Broadband Policies for Latin America and the Caribbean
A Digital Economy Toolkit

Chapter 3

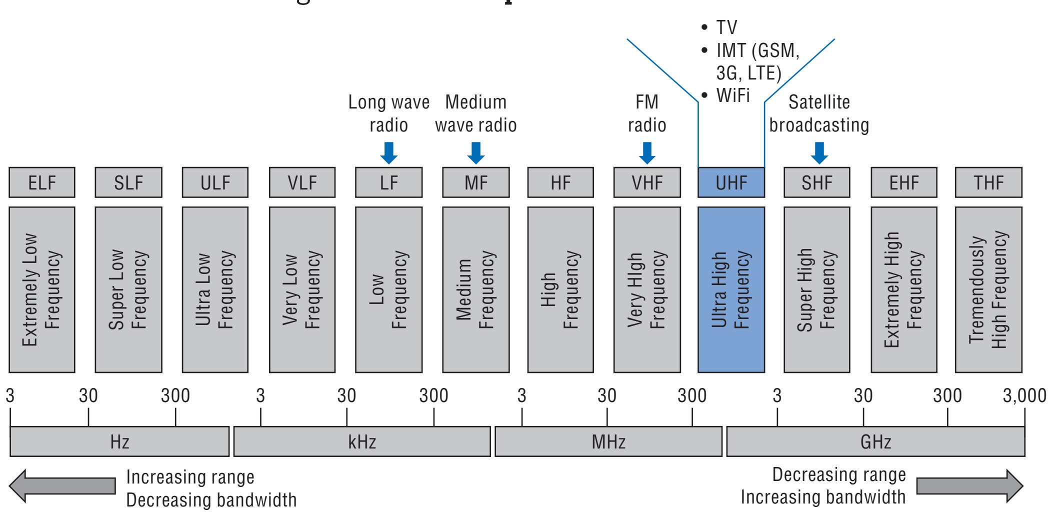
Spectrum policy

This chapter addresses the topics of spectrum planning, management, licensing, assignment and valuation, as well as policies to promote the efficient use of spectrum, such as spectrum trading, sharing and refarming. Spectrum is a key resource for expanding wireless access to broadband services and a crucial element for broadband policy making. Moreover, this chapter aims to shed light on the current challenges of spectrum management, such as those related to the switch-over to digital terrestrial television (DTT) and the increased need for spectrum resources for wireless broadband.

Spectrum is a scarce resource essential for providing wireless telecommunication and broadcasting services. Spectrum assignment and use is associated with important social and economic trade-offs that need to be carefully considered.

From a technical perspective, radio spectrum, commonly referred to in telecommunications as "spectrum", is the part of the electromagnetic spectrum whose frequencies span the 3 hertz (Hz) to 3 000 gigahertz (GHz) range. The International Telecommunication Union (ITU) has divided the radio spectrum into different bands (Figure 3.1). Ultrahigh frequency spectrum, from 300 megahertz (MHz) to 3 GHz, is the most suitable for telecommunications services. Bandwidth increases with higher frequencies, but their reach decreases. Thus, higher frequencies are more suitable for dense areas that require bandwidth, whereas lower frequencies are more appropriate for coverage purposes, as fewer base stations are required to provide service in any given area.

Figure 3.1. **Radio spectrum and its uses**



Source: Adapted from ITU (2011), *Telecommunications Regulation Handbook*, *www.itu.int/pub/D-PREF-TRH.1-2011*.

From an economic perspective, spectrum is a scarce resource in any given place or time, meaning that only a finite amount of spectrum can be used. It cannot be stored, as opposed to many other scarce resources such as minerals or oil, and it cannot be transported, although, at least in theory, it can be traded, given that the rights of use can be transferred.

As spectrum is used for the delivery of services that are considered essential, public authorities have an underlying obligation to guarantee that it is used in the most efficient way. Only careful management can reach a balance between licensing processes and conditions (including costs), as well as coverage, deployment and quality obligations associated with the spectrum, together with competition considerations. This management is essential for maximising the use of the spectrum, socially and economically.

Spectrum policy has undergone dramatic changes in many OECD countries. These are, or soon will be, affecting all Latin America and Caribbean (LAC) countries. The switch-over to digital terrestrial television (DTT), together with the increased need for spectrum resources for wireless broadband, is challenging spectrum regimes. More spectrum resources need to be released and made available for wireless broadband services, while maintaining a competitive level playing field. This chapter addresses spectrum management, licensing and valuation.

Except when explicitly stated, this chapter refers to spectrum used for the provision of telecommunications, and especially broadband services. Several references are made to changes in allocation, which have been crucial for the transition to DTT and the "first digital dividend" (the 700 MHz band in Latin America). A potential "second digital dividend" (the sub-700 MHz band, which encompasses the frequencies in the 470-698 MHz range) will require the evaluation of spectrum use for telecommunications in relation to broadcasting.

Key policy objectives for the LAC region

For the LAC region, spectrum policy and efficient spectrum management is especially important in the context of broadband development. In many geographical regions without fixed telecommunications, infrastructure broadband development will depend on wireless access. The main spectrum policy objective can be broadly defined as guaranteeing its "efficient use". This general objective has several more specific objectives:

- **Maximise the social and economic utility of spectrum use**. As spectrum is a scarce resource essential for the provision of services that have positive externalities, active management is required to maximise these externalities, both from an economic and social perspective.
- **Increase the availability, penetration and use of telecommunications services**. Inefficient management of spectrum usually translates into insufficient wireless telecommunications infrastructure and investment, inadequate coverage for the population of wireless telecommunication networks, low quality and high prices. These facts reduce availability (thus impacting the possibility of universal access), slow down penetration, and hinder demand for telecommunications services. Usage of services is the main cause of the economic spillover effects attributed to telecommunications services, and the lever that policy makers should aim to increase. Wireless networks are often the most cost-effective way of reaching rural and remote areas, especially with the advent of technologies that use lower frequencies with a wider reach.
- **Provide a level field for competition in allocating spectrum**. Spectrum plays a fundamental role in developing competition. First, as spectrum is limited, and there is a minimum amount of spectrum needed to operate, the number of licences that can be made available in any given place is very low; this leads, naturally, to concentrated markets. (Even six locally concurrent licenses, which is rare, implies a minimum Herfindahl-Hirschman Index of 1 667, which falls in the range of what is considered a "moderately concentrated market"). Secondly, not all spectrum bands are equal. Higher frequency bands, although they can accommodate more bandwidth, have lower reach, which translates into a larger number of radio base stations required for similar coverage than if lower frequencies are used; this, in turn, implies higher investment requirements, which influence costs and end-user prices. Thirdly, spectrum is valued very differently by different players. As a rule, incumbents value it more than new entrants, which means that unmanaged spectrum auctions may provide less scope for new entrants. Policy makers have to consider these three facts when managing spectrum, to encourage effective competition.

Tools for measurement and analysis in the LAC region

With the rapid evolution of telecommunication services that require spectrum, and with the difficulty of pulling regulatory levers expeditiously to respond to the ever-changing technological environment, spectrum management requires detailed long-term planning, backed by certain tools (some of which have been in use for a long time) and objective periodic measurements.

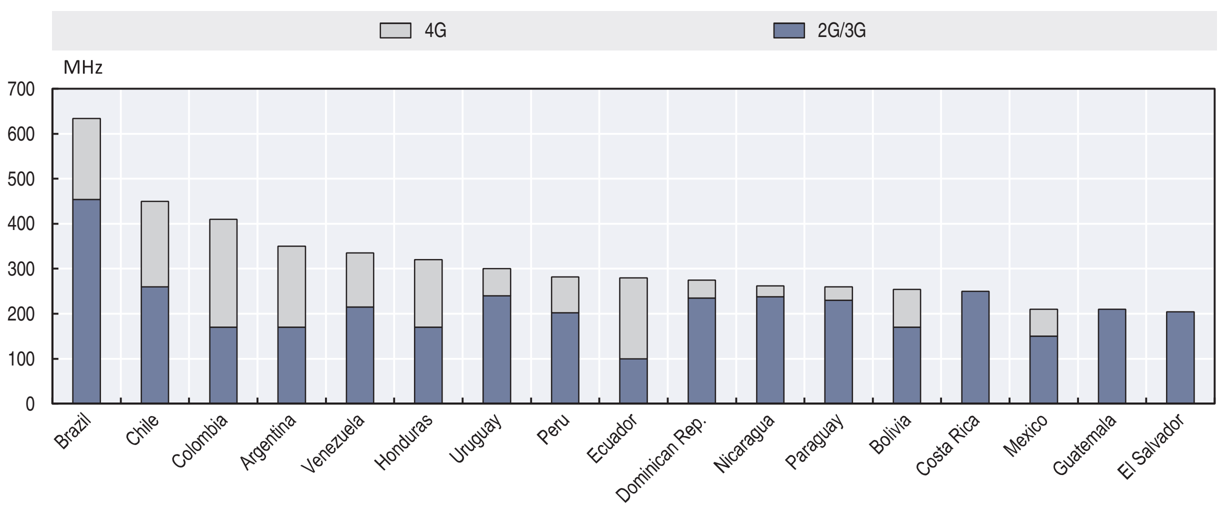
- **National frequency allocation tables (NFAT).** Allocations are entries in a table that sets out the use of a given frequency band for use by one or more radio communication services. Frequency allocation tables, which have been in use for a long time, describe which radio communication services can be provided in each portion of the spectrum. These tables should comply with international agreements and technical characteristics, but can be adjusted depending on national priorities and policy objectives. The tables are updated frequently. A good practice is to have a well-defined process for changing allocations, with documented support behind the decision.
- **Spectrum inventories and licensee database**. An exhaustive mapping of all spectrum, whether licensed or not, is fundamental for its management. The database should include all relevant information (area, licensee, granting and expiration dates, conditions and obligations, etc.). A good practice is to make the database public and easy to access, updated on an ongoing basis.
- **Long-term planning**. A prospective long-term public document that outlines plans for spectrum use, including short-term actions (e.g. future auctions) as well as areas that will be studied and evaluated (e.g. possible allocation changes) is a good tool that can provide greater certainty to the market and allows regulators to focus their efforts. Though it covers several years, the document should be updated at shorter intervals. This will reflect potential changes mostly for accomplishing short-term objectives, technological advances, international agreements and user and market trends and developments. The document may also contain a plan to release spectrum based on the expected need, for all or some of the telecommunications services.
- **Measurement of efficient use**. Measuring how well spectrum is being used is crucial to measure "efficiency", a loosely used word. Occupancy and data rates are two of these measures, but they fail to account for certain critical aspects mostly associated with the value generated (e.g. public safety and emergencies). However, measuring periodically how spectrum is being used (e.g. number of users, intensity of use, data rates, data transported, investment) gives a reasonable picture of how well objectives are being met, especially when compared among players using similar bands attributed to similar or identical services. There are no standard ways to measure efficiency comprehensively; several indicators need to be measured and normalised, taking into consideration the specific characteristics of each market.
- **International benchmarking.** Evaluating spectrum efficiency relative to other countries provides insight into how well spectrum is being used to meet objectives. Standard definitions of indicators, including processes for measuring and collecting data, must thus be applied.

Overview of the situation in the LAC region

Mobile communications have become ubiquitous in the LAC region. Although penetration was low in the late 1990s, they have become the preferred way for voice communication and broadband access. The advent of prepaid mobile plans, which allow users to control their telecommunications spending without recurrent financial commitment and to top up with very small amounts, has dramatically increased the number of users. The combination of decreasing prices for mobile access and the growing use of new devices (e.g. smartphones and tablets), as well as the burgeoning use of Internet applications, has substantially increased the demand for spectrum.

Historically, LAC countries have not been generous with the licensing of spectrum. In 2003, on average only 104 MHz had been assigned to mobile operators, equivalent to less than 38% of the amount licensed in OECD countries. By 2011, this number had increased to 195 MHz, but it still represented only 46%. As of September 2015, after several years of intense regulatory activity in the region, the average had grown to 311 MHz (Figure 3.2). Though the amount of licensed spectrum grew by 60% in only four years, it is still below the OECD (less than 60%) and well below the International Telecommunication Union (ITU) recommendation of spectrum required. For 2020, ITU recommends that 1 280-1 720 MHz be made available for wireless communications (ITU, 2006); LAC countries have only assigned around 20%.

Figure 3.2. **Spectrum assigned in the LAC region**



Source: GSMA (2016), *Spectrum in Latin America*, *www.gsma.com/latinamerica/es/espectro-en-america-latina*.

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Spectrum management and its licensing to service providers have resulted in the adoption of different approaches in the LAC region: from a full "command and control" regime, where regulators are the central axis in the assignment and other relevant usage rules (service regulation, secondary markets, etc.), to a fully liberalised market, where regulators mostly just dictate rules to avoid interference. As in most of the world, the LAC region still exercises significant command and control over the spectrum, its assignment, and the rules and obligations that govern its use for the provision of mobile telecommunications services.

Before the liberalisation of markets in the early 1990s, most licenses were awarded through a comparative selection (sometimes called a "beauty contest"). Interested parties were evaluated in terms of their announced plans (investment, coverage, prices to end consumers, etc.) and licenses were awarded to the candidates that best suited the regulator's formula. In practice, though, this award system was extremely discretionary and not transparent, deterring the entry of players and not maximising efficiency and benefits of spectrum use. In fact, almost as a rule, all fixed-line telecommunications providers were awarded a mobile license, as they were deemed to be the natural candidates. Some, though not all, of the LAC markets went on to create a duopoly structure, similar to the one defined in the United Kingdom and the United States when they first licensed additional players. The market was considered to be relatively small, primarily aimed at business users, and the licensing process and competition was not considered to be a priority for governments.

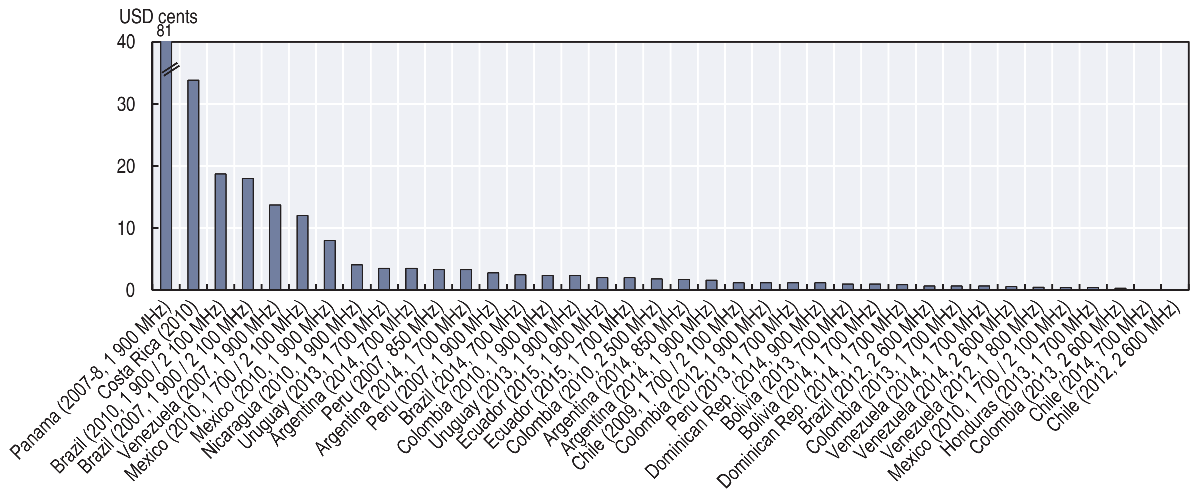
In the 1990s, beginning in the United States, a substantial change in the approach to licensing spectrum took place. Though alternatives had been tried to comparative selections (e.g. lottery), some of the advantages of auctions began to bear fruit. Observing these experiences, countries in the LAC region also embarked on assigning spectrum through auction processes. While their widespread introduction took some time, most countries now carry out one of several forms of auctions to assign spectrum to private users. Since 2007, more than 35 processes of spectrum assignment have been concluded, with proceeds exceeding USD 7.25 billion, and only a few are carried out through a comparative selection process (Table 3.1).

Table 3.1. **Spectrum licensing in the LAC region**

	Year	Frequency band	Frequency	Amount (USD million)	Amount paid per MHz per pop (USD cents)	Assignment procedure
Venezuela	2007	1.900 MHz	60 MHz	240	14.46	Auction
Peru	2007	850 MHz	25 MHz	22	3.11	Auction
Peru	2007	1.9 GHz	35 MHz	27	2.73	Auction
Panama	2007-8	1.900 GHz	80 MHz	229	83.25	Comparative selection
Brazil	2007	1.9 GHz/2.1 GHz	90 MHz	3 096	17.84	Auction
Chile	2009	1.7 GHz /2.1 GHz	90 MHz	18	1.19	Comparative selection
Mexico	2010	1.7 GHz /2.1 GHz	30 MHz	405	11.38	Auction
Mexico	2010	1.9 GHz	30 MHz	217	6.1	Auction
Mexico	2010	1.7 GHz /2.1 GHz	30 MHz	14	0.39	Auction
Brazil	2010	1.9 GHz/2.1 GHz	20 MHz	712	17.92	Auction
Colombia	2010	1.9 GHz	20 MHz	22	4.35	Direct
Colombia	2010	2.5 GHz	50 MHz	42	1.83	Auction
Costa Rica	2010	Several	130.6 MHz	170	28.64	Auction
Nicaragua	2010	1.9 GHz	50 MHz	12	4.18	Auction
Brazil	2012	2.6 GHz	120 MHz	1 396	5.75	Auction
Chile	2012	2.6 GHz	120 MHz	12	0.58	Comparative selection
Colombia	2012	1.9 GHz	25 MHz	51	4.35	Auction
Venezuela	2012	1.8 GHz	30 MHz	85	9.49	Mixed
Bolivia	2013	700 MHz	24 MHz	19	7.61	Auction
Colombia	2013	1.7 GHz	90 MHz	270	6.34	Auction
Colombia	2013	2.6 GHz	100 MHz	145	3.06	Auction
Honduras	2013	1.7 GHz	80 MHz	24	3.82	Auction
Peru	2013	1.7 GHz	80 MHz	257	10.51	Auction
Uruguay	2013	1.7 GHz	60 MHz	68	33.26	Mixed
Uruguay	2013	1.9 GHz	60 MHz	47	22.99	Mixed
Argentina	2014	700 MHz	90 MHz	1 044	26.99	Auction
Argentina	2014	850 MHz	8 MHz	45	13.09	Auction
Argentina	2014	1.7 GHz	90 MHz	1 000	25.85	Auction
Argentina	2014	1.9 GHz	30 MHz	163	12.64	Auction
Bolivia	2014	1.7 GHz	30 MHz	23	7.26	Auction
Brazil	2014	700 MHz	60 MHz	2 410	19.49	Auction
Chile	2014	700 MHz	70 MHz	22	1.77	Comparative selection
Dominican Republic	2014	900 MHz	20 MHz	28	13.45	Auction
Dominican Republic	2014	1,7 GHz	40 MHz	42	10.09	Auction
Venezuela	2014	2.6 GHz	80 MHz	240	9.77	Mixed
Venezuela	2014	1.7 GHz	40 MHz	148	12.05	Mixed
Ecuador	2015	1.7 GHz	40 MHz	120	18.49	Comparative selection
Ecuador	2015	1.9 GHz	70 MHz	210	18.49	Comparative selection
Mexico	2016	1.7/2.1 GHz	80 MHz	240	9.77	Auction

The sums paid per spectrum assignments have varied substantially in recent years (Figure 3.3). That being said, except for a few assignments, where the high price paid can be explained by specific characteristics of the market and the timing of the auction, normalised prices (that is, USD cents per megahertz per population) tend to be under USD 0.05. It is important to emphasise that these prices are not fully comparable, as several countries impose recurring spectrum fees, which affect the price of spectrum at the outset.

Figure 3.3. **Spectrum prices in the LAC region (USD cents)**



Note: Panama (2007-08) and Costa Rica (2010), with values of USD 81.3 cents and USD 28.6 cents respectively, were omitted from the figure. Year of auction and frequencies auctioned are indicated but type of offers may differ.

Sources: Regulators; Katz (2015), *Directrices de política y aspectos económicos de asignación y uso del espectro radioeléctrico www.itu.int/es/ITU-D/Regional-Presence/Americas/Pages/EVENTS/2015/0831-NI-cosydirc.aspx.*

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Spectrum trading is an emerging practice in the region and to date there is still limited experience outside of Mexico, Guatemala and El Salvador. In 2004, for example, the Mexican subsidiary of América Móvil (Telcel) purchased 8.4-megahertz of spectrum in the 1.9 GHz frequency band from Unefón. Some other countries in the region are awaiting a regulatory framework specifying the terms and rules for trading to be put in place. The regulatory authority in Chile, for example, sent a bill to the National Congress in September 2014 to create a secondary RF spectrum market and approval is pending.

One of the main pillars of the evolution of spectrum use relies on a successful migration from analogue to digital terrestrial television. The aim is to free the 700 MHz band, as digital terrestrial television is much more efficient in using the spectrum. This band is especially useful for mobile communications, due to its propagation characteristics. This allows the 700 MHz signals to more easily penetrate buildings and walls, covering larger geographical areas with less infrastructure and therefore at a lower cost. Though most OECD countries have already completed the analogue switch-off, Latin America is lagging. Most countries plan to end analogue transmissions by the end of the decade, though a few are expected beyond 2020.

Good practices for the LAC region

Spectrum planning, management and control

For spectrum to be rationally and efficiently used across borders, **international co-ordination** is necessary. At the highest level, the governance of spectrum use on a global basis is one of the main responsibilities of the ITU, a specialised agency of the United Nations, mostly carried out through its Radiocommunication Sector (ITU-R). The mission of the ITU-R is, among other things, "to ensure rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including those using satellite orbits, and to carry out studies and adopt recommendations on radiocommunication matters" (ITU, 2016). It helps meet the ITU's objective of "maintaining and extending international co-operation among all the Member States of the Union for the improvement and rational use of telecommunications of all kinds". Its activities focus on ensuring interference-free operations of radiocommunication systems by implementing the Radio Regulations and regional agreements. These include establishing recommendations to ensure performance and quality in operating radiocommunication systems, seeking ways to ensure good use of the radiofrequency spectrum and satellite-orbit resources and to promote flexibility for future expansion and new technological developments. The ITU-R holds periodic world (WRC) and regional (RRC) radiocommunications conferences. WRCs are held every three to four years, in order to review and, if necessary, to revise the international treaty governing the use of the radio-frequency spectrum and the geostationary and non-geostationary satellite orbits (jointly referred to as Radio Regulations). During these conferences, frequency assignments and allotment plans are revised. RRCs are conferences of either an ITU region or a group of countries with a mandate to develop an agreement on a particular radiocommunication service or frequency band; these conferences cannot modify the Radio Regulations.

At the regional level, the Inter-American Telecommunications Union (CITEL), an entity of the Organization of American States (OAS), is a key player in matters of the spectrum. Its main objectives are to co-ordinate the rules needed to facilitate infrastructure deployment and telecommunication service delivery, harmonising the radio frequency spectrum to reduce the cost of providing wireless services, training in information and communications technologies (ICTs), and helping countries devise telecommunications development strategies. The Caribbean Telecommunications Union (CTU), an intergovernmental organisation dedicated to facilitating the development of the sector in the region, also plays a role.

LAC countries are active in all these international fora. Common regional positions are important for the development of the sector and for more effective positions at meetings for international negotiations. LAC participation in international fora, and especially in regional ones, is addressed in Chapter 8 on regional integration.

Another key element of spectrum management involves considering the economic impact of spectrum resources. As an essential but scarce input for the provision of broadband, spectrum has immense value for the economy. As in many LAC countries, the fixed telecommunication infrastructure does not have nationwide coverage, wireless broadband has become the alternative way to access the Internet, a key input for the digital economy. It is therefore vital that decisions influencing the way spectrum is managed – whether in terms of attribution, allocations or assignments – are evaluated within a framework that considers value creation and externalities. An appreciation of externalities for the potential effects on GDP, job creation, investment, social welfare, and consumer and producer surpluses is essential.

It is vital to consider the potential **alternative use of spectrum**. This has been critical in assisting LAC countries to benefit from the digital dividend, since auctions allowed the market to help determine the value of the different uses of spectrum for the economy. The outcomes generally indicate that the market for mobile services places a higher value on spectrum than other potential forms of use and that there is still likely unmet demand of several hundred megahertz (AHCIET GSMA, 2012) if countries are to meet the ITU spectrum requirement recommendation. This means alternatives will have to be constantly evaluated through authorities with the necessary tools and skills, but also with the acknowledgement that market forces can help reveal the knowledge held by the private sector. Spectrum needs differ among countries in the region, depending on issues like the intensity of the use of mobile broadband, coverage and penetration.

One challenging area in spectrum management can be the decision as to which bands are allocated for **use by public authorities**, such as emergency services. In any such decision, a good practice can be to conduct a cost-benefit analysis. Assessing information on alternative uses of the spectrum makes it possible to compare the costs and benefits and to make better decisions to suit national needs and government objectives. Part of such analysis requires evaluating how best to meet objectives including the most efficient delivery of public services, alongside the consideration of spectrum management. By way of example, see the Australian experience (Box 3.1).

Box 3.1. **Securing broadband capability of public safety agencies in Australia**

In 2015, the Australian Productivity Commission examined the best way to secure a mobile broadband capability to meet the long-term needs of Australia's public safety agencies (PSAs), the police, fire, ambulance and emergency services.[1] To do this, they were asked to:

- undertake a "first principles" analysis of the most efficient, effective and economical way of delivering mobile broadband capability to PSAs by 2020
- consider the most cost-effective combination of private and public input, services and expertise to deliver the capability
- consider aspects of this capability such as national interoperability across jurisdictions and agencies, coverage, integration of voice services, security, capacity, resilience, sustainability of arrangements into the future and compatibility with end-user devices
- consider domestic and international developments that might be applicable to Australia.

The **economic valuation of the radio spectrum** is a challenging, if not daunting, task. Firstly, it necessarily requires a multiyear evaluation – ten or more years – in a sector characterised by technological breakthroughs and discontinuities. Few envisaged, for example, the high rate of smartphone uptake around the world. Secondly, country-specific and market conditions influence any valuation. Thirdly, even among similar players and uses, the value for each player could be significantly different depending on specific circumstances. Assigning the spectrum to a player that values it the most does not necessarily maximise the value to the economy. This is part of the rationale behind spectrum caps, which try to protect competition by pre-empting possible spectrum hoarding, which increases barriers to entry. Fourthly, the valuation might require a comparison of distinctly different things, as was the case for broadcasting and broadband. In such scenarios, certain aspects are very hard – if not impossible – to measure. In countries where most households predominantly access free-to-air (FTA) television broadcasting, either because of income restrictions or because pay television infrastructure is not ubiquitous, the social value of the service is high and challenging to quantify.

There are three broad approaches to measuring the value of the spectrum to an economy (OECD, 2014):

- **Economic welfare.** This approach is based on estimating consumer and producer surpluses. Consumer surplus is defined as the difference between the amount each consumer is willing to pay and the actual price of the service. Producer surplus is usually defined as the difference in price and the marginal cost of production. This methodology is meaningful given that it includes both the effect of lower prices and the increase of the subscriber base, as well as the production function, which considers the cost of providing the services. Though simple enough in theory, the actual estimation requires evaluating demand and supply curves, and thus, will require a significant simplification of assumptions. Even more, when the analysis is a multiyear, forward- looking exercise, the evolution of demand and supply curves will need to be incorporated. Special attention needs to be paid to the fact that, on the demand side, many services are bought in bundles, and on the supply side, services are provided through a multiservice platform.

- **Economic contribution**. Another way of valuing spectrum use is to measure the total value added created in the economy. This looks at the different stages of the value chain to produce the service and estimates how much value added is created in each of the steps. For example, it considers how much investment and labour are required to build and run a network, how much effort is necessary to distribute, market and sell the services, and how much is required for customer care. In broadcasting, a crucial link in the value of a chain is the development of content. This approach is simple, as it is based on input-output tables, which are usually available, but it does not fully account for all indirect externalities and fails to estimate consumer surplus and broader productivity increases.
- **Productivity increase**. This third approach tries to estimate the impact on the economy attributed to the use of services provided through the spectrum. For example, a given workforce could be able to produce more output if it were aided by mobile communications (for example, better routes for the delivery of goods could be chosen, reducing time spent and increasing deliveries at any given period). Higher productivity translates into higher GDP. Several studies have recently been conducted to assess the effects of broadband, but significant work needs to be carried out.

It is important to note that spectrum in the LAC region carries more relative weight and relevance for broadband access and use than in OECD countries, because fixed networks are much less developed. At the end of 2014, fixed broadband penetration in Western Europe was 32.8%, whereas in the LAC region it had reached 7.9%. Wireless broadband in the area is more a substitute for fixed broadband than a mere complement. Millions of people will mostly only have access to broadband networks through infrastructure that relies on the use of spectrum. Spectrum thus plays a fundamental role in reducing the digital divide, not only between developed and emerging economies but within countries. It has become an important tool for tackling inequality and bridging income gaps. In a geographical region where between 15% and 20% of the population live in rural areas, spectrum can often provide broadband services more efficiently from a cost and deployment perspective.

As technology evolves, consumer preferences change, and as the relative value of spectrum changes, policy makers have the obligation to facilitate a shift from less to more valuable uses of spectrum. Spectrum is a public good, and policy makers should ensure that it maximises public benefit.

Managed market-based approaches have proven effective in maximising public value. These require a market-based approach to licensing spectrum (usually through auctions, see below). They also require few barriers for sharing and transferring spectrum holdings, few or no technological requirements, greater license flexibility, and rules that guarantee that the market for services is competitive.

Moreover, **institutional issues** arise with spectrum management, since the use of spectrum affects not only the telecommunications and broadcasting industries, with their overall impact on the economy and social welfare, but also other users, such as certain government tasks (e.g. transport), the military, public safety agencies and the research community. The different needs and objectives are not necessarily fully aligned, or can even be divergent, demanding a whole-of-government approach. Both international co-ordination and high-level national co-ordination are needed.

From a broad perspective, two potential institutional arrangements are possible:

- **Single institution**. A single entity is responsible for all aspects of spectrum management at the national level, in charge of planning, licensing and monitoring spectrum. This model centralises decision making, and, if the entity is fully autonomous, it has all the attributes necessary to take a long-term perspective based on welfare creation. IFT, Mexico's recently established regulator, Ofcom in the United Kingdom and the Australian Communications and Media Authority (ACMA) follow this model.
- **Shared responsibilities**. This is the most common model, with responsibilities assigned to different government entities based on various criteria.
  - In the United States, the Federal Communications Commission (FCC) administers spectrum for nonfederal use (business, state and local, government, entertainment, commercial, private), whereas the National Telecommunications and Information Administration (NTIA), a unit of the United States Department of Commerce, administers spectrum for federal use (national defence, law enforcement and security, transport, resource management and control, emergencies). The Interdepartment Radio Advisory Committee, chaired by the NTIA, ensures co-ordination between the two agencies.
  - Some countries divide spectrum management by service (e.g. broadcasting and telecommunication services). In Colombia, the *Autoridad Nacional de Televisión* (ANTV) oversees TV broadcasting and grants spectrum licenses. The ICT Ministry oversees TV radio broadcasting and grants spectrum licenses. Meanwhile, the *Agencia Nacional del Espectro* (ANE), is in charge of planning, managing, allocating all services (including broadcasting), and gives technical support to the *Ministerio de Tecnologías de la Información y las Comunicaciones* (MinTIC), which is responsible mainly for the licensing phase in the spectrum management process for the remaining services.
  - Other models incorporate the federal and state dimensions. In Germany, the *Bundesnetzagentur* (BNetzA), reporting to the Ministry of Economics and Technology, regulates several public utilities (telecommunications, electricity, gas, post office and railways). The German Federal Council (*Bundesrat*), the legislative body that represents the 16 federal states at the national level, is a member of the advisory council of BNetzA.

No model is without pitfalls, but even in those without shared responsibilities and significant autonomy, co-ordination among the different institutions is vital to guarantee that all objectives are met.

Spectrum resources have important implications for competition dynamics. For example, the decisions taken on setting spectrum caps on operators during spectrum auctions are likely to shape a market in the subsequent years. While the use of caps in spectrum auctions can facilitate new entrants, in markets that lack adequate competition, it could also have a potential for spectrum fragmentation and market inefficiencies if not undertaken with due consideration to the costs and benefits. Likewise, spectrum planning and management tasks are key decisions for the future of communications, both from an operational (e.g. assigning spectrum to mobile stations) and a strategic point of view (e.g. band segmentation plans, migration schedule). Given the highly technical nature of these issues and their implications for competition in communication markets, regulatory authorities should have the authority to conduct spectrum auctions or, at a minimum, be able to establish competition-related conditions for spectrum auctions. The government should in any case retain control of the bands used for government-related purposes (e.g. military, police) under the designated framework.

In all cases, especially those where the communications authority is not in charge of assigning spectrum, it is essential that all parties work closely with the competition authority to guarantee that spectrum use promotes effective competition. The relationship in Chile between the *Subsecretaría de Comunicaciones* (SUBTEL) and the *Fiscalía Nacional Económica* (FNE), which is responsible for defending and promoting competition, demonstrates good practice.

Spectrum harmonisation, defined as the uniform allocation of radio frequency bands across entire regions, is an important government responsibility. Harmonisation aims to minimise radio interference along borders, facilitating international roaming, and sharing the economies of scale that arise from international standards and the creation of large markets. The ITU, as the United Nations agency responsible for radio communications, is responsible for harmonisation at the global or regional level.

The benefits of harmonisation are clear, although the process for reaching consensus is not. Certain parties will argue for total, compulsory harmonisation, and others for a more liberal approach that allows more autonomous management and new policies (e.g. spectrum trading) and that allocates spectrum to those who value it the most. Nevertheless, it can be argued that the current preference for harmonisation has served the industry well and is one of the chief factors facilitating the advent of wireless digital telecommunication services, leading to lower costs and benefiting consumers.

Apart from each country's approach to spectrum management, it is imperative that all LAC countries actively participate in the global harmonising forums (ITU-R and the preparatory conferences). It is also important to strengthen regional organisations, the Caribbean Telecommunications Union (CTU) and the *Comisión Técnica Regional de Telecomunicaciones* (COMTELCA), and to increase their participation in the Inter-American Telecommunications Commission (CITEL), while enhancing CITEL's role.

Moreover, **spectrum licensing frameworks** are key to managing spectrum consistently. From a high-level perspective, there are three possible licensing agreements:

- **Exclusive assignment**. Licensing of a given band to a party that has exclusive rights over its use has been a common model in the assignment of spectrum. The original rationale behind this was that, because of technological limitations, interference could become a problem, which could be minimised by giving the rights of use to a single party. How spectrum is assigned, though, can vary widely from the type of band and country (e.g. direct assignment, "beauty contest", auction, lottery, etc.). These licenses come with restrictions on how spectrum is used, to avoid interference with other users in other bands.
- **Unlicensed spectrum**. Sometimes also referred to as open or free spectrum, unlicensed spectrum (or license-exempt spectrum) can be used by any entity for any private or public purpose. In practice, to minimise interference, equipment using unlicensed spectrum must comply with certification rules, and adhere to certain standardised protocols. Most importantly, there is no regulatory protection against interference. Unlicensed spectrum is adequate for services and devices based on low-power radiation, where potential interference can be managed in a reasonable way. Wi-Fi spectrum, which is unlicensed, has become one of the most common means to access broadband networks. Other technologies and devices that use unlicensed spectrum are Bluetooth (which allows communications

over very short distances), ZigBee (low-power wireless communications mesh network, also for short distances), WirelessHART (used for monitoring industrial processes and power consumption), WirelessHD (used for high-definition television sets), WiGig (for multi-gigabit transmissions at very short distances), and RFID (automatic identification of tagged objects or living entities).

- **Licensed Shared Access (LSA) and Authorised Shared Access (ASA)**. Only recently introduced, LSA/ASA allows spectrum that has been licensed to be used by more than one entity. It introduces additional licensed users on a given band, further increasing spectrum efficiency and unlocking additional spectrum capacity. Though they could potentially lower overall industry costs and accelerate spectrum harmonisation, these licensing frameworks have not fully taken off and are not yet mainstream in any country, because by definition, the use of the spectrum is binary (either one or the other can use it at the same time, location and frequency) and thus requires clear sharing rules that guarantee predictable quality of service.

The exclusive licensing agreement has been the traditional approach to granting private entities the use of spectrum. It has successfully allowed wireless telecommunication services to grow rapidly and become ever more diverse within a framework of legal and operating certainty. Unlicensed spectrum has become a widespread complement for the last 100 feet (or less) of communications networks, either wireless or wireline. With the advent of machine-to-machine communications and Internet of Things (further addressed in Chapter 8), it will become much more widely used.

The LSA/ASA approach has only recently been developed. Though its theoretical benefits – better use of a scarce resource, especially when it is underutilised – are clear, it poses certain technical issues (interference), most of which are currently being resolved. It is also facing opposition from incumbent exclusive license holders that acquired spectrum through an award procedure. Other types of agreements use underutilised spectrum, such as white spaces. White spaces are part of the spectrum that is left unused, mostly because it is required for historical technical reasons, such as the use of guard bands or between adjacent analogue broadcasting channels, to avoid interference. Advances in modulation techniques and technical characteristics of equipment allow for using and sharing these white spaces. This can potentially increase the amount of spectrum available for international mobile telecommunications (IMT), but their widespread adoption is not imminent in the very short term. Experience on the use of white spaces to make more spectrum available includes research and projects on dynamic spectrum and television white spaces carried out by Microsoft.[2]

As a general practice, following historically successful worldwide trends, authorities should continue to grant exclusive spectrum licenses for IMT. More spectrum should be identified for such purposes; IMT spectrum that is not being used should be offered following a well-thought out medium- to long-term strategy based on maximising spectrum efficiency and competition. Additionally, unlicensed spectrum should be promoted, as its complementary value to licensed spectrum is well proven, and because it has become a hotbed of technological development. Given the worldwide success of Wi-Fi technology, and the important role it plays in mobile traffic offloading, policy makers in the region should conduct needs assessment for unlicensed spectrum, to avoid congestion (promoting, for example, the use of the 5 Ghz band). LSA/ASA regimes and other approaches such as white spaces should be used experimentally with caution. LAC countries could use international experience to guide use of these regimes, as significant advantages are to be gained from the successes and failures of first movers.

As a rule, all regimes should be as flexible as possible, imposing minimal requirements, except when interference is an issue that compromises services and spectrum efficiency. Many unforeseen issues could potentially be handled with *ex post* regulation. To increase legal certainty, regulatory regimes should explicitly allow for such intervention if certain conditions, expressed *ex ante*, are met. Where certain conditions have been imposed during the licensing process, such as coverage and utilisation, these should be well-defined and measurable.

It is well-known that legal certainty and strong institutions favour an environment for long-term investment and innovation, reducing the cost of capital and increasing risk taking. Significant economic and social benefits emerge when rules are clear and when adjusting them to a changing marketplace, technological advancements and shifts in social and economic needs is based on careful evidence assessment involving public discussion.

All licensing regimes require legal certainty. Specifically, exclusive licensing arrangements require strict rules of temporary property rights and protection from interference. Deployments of telecommunications infrastructure typically need significant up-front investments, which then have a long useful lifespan. Licensing terms should reflect this: long terms with high renewal expectations are accompanied by constant investments in network upgrades. Uncertainty in the renewal of licenses usually translates into insufficient investment towards the end of the license term, which results in poor service and lack of supply. This situation is exacerbated with short licensing terms, as insufficient investment periods become more frequent. In general, spectrum licenses should be awarded for periods of more than ten years. Conditions for renewal should be known well in advance and the proceedings should be conducted through open and transparent procedures.

Long licensing regimes and transparent, high-probability renewal processes do not mean that authorities cannot revoke licenses. Governments should always retain the authority for this purpose under predefined circumstances, such as infringement of the law (especially with recurrent breaches) and inefficient use. Another situation to consider is long-term spectrum planning and the possibility of attribution changes. The advent of digital terrestrial television and the possibility of using the 2.6 GHz band for IMT has proven that revocation can be needed for better spectrum use. Governments should be able to appeal to this evidence.

Some countries, such as the United Kingdom, removed predefined license terms to increase certainty surrounding spectrum licenses. Nevertheless, the regulator can revoke any license for spectrum planning purposes, with a five-year notice. This guarantees that it can recover any spectrum if it is required to do so, but ensures that services using such spectrum are not degraded and that deployment investors can use the spectrum for a time that is financially sustainable.

Certain situations should be avoided if possible. The need for greenfield renewal after expiry creates uncertainty on several fronts (likelihood of renewal and price). Some of the recent renewal processes in the LAC area lacked clarity on the price; in another case in the region, this, and a long and uncertain injunction process, has left the 2.6 GHz band idle. Pricing of licenses, and, more importantly, renewals of licenses, should be transparent, known in advance as far as possible, and nondiscretionary. In addition, policy makers should monitor the evolution of the market and define in advance any update on conditions for renewal of licences, if needed.

Policies to promote efficient use of spectrum

It is important to outline some general principles for promoting the efficient use of spectrum. The term "efficient use" can refer to several broad objectives, which makes it hard to establish uniform metrics. This is particularly true in comparing different services. For example, discussions for changing the allocation of the digital dividend spectrum, which meant comparing broadcasting to mobile broadband, entailed not only evaluating the economic value of each sector, but also their social value. In other instances, spectrum used for military or national security is compared with traditional telecommunications services. It is crucial to define the objective intended in conjunction with the measurement of efficiency.

Apart from the particular definition and objective, certain policies promote good use of the spectrum. In general terms, **transparency** (in terms of assignment procedures, conditions of use and renewal, and statistics on actual use) **and assignments that promote competition** are good practices. In terms of use, flexibility should be paramount, lest it hamper competition and innovation. This should involve not only technology (to which the coinage "technological neutrality" refers, essentially meaning not defining technologies as long as they are interoperable with the system), but also service ("service neutrality" refers to allowing all services, as long as they are compatible with the allocation of the spectrum band).

An almost unsurmountable challenge arises from the fact that significant parts of the spectrum are not subject to market incentives. This is the case for almost all spectrum held by the state or governments. It can also be argued that this is true of spectrum that, though allocated, has not been assigned. As spectrum cannot be stored, unused spectrum has a significant opportunity cost.

As an almost universal rule, government agencies (military, national security, transport, etc.) receive spectrum assigned directly for free and are restricted from using it for other applications. Many of the considerations for such policies are subjective and follow a public policy (if not political) agenda. One way of promoting more efficient use of such spectrum is to create **incentives that mimic market-based incentives**. A good example is an "administered (or administrative) incentive pricing" regime. In such regimes, fees are replaced by prices set by a regulatory authority attempting to reflect the opportunity cost of the spectrum. Meanwhile, they also incorporate potential incentives, which then promote efficient use. Ofcom in the United Kingdom has used this methodology successfully since 1998. As a consequence, Ofcom cites the release of 384.5 MHz used by radio astronomy, the return of some UHF spectrum used by the police in Scotland, and the removal of legacy fixed links in the 4 GHz point-to-point band. In any case, acknowledging that spectrum used by public agencies or other nonprofit organisations has an economic value, for which the economy as a whole is paying, ought to create incentives for more efficient use.

A further policy that can increase efficient use of the spectrum that has recently been discussed or used in several countries is **spectrum trading and the development of secondary markets**. Spectrum trading brings more flexibility to the formation of better market structures. It allows spectrum to be transferred to those that value it the most, provided that conditions for spectrum trading are well designed and set clear conditions and timely procedures. Subdivisions and regroupings of licenses based on market prices will most likely produce a more efficient solution (OECD, 2005). For example, the Australian Communications and Media Authority allows combining or subdividing existing licenses to form new licenses, but the subdivisions cannot be smaller than the "standard trading unit" (STU – defined as an area of 5 minutes by 5 minutes of arc, approximately 9 square kilometres, with 1 Hz frequency band).[3] New Zealand defines radio spectrum in terms of property rights (MRR – Management Rights Regime). Management rights spectrum can be sold to service providers ("right-holders") and subsequently traded between them (New Zealand, 2005). In the United States, spectrum trading is an incipient reality. Licenses are tradable and can be converted to other uses (though regulatory sanctioning is required). The United States also allows leasing and subleasing of spectrum. Several agreements have been reached since 2003, when it first published leasing rules.

All these policies imply transferring the rights of use (and the obligations that the licenses carry), either temporarily or permanently (until the expiration of the license) and are fraught with economic and regulatory barriers. Administrative processes are lengthy and complicated, regulatory approval is usually required, and incentives for current holders are low due to scarcity (either because spectrum might be worth more in the future or because they might need it for future expansion).

Nevertheless, it is too early to assess their impact, and good practice in this area is to gear resources towards understanding these figures and closely following international trends. At least in theory, they provide a market-based approach to a better use of spectrum and as such, are worth considering. Although legal, competition restrictions must be taken into account, and technical issues (most importantly, interference) need to be incorporated into any trading framework. This creates a mechanism not only to correct any deficiencies that might have arisen during the original licensing process but also to adjust to the evolution of the market.

In addition to unlicensed and LSA/ASA agreements, **spectrum sharing** is another policy that would increase spectrum efficiency use. In principle, this refers to multiple wireless systems operating in the same frequency band, without causing interference to other users, through at least one of several dimensions (time, space or geography) and could be administrative, technical or market-based. According to a European study (Werbach and Mehta, 2014), the average occupancy rate for a dedicated band was below 10% of the band's capacity, so there is significant room to increase its use. As concerns over spectrum scarcity increase, sharing may well become the norm, as it increases supply and provides greater access to a scarce resource. Sharing involves a process of continual reallocation, including even reallocation to different services, such as data and broadcasting. Needless to say, if well implemented, sharing reduces waste and increases efficiency.

One of the main criticisms of spectrum sharing is the limitations of managing interference between different users. This is the main reason why spectrum has traditionally been licensed for exclusive use. It is often mentioned that, absent usage rules, sharing can lead to the "tragedy of the commons", whereby increasing the number of users results in a lower quality of service for everyone. Nevertheless, technological advances (e.g. cognitive radios, which are designed to be able to use several spectrum channels), regulation (e.g. rules of "etiquette" and co-operative approaches that govern common usage), and economic incentives (pricing and penalties) are helping to alleviate most of the existing concerns. A long road lies ahead, but sharing promises to address the demand for increased spectrum for broadband services. LAC regulators should follow international developments in this respect, as other countries are bound to face spectrum scarcity problems earlier than in the region and thus are impelled to work out the details and hurdles in its implementation. As with the implementation of secondary markets, important competition considerations need to be taken into account.

Spectrum refarming has proven to be a frequently sought-out tool that significantly increases spectrum use efficiency. Refarming – defined as changing the use of frequency bands – has been quite common for some time, but it attracted little attention, due to limited demand for spectrum and the sparsity of usage and ownership. Due to technological advancements, spectrum scarcity and ever-changing social demands, refarming is now not only common but in many cases contentious. Some types of refarming (e.g. from broadcasting to broadband) are fiercely defended and opposed by several parties, and thus take a long time to be approved and implemented. Other types of refarming (e.g. reallocating spectrum from fixed to mobile networks) can also be quite contentious, but are much easier to justify. Finally, the most common kinds (e.g. the evolution of wireless telecommunication technologies, from analogue to Long Term Evolution (LTE) tend to occur in a seamless manner.

Most spectrum refarming requires regulatory intervention through a lengthy and expensive process (e.g. allocation of the digital dividend, incentive auctions in the United States to free up additional low-frequency spectrum for broadband beyond 700 MHz). It usually entails the displacement of providers and end users and requires new equipment (CPEs/handsets and network), which can be costly. It should, though, be promoted once the alternative uses of the spectrum have been evaluated (as described before in this chapter).

Refarming can also bring more competition for existing providers, and should be carried out in a competitively neutral fashion, without creating artificial advantages or disadvantages for any of the players. Spectrum used for fixed networks has usually been awarded at much lower prices than spectrum used for mobile networks. From the perspective of economic benefit, it is hard to argue against fixed spectrum being used for mobile telecommunications. Nevertheless, allowing this to happen without an economic compensation mechanism to level the playing field creates unfair distortions. This could significantly damage the market and create unjustified advantages to certain players attributable to a regulatory anomaly. Implementing rules for technological neutrality, as well as flexibility on the use of the spectrum, is a way of facilitating refarming agreements among market players for optimal use of spectrum.

Spectrum refarming that is more akin to technological upgrades is much easier to implement. The original refarming of mobile technologies (from analogue or 1G to 2G, and from 2G to 3G, or even from 2G CDMA to 2G GSM) met significant restrictions from regulators, but further upgrades have gone smoothly. Refarmings are now understood for what they are: spectrum being utilised for IMT that operators choose to use more efficiently to provide better and cheaper services. Some countries still require regulatory approvals for operator-centric refarmings, which, in essence, complicate and slow upgrading a network, and make it more expensive. As long as interference restrictions are met and band re-segmentations are not required (as the spectrum used for Motorola's integrated digital enhanced networks, or iDEN, requires if it is used for traditional mobile networks) or do not affect interoperability in the market, these refarmings should not only be allowed but promoted. Regulatory intervention against this practice could hold back the evolution of wireless telecommunication services. It could also slow the deployment of last-generation networks, the increase in competition, the creation of social and economic welfare, and better use of the spectrum.

Spectrum assignment procedures

Historically, spectrum has been assigned by several distinct methods. Licenses can be awarded by **non-market-based procedures**, such as through a direct administrative procedure. This assignment procedure is widely used to grant government agencies the use of spectrum, but was also prevalent in monopolistic markets when spectrum was awarded to incumbents. Some recent examples of direct spectrum assignments include the *Instituto Costarricense de Electricidad* (ICE) in Costa Rica and Arsat in Argentina in 2012.

Spectrum has also been awarded through other **procedures that lack market incentives**. The FCC in the United States in 1992 awarded licences through a lottery process. Since consolidation was later allowed, significant value was transferred from public to private hands by a process with a random component. The FCC abandoned this process and moved to an auction-based system. LAC countries have not used lottery assignments. Except in certain specific situations, such assignments should be avoided, as they are not efficient from an economic perspective. The OECD supports market-based mechanisms to assign spectrum.

All other assignment mechanisms fall into the **contest category**, but it is important to point out that not all contests are market driven. The most widespread mechanism is one of **comparative selection**, where the license is awarded to candidates that submit the best plan based on a series of promises usually linked to some aspect of "social" or "public welfare" (e.g. coverage, technology, investment, prices, financial strength, etc.). Even if this mechanism is recommended by the mobile industry, it could potentially have nontransparent results as it can easily be designed to favour a certain operator. In practice, a significant arbitrary and discretionary component remains in such procedures, given that some criteria might not be fully relevant to judge appropriateness, and the weight given to the different variables is often subjective.

The price paid for the spectrum under the contest model tends to be low (or nonexistent), which suggests that the state may be handing a subsidy to a private stakeholder. Contests do not allow for a real valuation of the economic value of spectrum resources, as information between the regulatory authorities and the operators is asymmetrical. Comparative selection procedures have been common in the region, but **auctions** are increasingly being used.

Auction theory is a complex area in which significant progress has been made in recent years. Well-designed auctions provide the right incentives for players to use spectrum efficiently and to price it accordingly. Needless to say, one of the main reasons auctions have become common in the industry, including in the LAC region, is that they tend to generate important revenues for governments.

Auctions are an efficient assignment mechanism. They make it possible to answer two questions simultaneously: whom to assign the spectrum to and how much to charge. Well-conducted auctions have detailed rules published in advance. Prices paid by winners are defined by all players in terms of their strategy and skills. Auctions allow efficient assignment of spectrum to the players that value it most. They also help answer the pre-eminent question of value. Auctions, if well designed, can be an invaluable price discovery mechanism, leaving to the regulator the more basic question of setting a minimum reference price. It is a process that avoids the pitfalls of other alternatives, becoming significantly less discretionary and increasing certainty to markets. Several types of auctions exist:

- In **sealed price auctions**, all pre-qualified participants submit one bid. In a sealed first-price auction, the license is awarded to the highest bidder, who then pays the proposed price. In "Vickrey auctions", or sealed second-price auctions, the license is awarded to the highest bidder, who in turn pays the second-highest price.
- In **ascending price auctions** (English auctions), participants progressively increase their bid. The auction is over when there are no more bids; the winner is the entity that offers the highest bid. In descending price auctions (Dutch auctions), the auctioneer sets a price and progressively lowers it until one of the bidders accepts it. English and Dutch auctions can be done in successive rounds, where all participants submit a bid; the bidding information is then made available to participants, who then proceed to the next round.
- **Multiple round auctions** are advantageous in that they are easy to understand for participants. Giving information to participants after each round increases confidence in all the players involved. Nevertheless, it is a mechanism that can be distorted by players, for example, by signalling during the process or even colluding.
- **Combinatorial auctions** have become common in many countries to address such issues. These are auctions for the simultaneous sale of more than one item, such as blocks of spectrum bands with geographical delimitations. Participants place bids on combinations of the items on offer and the winning bids are those that maximise overall value to the auctioneer. The larger the number of items on offer, the more complex determining the winners becomes, and the more uncertainty for operators to ensure that the final distribution of spectrum matches their preferences, which can discourage participation. The maximising solution could potentially mean leaving some items unassigned. These auctions have been used in Canada and the United Kingdom.

In principle, any auction can incorporate **restrictions and obligations**. Some of the most common ones are spectrum caps (where bidders cannot exceed maximum spectrum holdings) and coverage obligations. Given the investments required to deploy a nationwide network, it makes sense to implement clearly defined and reasonable coverage obligations for operators being awarded spectrum. This can provide some certainty about the future coverage of networks.

Ambitious coverage obligations are difficult to enforce and may increase regulatory risk. Any obligation imposed should be carefully designed to balance benefits from larger coverage against lower auction receipts for the state and slowing market entry and competition. However, coverage for rural areas where network rollout is less or even not profitable can be included among the obligations stipulated. Extending mobile broadband and telephony access and/or introducing competition in rural areas may be advisable, and a case-by-case analysis is needed to provide adequate coverage to maximise benefits for citizens.

Some elements in assignment procedures to promote competition should be noted. Auctions can be designed to promote competition in the marketplace. A common restriction is the setting of spectrum caps, which, even though they can potentially reduce the number of participants in the auction, avoid spectrum hoarding, eliminate pre-emptive strategies, create some equilibrium in spectrum holdings, and increase efficiency of spectrum use. Spectrum caps are common in OECD countries, where they are widely used for encouraging entry and addressing situations of dominance. To promote competition, special care should be taken to continue to ensure that smaller players have access to sufficient spectrum resources, by setting spectrum caps or set-asides in auction design (i.e. reserved blocks for entrants where incumbents or dominant operators cannot bid), bearing in mind the balance between higher and lower spectrum bands. Caps have been used in Argentina, Brazil, Chile, Colombia, Ecuador, Mexico and Peru; they vary widely, as they respond to the specific characteristics of each market at the time they were set. For example, Mexico has set a cap of 80 MHz in its latest AWS (Advanced Wireless Service) auction. Colombia applies different caps for lower-frequency (30 MHz below 1 GHz) and higher-frequency bands (85 MHz). Caps are usually updated whenever more spectrum is auctioned or when consolidation activity results in spectrum accumulation that is deemed to affect competition in the marketplace.

In addition, consideration should be given to introducing a spectrum floor. This novel approach, recently introduced by Ofcom in the United Kingdom, will not accept the outcome of a combinatorial bidding process if it does not offer a specified amount of spectrum to at least one newcomer. In effect, this gives preference to a lower bid from an entrant, over a higher bid from an incumbent.

Other commonly used elements are the incorporation of obligations to offer wholesale services for the hosting of mobile virtual network operators (MVNOs). As addressed in Chapter 4, on competition and infrastructure bottlenecks, entry of MVNOs, can be further facilitated by obligations imposed in the license. For example, the regulator can also introduce mechanisms to make the competitive environment more favourable to MVNOs, by making national roaming obligatory among operators, so that MVNOs can offer the same coverage as MNOs. Although non-facilities-based competition exerts a limited discipline on facilities-based carriers, non facilities-based entry may be a legitimate entry strategy for new players. In addition, facilitating resale may enhance the value and therefore incentives to invest in new infrastructure.

Other issues that have arisen in dealing with spectrum are related to the clearing of the bands. Some countries (Colombia and Brazil) have opted to impose this obligation as a condition to be awarded the spectrum license. This is bound to become more common as more spectrum is allocated to IMT, but is occupied by other tenants (e.g. the 600 MHz band in the United States). Well-designed migration processes and clearing of band obligations during an auction could be an efficient way of dealing with the issue and could accelerate the expansion of wireless broadband networks.

Governments should avoid restricting assignment to existing players. This thwarts competition and allows the government to decide administratively what the market structure ought to be, rather than leaving this to market forces. Generally speaking, “beauty contests” are not recommended, as they tend to be subjective, operators tend to underpay for the real value of the spectrum, and economic rents are transferred to private companies.

Finally, some countries in the LAC region include conditions for spectrum auction procedures, such as the distribution of tablets or contributions for universal service funds, that can create distortions and risk reducing the cost-effectiveness of public funds. These programmes should be run independently of spectrum auctions, and in general, cross-subsidies from spectrum fees to fund public interest programmes should be avoided.

Spectrum valuation

One of the most challenging tasks authorities face when licensing the spectrum is setting a fair price. There is no doubt that the market is best positioned to determine the value of the spectrum, but this alternative is not always available. Auctions are the best price-discovery mechanism, but it is still necessary to set a minimum reference price, which can be different from one auction to another. Excessive prices can leave spectrum unsold and hamper the sector in meeting policy goals. A balance should, therefore, be found to maximise the value generated by spectrum bands.

There are basically five different ways to estimate the value of the spectrum. In practice, regulators need to analyse all of them and then adjust the value, depending on the objectives sought and other specific conditions of the problem at hand. For example, if few bidders are expected at a given auction, the reference price plays a fundamental role in an auction. The main reference for the minimum price is given by the avoided-cost methodology (described below), as it reflects the indifference point, which considers that an operator would not pay less than what it would cost to find an alternative solution to accommodate future demand. An auction would then throw up a price between the avoided-cost price and the net present value of cash flows obtained by using the spectrum.

Any estimation of the value of spectrum should be approached with caution, especially when valuing the future use of spectrum, as this is essentially a forward-looking exercise where many factors may vary substantially in the medium and long term. This can be done through:

- **Benchmarking** compares prices paid at other similar auctions (national, regional or international) in a normalised fashion (usually price per megahertz per population). It is probably the most common spectrum valuation methodology, simple and easy to explain, but its main pitfalls arise because real value depends on several factors, such as market potential, spectrum already allocated, competition level, license periods and additional fees, which a simple price comparison does not consider, but that can be addressed by econometric analyses. The comparison, to be fair, should consider total price paid (that is, not only the amount paid at the auction but also any recurring fees linked to the spectrum tenancy) as well as the assignment methodology (that is, it is not advisable or sensible to compare an auction price with a the price paid at a "beauty contest", as this last assignment probably does not reflect a market price). Chile awarded the 700 MHz band for USD 0.1 cent per megahertz per population in 2014, whereas Brazil, almost at the same time, licensed it for 25 times as much.
- **Econometric analysis** assess the value of the spectrum as dependent on a large number of variables. By accounting for them, it makes the benchmarking of different prices more reliable. Some variables that need to be considered reflect the general conditions of the market (GDP per capita, population, urbanisation, etc.), while others are intrinsic to the spectrum and the auction (band, amount of megahertz on offer, timing, duration of the license, market structure, etc.). An econometric analysis where price is the dependent variable can be performed using some of these variables as controlling factors. The main disadvantage of this methodology arises from the lack of enough data points to be able to incorporate several independent variables. Attention needs to be paid to the definition of the controlling variables, as they could be measured differently in different countries, and the analysis could thus yield misleading results.
- The **estimation of avoided costs** is based on calculating the cost reduction for a given operator of being able to use additional spectrum. The model assumes that operators have to satisfy increasing demand, which entails a different cost structure if more spectrum is made available. Network capacity can be increased by technological improvements, frequency reuse, increase in the number of radio base stations, simultaneous use of different networks (for example, Wi-Fi local networks or buying capacity from other operators), or, ultimately, using additional or a different band of the spectrum. Due to its propagation characteristics, higher frequencies allow for more capacity, reducing coverage per base station, while lower frequencies allow for higher coverage per base station, but less bandwidth capacity. Avoided cost is defined as the investment required to deploy the

first four options without being able to use additional spectrum. The estimation is intrinsic to each market, can be done for each operator, and does not depend on any benchmarking analysis. Its main disadvantage arises from the limited information regulators have on the cost structure of operators, as well as the need to build a hypothetical network as complement to existing networks. It also requires estimating future demand, which recent history has shown to be extremely difficult in the LAC and elsewhere. This methodology is widely used by operators, as they can easily estimate their own avoided costs.

- The estimation by **business case** is based on the cash flow of the business using the spectrum. The main assumption behind this methodology is that an operator would never be willing to pay more than the net present value of the cash generated by the business. It is usually the most realistic way to estimate the price of the spectrum for new entrants. It is important to note that the avoided-cost methodology is a comparison of the discounted cash flow of two distinct business cases: with and without spectrum. Both require the estimation of the cost of capital, which can, from a regulator's perspective, become a contentious issue.
- **Opportunity cost** is defined as the value created when something is put to an alternative use. In the case of spectrum, it is the value not generated when it is used for one alternative instead of another. This methodology is used to compare the value of the spectrum used for different telecommunications services (e.g. mobile versus fixed, mobile versus satellite, broadcasting versus IMT). In practice, calculating the opportunity cost of the spectrum relies on estimating avoided costs and discounted cash flows, as well as estimating the economic externalities generated by each of the alternative uses. For example, many of the economic and social benefit estimations of the value of the digital dividend include a detailed analysis of the opportunity costs of the spectrum.

Digital television, digital dividend and analogue switch-over

The **digital dividend** – the 700 MHz band in LAC countries – is, without any doubt, at the heart of all digital inclusion initiatives in the region, as it promises to bring broadband access to areas not reached by existing networks and to lower the price of service. Compared to other IMT bands, the 700 MHz band has significant propagation advantages; more coverage is attained with every cell site.

This band was allocated to broadcasting services in most LAC countries, with intensity of occupation varying significantly. With the advent of digital television, which allows more channels with higher quality to be transmitted through the same bandwidth, less spectrum can be assigned to broadcasting without compromising either the number of signals transmitted or their quality, making possible a greater choice of television channels and licenced broadcasters. This could increase competition in broadcasting and the development of more local content. This transition constitutes a unique opportunity to release spectrum resources, as a result of greater spectrum efficiency, and make them available for advanced mobile services, such as mobile broadband.

With the possibility of using this spectrum for mobile broadband in the LAC region, the case for changing the allocation of the band seemed reasonably straightforward. Nevertheless, the debate was intense and lasted several years. By 2010, two years after this band had already been auctioned for IMT and one year after the analogue switch-off of full power television had been completed in the United States, LAC countries had just started the debate to change its allocation. Most countries have already proceeded with the change and some have even auctioned this spectrum (the Plurinational State of Bolivia [hereafter "Bolivia"] in 2013; Brazil, Chile, and Argentina in 2014). This is a good example of transferring spectrum to more beneficial uses, responding to technological evolution and the demands of society. Nevertheless, the migration to digital television has not been a smooth, as it involves significant investment on both sides of this two-sided market (broadcasters and households). Even though digital signals are already being transmitted almost everywhere, the switch-off is still many years away in most countries (Table 3.2). Broadcasters have been reticent about ceasing analogue transmission, as the installed base of digital TV sets in the region is still low. Insufficient incentives and lack of information, as well as limited purchasing power, have made the transition very slow. As free over-the-air television is deemed to be extremely important from the civic, cultural and social perspective, forcing the switch-off unilaterally is not considered to be an option; Free to Air (FTA) television is the only affordable television service for many households. As broadcasters have prominent positions in this area of public policy and have influential lobbying skills, the debate is still open in most countries. Nevertheless, all countries are moving in the same direction, and the spectrum being freed from the switch-off will be used more efficiently from an economic and social perspective, based on a broader consideration of all potential costs and benefits.

Another important part of the debate has been the choice of **standard for digital TV**. Most countries in South America opted for the Brazilian standard (ISDB-Tb, based on the Japanese standard); in turn, the debate to choose the standard in Brazil, concluded in 2006, was heated and lasted several years. Brazil opted to modify the Japanese standard and then proposed that neighbouring countries to adopt it. Peru, Chile, Argentina and Venezuela announced their decision in 2009, followed by Ecuador, Bolivia, Uruguay, Nicaragua, Costa Rica (Box 3.2) and Paraguay in 2010. The widespread adoption of this standard will give it reasonable economies of scale (more than 450 million people), which can help bring down equipment costs and ensure innovation and research and development (R&D)-related investment. Countries that opted for other standards will achieve similar or higher economies of scale, as they can "piggyback" on larger and more developed markets, such as in Europe and the United States.

Table 3.2. **Digital switch-over in the LAC region**

	Expected date	Digital TV standard
Argentina	2019	ISDB-Tb
Bolivia	2020	DVB/T
Brazil	2018	ISDB-Tb
Chile	2020	ISDB-Tb
Colombia	2019	DVB/T
Costa Rica	2017	ISDB-Tb
Dominican Republic	2015	ATSC
Ecuador	2017	ISDB-Tb
El Salvador	2018	Not defined (decision to implement ATSC was suspended in 2012)
Guatemala	2021	ISDB-Tb
Honduras	2020	ISDB-Tb
Mexico	2015	ATSC
Nicaragua	2020	ISDB-Tb
Panama	2017	DVB/T
Paraguay	2024	ISDB-Tb
Peru	2020	ISDB-Tb
Uruguay	2019	ISDB-Tb
Venezuela	2020	1.9 GHz

Box 3.2. **Selection of the standard for digital broadcasting in Costa Rica**

In the interests of greater transparency and technical objectivity, Costa Rica appointed a Joint Commission to recommend to its executive branch, through a nonbinding technical report, the standard for digital television broadcasting in the country. The committee included government personnel, representatives of broadcasters, the telecommunications regulatory body and officials from the state channel and representatives from academia.

After several field tests in different parts of the country analysing the various standards available for digital television, the recommendation of the ISDB-Tb standard was issued. The results were documented and recorded, ensuring the portability of the recommendations issued to the executive.

Sources: Costa Rica (2010a), *Decreto Ejecutivo sobre la Definición de Estándar de Televisión Digital y reforma Crea Comisión Especial Mixta Analizar e Informar Rector del Sector Telecomunicaciones posible Estándar Aplicable País e Implicaciones Tecnológicas, Industriales, Comerciales y Sociales de Transición*, *www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?param1=NRTC&nValor1=1&nValor2=67968&nValor3=80763&strTipM=TC*; Costa Rica (2010b) *Informe Final de la Comisión Mixta de TV Digital sobre el Estándar de Televisón Digital Recomendable a Costa Rica*, *http://new.infocom.cr/wp-content/uploads/2014/02/INFORME-FINAL-TVD-Comision-Mixta-25-11-10.pdf*; Costa Rica (2011), *Decreto Ejecutivo sobre la Creación de la Comisión Mixta para la Implementación de la Televisión Digital Terrestre en Costa Rica*, *https://cgrfiles.cgr.go.cr/publico/jaguar/USI/normativa/2011/DECRETOS/DE-36775.pdf*.

Another important issue that arose after the digital dividend was allocated to IMT concerned the **segmentation of the band**. The United States, which adopted its own band plan in 2007, assigns a total of 60 MHz to mobile broadband and 24 MHz to a public safety broadband network. The Asia-Pacific Telecommunity (APT) published its recommendation for harmonised frequency arrangements in 2010: the arrangement allows for full use of the 90 MHz, that is, 30 MHz more than the US plan. Though discussions were intense, with some urging the adoption of the American band plan, most LAC countries opted for the APT standard. Argentina was the first country to announce its intentions in 2011, but Colombia was the first to officially adopt it in 2012; it was followed almost immediately by Mexico, Panama, Ecuador, Chile and Costa Rica. Only two countries, Bolivia and Paraguay, opted for the United States' band plan. The adoption of a harmonised plan in the region is important, as it will ensure interoperability, allow economies of scale and minimise interference problems.

As the LAC region switches off the analogue broadcasting networks, many aspects need to be considered for a smooth **transition**. Public funding will most likely be required. The first is that the population needs to be well informed about the transition and what it means to them. Some countries have not sufficiently raised public awareness of the issue. Such campaigns take a long time to take hold, but once they have been understood, an important part of the burden shifts to the population, and the transition speeds up, reducing the need for aggressive campaigns to subsidise decoders and television sets. Broadcasters also face significant costs as their networks migrate to the digital standard; commercial broadcasters, except for small networks, usually have no trouble meeting these costs, though public networks can potentially need public funding. Better quality and the possibility of multiplexing, in principle, make reasonable financial sense for action in this respect. Concluding the analogue switch-off is important, as it allows countries to enjoy the benefits of the 700 MHz band sooner. According to some estimates (Flores-Roux, 2013), each year that its use is delayed has an impact of around 1% of GDP six years later. This suggests that subsidising the transition to digital television is the correct strategy, but that a well-planned and orderly transition, as well as targeted subsidies, will minimise the cost.

Conclusion

This chapter addressed policy considerations regarding spectrum management. First, it noted that spectrum management frameworks should be transparent and stable. Their main goal should be encouraging investment and competition to increase availability and penetration of telecommunication services. Meanwhile, such frameworks should take into account the effect of value creation and externalities on GDP, job creation, investment, social welfare, and consumer and producer surpluses. National spectrum licensing frameworks (for the different types of agreements, whether exclusive, unlicensed or LSA/ASA) are key for managing spectrum consistently and establishing legal certainty, so that deployments and upgrades of infrastructure can be carried out with a long-term perspective and with a high expectation of renewal.

The main tools for spectrum management are national frequency allocation tables (NFAT), spectrum inventories, licence databases, long-term planning and measurements of efficient use. Moreover, as they undertake the challenging task of economic valuation of radio spectrum, policy makers can choose between tools of econometric analysis, benchmarking, avoided costs, and financial and opportunity costs.

This chapter raises important implications of spectrum management for competition dynamics. Close collaboration with the competition authority is advised, as is flexibility in assignment, not only in terms of technological neutrality, but also in terms of service ("service neutrality"). Setting spectrum caps, spectrum trading, development of secondary markets, spectrum sharing and spectrum refarming are other tools policy makers can use to increase competition and the efficient use of spectrum.

While spectrum may be assigned via non-market-based procedures (whether by lotteries or direct administrative channels) and different contest procedures (such as comparative selection), this chapter demonstrates that the most efficient mechanism of spectrum assignment is through auctions. Well-designed auctions are less discretionary, increase market certainty and can be an invaluable price-discovery mechanism, leaving the regulator the role of setting minimum reference prices, setting aside blocks for entrants and/or establishing restrictions (such as caps) and obligations (such as coverage or offering wholesale service to MVNOs) as necessary for attaining policy goals.

Finally, this chapter addresses the current challenges associated with the digital dividend (the 700 MHz band in LAC countries) and the switch-over to digital terrestrial television. To ensure a smooth transition and greater spectrum efficiency, well-planned, orderly transitions, public awareness campaigns and targeted subsidies (for decoders or migration costs of broadcasters), will help to minimise public and private costs involved in the transition.

Notes

1. See *www.pc.gov.au/inquiries/completed/public-safety-mobile-broadband#report*.
2. See *http://research.microsoft.com/en-us/projects/spectrum/default.aspx*.
3. See *www.acma.gov.au/Industry/Spectrum/Radiocomms-licensing/Spectrum-licences/spectrum_21*. In addition, in February 2016, ACMA outlined its strategy for addressing the growth in mobile broadband capacity in its work plan, based on its experience. See *www.acma.gov.au/Industry/Spectrum/Spectrum-planning/About-spectrum-planning/mobile-broadband-strategy-caps-off-decade-of-work*.

References

AHCIET GSMA (2012), *Beneficios Económicos del Dividendo Digital para América Latina* (Economic Benefits of Digital Dividend for Latin America), Asociación Iberoamericana de Centros de Investigación y Empresas de Telecomunicaciones, Montevideo, *www.gsma.com/latinamerica/wp-content/uploads/2012/06/GSMA_DocFinal.pdf*.

Costa Rica (2011), *Decreto Ejecutivo sobre la Creación de la Comisión Mixta para la Implementación de la Televisión Digital Terrestre en Costa Rica* (Executive Decree on the Establishment of the Joint Commission for the Implementation of Digital Terrestrial Television in Costa Rica), No. 36775-MINAET, Ministerio de Medio Ciencia, Tecnología y Telecomunicaciones, San José, *https://cgrfiles.cgr.go.cr/publico/jaguar/USI/normativa/2011/DECRETOS/DE-36775.pdf*.

Costa Rica (2010a), *Decreto Ejecutivo sobre la Definición de Estándar de Televisión Digital y reforma Crea Comisión Especial Mixta Analizar e Informar Rector del Sector Telecomunicaciones posible Estándar Aplicable País e Implicaciones Tecnológicas, Industriales, Comerciales y Sociales de Transición* (Executive Decree on Standard Definition Digital Television and Reform Creates special Joint Commission to Analyse and Report Possible Rector Telecommunications Sector-applicable Standard Country and Technological Implications, Industrial, Commercial and Social Transition), No. 36009 MP-MINAET, Ministerio de la Presidencia y Ministerio de Ciencia, Tecnología y Telecomunicaciones, San José, *www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_texto_completo.aspx?param1=NRTC&nValor1=1&nValor2=67968&nValor3=80763&strTipM=TC*.

Costa Rica (2010b), *Informe Final de la Comisión Mixta de TV Digital sobre el Estándar de Televisón Digital Recomendable a Costa Rica* (End of the Joint Commission on Digital TV Digital Television Standard Recommended Report to Costa Rica), Ministerio de Ciencia, Tecnología y Telecomunicaciones, San José, *http://new.infocom.cr/wp-content/uploads/2014/02/INFORME-FINAL-TVD-Comision-Mixta-25-11-10.pdf*.

Flores-Roux, Ernesto M. (2013), "*Banda ancha móvil: la urgencia de acelerar su despliegue*", in V. Jordán, H. Galperin and W. Peres (eds.), *Banda ancha en América Latina: más allá de la conectividad* (Broadband in Latin America: Beyond connectivity), CEPAL, Chile, *www.cepal.org/en/publications/broadband-latin-america-beyond-connectivity*.

GSMA (2016), *Spectrum in Latin America*, GSMA Association, London, *www.gsma.com/latinamerica/es/espectro-en-america-latina*.

ITU (2016), *ITU-R Mission Statement, International Telecommunication Union*, International Telecommunications Union, *www.itu.int/en/ITU-R/information/Pages/mission-statement.aspx*.

ITU (2011), *Telecommunications Regulation Handbook*, International Telecommunication Union, Geneva, *www.itu.int/pub/D-PREF-TRH.1-2011*.

ITU (2006), "Estimated Spectrum Bandwidth Requirements for the Future Development of IMT-2000 and IMT-Advanced", *Report ITU-R M.2078*, International Telecommunication Union, Geneva, *www.itu.int/pub/R-REP-M.2078*.

Katz, R. (2015), *Directrices de política y aspectos económicos de asignación y uso del espectro radioeléctrico* (Policy Guidelines and Economic Aspects of Allocation and Use of Radio Spectrum), *www.itu.int/es/ITU-D/Regional-Presence/Americas/Pages/EVENTS/2015/0831-NI-cosydirc.aspx*.

New Zealand (2005), *Review of Radio Spectrum Policy in New Zealand*, International Telecommunications Union and Ministry of Economic Development, New Zealand, *www.itu.int/osg/spu/stn/spectrum/spectrum_resources/general_resources/report_NewZealand.pdf*.

OECD (2005), *Secondary Markets for Spectrum: Policy Issues*, OECD Publishing, Paris, *www.oecd.org/sti/ieconomy/34758854.pdf*.

Werbach, K and Mehta, A. (2014), The Spectrum Opportunity: Sharing as the Solution to the Wireless Crunch, International Journal of Communications, Vol. 8, pp. 128-149, *http://ijoc.org/index.php/ijoc/article/view/2239/1054*.

Further reading

AHCIET (2012a), *Gestión y asignación del dominio público radioeléctrico* (Management and Allocation of Public Radio), Asociación Iberoamericana de Centros de Investigación y Empresas de Telecomunicaciones, Montevideo, Uruguay, *www.gsma.com/latinamerica/wp-content/uploads/2012/06/GSMA_DocFinal.pdf*.

AHCIET (2012b), *Hacia una gestión eficaz del espectro: Reflexiones y recomendaciones de acción* (Towards Effective Spectrum Management: Reflections and Recommendations for Action), *Asociación Iberoamericana de Centros de Investigación y Empresas de Telecomunicaciones*, Montevideo, Uruguay, *http://cet.la/blog/course/hacia-una-gestion-eficaz-del-espectro-reflexiones-y-recomendaciones-de-accion/*.

Australian Government Department of Communications (2015), *Spectrum Review Report*, Commonwealth of Australia, Canberra, *www.communications.gov.au/publications/spectrum-review-report*.

Benkler, Y. (2012), "Open Wireless vs. Licensed Spectrum: Evidence from Market Adoption", *Harvard Journal of Law and Technology*, Vol. 26, No 1, Cambridge, MA, *http://jolt.law.harvard.edu/articles/pdf/v26/26HarvJLTech69.pdf*.

CEPAL and DIRSI (2013), "*Banda ancha móvil: La urgencia de acelerar su despliegue*" in *Banda Ancha en América Latina: Más allá de la conectividad* (Broadband in Latin America: Beyond connectivity) Chapter 5, pp. 131-150, Economic Commission for Latin America (CEPAL) and the Caribbean and Diálogo Regional sobre Sociedad de la Información (DIRSI), Santiago, Chile, *http://repositorio.cepal.org/handle/11362/35427*.

CSMAC (2008), "Definitions of Efficiency in Spectrum Use", Commerce Spectrum Management Advisory Committee Working Group 1, National Telecommunications and Information Administration (NTIA), Washington DC, *www.ntia.doc.gov/files/ntia/publications/spectral_efficiency_final.pdf*.

GSMA (2015), *Key Considerations in Mobile Spectrum Licensing Latin America*, GSM Association, London, *www.gsma.com/latinamerica/mobile-spectrum-licensing-latin-america*.

GSMA (2014), *Assessing the Socio-Economic Impact of Identifying the L-band for IMT Services*, GSM Association, London, *www.gsma.com/spectrum/wp-content/uploads/2014/11/GSMA-Bluenote-Report-on-Assessing-the-socio-economic-impact-of-identifying-the-L-Band-for-IMT-services.-Oct2014.pdf*.

IDB (2015), *Spectrum Management: The Key Lever for Universality*, Inter-American Development Bank, Washington DC, *http://dx.doi.org/10.18235/0000072*.

ITU (2012), "Exploring the Value and Economic Valuation of Spectrum", *Broadband Series*, International Telecommunication Union, Geneva, *www.itu.int/ITU-D/treg/broadband/ITU-BB-Reports_SpectrumValue.pdf*.

OECD (2014), "New Approaches to Spectrum Management", *OECD Digital Economy Papers*, No. 235, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5jz44fnq066c-en*.

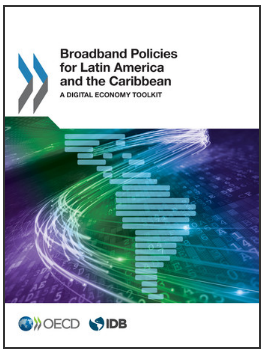
OECD (2014), "Wireless Market Structures and Network Sharing", *OECD Digital Economy Papers*, No. 243, OECD Publishing, Paris, *http://dx.doi.org/10.1787/5jxt46dzl9r2-en*.

OECD (2007), "The Spectrum Dividend: Spectrum Management Issues", *OECD Digital Economy Papers*, No. 125, OECD Publishing, Paris, *http://dx.doi.org/10.1787/231084750678*.

PCAST Report (2012), *Realizing the Full Potential of Government-held Spectrum to Spur Economic Growth*, President's Council of Advisors on Spectrum and Technology, Washington DC, *https://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast_spectrum_report_final_july_20_2012.pdf*.

Toledano, J. (2014), *Une gestion dynamique du spectre pour l'innovation et la croissance* (Dynamic Spectrum Management for Innovation and Growth), Agence Nationale des Fréquences (ANF), Paris, *www.anfr.fr/fileadmin/mediatheque/documents/organisation/rapport-gestion-dynamique-spectre-2014-06-30.pdf*.

Werbach, K. and A. Mehta (2014), "The Spectrum Opportunity: Sharing as the Solution to the Wireless Crunch", *International Journal of Communications*, Vol. 8, pp. 128-149, *http://ijoc.org/index.php/ijoc/article/view/2239/1054*.



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