Radio Spectrum Allocation and Management in Central American Countries and their Impact on the Development of the Mobile Telecommunications Services Sector

December, 2010

Regional Dialogue on the Information Society

This work was undertaken with the help of funds allocated to the IEP by the International Development Research Centre and the Canadian International Development Agency, Ottawa, Canada.

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Radio Spectrum Allocation and Management in Central American Countries and their Impact on the Development of the Mobile Telecommunications Services Sector. Lima: Regional Dialogue on the Information Society, 2010. 44 p.

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Summary

This paper identifies the main regulatory aspects associated with policies on spectrum use and allocation which have led to greater competition in the telecommunications sector in Central American countries: Costa Rica (CRC), El Salvador (ESA), Guatemala (GUA), Nicaragua (NCA) and Panama (PAN). The research findings help us make inferences about the significance of spectrum allocation in the reduction of prices of mobile services provided in telecommunications. They also show that spectrum allocation policy is one of the most effective instruments in promoting greater competition in the telecommunications sector and, consequently, the provision of lower-cost services in the region. Spectrum allocations have allowed the general public to access communication services and created possibilities for network integration and job and business opportunities. The research finishes with a number of policy recommendations on the allocation and use of radio spectrum.

Introduction

The telecommunications sector in Central America has shown strong dynamism in recent years. In particular, mobile telephony reached an average penetration rate of 107 lines every 100 inhabitants in 2009 and an average year-on-year price reduction of 22 per cent for three-minute mobile telephony calls between 2003 and 2009. The telecommunications sector has also been shown to be an attractive market for testing new wireless broadband technologies.

This dynamism has largely been associated with the process of deregulating the telecommunications sector and opening it up to competition in the countries of the region, particularly in El Salvador, Guatemala and Panama.

Given the strong correlation between effective promotion of competition in telecommunications and the economic performance of countries (Crandall et al, 2007), the dynamism of this sector could be expected to improve the region's competitiveness in the international context and lead to the development of other sectors of the economy due to the high impact of telecommunications on innovation and competitiveness (OECD, 2007, Porter et al, 2008).

One of the most important tools used by regulators in countries in the region to encourage greater competition in the telecommunications market is Radio Spectrum Management Regulations, i.e. the legal and operational framework governing spectrum allocation and defining the rules for spectrum use, transfer and exploitation.

In support of this proposition, Hazlett and Muñoz (2009a and 2009b) have shown that the Latin American countries that have allocated more of their spectrum have achieved greater benefits in social welfare, measured in terms of consumer surplus. In particular, these authors have found that an increase in the allocation of the 100 to 200 MHz frequency bands in these countries has resulted in an average price reduction of 22.5-19.0 ¢ per minute in mobile telephony services.

Therefore, the efficiency of spectrum allocation mechanisms and regulations that promote spectrum exploitation would significantly determine the degree of development and competition in the telecommunications market.

In this respect, it must be pointed out that regulatory authorities in developed countries have recently taken steps to develop policies that will enable them to implement more efficient and expeditious spectrum allocation and management mechanisms, promote optimum spectrum use, greater innovation, competition and better services at lower prices for consumers.

For example, in order to measure the impact of the exploitation of radio spectrum, its use is estimated to have resulted in a profit of £ 42.4 billion in the UK in 2006 (Europe Economics, 2006). Faced with similar circumstances in the U.S., the Federal Communications Commission (FCC) established the Spectrum Policy Task Force in 2002, which is responsible for systematically reviewing the policy on spectrum management so as to provide the FCC with advice and recommendations on economic, technical, and policy issues related to management and use of this resource.

In this respect, the increase in spectrum allocation in Central American, measured against international standards and potential spectrum use based on available technology, is one of the key elements that have contributed to greater competition in the sector and, consequently, greater economic benefits. Authorities in the region have used this tool to encourage the entry of new operators and create better conditions for competition in the wireless service sector.

This paper aims to identify the main regulatory aspects associated with policies on spectrum use and allocation which have led to greater competition in the telecommunications sector in Central American countries: Costa Rica (CRC), El Salvador (ESA), Guatemala (GUA), Nicaragua (NCA) and Panama (PAN)[1].

The next two sections present a conceptual framework for spectrum management policies and a description of allocation mechanisms, followed by a review of the international experience of spectrum management. We also review the experience of each country in the region in its process of opening up the telecommunications sector. Next, we present empirical evidence supporting the hypothesis that increased radio spectrum allocation is accompanied by greater competition and lower prices in the sector. Then, we analyse the implications it has had on the development and use of information and communication technologies. The conclusions bring the paper to a close.

[1] Belize and Honduras are not included in the analysis due to the lack of reliable sources on telecommunications services for these two countries.

1 Conceptual framework for radio spectrum regulation

One of the main objectives of State regulators is greater growth and competition in the telecommunications sector. To do this, they have at their disposal, among other policy instruments, mechanisms that help promote efficiency in the allocation and use of radio spectrum.

In addition to the regulatory structure in each country, there are changing technological and economic factors that make it necessary to redefine the terms for spectrum access, which complicates management by the authorities. In particular, rapid technological changes accompanied by a hard-to-predict demand prevent them from responding to requests for spectrum allocation promptly.

An additional component is the globalization of telecommunications, which increases the need to ensure that the regulatory framework will guarantee efficient spectrum allocation among different uses in keeping with international standards.

That is why in recent years governments in several countries have made significant efforts to include a specific policy on radio spectrum allocation and exploitation on their agendas for the telecommunications sector.

Regulatory authorities have resorted to two major routes: the design of spectrum allocation mechanisms (ex-ante) and the implementation of management policies (ex-post) to govern spectrum use, transfer and exploitation. Both have been shown to be separate but interdependent routes, that is, the way radio spectrum is allocated largely determines the frame of reference for its management and vice versa. For instance, the greater the flexibility of spectrum use, the greater the incentives for new entrants in the various spectrum auctions. If we look at it the other way round, the more the allocation method contributes to spectrum allocation to those who value it most, the greater the degree of freedom of the policies governing its use and exploitation.

An increasing number of regulatory authorities at the international level are choosing to design and implement market mechanisms for both allocation (auctions) and ex-post spectrum management (flexibility criteria for resource exploitation and the development of secondary markets). Both stages play a key role – in their respective areas – in the development of competition in the markets for final mobile telephony services.

The main factor that largely determines the regulation of spectrum management is avoiding signal interference between different spectrum users, for which regulators implement a licensing-based model which establishes the users' rights. The regulatory framework associated with these policies is called "command-and-control." Basically, it consists of a management model centralized by the regulator whereby frequencies are allocated to a limited number of users for purposes defined by the government. Table 1 summarizes the advantages and disadvantages of using these mechanisms.

Table 1 Advantages and disadvantages of using "command-and-control" management mechanisms

Source: Author

	Advantages	Disadvantages
Restrictive licences	Greater certainty for licensees. Greater flexibility for the regulator. Easier interference resolution.	Slow regulator response to market changes.
Allocation through comparative hearings	Regulator can consider social value explicitly, assuming he has access to sufficient information.	Lack of transparency about opportunity costs. Regulator does not have enough information on the present and future value of spectrum

There are growing concerns about this model, mainly because:

i) It does not ensure that radio spectrum is used efficiently (or used at all) once the corresponding licences have been issued.
ii) The allocation model is too slow and inflexible.
iii) It does not allow licensees to modify spectrum uses for new services.
iv) It limits innovative uses of new technologies.

In other words, the benefits of this model are reduced in an environment of rapid and frequent changes, and in which the responsibility for predicting how the new technologies will be used rests with the regulator.

It is therefore increasingly common to see the adoption of spectrum management alternatives aiming at market mechanisms and consistent with criteria defined by authorities in the field of economic competition, such as:

i) Definition of private property rights for radio spectrum.
ii) Development of flexible licensing rules.
iii) Consent for trading the resource.
iv) Use of auctions as an allocation mechanism.

Table 2 summarizes the advantages and disadvantages of these mechanisms.

Table 2 Advantages and disadvantages of using market mechanisms

	Advantages	Disadvantages
Flexible licences	Easy to move to higher-value uses. More innovation	Risk of interference
Allocation through auctions	Opportunity cost revealed. Allows allocation to user attributing the greatest value to the resource. Uses information from spectrum users, who usually have more and better information. Usually generates endogenous incentives for the effective use of bands.	Spectrum for uses with high social value that is not reflected in provider income might not be assured. Market power may lead to inefficient allocation. Costs of coordinated positions.

Source: Author

The purpose of these measures is to liberalize spectrum use by making it more flexible and allowing the development of secondary markets. Two of the main spectrum management models adopting some of these criteria are:

i) Exclusive use model: The licensee has exclusivity and transfer rights over the use of certain spectrum frequencies, with usage rights that are regulated mostly by technical standards, but with no guaranteed protection against interference. This model does not necessarily require the granting of property rights to private individuals.

ii) Open access or "commons" model: It involves allowing an unlimited number of unlicensed users to share frequencies, with usage rights that are regulated by technical standards, but with no guaranteed protection against interference. Under this model, spectrum is available to all users meeting the technical requirements for access.

Although there is some overlap among the three regulatory models, the most important distinction between the spectrum regulated under the last two models and the first is that the "command-and-control" model imposes greater restrictions, limiting flexibility in spectrum exploitation.

In fact, the implementation of the "command-and-control" model is associated with the generation of artificial shortages by regulators. In particular, Minervini and Piacentino (2007) identify three types of shortages generated by the controller:

i) As a result of not making enough spectrum available.
ii) As a result of poorly regulated spectrum access, stemming from inflexibility in the design of licences and rights to use spectrum. This leads to situations where valuable frequency bands may remain unused.
iii) As a result of inhibiting research and development of mechanisms for reducing shortages and using spectrum more intensively and efficiently.

The exclusive use and open access models have received considerable attention from experts in the field, as they allow intensive spectrum use and encourage technological innovation. Opponents of the exclusive use model point out that users would be motivated exclusively by control over access to the resource which will guarantee a profit for them, and not by intensive exploitation of the resource. Opponents to the open access model point out that open access to spectrum would take a toll on the resource as a result of its overexploitation.

According to the OECD (2005), rapid technological change and the convergence and growth in demand for spectrum have led to growing discontent with the "command-and-control" model, which restricts competitive entry, efficient transfer to higher-value uses and limits innovation.

In this context, the organization recognizes the significance of the concepts of spectrum trading and liberalization in the context of an exclusive use model. Firstly, liberalization gives spectrum users the flexibility to adapt to new technologies and offer new services. Secondly, trading, together with liberalization, allows markets to decide the amount of spectrum to be allocated for the different uses, contributes to faster, more flexible access to the resource, including underused or unused spectrum, helps promote the development of new technologies that make better use of spectrum, and encourages innovation in its exploitation. Moreover, spectrum trading allows the opportunity cost of the frequencies allocated by the traditional "command-and-control" model to be imputed from those that are traded. Those holding spectrum exploitation rights will therefore have incentives to use spectrum more efficiently. This model also provides incentives for operators to trade spectrum, since it increases the cost of keeping spectrum that they do not need.

The experience related to spectrum trading has been limited to countries like Australia, New Zealand, the US, Canada and Guatemala. It should be pointed out that after several years working under this model, the interest in continuing the development of

secondary markets for spectrum still exists in these countries.

Moreover, according to the OECD, there are still serious concerns in many countries about radio spectrum trading and liberalization, including:

i) Slack business
ii) Inefficient use of spectrum
iii) High transaction costs
iv) Risk of increased interference
v) Impact of spectrum trading on anticompetitive behaviours
vi) Limited impact on investment and innovation
vii) Impact on international coordination
viii) Reduced ability to achieve public interest goals

In particular, these concerns have led countries like the United Kingdom to phase in spectrum trading, initially adopting this model in service areas such as fixed links and fixed wireless access.

It should also be stressed that despite the abundant evidence supporting a shift from a "command-and-control" model to market mechanisms, it is important to recognize that regulators' decisions are limited by the structure of the rights historically acquired by operators. Modifications to these rights may be interpreted by established companies as unfair and occurring after the terms originally agreed upon, so the authority is bound to encounter strong opposition to change (Minervini and Piacentino, 2007).

It must be noted that although the benefits of using market tools for spectrum management have been widely recognized, the various regulatory authorities recognize the need to sacrifice "efficiencies" in spectrum management in order to safeguard the provision of certain public services in the areas of public defence, security and broadcasting. In particular cases, some other government operations and services provided by government agencies are also given priority.

Finally, on account of the importance that regulatory authorities have identified in the spectrum management process, specific policies have been designed for this purpose in several countries which are revised periodically for adaptation to changing market conditions and new technologies. Task forces specializing in this area have also been set up whose main role is to analyse, develop and recommend policies aimed at increasing

competition in the telecommunications markets through the exploitation of radio spectrum.

Particular cases, which are explained later, are the US with the formation of a specialized task force within the Federal Communications Commission (Spectrum Task Force), Canada with the development of guidelines on spectrum auctions (the first edition of the document *Framework for Spectrum Auctions* in Canada is from 1998) and regulatory policy (*Spectrum Policy Framework for Canada*, whose first version dates back to 1992), and Australia with guidelines established in the document *Spectrum Management Principles* (2008) and *Five-year Spectrum Outlook*, 2009-2014 (2008), among others.

2 Radio spectrum allocation mechanisms

As mentioned in the previous section, the final outcome of allocation will largely determine the ability to regulate competition in the telecommunications sector on an ex-post basis by means of spectrum management policies determined by the authority. Several mechanisms have been suggested and studied for the allocation of frequency bands. Among the best known are lotteries, comparative hearings and auctions.

2.1 Lotteries

Lotteries contribute to transparent and expeditious allocation. However, it involves transaction costs and uncertainty in the business plans of companies interested in acquiring licences for the provision of services in the telecommunications sector, which results in slow network deployment and a fragmented telecommunications market. Milgrom (2004) cites as an example the experience of the Federal Communications Commission (FCC) in the US in the '80s. Furthermore, due to asymmetries of information regarding valuations of radio frequencies, the chances of inefficiencies in final allocation are significant and insurmountable (Myerson & Satterthwaite, 1983). In this respect, those most interested in obtaining radio frequency licences would encounter strong operational, financial and information restrictions, since they would have to negotiate with hundreds of recipients of licences scattered across the country.

2.2 Comparative Hearings

Comparative hearings, also known as beauty contests, are some of the most traditional forms of spectrum allocation. They come down to allocation based on various issues, including technical, financial, legal, administrative and business criteria. It is an allocation mechanism that involves a high degree of discretionality, slow allocation, lack of transparency, with incentives for corruption and supervision costs for the regulator.

Additionally, free allocation of spectrum is equivalent to the State subsidising the sector. It is also an inefficient mechanism, given the presence of asymmetric information from regulators regarding the assessment of operators applying for licences. Even though some participating companies may be benefited by this mechanism, the discretionality, slowness and lack of transparency of the process would

further delay their business plans (Klemperer, 2004) and, consequently, the development of the sector.

2.3 Auctions

Auctions have been shown to be efficient when allocating objects to agents receiving the most favourable assessments in a transparent, expeditious manner. It also provides the State with a source of revenue.

The implementation of auctions as a spectrum allocation mechanism has come in for a great deal of criticism. In particular, it has been pointed out that they involve a transfer in the prices of services and/or reduced levels of investment in the sector. The significance of both effects has been played down by several specialists, who argue, for instance, that investments in the sector have been greater in spectrum areas for which more has been paid (Klemperer, 2004), and the conditions of demand for telecommunications services should be exceptional for sunk costs in the purchase of licences to affect the development of the sector (Burguet & McAfee, 2008). Finally, if the prices of telecommunications services are determined on the basis of supply and demand in the market, the operators will place their bids in the auction on the basis of the prices at which they will be in a position to offer their services. That is, the bids will depend on prices and not the other way round.

The greatest difficulties arising when developing the rules governing auctions are, for one thing, the danger that discouraging new entrants and/or predation by incumbents will result in a highly concentrated telecommunications market. Another drawback is that the possibility of collusion among participants may affect revenue-raising capacity, even if it does not necessarily affect efficiency. Finally, the financial capacity of some bidders may be undermined by the phenomenon known as "winner's curse", whereby a bidder may win the auctioned object after overestimating its value.

The appeal of auctions has also resulted in the State's interest in delaying spectrum allocation processes to let the price of spectrum rise and increase the likelihood of greater extra resources for the purchase of licences for spectrum exploitation. However, this policy might affect the efficiency and natural growth of the sector (Hazlett and Muñoz, 2009a).

2.3.1 Conditions contributing to competitive auction markets

The following is a set of features suggested by Klemperer (2005) that make the existence of a competitive bidding market possible:

i) The winning bidder gets all or none of the object being auctioned. This causes the relationship between the price offered and the amount purchased to be nonlinear, and sometimes erratic.
ii) Each bidder's capacity for acquisition in a period is less than the size of what is auctioned.
iii) The outcome of an auction does not significantly determine the outcome of any other auction.
iv) There are no significant barriers to entry by other competitors.
v) There is a bidding process or auction mechanism.

The first three requirements imply the possibility of Bertrand price competition. The fourth feature additionally allows the existence of potential competitors to ensure competition. Therefore, the presence of a bidding process does not per se ensure that bidders do not have market power.

2.3.2 Incentives for the promotion of competition in auctions

The promotion of competition in auction markets lies in the incentives provided by each auction format for the participation of new entrants and the removal of collusive behaviour and predatory practices. Similarly, the auction method used can facilitate the process of information aggregation and disclosure that will contribute to better allocation of auctioned items and to alleviating the "winner's curse" phenomenon. Some of the features of different auction formats that may help to compound or alleviate some of these problems are listed and discussed bellow.

i) Ascending price auctions tend to discourage the entry of new participants in auctions, while first-price auctions encourage it. The reasoning is as follows: In ascending price auctions, a strong bidder (e.g., the incumbent) will remain active until the end of the auction and weak bidders will therefore not have the (ex-ante) incentive to incur costs to prepare their bids. In the presence of such type of asymmetry, weak bidders in a first-price auction will instead have a chance to win the auction due to the incentives to be more aggressive (Maskin & Riley, 2000; Landsberger et al., 2000 and Klemperer,

2004).

ii) Another way to promote the participation of new entrants is by reducing the costs of participation. In this regard, auctioneers can reduce them by providing as much information available as possible on the object being auctioned. They can also encourage weaker bidders through mechanisms such as bidding credits, whereby bidders are allowed to pay a fraction of their winning bids, or by providing new bidders with exclusivity in the acquisition of certain licences. Another way of promoting entry is by establishing purchasing caps on incumbents. Regarding the setting of upper limits, the FCC recently decided to implement case-by-case analyses rather than drawing a clear ex-ante line on how much each bidder can acquire (spectrum caps). Finally, another way of promoting entry is by dividing objects being auctioned into smaller pieces.

iii) In the 3G auction in Europe, after the Netherlands' failure to attract more participants using an ascending auction, Denmark managed to increase the number of bidders by deciding to use a uniform-price auction, keeping the number of participants secret. In the case of the UK auction, Klemperer (2004) suggested the use of an auction that he called Anglo-Dutch auction, which would be able to attract new participants. The auction involves starting a uniform-price auction until there are only two bidders left. They are then asked to participate in a first-price auction, taking the third highest price as the reserve price. This method was not implemented, since in the end, a large number of participants turned out.

iv) Ascending price auctions also tend to promote collusive behaviour, particularly in the case of multiple-unit auctions or when a single unit is auctioned repeatedly. In the process of radio spectrum auctions, the FCC decided to implement a process of ascending price auction with a common finish time. According to the auction designers, the fact that the auction was simultaneous allowed bidders to gradually piece together their spectrum licence portfolios across the US. However, signalling processes were observed indicating serious attempts at coordination among the bidders. This led to the inclusion of new bidding rules such as the need for predetermined increases in bids (Cramton & Schwartz, 2004).

v) Other factors that contribute to collusion are the disclosure of the bidders' identities or the possibility of signals being sent. Factors that weaken collusive agreements include the use of sequential auction finish times and the setting of auctioneer reserve

prices. Regarding this mechanism, credibility is important in the event the object is not sold. Furthermore, the setting of very high reserve prices may discourage the participation of new entrants.

vi) Two major problems are noticeable in auctions for multiple objects in the ascending price formats: demand reduction and exposure. The problem of demand reduction has to do with high bidders having an incentive to reduce their demand in order to pay less for what they get. The problem of exposure has to do with bidders being interested in getting a set of objects and willing to pay a "premium." Bidders with such interests are exposed to placing excessive bids to acquire some of the set of licences in which they are interested, sometimes failing to acquire the full package due to financial restrictions. To address this problem of exposure and alleviate the problem of demand reduction, the FCC recently designed and implemented combinatorial auctions (Cramton et al., 2006).

vii) The ascending price auction also allows information aggregation and disclosure in multiple-unit auctions (preferably when they are complementary) and alleviates "winner's curse" problems. In this respect, the policy of the auctioneer disclosing information on the characteristics of the object being auctioned applies.

viii) The existence of a resale market encourages the participation of new agents and increased competition in auctions.

3 Experience of opening up telecommunications, spectrum management and mobile telephony services

The following is a brief description of the experience of each of the selected countries of Central America related to the opening up of the telecommunications sector, spectrum allocations and their impact on mobile telephony services. Table 3 shows a set of basic statistics on mobile and fixed telephony for each of the Central American countries analysed. Additionally, this section ends with a description of the experience in the main regions that began the process of opening up the telecommunications sector at the international level (the United States and the European Union).

Table 3 Basic statistics on fixed and mobile telephony (2009)

(1) Data collected from the websites of the main mobile telephony providers in each country
(2) Data collected from telecommunications regulators in each country.

Country	Average Mobile Price Per Minute (USD) (1)	Penetration of mobile lines (%) (1)	Average Fixed Price for 3 min. (USD) (2)	Penetration of fixed lines (%) (1)	HHI (1-10000) (3)	Spectrum (Mhz) (2)	Population (millions) (4)	PPP-adjusted GNP per capita (USD) (4)
Costa Rica	0.056	42.2	0.169	32.3	10000	117	5	10564
El Salvador	0.013	122.4	0.021	17.8	2668	177	6	7355
Guatemala	0.063	123.5	0.189	10.1	3524	183	14	4831
Nicaragua	0.007	54.7	0.487	4.8	5339	134	6	2892
Panama	0.082	175.8	0.247	15.5	3727	125	4	11776

(3) Author's calculations based on data collected from regulatory agencies in each country.
(4) World Economic Outlook Database (October 2010), IMF.

3.1 Costa Rica

The *Instituto Costarricense de Electricidad* (ICE) is the public utility that provides basic electricity and telecommunications services in Costa Rica. The ICE is a state monopoly that has managed both fixed and mobile telephony and the provision of broadband services through its subsidiary *Radiográfica Costarricense* (RACSA). Although the Costa Rican government tried to liberalize the sector in 2000, public demonstrations organized mainly by unions associated with the ICE prevented progress in this process. The exploitation of telecommunications has therefore remained exclusively in the Costa Rican State's hands[2].

[2] Only paging and cable TV services are subject to competition.

In 2006, the General Telecommunications Act was passed to help modernize and streamline the telecommunications sector, which in turn led to the creation of SUTEL (*Superintendencia de Telecomunicaciones,* or Superintendency of Telecommunications) as regulator of the sector, operating under ARESEP (*Autoridad Reguladora del los Servicios Públicos,* or Regulatory Authority for Public Services). SUTEL was created to regulate, oversee, enforce, monitor and control the legislation on telecommunications. In addition, the Fonatel (*Fondo Nacional de Telecomunicaciones,* or National Telecommunications Fund) was created as a parafiscal levy mechanism for the purpose of promoting universal access and universal service and serving vulnerable low-income groups, which the Act establishes as some of its fundamental principles in the telecommunications sector.

As regards its advances in telecommunications, Costa Rica digitized its fixed network in 2005 and has the highest fixed telephony penetration rate (32 every 100 inhabitants) in the region. As regards radio spectrum use, Costa Rica decided to reserve its management and economic exploitation and prevented the entry of new operators. However, the Costa Rican government has continued to increase spectrum release to its only operator – from 93 MHz in 2003 to 117 MHz in 2009 – for commercial use. These deliveries were accompanied by a reduction of approximately 7% in the prices of 3-minute calls and an increase in penetration rate from 19 to 42 lines every 100 inhabitants during the same period. However, the almost nonexistent supply of prepaid cards, the absence of competition, poor service, inefficiency and limited supply of new mobile lines have probably been the reasons for the low penetration rate of mobile telephony services in the Costa Rican population, which remains the lowest in the region. Finally, due to the same inefficiencies in the mobile telecommunications subsector, mobile broadband services in 2009 were virtually nonexistent.

3.2 El Salvador

El Salvador began to undergo a regulatory change in telecommunications in 1996. That year, SIGET (*Superintendencia General de Electricidad y Telecomunicaciones, or* Superintendency of Electricity and Telecommunications) was created as the industry's new regulatory body, the Telecommunications Act was passed to reform the policies in the sector, and the state-owned monopoly that provided telecommunications services

was privatized. [3]

Under the Act, the main responsibilities of the SIGET are monitoring spectrum use, detecting and limiting illegal spectrum uses and settle disputes arising between participants. The spectrum allocation strategy was similar to that implemented by Guatemala, with the difference that in El Salvador, licensees are supposed to pay annual fees for spectrum use. Between 2003 and 2009, radio spectrum availability increased from 138 Mhz to 177 Mhz. These new releases of spectrum have been accompanied by 34% year-on-year reductions in average prices and an increase in penetration rate from 16 lines to 107 lines every 100 inhabitants. However, fixed telephony penetration is still lagging behind, remaining at 15 lines every 100 inhabitants. The combination of these two phenomena caused the ratio between mobile and fixed lines to reach 7 mobile lines per fixed line in 2009.

Overall, the release of spectrum and the regulatory framework that was implemented facilitated the entry of six mobile telephony operators in a market of 7 million people, most of whom live in poverty. Consumers today have at their disposal different types of mobile phone technologies that allow them to access joint digital telephony, radio communication, paging, data transmission and fax services.

3.3 Guatemala

Like El Salvador, Guatemala changed the regulation of telecommunications in 1996. Before then, the telecommunications market was regulated by an agency that controlled the frequencies below 800MHz, while a state-owned company controlled frequencies above 800Mhz. Additionally, a private company obtained the exclusive right to mobile telephony in 1989, with a share of its profits going to the state-owned company.

Since 1996, when the General Telecommunications Act came into force, the telecommunications sector in Guatemala has experienced a spectrum policy liberalization process based on two principles: The first principle is that all unallocated spectrum may be requested by any agent for the required purposes. The second principle is that the user is given the right to exploit the spectrum, which includes

[3] Some key aspects of the liberalization of the telecommunications sector in El Salvador are similar to those seen in Guatemala, which we will see later.

changes in spectrum use over time. This contributes to the emergence of secondary spectrum markets.

In addition to establishing new regulations, the General Telecommunications Act creates the SIT (*Superintendencia de Telecomunicaciones*, or Superintendency of Telecommunications), whose main responsibilities are to manage and monitor radio spectrum and resolve any disputes that may arise between different parties owning spectrum, with a view to optimizing resources in the telecommunications sector in a competitive environment.

The SIT established the way in which every public auction should be carried out, with one or several rounds. Should the SIT decide to fragment a band, the fractions must be auctioned simultaneously with multiple rounds and a clear specification of the minimum acceptable increases and the way to close the auction. As regards the amount of spectrum released, Guatemala is the country with the largest amount released in the region, with an increase from 140MHz in 2003 to 183MHz in 2009. These releases were accompanied by price reductions for three-minute mobile calls (9% year on year) and greater service penetration (124 lines every 100 inhabitants).

As a result of the opening up of the telecommunications sector and the introduction of regulations regarding the management of radio spectrum, the penetration of fixed telephony in Guatemala contrasts with that of mobile telephony, like in El Salvador. The penetration of fixed telephony in 2009 was only 10 lines every 100 inhabitants, which caused the ratio between mobile and fixed lines to reach 12 mobile lines per fixed line.

3.4 Nicaragua

The regulator of telecommunications services in Nicaragua is TELECOR (*Instituto Nicaragüense de Telecomunicaciones y Correos,* or Nicaraguan Institute of Telecommunications and Postal Services), whose responsibilities are regulatory design, technical planning, monitoring and enforcement of legal regulations in telecommunications services. It also regulates and manages radio spectrum, which includes issuing permits to interested parties. The General Telecommunications and Postal Services Act passed in 1995 is the legal framework governing the sector and the activity of TELECOR, which promotes competitive practices.

The process of privatization of the state monopoly of telecommunications in Nicaragua (ENITEL), which had begun in 1995, was completed in 2001. In 2004, the SISEP was created as the public services watchdog for the purpose of bringing together the regulators of utilities (water, electricity and telecommunications) and for coordination with the body responsible for promoting competition. This created an atmosphere of institutional confusion as to which body to respond to, as TELECOR operates under the Executive and SISEP under the National Assembly. This situation, coupled with the political tension in the country, has resulted in institutional weakness when it comes to identifying, investigating and penalizing anti-monopoly practices.

Given this regulatory framework for telecommunications, the development of telecommunications in Nicaragua is lagging far behind that observed in the region. Nicaragua still has the lowest fixed telephony penetration rate in the region with 5 lines every 100 inhabitants, while the penetration rate of mobile telephony is 54 lines every 100 inhabitants. The significant mismatch between fixed and mobile telecommunications caused the ratio between mobile and fixed lines to reach 10 mobile lines per fixed line in 2009.

However, the opening up of the sector to competition and the spectrum allocation policy (85 MHz to 134 MHz) allowed an increase from 8 to 54 lines every 100 inhabitants in the penetration of mobile telephony from 2003 to 2009 and a substantial reduction in average prices for three-minute calls (45% year on year).

3.5 Panama

The telecommunications market in Panama has gone from being an unregulated

private monopoly until 1969 to being a state monopoly from 1970 to 1996, only to become a regulated private monopoly between 1997 and 2002, and, finally, a competitive market as of 2003.

The National Authority of Public Services (ASEP) is the entity charged with regulating the different utilities (water, electricity, telecommunications and television). ASEP's responsibilities are, among others, to allocate and monitor the use of radio spectrum, issue licences and concessions, and promote competition in the telecommunications sector.

The opening up of the telecommunications sector to competition in mobile telephony caused the penetration of mobile telephony to increase from 36 lines every 100 inhabitants in 2003 to 175 lines every 100 inhabitants in 2009, which positioned it as the country with the highest penetration rate in the region. This disparity between the growths of mobile telephony and fixed telephony has resulted in a ratio of 17 mobile lines per fixed line. Furthermore, the systematic release of spectrum for use in mobile telephony services since 2003 was accompanied by a substantial year-on-year price reduction of 20% for three-minute calls until 2009.

3.6 Radio spectrum regulation experiences in the rest of the world

For some years, some countries have been making significant efforts to include policies on radio spectrum allocation and exploitation among their priorities regarding the telecommunications sector. The particular cases of the United States and the European Union are discussed below.

3.6.1 United States of America (USA)

In 1999, the FCC laid down the general principles of spectrum management. The establishment of these principles led to the consolidation of the US as a leader in the use of market mechanisms for allocation and award of licenses for spectrum exploitation. In recent years, this agency has promoted liberalization in the following ways:

i) By establishing a task force (Spectrum Policy Task Force) to make specific recommendations on ways to evolve from a "command-and-control" mechanism to a more integrated market-oriented spectrum policy.

ii) By developing the secondary market initiative to remove regulatory barriers and facilitate efficient spectrum reallocation to higher-value uses.
iii) By allocating Advanced Wireless Services (AWS) on the 1710-1755 MHz and 2110-2155 MHz bands. Simple interference mitigation rules are defined and 2G and 3G (or 4G) migration is simplified.

3.6.2 European Union

A few years ago, the European Union (EU) embarked on a spectrum reform following the recommendations of the report by the Radio Spectrum Policy Group (RSPG) on the implementation of concepts such as spectrum trading and liberalization.

In most EU countries the "command and control" model remains dominant for spectrum allocation. Some countries, however, solve competition issues by means of auctions.

The amendments to spectrum management seek to make regulations in Europe less restrictive and strengthen spectrum management in EU member states. In fact, according to the European Commission, the introduction of spectrum management mechanisms based on market mechanisms, coupled with more flexible usage rights, might add 8-9 billion euros per year to the telecommunications market in the member states.

The opening up of frequency bands set aside for mobile communications, such as those for 3G mobile services, is one of the Commission's initiatives. The liberalization of broadcasting spectrum deriving from digital conversion is intended to be the next strategy.

4 Spectrum allocation and competition in the telecommunications market

The description given of the experience of Central American countries in their process of opening up telecommunications is a sign of a relationship between the release of radio spectrum and prices, competition levels and penetration levels of mobile telephony.

In order to establish a more formal relationship between spectrum allocation and its impact on the telecommunications market, we must take as a conceptual basis a theoretical model with two or more companies which, as a first stage, decide how much to invest in an essential input for production – in our case, the amount of available radio spectrum – and, in the second stage, decide to start a Bertrand price competition for the service (Hazlett and Muñoz, 2009b). In this way, each company's investment in availability of the key input in the first stage determines its ability to compete in prices in the second stage.

Since the structural estimate of this equation system requires specific information that we unfortunately do not have, we will now go on to review a series of indicators for Central American countries in the area of spectrum allocation and competition in the telecommunications market, which can be interpreted in the light of the model briefly described.

Figure 1 shows spectrum allocations for the years 2003 and 2009, measured in megahertz (MHz). In all these countries there is a significant increase in the release of radio spectrum, with a regional year-on-year average of 7.5%.

Figures 2, 3 and 4 show the average prices of wireless calls, the Herfindahl-Hirschman Index (HHI) of wireless telephony market concentration, and mobile phone penetration rate, respectively. During this period, the average reduction in the price of three-minute mobile phone calls was 22.8% year on year, the HHI declined by 1.5% year on year and penetration rate grew by 36% year on year.

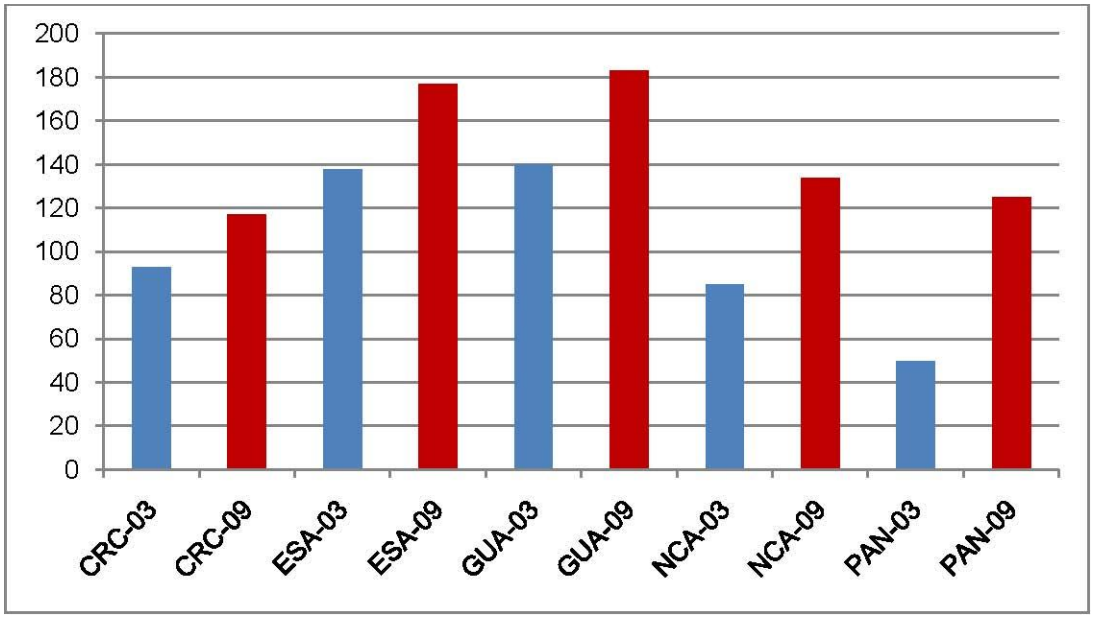
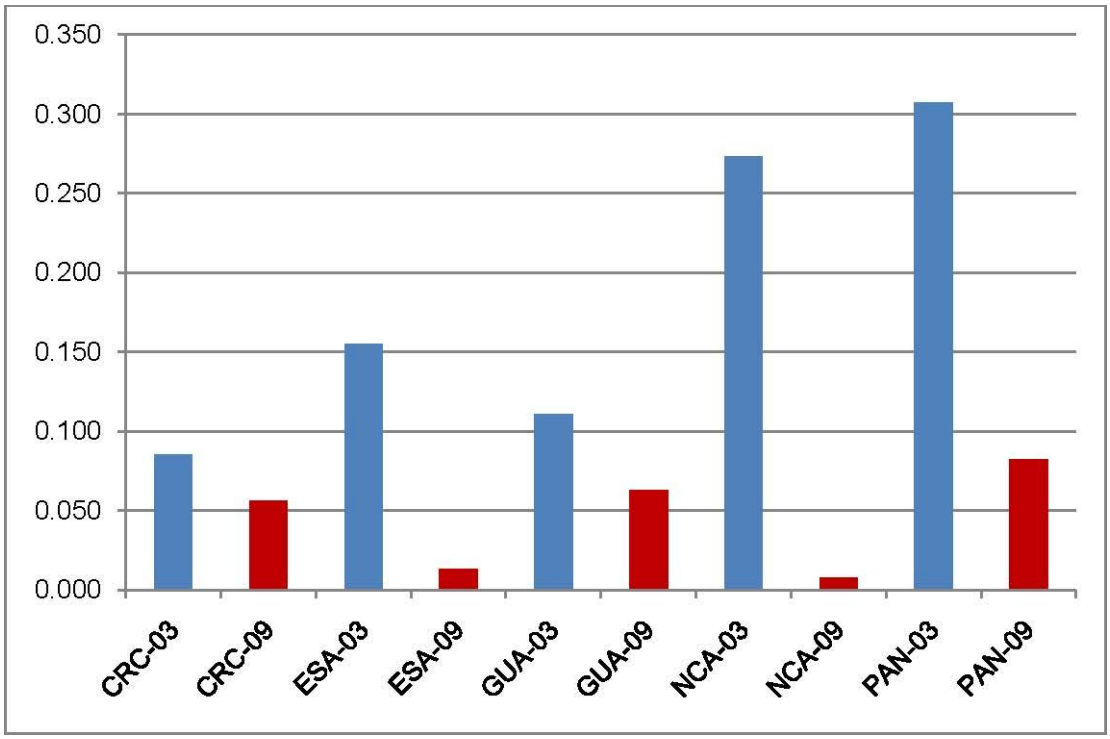


Figure 1 Spectrum allocation in 2003 and 2009 (MHz)

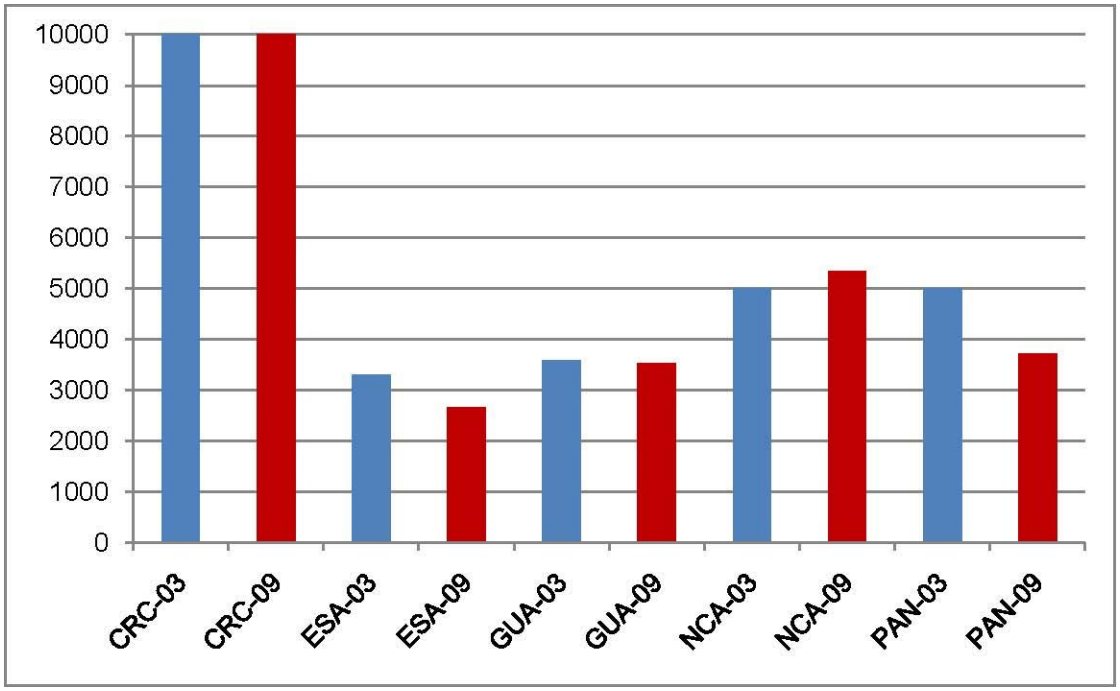


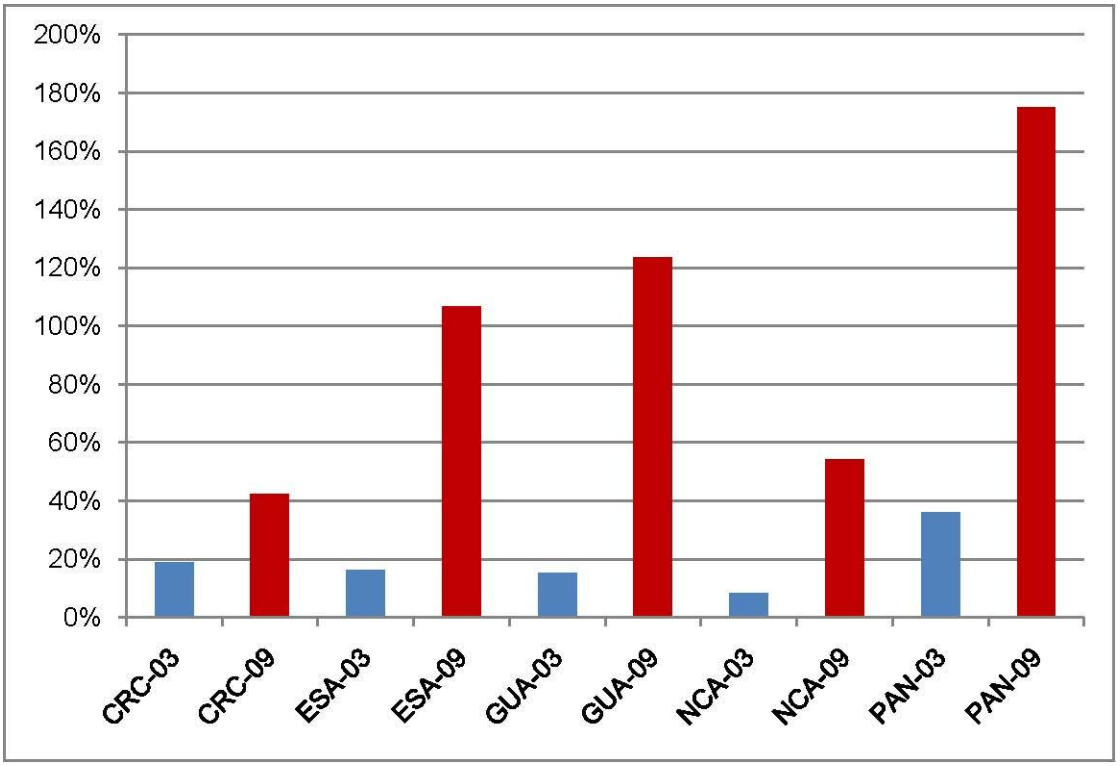
Source: Sutel (CRC), Siget (ESA), SIT (GUA), Telcor (NCA), ANSP (PAN)

Figure 2 Average price per minute in 2003 and 2009 (US$/min)

Source: Sutel (CRC), Siget (ESA), SIT (GUA), Telcor (NCA), ANSP (PAN)

Figure 3 Herfindahl-Hirschman Index of telephony market concentration





in 2003 and 2009

Source: Sutel (CRC), Siget (ESA), SIT (GUA), Telcor (NCA), ANSP (PAN)

Figure 4 Percentage rate of mobile phone penetration

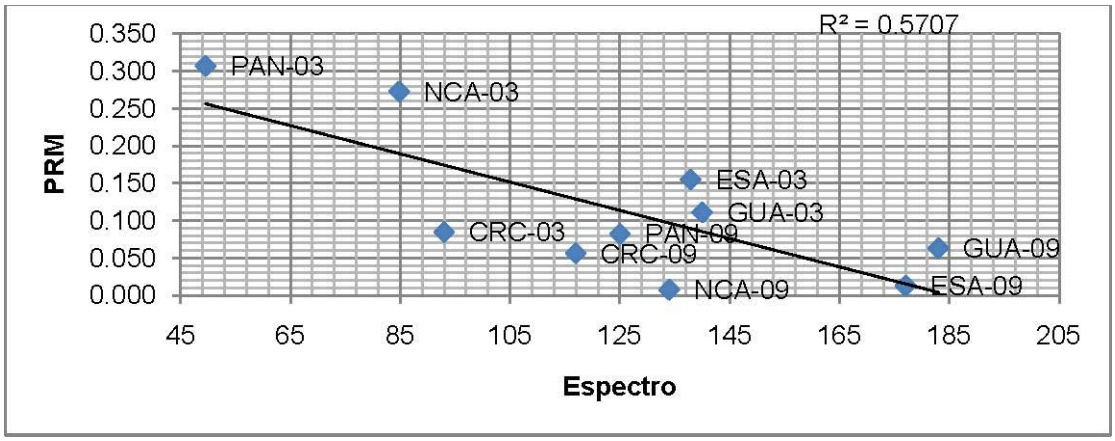
Source: Sutel (CRC), Siget (ESA), SIT (GUA), Telcor (NCA), ANSP (PAN)

Figure 5 below provides a graphic representation establishing a linear relationship between the amount of spectrum allocated and average prices. The figure confirms the impact of greater spectrum allocation on price reduction in the mobile telecommunications sector.[4]

Then, figure 6 shows us a linear relationship between the amount of spectrum allocated and the degree of concentration measured by the HHI. The negative relationship between both variables, although weaker than the previous one, shows an improvement in the sector's competition indices, with the exception of Costa Rica, where the opening up of telecommunications has been lagging behind the other countries in the region.

Finally, figure 7 shows a linear relationship between the amount of spectrum allocated and the degree of mobile phone penetration in the population. The positive relationship between both variables is a sign of improvement in penetration rates in countries in the region.

Figure 5 Radio spectrum allocations in 2003 and 2009 (MHz) and their relation to average prices per minute (US$/min)

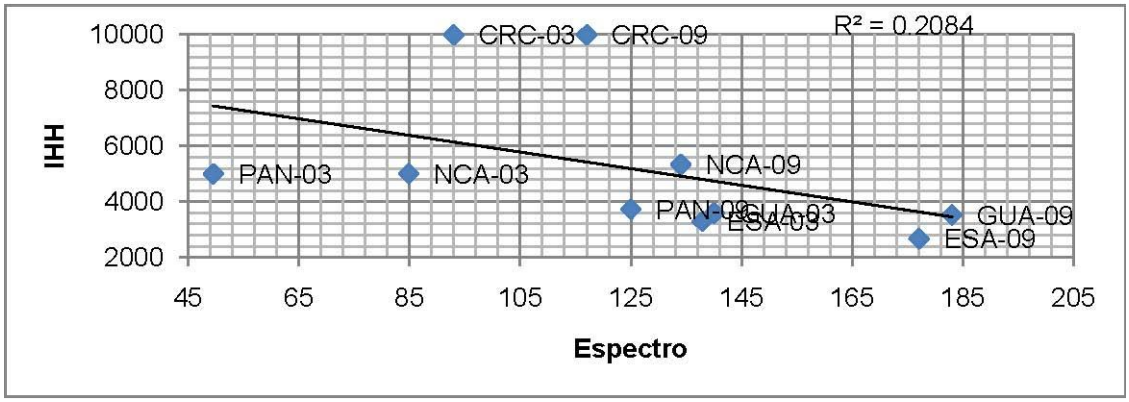


Prices per Minute **Spectrum**

Source: Sutel (CRC), Siget (ESA), SIT (GUA), Telcor (NCA), ANSP (PAN)

[4] Linear regressions developed for figures 5, 6 and 7 show correlations between the variables represented. These correlations, however, would require a more thorough econometric analysis, because other significant variables that could reduce the degree of relationship would not be included. An analysis of this nature required more specific and reliable data and a structural equation system that would take into account elements of endogeneity and correct specification.

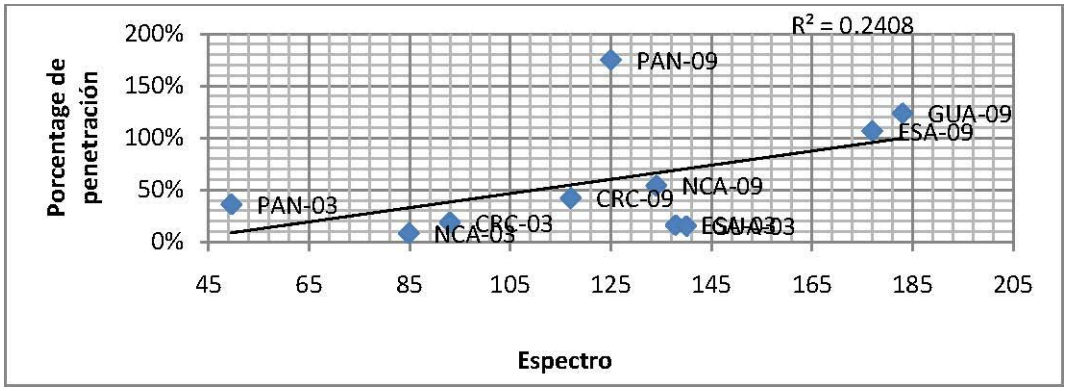
Figure 6 Radio spectrum allocations in 2003 and 2009 (MHz) and their relation to the Herfindahl-Hirschman Index of market concentration



HHI **Spectrum**

Source: Sutel (CRC), Siget (ESA), SIT (GUA), Telcor (NCA), ANSP (PAN)

Figure 7 Radio spectrum allocations in 2003 and 2009 (MHz) and their relation to the penetration percentage rate



Penetration percentage **Spectrum**

Source: Sutel (CRC), Siget (ESA), SIT (GUA), Telcor (NCA), ANSP (PAN)

These findings help us make inferences about the significance of spectrum allocation in reducing the prices of mobile services provided in telecommunications. The results show us that spectrum allocation policy can be regarded as an effective tool for the promotion of greater competition in the telecommunications sector and, consequently, for the provision of lower-cost services in the region. Furthermore, spectrum allocations have allowed the general public to access communication services, opening network integration possibilities as well as job and business opportunities.

One way to interpret these results in the region was posited by Hazlett, Ibarguen & Leighton (2007). According to these authors, the regulatory framework for spectrum management and use has implications for consumer welfare and efficiency in the

sector, since spectrum is an essential input in the production process of telecommunications services.

Hazlett et al. specifically discuss the impacts of granting exclusive spectrum property rights on the sector's competition levels, mobile telephony prices and the increase in mobile telephony services. The authors found empirical results by using annual data from 2000 to 2004 on the following Latin American countries: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay and Venezuela.[5]

Excluding El Salvador and Guatemala, the average spectrum allocated in these countries was 90 Mhz, while Guatemala and El Salvador had allocated 140 MHz and 138 MHz respectively, which positioned them above the average of the other countries considered in the sample. As regards Nicaragua and Panama, they were below the average levels, at 40-60 Mhz. The authors found that the difference in spectrum allocated in Guatemala and El Salvador was significantly different compared to the other countries in the sample.

The authors also found that the relationship between the logarithm of the allocated spectrum (MHz) and the logarithm of GDP (thousands of dollars per capita) was positive, and the coefficient of the Liberalization variable was significant in the regressions developed to account for the relationship between the above-mentioned variables. While Guatemala and El Salvador were above the regression line, Nicaragua and Panama were below it.

The authors also analyzed the spectrum allocated every one thousand dollars of GDP per capita, and found that the liberalization process had increased the spectrum available to providers of mobile services on 16 MHz every one thousand dollars of GDP per capita. Guatemala and El Salvador were above the average, while Nicaragua was average and Panama was below the average and below the other countries that were below the average. These results confirmed the hypothesis that a liberal regulatory framework implied a larger amount of allocated spectrum.

To analyze the effect of competition on the mobile telephony sector, the authors calculated the HHI for that sector. The average of countries excluding Guatemala and

[5] Costa Rica was excluded from the sample because there is a state monopoly in the provision of mobile telephony, which makes the interpretation of the data difficult.

El Salvador was 4892. At the time, the indices of Guatemala and El Salvador were in the region of 3000-4000, while Nicaragua had an index in the region of 6500-7000, and Panama's index was similar to the calculated average. This result showed that liberalization caused the index to fall.

The authors used the mobile service providers' average revenue per minute as a proxy for the price of such services. Guatemala was below the average of countries excluding Guatemala and El Salvador, while El Salvador was just above the average of 0.25. In addition, the average revenue per minute of Nicaragua and Panama was above the average price, these countries having had the highest values in the sample. The results of the regression analysis performed by the authors allowed them to conclude that liberalization caused average revenue per minute to decrease, but this result was only statistically significant for Guatemala when El Salvador was excluded from the sample.

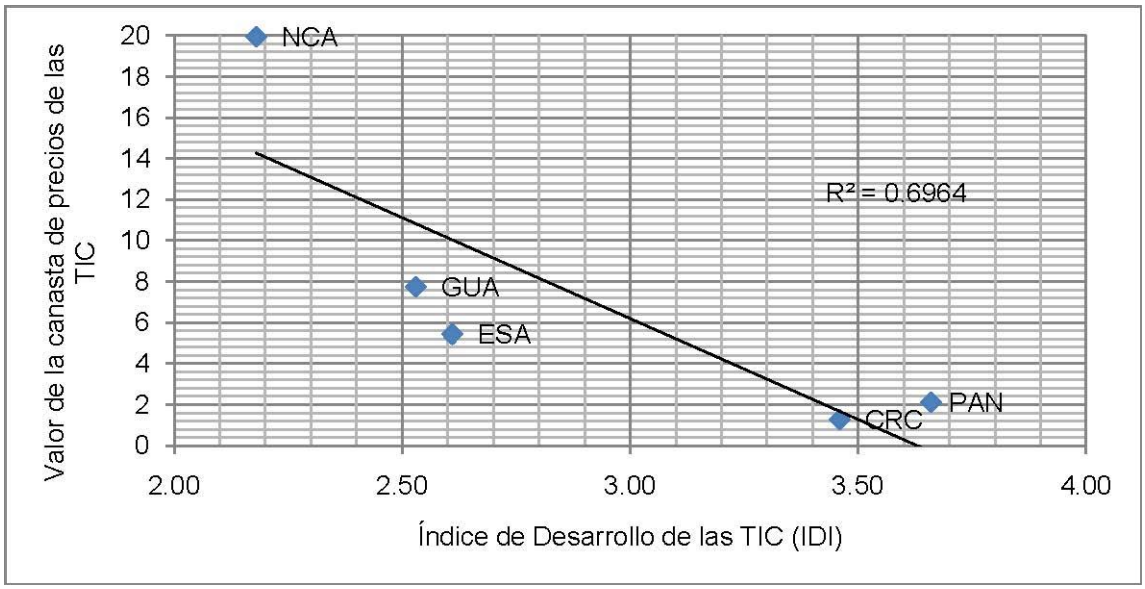
Finally, to measure the level of production in mobile telephony, the authors defined it as total minutes of mobile phone use per person per month. Guatemala was above the average for countries in the sample excluding Guatemala and El Salvador, while El Salvador was below. The value for Panama was the same as the average and Nicaragua was below the average and below all the other countries in that situation. The authors proved that there was a positive relationship between total minutes of mobile phone use per person per month and GDP per capita, measured in thousands of dollars. Guatemala and El Salvador were above the regression line, Panama was right on the regression line and Nicaragua was below it. They proved that the liberalization process in Guatemala and El Salvador was associated with an increase in minutes of use (per person per month per thousand dollars of GDP per capita) and the effect was statistically significant.

From the description and analysis in the previous section, we can infer that spectrum management policies have a significant impact on the development of telecommunications, particularly mobile telephony, as well as the opportunities to experiment with other wireless media, such as mobile broadband.

Lower prices in mobile telecommunications also involve improvements in the use of information and communication technologies (ICTs) (fixed and mobile telephony, and broadband), as revealed by the study by the ITU (2010). This is illustrated in Figure 8, which shows a relationship between ICT price basket values and the ICT development index for countries in the region in 2008.

Figure 8 ICT Development Index (IDI) and its relation to prices in 2008

Source: ITU (2010)



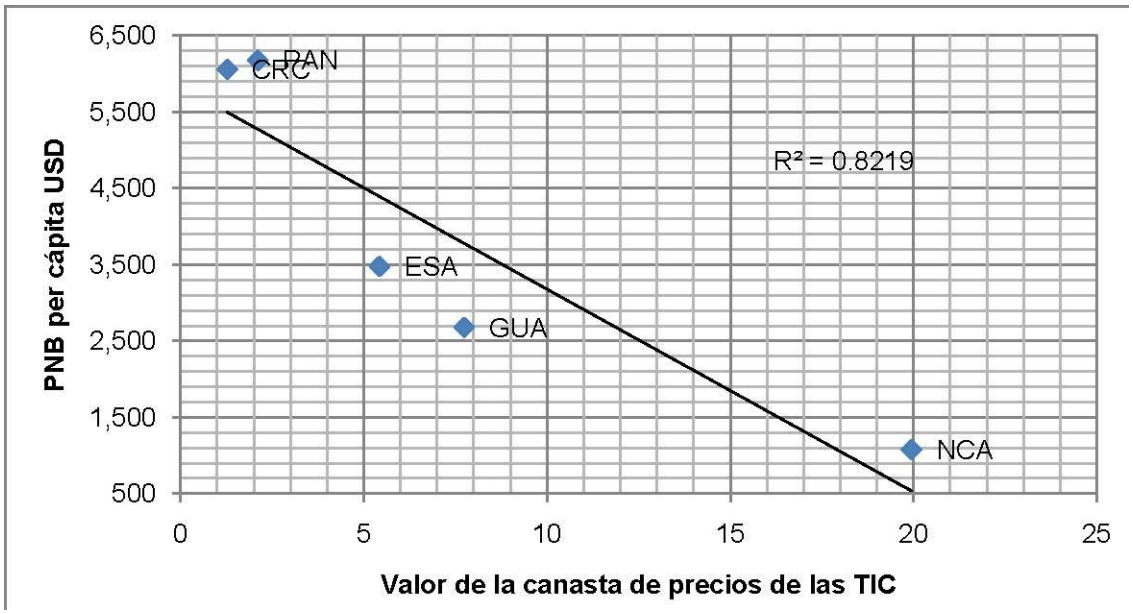
ICT price basket value

ICT Development Index

Notably, Costa Rica's best performance as regards the IDI is due to the strong performance of fixed telephony compared to Guatemala and El Salvador, even though these countries have fared better in mobile phone penetration.

Similarly, the economic growth of gross national product (GNP) per capita and human development indices (HDI) are accompanied by lower ICT price basket values. We illustrate this relationship with figures 9 and 10. In 2008, lower ICT price basket values are associated with higher levels of GNP per capita and higher HDI values.

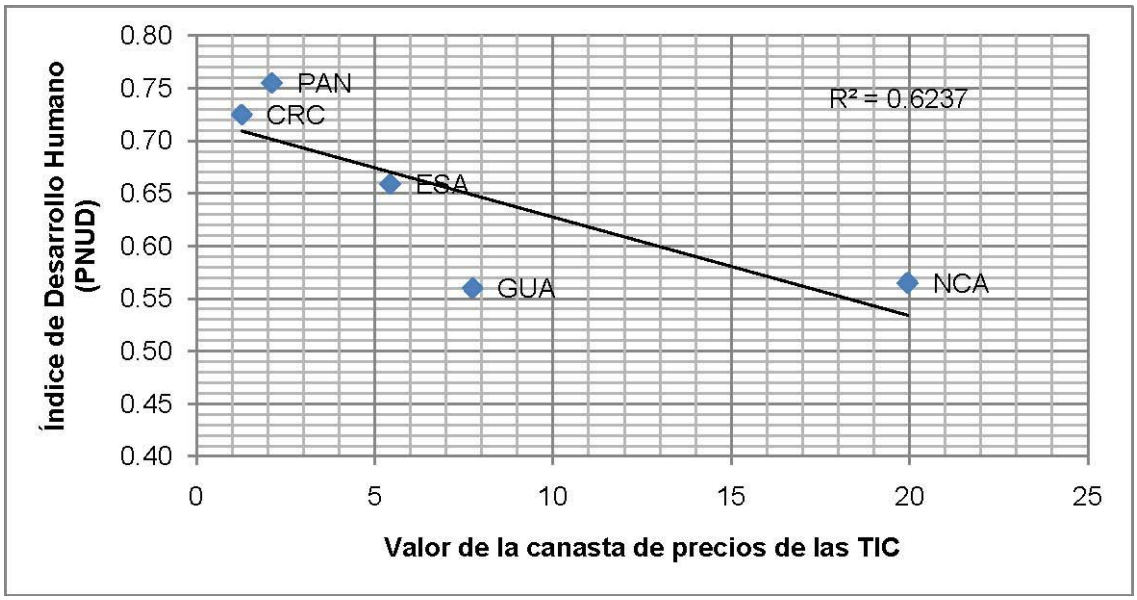
Figure 9 Value of the ICT price basket and its relation to GNP per capita



GNP per capita USD **Value of the ICT price basket**

Source: ITU (2010)

Figure 10 Value of the ICT price basket and its relation to the HDI in 2008



Human Development Index (UNDP) **Value of the ICT price basket**

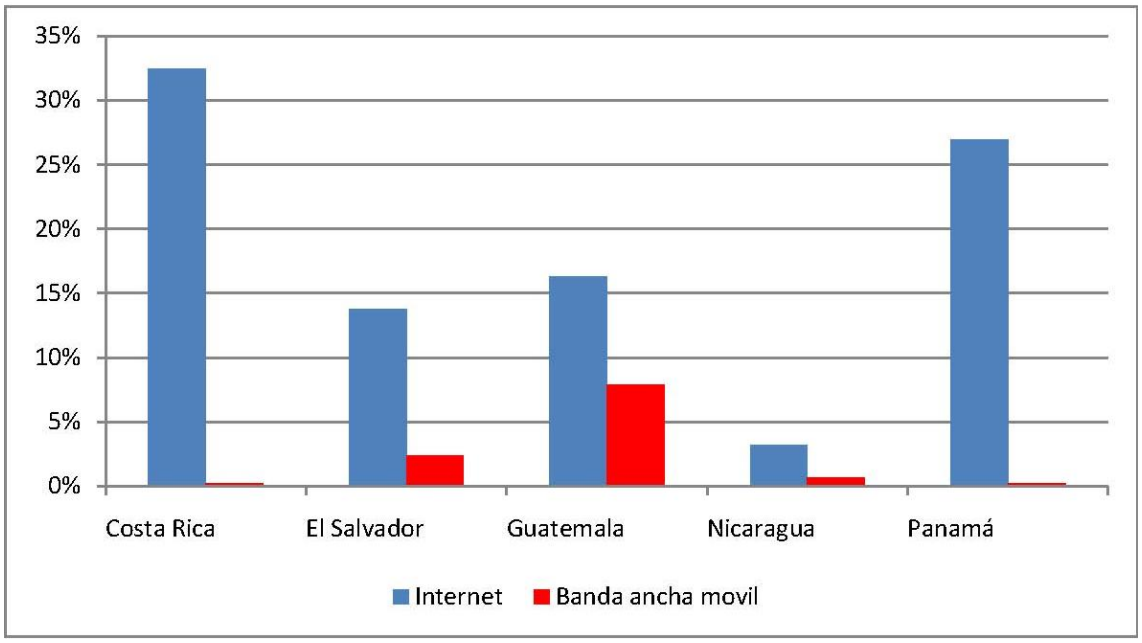
Source: ITU (2010)

To conclude, I will briefly analyze the development of mobile broadband services in Central America. Although the use of Internet services has grown in penetration,

mobile broadband services are still lagging far behind in the region. This can be seen in Figure 11, which shows the disparity between Internet and mobile broadband penetration rates in the region in 2008.

Broadband service has primarily been tied to the development of mobile telephony services. Therefore, the mobile telephony market must mature before growth can be noticed in the mobile broadband sector. However, the strong presence of fixed broadband services in these countries could lead us to believe that the potential for the mobile broadband market is very high. As shown in Figure 12, the percentage of broadband services in relation to GNP significantly exceeds that of fixed telephony and mobile services, which makes it very attractive for any mobile phone company to expand its operations and provide this service.

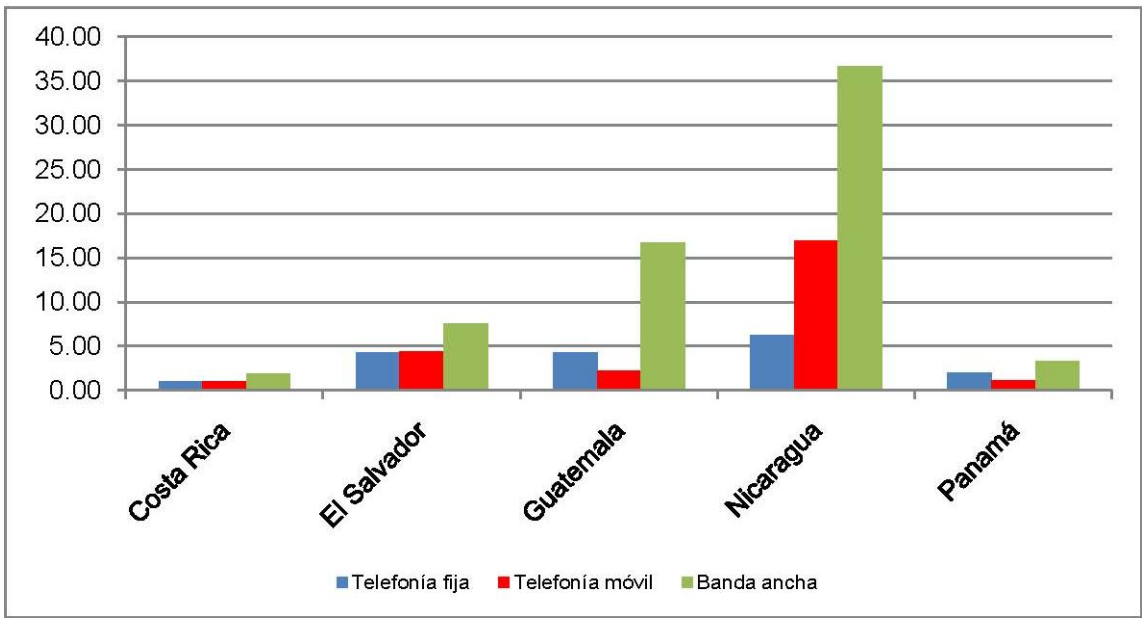
Figure 11 Internet and mobile broadband penetration percentage in 2008



Internet Mobile broadband

Source: ITU (2010)

Figure 12 Spending on the different telecommunications services as a percentage of GNP in the year 2008



Fixed telephony Mobile telephony Broadband

GNP in 2008

Source: ITU (2010)

Conclusions

This paper aims to identify the main regulatory aspects associated with policies on spectrum use and allocation which have led to greater competition in the telecommunications sector in Central American countries: Costa Rica (CRC), El Salvador (ESA), Guatemala (GUA), Nicaragua (NCA) and Panama (PAN).

In the sections above, we found evidence that for Central American countries, increased spectrum allocation is positively associated with price reduction in the mobile telecommunications sector, which reduces the degree of measured concentration and results in improved mobile phone penetration rates in Central American countries. We also found evidence of how the regulatory framework for spectrum management and use has implications for consumer welfare and efficiency in the sector, since spectrum is an essential input in the production process of telecommunications services. Finally, we found evidence that lower prices in mobile telecommunications also involve improvements in the use of information and communication technologies (ICTs) (fixed and mobile telephony, and broadband), which is reflected in an improved ICT development index for the region as a result of lower prices of ICT services.

From this evidence, it is clear that the spectrum management model in Central America must be improved so that it is suited to the economic, technological and market contexts and contributes to optimizing spectrum use and maximizing the welfare provided by the telecommunications sector.

It must be pointed out that the countries with a market-oriented regulation model are the ones that have been able to obtain the highest growth rates and lowest prices in the mobile telephony sector. In particular, allocating greater amounts of spectrum through the auction process for exploitation by those who value it the most results in fast, transparent, profitable allocation for countries. Furthermore, greater spectrum releases have facilitated the entry of new competitors, which encourages lower prices through competition.

However, not all regulatory authorities have managed to respond to the needs of operators in a timely manner, particularly Costa Rica and Nicaragua, so the implementation of regulations in force is hindering the full development of mobile telecommunications.

International experience and economic theory strongly support the idea of migrating from a "command-and-control" model to one based on market mechanisms, particularly when technological progress allows services to have different functions, reduce differences between services and provide services that the networks were not originally designed for.

The design of an integrated policy for spectrum management should be based on the idea of allowing network owners to make full use of infrastructure so that they can provide the services they want to.

In this regard, wide allocation of spectrum through public auctions that facilitate the entry of new operators, and the removal of regulatory barriers to contribute to flexibility of spectrum use by a licensee and potential spectrum trading in a secondary market look in principle as key instruments of a spectrum allocation and management policy that will support the development of the telecommunications services sector.

Against the background described in the main body of the document, it becomes apparent that governments in the region need to define a set of clear policies regarding spectrum allocation and management.

Bibliography

Australian Communications and Media Authority. 2008. "Spectrum Management Principles, Consultation on ACMA's draft spectrum management principles" http://www.acma.gov.au.

Ausubel, Larry M. 2004. "An Efficient Ascending-Bid Auction for Multiple Objects." *American Economic Review*, 94:1452-1475.

Ausubel, Lawrence M. and Peter Cramton. 2002. "Demand Reduction and Inefficiency ***in Multi-Unit Auctions."*** ***http://www.cramton.umd.edu/papers1995-1999/98wp-demand-reduction.pdf.***

Ausubel, Lawrence M. and Paul Milgrom. 2002. "Ascending Auctions with Package Bidding." Frontiers of Theoretical Economics, 1. http://www.bepress.com/bejte/frontiers/ vol1/iss1/art1.

Burguet, Roberto and R. Preston McAfee. 2008. "License Prices for Financially Constrained Firms." Caltech, Working Paper.

Cramton, Peter and Jesse A. Schwartz. 2000. "Collusive Bidding: Lessons from the FCC Spectrum Auctions." *Journal of Regulatory Economics*, 17: 229-252.

Cramton, Peter, Yoav Shoham, and Richard Steinberg. 2006. *Combinatorial Auctions*. MIT Press.

Crandall, R., W. Lehr y R. Litan. 2007. "The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data." Issues in Economic Policy, The Brookings Institution, No. 6, July 2007.

Elbittar, Alexander. 2009. "Information Impact of Ranking of Valuation on Bidding Behavior in First Price Auctions: A Laboratory Study," *Journal of Economic Behavior and Organization*, 69: 75-85.

Elbittar, Alexander and Andrei Gomberg. 2008. "A laboratory study of Demand Reduction and Collusion in Uniform- and Discriminatory-Price Auctions", CIDE, Working Paper.

Europe Economics. 2006. "Economic impact of the use of radio spectrum in the UK." A report by Europe Economics, November 16, 2006.

Gabino Fraga. 1997. *Derecho Administrativo*, Edit, Porrúa.

Hazlett, T. W., G. Ibarguen & W. Leighton. 2007. "Property Rights to Radio Spectrum in Guatemala and El Salvador: An Experiment in Liberalization" *Review of Law & Economics*, 3: 437-484.

Hazlett, T. W. & R. Muñoz. 2009a. "A Welfare Analysis of Spectrum Allocation Policies." *The Rand Journal of Economics*, 40: 424-454.

Hazlett, T. W. & R. Muñoz. 2009b. "Spectrum Allocation in Latin America: An Economic Analysis." ***Information Economics and Policy***, 21: 261-78.

Kagel, John H. 1995. "Auctions: A Survey of Experimental Research" In The Handbook of Experimental Economics, ed. J. Kagel and A. Roth, 501-586. Princeton University Press.

Katok, Elena & Anthony M. Kwasnica. 2008. "Time is money: The effect of clock speed on seller's revenue in Dutch auctions." *Experimental Economics*, 11: 344 – 357

Klemperer, Paul. 2004. *Auctions: Theory and Practice*, Princeton University Press.

Klemperer, Paul. 2005. "Bidding Markets." http://ideas.repec.org/p/wpa/wuwple/0508007. html.

Krishna, Vijay. 2002. *Auction Theory,* Academic Press.

Landsberger M., J. Rubinstein, E. Wolfstetter, and S. Zamir. 2000. "First-Price Auctions when the Ranking of Valuations is Common Knowledge", *Review of Economic Design*, 6: 461-480.

Li, Huagang and John Riley. 2007. "Auction choice", *International Journal of Industrial Organization*, 25: 1269-1298.

Maskin, Eric and John Riley. 2000. "Asymmetric Auctions," Review of Economic Studies 67: 413-38.

Milgrom, Paul and Robert J. Weber. 1982. "A Theory of Auction and Competitive Bidding," *Econometrica* 50: 1089-1122.

Milgrom, Paul. 2004. *Putting Auction Theory to Work*. Cambridge University Press.

Myerson, Roger B., Mark A. Satterthwaite. 1983. "Efficient Mechanisms for Bilateral Trading." *Journal of Economic Theory* 29: 265-281.

Minervini, Fulvio, and Diego Piacentino. 2007. "Spectrum Management and Regulation: Towards a Full- Fledged Market for Spectrum Bands?" Universitá di Macerata. Working paper No 07-2007.

OECD. 2005. "Secondary Markets for Spectrum: Policy Issues." Working Party on Telecommunications and Information Services Policies, OECD.

OECD. 2006 "Competition in Bidding Markets." Policy Roundtables, http://www.oecd.org/ dataoecd/44/1/38773965.pdf

OECD. 2007. "Guía de la OCDE para evaluar la competencia, versión 1.0." OECD.

OECD. 2007. "Communication Outlook 2007." OECD.

Ofcom. 2008. "Spectrum Usage Rights." http://www.ofcom.org.uk/radiocomms/, June, 2008.

Porter, M. E., K. Schwab y X. Sala-I-Martin. 2008. "The Global Competitiveness Report 2007-2008" World Economic Forum.

Spectrum Management and Telecommunications. 2001. "Framework for Spectrum Auctions in Canada." Canada, Issue 2, October 2001.

Spectrum Management and Telecommunications. 2004. "A Brief History of Cellular and PCS Licensing." Canada.

Spectrum Management and Telecommunications. 2007. "Spectrum Policy Framework for Canada". Canada.

Unión Internacional de Telecomunicaciones. 2010. "Medición de la Sociedad de la Información". Switzerland.

Vickrey, William. 1961. "Counterspeculation, Auctions, and Competitive Sealed Tenders." *Journal of Finance*, 16: 8-37.

Von der Emden, Dirk-Oliver. 2007. *Administrative Incentive Pricing (AIP)*, Federal Office of Communications, Switzerland. Presentation at the Caribbean Spectrum Management Workshop, August, 2007.