be overused, resulting in reduced data rates • irreversibility of deregulation • loss of government control over spectrum and related revenues • commons possibly not as attractive for large investments as exclusive rights

Table 5.2 Scope of Application of Different Spectrum Management Regimes			
	Improved administration	Tradable rights	Commons
Useful	<ul style="list-style-type: none"> Traditionally used throughout the radio spectrum 	<ul style="list-style-type: none"> Potentially applicable throughout the radio spectrum 	<ul style="list-style-type: none"> Arguably applicable for significant segments of the radio spectrum
Most effective or uniquely suited	<ul style="list-style-type: none"> Manage spectrum used by government Manage spectrum necessary to accomplish compelling public interest objectives Perform certain government functions that cannot be delegated to markets or users 	<ul style="list-style-type: none"> Best where there is acute spectrum scarcity and low transaction costs of moving spectrum from low to high value uses Good in greenfield situations where there are few existing 	<ul style="list-style-type: none"> Best for bands used for short range communication, in relatively closed spaces, or where spectrum utilization is low Good to try out new services and business models licensees
Least effective or not suitable	<ul style="list-style-type: none"> Least effective in bands where technology or demand change rapidly, or where spectrum enables downstream competition 	<ul style="list-style-type: none"> Not suitable to manage aeronautical and maritime, navigation, ISM and short range, scientific, and amateur and CB bands 	<ul style="list-style-type: none"> Not suitable where the users' business models require legal protection from interference

Table 5.3 Critical Building Blocks of Spectrum Management				
		Main functions		
Building blocks	Outline	Improved administration	Tradable rights	Commons
Allocation	Determines what each frequency band may be used for, and under what conditions	<ul style="list-style-type: none"> Detailed allocation of bands to classes of uses, with conditions of use under each allocation 	<ul style="list-style-type: none"> Establish any limits for changing use of assigned spectrum rights 	<ul style="list-style-type: none"> Make bands available for commons use as needed
Rules	Regulations and procedures that provide the primary tools for day-to-day spectrum management	<ul style="list-style-type: none"> Establish detailed technical standards and operating rules to prevent harmful interference among spectrum users 	<ul style="list-style-type: none"> Define spectrum rights and obligations, mainly regarding interference 	<ul style="list-style-type: none"> Set minimal technical standards (e.g., power limits) to contain interference
Authorization	Process by which users and equipment gain access to the radio spectrum	<ul style="list-style-type: none"> Assign frequencies to individual users for individual or shared use Test and certify radio equipment 	<ul style="list-style-type: none"> Assign spectrum rights initially to individual users 	<ul style="list-style-type: none"> Issue general authorization for use of commons Authorize equipment if needed to embed technical standards
Enforcement: <ul style="list-style-type: none"> interference fair competition 	<p>Deals with interference problems</p> <p>Deals with anticompetitive behavior</p>	<ul style="list-style-type: none"> Monitor and enforce compliance with allocations, rules, and authorizations Ocasionaly revise frequency assignments if needed to contain market power 	<ul style="list-style-type: none"> Resolve disputes on interference among spectrum rights holders Apply general competition law and merger control rules to use and trade of spectrum rights 	

Table 5.4 Support Functions for Spectrum Management					
Support function	Outline	Intensity of use			
		ADM	RGT	COM	
Data	Detailed information on current spectrum use	+++	++	+	
Analysis	Analytical skills, methods, and tools—engineering, economics, legal	+++	++	+	
Administration	Administrative processes and methods to handle routine tasks	+++	+	+	
Monitoring & enforcement	Ensuring compliance with allocations, rules, and authorizations	+++	++	+	
International affairs	Participating in ITU and other organizations on spectrum matters	++	++	++	
ADM	Improved administration				
RGT	Tradable rights				
COM	Commons				

The design of the building blocks depends on the initial focus and balance among approaches chosen, and adjustments may be required along the way to reflect the changing balance. Consider, for example, the different ways in which the risk of interference is managed. Under the administration approach, harmful interference is largely handled *ex ante* as part of the authorization process followed by monitoring and enforcing compliance with detailed technical and operating rules. In a spectrum rights regime, the risk of interference is higher, especially when changes of use are allowed. Addressing interference problems, when they happen, may require assessing whether interference levels (at the geographical and frequency boundaries of the spectrum rights) have been violated, corrective action by the parties themselves, and perhaps formal dispute resolution. In the commons approach, minimal technical rules (e.g., maximum power transmitted) provide some protection against interference levels building up among commoners as a group. But interference-free operation is not assured, and users rely primarily on technologies, protocols, and codes of conduct that themselves reduce the risk of interference among users and handle problems when they arise.

Five support functions are required for the critical building blocks to work well. These support functions provide data, analytical, administrative, monitoring, and international capabilities.¹²⁸ The scope and importance of each of these support functions also vary considerably among approaches to spectrum management. Table 5.4 outlines these support functions and gives an impression of their relative intensity of use under each approach to spectrum management. To some extent the choices among approaches are influenced by their support requirements and the extent to which these can be met under given country conditions. Rights and commons

¹²⁸Support functions are discussed in considerable detail in module 5 of infoDev's online toolkit for ICT regulation (infoDev 2006).

solutions tend to demand less support than administration. For example, government administration requires a comprehensive national database of all frequencies in use, identifying individual users and their locations as well as functions and technical characteristics of the equipment used. Under the spectrum rights approach the main data requirement is limited to a register of all rights owners, kept up to date as these rights are traded. And under the spectrum commons approach, users are anonymous.

5.2 Making the New Approaches Work in Developing Countries

It would be impractical to ask which of the three approaches to spectrum management is likely to work best in developing countries as a group. A single answer could not possibly apply to all. Rather, a case-by-case analysis is needed for specific country responses. This reflects the diversity of features and requirements of each approach. Also, developing countries comprise a heterogeneous group exhibiting wide variation of relevant physical and economic characteristics, critical spectrum issues driving change, and extent to which country conditions are conducive to effective implementation. In particular, the extent and pace at which spectrum management can be reformed in practice will be constrained by country governance and institutional capabilities, vested interests in the *status quo*, and willingness to use the necessary political capital.

Developing countries typically exhibit one or more features that are likely to influence the design of spectrum reform strategies:

- *Low income.* Small markets relative to population size. Large rural and low-income urban population. Modern sectors demanding advanced services coexist with a traditional economy. Relatively undeveloped private sector. Limited supply of skilled workers and professionals. Most technology and equipment imported. Shortage of investment capital.¹²⁹
- *Small base.* Incomplete infrastructure networks. Little or no service in rural areas. Few players despite liberalization. Important market segments still closed to competition.
- *Fast growth.* Substantial unmet demand for communication and information services. Rapid growth of wireless technologies by new entrants and incumbents, initially driven by mobile services.
- *Weak governance.* Limited tradition of rule of law. Weak enforcement. Ineffective or non-existent general competition law and merger controls. Slow and ineffective public administration. Overloaded and politicized judiciary. Government interference in regulatory affairs. Regulatory and policy capture by incumbents. Corruption.
- *High risk.* Regulatory uncertainty and often poor track record. Political risk and instability.¹³⁰ Large commercial risk rolling out new services.
- *Constrained fiscal space.* Spectrum and other fees are important sources of public revenue.

¹²⁹Income is the basis for defining development. Income is also highly correlated with education, occupation, and other social and economic indicators. The World Bank classifies all countries by *per capita* gross national income into high, upper-middle, lower-middle, and low income countries. The term *developing country* is used to refer collectively to countries in the last three categories.

¹³⁰Includes risk of expropriation of assets or profits through arbitrary taxation, exchange rates, restrictions on repatriation of profits, and other changes of the rules of the game.

Not all these features are present in every developing country. But as we examined current trends in spectrum management, largely originated in the developed world, we kept in mind these potential limitations. We now look more closely and note some implications and concerns that need to be taken into account when designing spectrum reform in an individual developing country.

Relevance for Developing Countries

The spectrum management issues typically found in low- and middle-income countries can be quite different from those that drive reforms in high-income countries. Developing countries may have a shortage of spectrum demand rather than of supply. Small markets with potential for fast growth, large areas without service, incomplete infrastructures, administrative restrictions on entry, and capital shortages all denote spectrum underutilization. Spectrum scarcity is often confined to certain services (especially mobile) and locales (business districts of large cities).¹³¹ Difficulty accessing spectrum, poor administration, high prices, corruption, and insufficient protection from interference may be more pressing problems than spectrum scarcity. Most developing countries are technology adopters rather than creators. In contrast, widespread spectrum shortages, inflexible use restricting innovation in services and technology, and inefficient allocation among uses, are common in high-income countries.

Does it make sense to adopt similar solutions to spectrum management in both environments? The tentative answer is affirmative. Given the rather wide range of issues and conditions prevailing in developing countries, it can be expected that elements of all three approaches will often find their way into individual country strategies. For example, spectrum congestion in dense urban areas coupled to extensive unserved rural areas suggest a combination of rights and commons. Also, given the diverse ways in which the various approaches to spectrum management can improve on traditional practice, it is unlikely that any one approach would be ruled out *ex ante*. For example, the tradable rights approach is a particularly effective tool to deal with acute spectrum scarcity. Yet it could also be the preferred solution even when spectrum congestion is not yet a pressing issue. In the absence of spectrum scarcity, the merit of a tradable spectrum rights regime is not so much in terms of efficient reassignment and reallocation of spectrum now but rather in removing barriers to entry, reducing the regulatory burden on both government and spectrum users, limiting the opportunity for corruption, and establishing a foundation for efficient spectrum use as it becomes scarcer in the future. Also, where there are no acute shortages, spectrum will not command high prices and introducing a rights regime will not lead to immediate windfall gains of existing licensees, which would facilitate the transition. The ultimate question of how to strike a balance among solutions and move forward effectively will be addressed in section 5.3 below.

Are there specific ways in which new spectrum management solutions should be adapted for use in developing countries? Indeed, for the conditions under which they would be imple-

¹³¹For example, in India an extensive revision of spectrum policy has been driven by insufficient availability of spectrum for expanding mobile services, while at the time in rural areas there is little use of wireless technology to overcome large service shortages.

mented are likely to be significantly different from those underlying their design. Second-best solutions, that would be less than optimal in more mature economies, can help overcome constraints on the viability or effectiveness of these approaches in developing countries. Making a tradable rights work in the absence of a strong culture of rule of law is a matter of concern for many analysts. We discuss this subject below to offer specific suggestions as well as an example of how less than ideal conditions can be dealt with. Two other subjects, namely, market limitations and fiscal impact, are briefly outlined.

Rule of Law

All three approaches to spectrum management are predicated on a strong tradition of rule of law and public administration, ability to undertake commitments that endure from one government to the next, and a judiciary that is impartial, immune to government and political pressures, and able to make enforceable decisions (Levy and Spiller 1996). The absence of a strong rules culture, as is the case in many developing countries, may complicate the implementation of both the tradable rights and the commons approaches. For those countries where abiding by regulations is not a deeply ingrained habit, introducing more flexibility may simply introduce more chaos than currently exists. In such conditions, is any one approach to spectrum management better than the others? What can be done to make them work?

Whether one approach to spectrum management will eventually prove to be clearly superior is as uncertain in developing countries as in more mature economies, but arguably any of the three can be made to work under less than ideal conditions. For example, compared with government administration, the tradable rights approach is more transparent and relies less on discretionary decisions by civil servants, thus being less prone to interference and corruption. It is also simpler and less costly to run once established, and it places less demands on scarce professional skills. But it would perform best in the context of an effective general competition law to which instances of anti-competitive spectrum trading could be referred once they occur, and of merger controls that would prevent the build-up of spectrum market power.

In the absence of effective general competition law, responsibility for enforcing fair competition in spectrum trade can be placed on sectoral regulators (telecommunications, broadcasting), the spectrum authority, or commerce law.¹³³ Simple *ex-ante* rules, such as limiting the amount of spectrum in a single hand, which would only be second-best in other legal environments, can be

¹³²Spectrum competition rules, including principles as well as specific practices that are prohibited, can be written into sector laws (telecommunications, broadcasting) and incorporated in spectrum rules and tradable rights. This is similar to mitigating regulatory risk in the telecommunications sector by writing the rights and obligations of an operator or class of operators into sector laws, licenses, and contracts (such as for the sale of a state enterprise) (Smith and Wellenius, 1999).

¹³³For example, spectrum hoarding can be prevented by setting quantitative limits to spectrum ownership, albeit at the cost of impeding legitimate long-term investment in spectrum. In the US the former FCC spectrum cap, while far from perfect, provided a simple screen for excessive concentration of spectrum highly suited to mobile services (cellular, PCS). It provided some certainty for bidders in the PCS auctions about how much spectrum they would be allowed to win.

adopted to restrict specific anti-competitive practices.¹³⁴ The incentive and opportunity for hoarding and other anti-competitive spectrum trades can be reduced by both placing all available spectrum on the market and allowing changes of use.¹³⁵

A spectrum commons may be less dependent on the rule of law than a tradable spectrum rights regime. Moreover, to some extent technology itself can help overcome breaches of the commons rules.¹³⁶ Yet also the commons will work best in a rules-based culture, just as the Internet polices itself through strong expectations about user behavior. In either case, delegating dispute resolution (e.g., on interference) to private parties may be difficult where the basic rule of law is fragile.

Market Limitations

To the extent that spectrum scarcity in developing countries is limited to some services and locales, the question arises as to whether a vibrant spectrum rights market can develop. Few spectrum buyers, sellers, and offerings would result in non-performing spectrum markets. Low spectrum prices, reflecting limited scarcity, would reduce the incentive to trade. Few transactions would limit economic and technical efficiency gains. Market power in the provision of downstream services would encourage anti-competitive spectrum trades. Whether all this more than offsets other benefits from the spectrum rights approach, some of which may be especially valuable in developing countries (e.g., reducing opportunity for corruption, lessening dependence on government intervention), needs to be assessed case by case.

Achieving more competition in the downstream markets (e.g., telecommunications services, networks) before or together with introducing a tradable spectrum rights regime would open the way to a more effective emerging spectrum market. The demand for spectrum would rise, the number of transactions increase, and incentives and opportunities for anti-competitive trades decrease. Removing impediments to effective competition in the downstream markets is also a proven measure to improve telecommunications sector performance overall. Constraints on growth and innovation of wireless services are especially relevant.

Fiscal Impact

Any proposal to reform how the spectrum is managed must examine its fiscal impact and include measures to offset revenue reductions, even if temporary. Spectrum licenses and fees are important sources of public funds used as general revenue, to finance the cost of spectrum and sector regulation, and occasionally earmarked to finance specific social programs (e.g., universal service in some Latin American countries). In the long-run spectrum reforms are

¹³⁴This alone may not suffice to prevent spectrum hoarding. Even if all spectrum were to be placed in the market, the attractive portions are a small subset, at least until new technological innovation brings value to the rest. Because of the way technology and spectrum regulation has evolved in the past, the most valuable parts of the spectrum are rather small (e.g., those used for mobile services). Also, propagation characteristics limit what bands are technically usable for specific purposes.

¹³⁵Modern equipment has the potential to overcome violations of some rules of a spectrum commons, such as power limits, at least in short-range applications (Rose 2005).

likely to increase fiscal revenue, as overall business volume and efficiency grow. There may, however, be short-term fiscal losses, which need to be addressed at the time these reforms are designed. And the increased revenues will largely flow beyond the reach of the spectrum and regulatory authorities that now channel and to some extent capture them. Loss of financial and political control may be significant factors in the political economy of spectrum reform.

Making a rapid transition from administration to rights and commons by placing all spectrum in the market in one fell swoop (Kwerel and Williams 2002) would initially provide large windfall revenues to the government, but reduced streams in the future. Unlicensed spectrum would clearly reduce direct revenues from a particular band, so implementation may be a hard sell in developing countries. Some analysts are concerned that reallocating spectrum for commons use would forego their contribution to defraying the costs of regulation and spectrum management, since users would be anonymous. In practice, however, for the foreseeable future only a small fraction of the total spectrum is likely to be allocated to commons. The bulk of users would come under the rights regime or remain subject to government administration. Under these two approaches, the issue is not whether regulatory costs can be recovered, but what is a fair and efficient way of doing it.

5.3 Striking the Right Balance and Moving Forward

The direction of change is clear: the responsibility for managing the radio spectrum is moving away from the government and toward markets and users.¹³⁶ But the end state is uncertain. The way ahead for developing countries may well comprise trying out new ideas in a scale large enough to obtain significant results, yet without committing exclusively to one or another solution (Benkler 1998). The debate on spectrum reform is still far from settled. Neither rights nor commons alone appear well-suited to manage the whole spectrum. Practical solutions are combining all three approaches, and the boundaries among these are becoming less distinct.¹³⁷ Experience implementing new solutions is still limited and found mostly in high-income countries. The market and technology changes that drive and shape spectrum reform show no signs of abating. Rather than looking for the best single model, the likely path of reform will combine the three approaches and find ways to adapt them to individual country conditions.

In most realistic scenarios for migrating from spectrum administration to rights and commons, government administration will continue to play a significant, if declining, role. This recognizes the existence of large vested interests and sunken costs associated with the outcomes of each approach, and the fact that reform will be constrained by institutional capability and country governance. Some extent of government intervention will also remain necessary, at least for the foreseeable future, to reconcile diverse public policy objectives, deal with market imperfections, and ensure that international obligations are respected.

¹³⁶This is starting to follow, belatedly, the same general direction taken from the 1980s by ownership and operation of the information infrastructure overall: from mostly state-owned monopolies to private-led, increasingly competitive markets. In a way, the radio spectrum is the last frontier of telecommunications sector reform.

¹³⁷For example, market tools (e.g., auctions, administrative incentive pricing) are used in the context of traditional government administration (see chapter 2) and spectrum rights with easements resemble some of the features of a commons (see chapter 3).

Spectrum management reforms should be tailored to individual countries. No generally applicable models can be prescribed at this time. Possibly a standard menu of issues and solutions will emerge gradually with experience, as it did with telecommunications sector reforms from the late 1980s.¹³⁸ Below we outline three of the many options that could be considered in a particular country.

Option 1: Do nothing. Both the rights and commons solutions are simpler and more cost-effective than government administration. Therefore, doing nothing would be a lost opportunity to improve spectrum usage and service delivery. That is probably true even if there were no spectrum scarcity and no shortage of services. The pace of change will depend on the country, the perceived problems with the current regime, and the market structure.

Option 2: Move as fast as possible. Whenever country conditions permit, it is preferable to move quickly. The benefits from spectrum management reform are likely to be largest when an aggressive agenda is pursued. For example, the rights approach will yield the greatest economic efficiency gains and least risk of anti-competitive behavior if all spectrum is placed on the market at once and at the same time restrictions on use and technology are lifted (Kwerel and Williams 2002).

Radical solutions may be easiest to implement when spectrum management is least developed. In greenfield situations, such as at the very early stages of telecommunications sector reform and in post-conflict countries, jumping ahead to market- and technology-driven solutions may be the best route from the start. Rapid deployment is easiest when there are rather few existing licenses that need case-by-case conversion. That was the case of Guatemala, which in 1996 established a tradable spectrum rights regime that applied immediately to all spectrum other than that reserved for government and amateur uses. This was done at the same time as the sole (state owned) operator was privatized and a liberal entry and competition regime was created for the supply of networks and services. While spectrum ownership remained with the state as required by the constitution, spectrum usage rights were issued on demand. Auctions were used to assign the rights when demand exceeded supply. By 2002 a total of over 5,000 rights titles had been issued, of which about 20 percent had been traded and others had been leased or used as collateral for bank loans (Ibarguen 2004). Jumping all the way ahead to industry self-regulation has occurred *de facto* when operators moved into a regulatory vacuum in post-conflict countries, such as in Somalia and Cambodia.

But the opportunity to leapfrog is often accompanied by weak governance. And it is in these countries that we know the least about how to make structural changes work. The example of Guatemala suggests that reliance on legislation and simple contracts, giving minimal discretion to the regulators, can work well enough. A closer look may be warranted, and experience in other countries will help understand better the relative merits of moving quickly.

¹³⁸By 1995 the World Bank had a well established sector reform practice that, after being presented to the Board of Directors, was summarized in a single sheet of paper printed on both sides—Operational Policy Note OP 4.50 of May, 1995. This practice had been essentially in place from the early 1990s and lasted unchanged well into the early 2000s. Spectrum management reform, a latecomer in the global movement from governments to markets, is nowhere near that end state.

In this context, spectrum reforms in developing countries could move simultaneously along the following broad directions:

- Carry out an audit of spectrum allocation and use, and identify priority spectrum issues that need to be addressed
- Establish a regime of tradable spectrum rights and deploy it as fast as possible in all spectrum segments for which it is likely to be suitable
- Gradually develop a spectrum commons, on demand
- Refocus government administration on
 - spectrum segments where rights and commons are unlikely to work well
 - government functions that cannot be delegated to markets or users
 - improving administrative performance
 - improving dispute prevention and resolution mechanisms to deal with interference and non-compliance
 - monitoring
 - reassessment of needs and management regimes

Option 3: Improve piecemeal at the margins. A third alternative is piecemeal change in the desired longer-term directions. This involves seeking opportunities to put in place elements of a new spectrum management regime by addressing specific problems following a consistent set of principles. New solutions are likely to be tried first in situations on which there is experience elsewhere and the risks are low, or where risks are higher but payoff in terms of economic or social benefits is large. Priority should be given to steps with potential to trigger or enable broader changes.¹³⁹ These piecemeal changes can be designed to gradually add up to a framework for spectrum management that is robust to market and technology changes.

This more gradual transition may be preferred in mature markets where much or all of the spectrum has already been assigned and there is an established tradition of government administration. Where a substantial body of government administration is already in place, emphasis can be given to simplifying and paring it down to the bare essence, improving the performance of remaining functions, and relying increasingly on market- and technology-driven solutions to handle growth and innovation. The Spectrum Framework Review published in the UK in 2005 foresees that by 2010 around 71 percent of the spectrum will be managed through market mechanisms (Ofcom 2005b). A gradual transition reduces disruption and enables users as well as the authorities to learn by doing, but limits the benefits from trading and liberalization, enables incumbents to delay change, and may create opportunities for interference and corruption especially in the context of weak governance.

The following are examples of piecemeal steps in spectrum reform that meet several of the criteria indicated above:

- *Remove restrictions on current spectrum use.* Flexibility in using existing spectrum assets, rather than access to new spectrum, may be what operators urgently need to

¹³⁹In a different context, licensing a major private-sector competitor to Morocco's state-owned incumbent telecommunications operator accelerated sector development well beyond the scope of the new license and created incentives for privatizing the incumbent (Wellenius and Rossotto 1999)

accelerate investment and introduce new services. Addressing the specific concerns of a major current spectrum user may also usher in wider liberalization of spectrum use.

- *Release spectrum held back by the authorities.* All unused spectrum, including government and military, could be made available immediately by issuing tradable spectrum rights without restrictions on use or technology beyond those strictly necessary to comply with international commitments. In addition to making better use of spectrum, this step can put in place the foundation of a spectrum rights regime that can be extended later to current users.
- *Bring market discipline to public sector spectrum use.* Where this cannot be done all at once, a step-wise approach can be followed (see again Box 2.1). This can start with undertaking an inventory and valuation of spectrum currently in public sector hands, and eventually lead to public sector entities participating fully in spectrum markets.
- *Introduce market tools in government administration.* Use auctions to assign scarce spectrum or place new or recovered spectrum on an emerging spectrum market. Price some public sector uses of the spectrum as a first step toward full integration of public and private users in a spectrum market.
- *Open up bands for unlicensed use.* While responding to immediate interests of manufacturers and local entrepreneurs, the rules created for initial unlicensed use can set the framework for further development of a commons regime.

Several issues may need to be addressed during the transition from government administration to a flexible regime combining administration, rights, and commons. Important questions arise especially regarding how to handle existing spectrum users and service obligations, fiscal impact, and windfall gains and losses. How these issues are resolved affects directly the balance among winners and losers and may be critical in managing the process of change.

For example, Box 5.1 suggests a way to set and apply interference thresholds when introducing tradable spectrum rights in a government administration environment where a significant proportion of rights will be granted for new or recovered spectrum (as distinct from rights of incumbent users) and the responsibility for managing interference will be placed primarily on the users (rather than the authorities). This may be a useful approach in countries with only moderate spectrum utilization and weak governance.¹⁴⁰

Whatever the initial boundaries among the different approaches, implementation will need to be monitored and revised over time. Going forward, spectrum management reform must respond to the effectiveness of the different solution elements in promoting economic and technical spectrum efficiency and in meeting market and community demands. It must also respond to new opportunities brought about by technological innovation and the evolution of the debate on spectrum management at international level.

A stable and predictable spectrum regime is, however, essential to create and maintain a favorable investment climate. Investors need to be convinced that the rules of the game under which they invest can be relied upon. In particular, they need to be confident that their investments are safe from *de facto* expropriation through arbitrary changes in prices, taxes, and service

¹⁴⁰Also see Ofcom 2006 for a careful attempt to define spectrum property rights that provide both flexibility of use and a high level of protection against actual interference.

Box 5.1 Setting Interference Thresholds for Moderate Spectrum Utilization under Weak Governance—A Hypothetical Model

- New tradable rights for spectrum use would be issued with defined default interference thresholds. These thresholds would be the maximum signal strengths that the spectrum rights user may impose on other users outside the frequency, space, and time domains for which the rights are granted and, in turn, that other users may impose on it.¹ Default interference thresholds would be set at levels that appear to be practical for the range of technologies in use or foreseen.² In-band power limits would also be set to prevent interference to receivers in adjacent bands.
- Interference levels that exceed the default thresholds could be agreed among parties. Interference levels would thus ultimately be set by the market. More critical than the precise level of the default interference threshold is defining interference rights and obligations clearly from the outset so a spectrum market can develop.
- The interference rights of incumbent spectrum users would be grandfathered. Incumbents would be allowed to cause interference to other users in excess of the default thresholds to the extent this is authorized under the existing rights. Likewise, incumbents would be protected from interference caused by new rights holders to the extent provided under the existing rights.³
- Grandfathered rights would revert to new rights with default thresholds when the existing rights are traded or otherwise modified.⁴ Rights for which increased thresholds are negotiated would also revert to the default threshold when traded.
- Users would monitor levels of interference. Determining whether interference thresholds have been exceeded would be referred to independent parties.
- All spectrum rights would include an obligation to negotiate interference management arrangements with other spectrum users in good faith as well as rules and incentives for negotiation.
- Unresolved disputes on interference would be referred to a dispute resolution mechanism within prescribed time frames. Ultimate responsibility for enforcement would rest with the spectrum authority.⁵

¹Field strength is usually defined in terms of both (a) maximum level at the boundary of the coverage area, to protect geographically adjacent users of the same frequencies, and (b) maximum level of out-of-band emissions, to protect users of adjacent frequencies in the same geographical area. It has been proposed that spectrum users need not be prohibited from exceeding thresholds provided that does not infringe on other users' rights, but would have to bring their transmissions into line with interference thresholds when other spectrum users come within their range (Spiller et al. 1999).

²In a sense, this means the default thresholds are not strictly technology-neutral. Different default thresholds could be set for different bands. This approach has been used in Australia.

³It may well be that existing spectrum users exceed default thresholds since their obligations regarding interference were designed with particular technologies and uses in mind. Incumbents may opt to exchange their existing rights for new rights with default interference thresholds.

⁴Perhaps simple trading (i.e., change in ownership only) might not require reverting to the new thresholds, since pure trading does not change the existing interference pattern.

⁵But the spectrum authority would not adjudicate the dispute. This reduces the risk of agency capture by entrenched incumbents.

obligations. Any changes in the rules of the game in response to changing circumstances must bear in mind that investors have sunk costs associated with specific designs and uses of a given spectrum band. Changing rules too often will endanger the investments and discourage growth and innovation in the long run.

The ability to change spectrum use and the rules governing use will be linked to the useful life of the particular technology involved. Policy makers should allow a reasonable time for returns on past investments to materialize before changing the rules of the game. Technology evolution will determine obsolescence of a given technology. The right time to change the rules will probably be somewhere in between. Transparent periodic market assessments with forward looking revisions, consultation, and notices of change would enhance investor confidence.

5.4 Institutional Considerations

All critical building blocks and support functions outlined above (section 5.1) are needed, in one form or another, for effective management of the radio spectrum. But there is considerable latitude as to whether these blocks and functions should be located in the government proper, in one or more spectrum authorities, or in the industry. Spectrum management can be undertaken directly by government as part of a ministry or by an independent regulator operating under a legislative mandate or policy guidelines. The spectrum can also be managed by industry on a self-regulating basis or be assigned to private parties such as band managers under a spectrum rights approach. The preferred solutions are likely to be highly country-specific. The following are some considerations to bear in mind.

There is no economic reason why the radio spectrum should be treated differently from any other economic asset. The long-term aim, therefore, should be for governments to get out of the business of managing the spectrum. From this viewpoint, whenever along the way there is a choice of institutional location of spectrum management functions, the default should be to move them closer to the industry and users themselves. Nonetheless, it will be the government's responsibility to articulate and mainstream spectrum policies into telecommunications and broadcasting reforms, decide on the right balance among approaches to spectrum management, ensure that the needed building blocks and support functions are in place somewhere, resolve the transition issues, and oversee progress and further changes.

In deciding on the institutional structure¹⁴¹ for spectrum management, the following considerations are relevant (Alden 2004):

- A strong case can be made for consolidating all spectrum management functions in a single organization. This is a powerful way to concentrate expertise, perpetuate institutional memory, and provide continuity between policy, rule-making, and enforcement. There are several options regarding placement of the spectrum organization relative to

¹⁴¹Institutional structure refers to the ensemble of government departments or ministries and agencies that are responsible for setting rules governing spectrum use and issuing authorizations to access the spectrum.

government and other regulatory authorities.¹⁴² Having said this, institutional diversity typically is more conducive to change than a centralized system.

- Where the risk of regulatory capture is high (as is likely to be the case in some developing markets), it may make more sense to ensure the spectrum managers are part of a stronger government institution, perhaps in the industry or finance department (recognizing the risks associated with the latter).
- An institutional mechanism is needed to balance a wide range of stakeholder interests. These include commercial interests, some of which have a direct bearing on meeting development objectives (e.g., universal service), as well as those of national defense, public safety, research, and others. All must be represented in major decisions about what to do with the country's spectrum.¹⁴³ A mechanism is also needed for parties to appeal decisions and ensure a balance between commercial and public interests.
- Capacity building is a critical factor of success. Spectrum management solutions will be largely ineffective if there are insufficient trained and experienced engineers, economists, lawyers, and administrative staff to handle core spectrum management tasks. In most cases, organizational and staffing changes in existing institutions will be required to shift emphasis from technical matters to economics and markets. Human resources must be supported by technical facilities, such as information technology for analytical and administrative functions and equipment to monitor spectrum use. Investment in equipment, however, should be modest and consistent with functional priorities.
- Transparency and due process are of the essence. Spectrum management should be carried out in plain view, with inputs from all stakeholders and the public at large. The spectrum authority should be governed by requirements to publish its work in draft and final form, and to solicit comments from concerned parties before its policies and plans are finalized.¹⁴⁴

Whatever the approach to spectrum management, the institutional structure must reconcile the interests of a large number of stakeholders, allow for appealing to decisions on how the spectrum is used, and maintaining a balance between public and commercial uses of the spectrum. Consultation with stakeholders is essential in virtually every aspect of spectrum management,

¹⁴²In Mexico, for example, all spectrum management responsibilities are vested in Comisión Federal de Telecomunicaciones (COFETEL), the telecommunications regulatory authority, which reports to the Ministry of Communication and Transport. The Office of Communications (Ofcom) in the UK is the independent regulator and competition authority for the UK communications industries, with responsibilities across television, radio, telecommunications, and wireless communications services. Ofcom was created from the previously separate telecommunications regulatory authority (OFTEL), the Radiocommunications Agency, the Radio Authority, the Broadcasting Standards Commission, and the Independent Television Commission. It is accountable to Parliament through various Parliamentary Committees and the National Audit Office.

¹⁴³In Morocco, for example, spectrum planning and allocation is directed by an administrative council drawn from several ministries, including finance and defense.

¹⁴⁴For example, Singapore's Infocomm Development Agency (IDA), as a general practice, holds public consultations in its deliberations of major policy issues or regulatory documents. In 2003 it released a consultation document on third-generation mobile virtual network operators, a key issue for upcoming 3G mobile service rollout. In issuing an invitation for comments, IDA noted that it intended to publish all comments on its web site.

including development of legislation and regulations, spectrum policies, and technical standards. While it is not always practical to consult individual spectrum users, often extensive consultations can take place with associations or bodies representing groups of users. In order to facilitate consultation on important issues, the spectrum authority should make its proposals public. Sometimes several options may be presented, inviting comment on them. Comments may be published so interested parties can respond to these as well. Increasingly the Internet is used for dissemination of proposals and comments. Deadlines should be set to receive comments. In all consultations, transparency and fairness are paramount.¹⁴⁵

Measures to mitigate regulatory risk in general can help the spectrum authority discharge its responsibilities effectively (Smith and Wellenius 1999):

- Reduce the need for agency decisions. Delegate spectrum management responsibilities to the industry as far as possible. Focus own efforts on major users. Rely increasingly on general competition law and enforcement as it becomes established.
- Enhance agency credibility. Adopt transparent processes that add credibility, legitimizes decisions, and helps keep vested interests at bay. Use public consultation to draw on stakeholder knowledge and educate politicians and the public. Commit to widely accepted principles and practices through international agreements, including the ITU and WTO.
- Use resources effectively. Outsource all functions that can be carried out by other entities, including user associations and private companies. Adopt alternative dispute resolution mechanisms to remove the agency from the process while retaining its ultimate responsibility for enforcement.

5.5 Managing the Transition: How to Go About It

Going forward, it will be necessary to find the right balance that is best suited to each particular country. Ultimately, this will have to be done on a case-by-case basis. Table 5.5 proposes a framework for developing a country's spectrum strategy in four phases: identify possible areas of improvement, develop strategic options, set up a consultation process, and implement priority actions. Preparing an inventory of existing spectrum assignments and use may be necessary at the start, as is identification of priority spectrum problems that need to be addressed (upper left hand corner of the table). The different activities proposed can involve substantial work, and therefore it may be advisable to stagger the components of reform along time. For example, at the end of phase I (identify possible areas for improvement) or at the beginning of phase II (develop strategic options), countries could choose to focus on some clusters of work (improving use of public sector spectrum) and defer others (assessing the scope for tradable rights)¹⁴⁶ to a later stage.

¹⁴⁵For further discussion of consultation and other established good practices of spectrum management, see the modules on authorization and on spectrum management in the online toolkit for ICT regulation developed by infoDev and the ITU.

¹⁴⁶For example, table 3.2 provides a framework for assessing the potential of tradable spectrum rights by examining each category of spectrum use (e.g., fixed links, terrestrial broadcasting, public mobile radio) in terms of existing rights and likely transaction costs, international commitments, risk of market failures, and conflicts with public policy. This activity would be under phase II (develop strategic options) and cluster V (use of tradable spectrum rights).

Table 5.5 Possible Structure of Spectrum management Reform Analysis and Design						
Clusters						
Phases	I. Current framework for spectrum management	II. Institutional setup in place	III. Piecemeal improvements of current spectrum regime	IV. Improving use of public sector spectrum	V. Use of tradable spectrum rights	VI. Use of spectrum commons
I. Identify possible areas of improvement. Scope and assess what needs to be done.	<ul style="list-style-type: none"> Inventory of how spectrum is currently being used Review of current spectrum management framework and spectrum management methods used in given country Identification of the main issues being faced (e.g., congestion/scarcity, not able to recover costs of regulation, do not have the right expertise, etc.) 	<ul style="list-style-type: none"> What is the current institutional framework? What competencies and expertise are available, what are the shortages? What spectrum monitoring facilities are available? 	<ul style="list-style-type: none"> What are the potential problems with the current administration regime (e.g., absence of pricing, auctions)? What are the challenges? 	<ul style="list-style-type: none"> How much spectrum is held by government? How is it allocated? Are there any mechanisms to ensure some discipline in spectrum use and incentives for optimization? 	<ul style="list-style-type: none"> Are any market trading mechanisms being used? 	<ul style="list-style-type: none"> Is there any unlicensed spectrum? How much? What are the current restrictions, and how is it being used?
II. Develop strategic options Develop a set of strategic options for the government on areas of improvement identified in Phase I. Agree on initial government position as input for consultation process.	<ul style="list-style-type: none"> What could be proposed as an overall action plan to improve spectrum management and resolve bottlenecks (identified in Phase I)? What are the areas that could be reformed? Introduce tradable rights and common? What is the right balance among these approaches? Choose some clusters for further work and consultation. 	<ul style="list-style-type: none"> What institutional framework could be proposed? What would need to happen to ensure the spectrum authority has the right tools and expertise? 	<ul style="list-style-type: none"> What mechanisms could be proposed to ensure spectrum is held by whoever values it most? How could spectrum pricing and auctions be designed? What restrictions could be easily removed to make the system more efficient and allow for easier exit and entry (otherwise pricing is just taxing)? 	<ul style="list-style-type: none"> What could be proposed to promote more efficient use: spectrum pricing applied to public sector, lease of public sector spectrum to private sector. 	<ul style="list-style-type: none"> What type of property rights could be defined? Does the government want to have any kind of property rights? 	<ul style="list-style-type: none"> How to deal with new technologies such as WiFi and WiMax, how to facilitate innovation in wireless markets? What would be the approach for spectrum commons or license-exempt bands? Does the government want to have commons?

continued

Table 5.5 Continued						
Clusters						
Phases	I. Current framework for spectrum management	II. Institutional setup in place Tools, equipment, building blocks, competencies	III. Piecemeal improvements of current spectrum regime Use of market tools (e.g., pricing, 3G auctions)	IV. Improving use of public sector spectrum Imposing discipline on public sector use	V. Use of tradable spectrum rights	VI. Use of spectrum commons License-exempt spectrum, commons (e.g., WiMax)
III. Set up a consultation process.	<ul style="list-style-type: none"> Develop consultations on specific areas chosen from the clusters identified in Phase II, or as appropriate. Consultation papers would include background for the “problem,” initial government position, areas in which government seeks input. Consultant would draft documents, assist in the consultation process, and help government summarize received views. 					
IV. Implement priority actions. Formulate government policy and action plan, taking into account output of consultation. Implement plan.	<ul style="list-style-type: none"> Formulate government policy for spectrum management framework. Formulate an action plan with priorities. 	<ul style="list-style-type: none"> Design training plan for spectrum authority. Identify needs for equipment, and undertake procurement as needed. 	<ul style="list-style-type: none"> Implement recommendations. 	<ul style="list-style-type: none"> Implement recommendations. 	<ul style="list-style-type: none"> Implement recommendations. 	<ul style="list-style-type: none"> Implement recommendations.

Any changes to the current spectrum management regimes should be accompanied by consultation. This will allow the different stakeholders to express their views, help preclude unanticipated consequences of the reforms, and promote a participatory reform program. Periodic reviews of the reform process are advisable.

5.6 High Visibility Challenges

This paper has discussed the administration, rights, and commons approaches to managing the radio spectrum, and has proposed elements of spectrum reform. While the discussion has centered on an overall reform agenda and on exploring options for sound management, governments and spectrum authorities are faced with specific challenges commanding high visibility. Examples are broadcasting and the transition to digital television, mobile telephony and the path to 3G, launching WiMax and related technologies, and releasing military spectrum. Annex I outlines these themes and the issues they raise.

High-visibility themes such as these sometimes not only raise issues that can be addressed in the context of spectrum reforms, but also may trigger such reforms. For example, the advent of 3G, WiFi, or digital TV can precipitate the debate on spectrum allocation, flexibility of use, the merits of license-exempt bands, and other topics that are at the core of each approach to spectrum management.

But a first examination of these big themes suggests that they are driven primarily by narrow yet influential interests of relatively small segments of the economy. Some of the issues result from the spectrum regime itself rather than from global technology and markets changes. And the outcomes are decided primarily in political rather than technical or economic terms. Thus, while big themes involving the spectrum should be properly informed by technical and economic analysis from a spectrum viewpoint, and the outcomes can have major implications on spectrum management, spectrum users, and the public at large, the big themes themselves are of limited interest for figuring out how a country should go about managing the spectrum.

6 Conclusion

Moving spectrum management closer to markets and users is long overdue. Spectrum management is, in a sense, the last frontier of the telecommunications sector reforms that the World Bank and other development organizations have been promoting and supporting for two decades. Whereas state monopolies have by now largely given way to private-led, increasingly competitive market structures, the spectrum, a key resource, remains firmly in the hands of governments. Well-managed spectrum has become critical for developing mobile services, broadcasting, and broadband access. Incumbents and new entrants increasingly resort to wireless technologies to modernize and expand their facilities. Only tinkering at the margin with existing spectrum management practice is no longer sufficient.

There is ample opportunity to improve spectrum management in developing countries. Initially this can be done by adapting practices being proposed and tried in mature markets. In turn, as spectrum reforms take hold, the developing world is likely to become itself a major source of replicable experiences. Examining various approaches to better spectrum management has shed considerable light on their merits and limitations and on how they can be applied in developing countries. But this provides only preliminary and often inconclusive answers to the questions raised in our first paper and cited at the start of this one. We offer these answers more as working hypotheses than conclusions.

The next step should be to validate the findings of this paper through actual field work in individual countries. In researching and writing this paper, we benefited from review and comment by many professionals from industry, academia, government, and the World Bank Group. Their views have largely been reflected in this final version. We submit that this is the right time to stop writing and start trying out the ideas in practice. The returns from additional analytical work would be higher once supported by feedback from the field.

Opportunities to take these ideas to the field may be developed in the context of World Bank operations in the information and communication sector. The Bank has been involved for many years in spectrum management, but has limited its support to incremental improvement of traditional government administration. This paper provides a framework in which Bank staff and clients can cast their nets more widely.

As practitioners seek to apply these ideas in specific country situations, they will face a number of challenges that have been outlined in this paper. High in the list are likely to be preventing anti-competitive accumulation of spectrum by dominant players, reconciling development and fiscal objectives of spectrum pricing, and managing the transition from spectrum administration to markets. Practitioners will also find opportunities to advance the spectrum reform agenda by linking it to mainstream policy objectives. In particular, good spectrum management is a key factor of extending information and communication to the least favored groups of society, now a government priority in many countries. Much remains to be learned on how to deal with these and other issues of spectrum reform.

Annex I Examples of Applications Under Debate

This Annex discusses four issues currently under debate, and how they may be tackled: broadcasting and the transition to digital television, mobile telephony and the path to 3G, launching WiMax and related technologies, and releasing military spectrum.

1 Broadcasting and the Transition to Digital TV

Spectrum allocated for television and radio broadcasting is generally in short supply. Many countries are in the process of introducing digital television and phasing out analog transmissions.¹⁴⁷ In addition to enabling the provision of a range of new information services and improving quality, digital broadcasting technology is also more spectrally efficient. For example, six or more digital TV services can be transmitted in the spectrum used by one equivalent analog service. The shift to digital television broadcasting is expected to free substantial spectrum,¹⁴⁸ and there is high demand for this spectrum by existing and potential new broadcasters, as well as by alternative public and commercial users. Examples include public safety networks, public mobile phone and data (e.g., cellular), public access mobile radio, private mobile radio, and unlicensed uses.

This is the conventional wisdom. But some analysts note that alternatives to broadcast TV, such as cable and Internet television, do not require dedicated spectrum but only bandwidth, however provided.¹⁴⁹ In this context, the main effects of government-mandated migration from analog to digital broadcast TV are to rekindle stagnant markets for TV sets, which benefits a narrow segment of the manufacturing industry, and to generate windfall government receipts from spectrum sales. The spectrum being vacated, it is argued, is primarily used for more TV channels, not for any compelling new services. It could be posited, further, that the move to digital broadcast TV constrains investment in higher capacity, higher-quality distribution networks (fiber, broadband wireless, broadband on power lines) that can convey more complex services. Lastly, the mandatory move to digital broadcast TV imposes large costs on consumers and content providers, who are forced to adopt the technology that supports digital reception and production in advance of its take-up by the market. This cost falls disproportionately on the lower-income population groups.

¹⁴⁷Malaysia is expected to begin digital television trials in 2006, extend service nationwide starting in 2007 or 2008, and end all on-the-air analog transmissions by 2015. In the Czech Republic, experimental digital broadcasting began in 2000, major channels were launched in 2005, and shut-down of analog transmitters is planned by 2012. Recent legislation in the US has postponed mandatory cut-off for several years, while Canada has left the pace of winding down analog television largely to the market.

¹⁴⁸For example, ending analog television broadcasting in the UK is expected to release about 112 MHz of spectrum (Ofcom 2005b). The shift to digital television is also driven by government expectations of large windfall fiscal revenues from auctioning vacated spectrum and by manufacturers' expectation of renewed demand in the stagnant market for television receivers.

¹⁴⁹This is happening in developing as well as developed countries. India has a higher penetration of cable television than the UK.

Issues for policy makers and spectrum authorities on the transition to digital television include the following:

- What are the triggers for changing from analog to digital TV, and are these likely to be present in developing countries?
- Should the transition be led by the regulator or by the current spectrum users (broadcasters)?
- What are the current spectrum users' incentives to vacate spectrum under the existing administration regime?
- What are the transition's consequences to broadcasters and end users that have analog equipment? Should they receive compensation?
- What happens to the spectrum released through the transition process? Should the current licensees be allowed to keep it? Or should it be reallocated to different uses? Which uses? What is the best way to reassign it among users (administration, market)?
- Should part or all of the spectrum be allocated to unlicensed use? Should the process be any different in developing vs. developed countries?
- How much spectrum could be freed, and for what other purposes could it best be used?

2 Mobile Telephony and the Path to 3G

The use of mobile technologies have in the last decade been extremely effective in providing connectivity and promoting rapid deployment of telecommunications services worldwide, in particular in developing countries. As technology evolves toward larger bandwidth applications and faster devices, 2.5G and 3G networks are being rolled out around the world.¹⁵⁰ Among the different spectrum uses, mobile service bands are particularly sought after, and it is a challenge to find available spectrum to develop these services. This partly explains the high values paid in some countries for 3G licenses.

The initial attribution of 3G spectrum goes beyond the challenge of finding suitable bands for this service, and also touches on industrial policy issues. The expansion of 2G networks was greatly facilitated by the adoption and explicit attribution of bands to the use of the GSM standard in Europe. On the other hand, it also locked in spectrum usage to a specific technology, from which equipment suppliers have benefited significantly. There is currently a multiplicity of 3G standards in use: WCDMA/UMTS has been driven mostly by Europe, and equipment is developed to allow for coexistence fully compatible with GSM, and is the natural evolution path for many countries in Europe, Australia, Africa, the Middle East, and Asia; CDMA2000 has a strong market position in the US, Korea, and Japan, being the natural evolution from 2G CDMA networks, although GSM has been gaining ground in some of these markets; TD-SCDMA has been developed and is being promoted by China.

¹⁵⁰3G is the name normally given to third-generation wireless technologies which allow wireless operators to provide data capabilities and Internet protocol interfaces. 2.5G refers to technologies such as GPRS, which offer speeds between 2nd generation and 3rd generation technologies.

The introduction of 3G also makes it necessary to clarify the transition arrangements for spectrum migrating from 2G to 3G services. The transition from 2G to 3G is likely to be gradual, and 2G will (possibly) continue to be used for lower bandwidth services such as voice.¹⁵¹ Both generations will coexist until a significant number of mobile customers consider migrating to the new generation of services, and until the current license holders (interested in offering next generation mobile) develop strategies to evolve their networks to 3G.

In addition, the debate over 2G vs. 3G and the transition may be misleading. From a users' standpoint what matters most is service, and there is an overlap in terms of the services that can be offered over 2G compared with 3G technology platforms. A flexible, glide-path approach might be the best strategy.

Issues for policy makers and spectrum authorities include the following:

- Should a specific 3G technology be explicitly mandated, or the choice be left to the market? Letting the market decide avoids second-guessing technological and business trends and business strategies, and protects against pressures from the large vested interests involved in these decisions. Considerations that may warrant regulator intervention include concerns about industrial policy and economies of scale that would favor a coordinated approach (i.e., technology choice), and the high transaction and coordination costs that may warrant a facilitation role to enable the transition.
- How to reconcile the prospect of using spectrum trading and liberalization with the need for standardization and harmonization across countries to ensure sufficiently widespread equipment availability for new bands?
- Some governments have made large profits out of auctioning rationed 3G spectrum, yet today some of these operators have had to write off these assets. How to reconcile the efficiency benefits of auctioning off spectrum, government and treasury interests, and the industry interests? What are the consequences for the consumer?
- Does the regulator need to decide whether a specific market is ripe for 3G (i.e., the moment at which 3G should be introduced)?
- Should 2G license holders be allowed to reuse their current spectrum and refarm it to support next generation services,¹⁵² or should operators have to return their spectrum at expiry period for reallocation? How should the regulator deal with windfall gains?
- Should the process be any different in developing and developed countries?

¹⁵¹3G is spectrally more efficient, even for voice. The main reason to use 2G for voice is that it remains more economical to roll out 2G networks and therefore 3G is likely to be limited for example in rural areas.¹⁵²This is a question primarily on the extent to which the regulator should be allowed to interfere in the market. 3G services can be provided using the 450 MHz band, and so they are, for example, in Russia and Romania. Users are interested in service, not the particular technology or band over which they are provided.

3 Launching WiMax

A set of emerging wireless technologies is poised to greatly increase the range of high-speed wireless broadband. WiMax and similar standards would enable the provision of broadband wireless access with data speeds of up to 40 Mb/s over distances of 10Km or greater using relatively inexpensive equipment. These same technologies could also offer faster data transfers to mobile devices than is possible over current third-generation mobile networks under certain conditions. There are several similar proprietary and non-proprietary solutions, and current developments concentrate in three bands: 2.5, 3.5 and 5.8 GHz. Depending on the specific standard being deployed, these technologies have the ability to dynamically manage and avoid interference (within certain limits) and can therefore be suitable for license-exempt use. This is particularly the case when the density of users is low, as interference in those circumstances is unlikely or more easily avoided. Currently, although specific regulation does differ per country, only the 5.8 GHz band is allocated for license-free use.

License-free bands are particularly attractive for bottom-up approaches and smaller users such as local communities, NGOs, and university campuses, as barriers to entry are low (no license and limited or no fees). Larger telecommunication operators have in some countries been opposed to the deployment of WiMax-like networks in the past, especially given the potential for competition with the 3G networks. But now they are increasingly embarking on the deployment of WiMax solutions themselves.

Larger telecommunication operators are interested in using licensed WiMax bands. The reasons may be two-fold: to protect their large-scale investment from interference, and to avoid unrestricted competition with their core business and 3G (especially given the large sums paid for these licenses in some countries). As a consequence, equipment manufacturers are developing WiMax equipment for licensed bands (2.5 and 3.5MHz bands) as a priority.

Issues for the regulator include:

- Should WiMax-like bands be licensed or license-free?
- Can simultaneous licensed and license-free WiMax bands distort the market—i.e., can the existence of licensed WiMax-like bands prevent the success of license-free bands because equipment is more expensive (and may therefore not be available)?
- What are the anti-competitive implications of having license-free spectrum coexist with licensed (and potentially expensive) 3G bands?
- How can interference in license-free bands be minimized?
- How should the licensed WiMax-like bands be assigned (by the regulator, by auction, left to the market)? Should the process be any different in developing and developed countries?

4 Releasing Military Spectrum

In many countries, the military is the largest user of the radio spectrum.¹⁵³ Radio provides support for strategic planning, operations, and a large variety of applications, mostly mobile. Military spectrum is usually managed separately from other government spectrum and civil spectrum. Reallocation of spectrum reserved for military use is underway in several countries, and some of it has been transferred to or shared with civil use.¹⁵⁴ In the context of accession to the EU, central and eastern European countries are reallocating military spectrum to conform with harmonized EU allocations for commercial use. Likewise, countries formerly organized under the Warsaw Pact are adjusting spectrum allocations to meet NATO norms.¹⁵⁵

While the spectrum rights approach may not be practical as the primary tool to apportion spectrum between military (and other government) uses and civilian uses, it can play an important role in promoting more efficient use of spectrum.¹⁵⁶ Spectrum trading could provide an incentive for the military to use the spectrum efficiently and release underutilized frequencies. A wide range of commercial applications could move into these bands and are likely to be interested in acquiring the rights of use. Reserved spectrum that is not used on a regular basis (e.g., during peace) could be leased for commercial uses, with the military retaining the right to regain immediate possession in case of emergencies (e.g., outbreak of war). While this clause may diminish the value of the spectrum for commercial users, given the limited occurrence of such emergencies it may nonetheless elicit considerable interest. Trading spectrum would provide the greatest incentive if the proceedings of these transactions would accrue to the military itself (Analysys et al. 2004).¹⁵⁷

Issues for policy makers and spectrum authorities include the following:

- Should military spectrum be managed separately from other government and from civil spectrum? What institutional arrangements are needed to resolve conflicts over spectrum use rights between the military and other users of the spectrum?
- What could be the triggers for reallocating spectrum reserved for military use?
- How can market tools be used to enhance efficiency in the use of military spectrum and prevent spectrum hoarding by military authorities?
- Is seasonal use of spectrum (e.g., in peace vs. war times) a possible option? What could be the major associated concerns?
- Would usage fees for the military be practicable?

¹⁵³For example, the UK Ministry of Defence holds about 28 percent of all assigned spectrum, including 48 percent of spectrum in the range 3–10 GHz as well as numerous frequencies in other parts of the spectrum. Other European countries have even larger shares of spectrum allocated to the military (Ofcom 2005b).

¹⁵⁴Over the last decade, about 250 MHz of military spectrum in the UK has become available for civil use in the particularly valuable range below 3 GHz (Ofcom 2005b).

¹⁵⁵Following the end of the Warsaw Pact in 1991 Hungary, the Czech Republic, and Poland joined NATO in 1999, seven more joined in 2004, and several others have expressed interest in joining.

¹⁵⁶The CIS countries are adopting spectrum usage fees that apply to private licensees as well as to governmental agencies. The idea is to promote more efficient use, and in the case of government agencies, to encourage returning unneeded spectrum. The adoption of new technologies, some developed specifically for military use, can result in significant spectrum efficiency gains. (Source: Robert Horvitz, communication to the authors, 2006.)

¹⁵⁷Alternatively, administrative incentive pricing of the public sector use of the spectrum, including the military, would create an incentive for the military to return spectrum for reallocation among civilian uses through trading.

References

This paper draws in various places on material developed by A. Foster, R. Jones, and M. Cave for the module on spectrum management of the online toolkit for ICT regulation developed by infoDev and the ITU. Specific references are omitted except where the reader is directed to this source for further information.

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