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PROPERTY RIGHTS TO RADIO SPECTRUM IN GUATEMALA AND EL SALVADOR: AN EXPERIMENT IN LIBERALIZATION

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06-07

GEORGE MASON UNIVERSITY LAW AND ECONOMICS RESEARCH PAPER SERIES

Property Rights to Radio Spectrum in Guatemala and El Salvador: An Experiment in Liberalization[1]

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March 10, 2006

In the United States and most other countries, wireless communications rely on administrative allocation of radio spectrum. The inefficiencies associated with this centralized approach have led economists, starting with Coase in 1959, to suggest "propertyzing" radio spectrum, enabling competitive markets to determine frequency use. Critics of this approach assert that property rights impose prohibitive transaction costs and limit development of competition and new services. Reforms enacted in Guatemala (in 1996) and El Salvador (in 1997) have moved sharply towards the market alternative suggested by Coase, yielding a natural experiment.

Under these two markedly liberal regimes, thousands of exclusive spectrum rights have been issued. Economic evidence generated in the mobile telephone market (comprising the dominant wireless application in terms of economic benefit) suggests that these regimes are associated with a relatively high degree of competitiveness in retail markets, and correspondingly high rates of deployment. Further, the liberal regimes are found to have a positive and statistically significant effect on spectrum availability, providing a link between liberal reforms and consumer welfare gains. Conversely, the irregular policy approach does not appear to generate net transaction costs in the public or private sectors. We conclude that the performance of the wireless phone markets governed by spectrum property rights can be seen to offer "proof of concept" for the normative model proposed by Coase.

Key words: spectrum allocation, telecommunications policy, wireless technology, mobile phone competition, property rights, transaction costs
JEL categories: D85, L96, O54, P14, Q29

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[1] The authors wish to thank Jaime Díaz, Alison Sexton, and Bruno Viani for outstanding research assistance. They are also grateful to Roberto Muñoz for extraordinarily helpful input. The opinions and analyses expressed herein are those of the authors and do not necessarily reflect the views of the institutions with which they are affiliated.

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I. INTRODUCTION.

> After the publication of my FCC article, I was invited [by the Rand Corporation]… to prepare a report on Problems of Radio Frequency Allocation… A draft report was prepared which advocated a market solution… [Reviews] were highly critical and as a result, the report was suppressed. Here is an example that illustrates the character of the comments that were made:
>
> "This is a remarkable document…. Time has somehow left the authors behind… [T]hey ignore the social, cultural, and political values which have come to inhere in mass communications, in particular, broadcasting, as well as fifty years of administrative law developments… I know of no country on the face of the globe – except for a few corrupt Latin American dictatorships – where the 'sale' of the spectrum could even be seriously proposed." (Coase 1998, p. 579)

A centralized system of government spectrum allocation was adopted in the United States and most other countries in the 1920s and 1930s (Hazlett 1998). This approach was criticized by Ronald Coase, Bill Meckling, and Jora Minasian as early as 1959 and 1960 in what at the time was seen as heresy (Coase 1959 and 1998). Today, economists have embraced the property rights approach (Noam 1998), and auctions are widely used to assign wireless licenses. But the underlying resource, radio spectrum, continues to be allocated administratively in the typical case, both in the US and elsewhere.

Exceptions now exist, however, "where the 'sale' of the spectrum could even be seriously proposed." In Guatemala in 1996 and El Salvador in 1997, sweeping telecommunications reforms were enacted by statute.[5] While technically quite distinct, they are highly similar in function. Private parties are granted exclusive control over the use of wireless bandwidth, and regulators are largely constrained to define, issue, and protect requested spectrum rights.

The policy innovation forms a laboratory experiment testing the property rights proposal. To the extent that these regimes succeed in improving efficiency in wireless markets, they constitute "proof of concept" for spectrum markets, and – conversely – vice versa. In addition, the procedures under which rights are established and distributed can yield empirical results advancing positive analysis of the institutions of spectrum policy.

Such research is important in four respects. First, radio spectrum is a fertile field for economic analysis, having led directly to discovery of the Coase Theorem (Coase 1959 and 1960). Dean Lueck writes that radio spectrum "occupies a high, holy place in

[5] Spectrum liberalization has also occurred in recent years in New Zealand and Australia. See: Crandall 1998, Australian Productivity Commission 2002, and Hazlett 2006.

law and economics."[6] Second, radio spectrum is increasingly important. Currently, wireless phone service adds about $100 billion annually to U.S. GDP, and is growing at about 15% per annum. This sectoral contribution gross domestic product will soon exceed that associated with agriculture (Entner and Lewin 2005). Waverman et al. estimate that the economic importance of wireless is actually much higher in the developing countries of Africa, where communications infrastructure is critical to economic growth (Waverman, Meschi, and Fuss 2005). Policies that allow greater efficiencies to be realized in this sector are likely to have substantial social impact. Third, spectrum property rights, while winning academic adherents, have yet to replace administrative allocation save in isolated instances.

Finally, while critiques of the Coasean view have persisted for more than four decades, these are usefully subjected to empirical verification. An opponent of spectrum liberalization wrote in 1980 that, "(r)ights to spectrum are not susceptible to legal enforcement as are private property rights. In the past, allocation by the market of rights to use the spectrum has been found to be impossible, or inefficient… The market cannot be an efficient substitute for the administrative process… in achieving allocational efficiency" (Melody 1980). More recently, proponents of categorical allocations of unlicensed bandwidth, often called "spectrum commons," have argued against exclusive spectrum rights by asserting that such rights reduce wealth due to transactions costs and monopolization. Such empirical conjectures are crucial to the ongoing policy debate over how to create, regulate, and distribute spectrum rights.[7] Careful analysis of the development of these spectrum markets based on property rights should help clarify the gains or losses associated with this approach and may offer a valuable perspective for policy reforms in several countries and international organizations (Cave 2002, FCC 2002, and ITU 2004).

This paper evaluates the policy experiments in airwave ownership in El Salvador and Guatemala. In Section II, we describe the standard approach to spectrum allocation as practiced by most countries. The next two sections describe, respectively, the Guatemalan and Salvadoran spectrum regimes. Section V considers administrative results of the reform efforts in these two countries by examining the number of rights assigned to commercial users. Section VI examines the effectiveness of the liberalized regimes in promoting competitive entry and consumer gains in the commercial wireless telephone market, comparing Guatemala and El Salvador to other countries in Latin America. Interference disputes are addressed in Section VII, as well as the public costs of regulation. A conclusion follows in Section VIII.

[6] "The broadcast spectrum holds a special, almost holy, place in the economic analysis of law and the economics of property rights." (Lueck 1995, p. 419).

[7] See, for example, Benkler (1998, 2002), Lessig (2001), Hazlett (2001), Buck (2002), Faulhaber and Farber (2002), Werbach (2004), Faulhaber (2005), Baumol & Robyn (2006), Hazlett & Spitzer (2006).

II. STANDARD SPECTRUM ALLOCATION.

The U.S. Radio Act of 1927 created an independent government agency to determine how radio waves were to be used according to "public interest, convenience, and necessity."[8] Even when license assignments moved from beauty contests to competitive bidding, as many countries did in the 1990s, the use of frequencies was still determined by the regulator (Hazlett 1998). Administrative spectrum allocation has thus pre-empted the formation of a market in wireless bandwidth.

This regime, which still prevails in the U.S. and has been adopted by most other nations, has long been criticized by economists. Coase (1959) noted that, by assigning exclusive spectrum rights to private parties, the "price system" would discover optimal resource use, including spillovers from interference. Minasian (1969) wrote that "government planning is inefficient, as it operates without the constraints of competition for profits…" In 2001, a petition to the Federal Communications Commission from 37 policy economists advocated widespread deregulation of frequency use by exclusive licensees.[9]

Despite consensus among economists,[10] a regime switch from administrative allocation to private ownership constitutes radical reform. As such, policy recommendations face a substantial burden. Indeed, prior to deciding that private property rights could effectively govern radio spectrum, Ronald Coase was undecided as to whether decentralized decision making would improve efficiency relative to government spectrum allocation. While Coase ultimately became convinced that market transactions would prove superior,[11] empirical observation of markets functioning with private spectrum ownership remains of keen interest.

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[8] Radio Act of 1927 (Public Law No. 632, February 23, 1927).

[9] The signatories were: Martin Neil Baily, Jonathan Baker, Timothy Bresnahan, Ronald Coase, Peter Cramton, Robert W. Crandall, Richard Gilbert, Shane Greenstein, Robert W. Hahn, Robert Hall, Barry Harris, Robert Harris, Jerry A. Hausman, Thomas W. Hazlett, Andrew Joskow, Alfred E. Kahn, Michael Katz, Robert E. Litan, Paul Milgrom, Roger G. Noll, Janusz Ordover, Bruce M. Owen, Michael Riordan, William Rogerson, Gregory L. Rosston, Daniel L. Rubinfeld, David Salant, Richard L. Schmalensee, Marius Schwartz, Howard Shelanski, J. Gregory Sidak, Pablo Spiller, David Teece, Michael Topper, Hal R. Varian, Leonard Waverman and Lawrence J. White.

[10] Similar proposals to enact rules enable a market in radio spectrum have been made over the years. (DeVany et al. 1969; Minasian 1975; Webbink 1980, 1988; Kwerel & Williams 1992, 2002; Rosston & Weisburg 1997; White 2000; Hazlett 2001, 2003).

[11] Coase came to favor private property rights for spectrum based on theoretical arguments, or rather the lack thereof. This sprang from a proposal for property rights advanced by University of Chicago law student Leo Herzel (1951). Herzel's proposal was then savaged by a critic (Smythe, 1952). Coase later summarized: "[O]n reading Herzel's article I did not immediately jump to the conclusion that a market with pricing would be superior to regulation by the FCC. It was necessary to take into account the existence of transaction costs. However, my investigations… led me to believe that the problem of establishing a system of property rights… was not as difficult as one might have supposed, and they certainly made it abundantly clear to me that the Federal Communications Commission conducted its affairs in an extremely imperfect way. The question of whether pricing should be used to allocate the use of the radio frequency spectrum was, however, clinched for me by the reply to Leo Herzel's article… written by Dallas Smythe, who had been chief economist of the Federal Communications Commission. His

Here we attempt such an examination of the spectrum property regimes initiated in Guatemala and El Salvador a decade ago. We will review the legal and administrative structure of their reforms, review evidence on the performance of mobile telephone markets (the wireless sector of greatest economic significance, and one that can be compared across countries), and investigate the level of transaction costs. It is understood at the outset that the relatively small economies of Guatemala and El Salvador are unlikely to produce highly idiosyncratic mobile phone network configurations. Scale economies make the purchase of technology and network infrastructure highly advantageous relative to non-standard products. The implications of global marketplace technology standards may help or hinder the case for private property rights in spectrum, but they strongly assist our analysis in one important respect. Because wireless networks in liberal regimes are built with inputs supplied on world markets, the services produced are directly comparable.

Overall, we find that private spectrum rights have been adopted without substantial administrative costs, that property rights are enforced at low cost, and that wireless phone markets perform relatively well, evidence suggesting substantial consumer welfare gains from liberalization. Most pointedly, the liberal spectrum regimes make a relatively abundant quantity of bandwidth available to wireless phone networks. This relaxes the input constraint imposed via centralized spectrum allocation regimes, promoting greater competition among carriers and more productive employment of radio spectrum, precisely the economic result anticipated by Coase.

III. GUATEMALA'S REFORM.

A. The 1996 Statute and Its Antecedents

Before the enactment of the 1996 *Ley General de Telecomunicaciones*, [12] private radio spectrum users were licensed under a model similar to that used by the U.S. Federal Communications Commission (FCC). An office inside Guatel,[13] the state telephone company privatized in 1997, was managed by a branch of the military. It zoned the radio spectrum, allotting blocks of bandwidth for particular uses patterned after the FCC's Table of Frequency Allocations. It then divvied the blocks into individual licenses, established rules of operation, and assigned these licenses to users. Foreign nationals were not allowed to apply for a license. The licenses were awarded free of charge;[14] with

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objections were so incredibly feeble (I refer to them in my [1959] article), that I concluded that, if this was the best that could be brought against his proposal, Leo Herzel was clearly right" (Coase 1993, p. 249).

[12] Ley General de Telecomunicaciones, Decreto 94-96, 14 de Noviembre de 1996 (Guatemala).

[13] The office was officially entitled, "Dirección General de Radiodifusión y Televisión Nacional." An office with this name still operates, but its duties have been dramatically reduced. Specifically, it manages the state radio station T.G.W., provides a register for radio announcers, coordinates radio and T.V. networks for official government communiqués, and oversees media content.

[14] Licensees purchased a nominal tax stamp (usually less than $40) and posted a moderately-priced bond as a performance guarantee.

demand for licenses exceeding supply, an extra-legal market arose whereby bribes and side payments rationed licenses.

The Guatemalan government granted rights to provide commercial mobile telephone service to a private company, Comcel, in 1989. This company paid a percentage of its profits to Guatel, and Guatel in turn stayed out of mobile telephony. At the end of 1996, the number of mobile subscribers was less than 50,000. When the majority of Guatel's assets were reorganized in 1997, the firm was renamed Telgua; it was then privatized in 1998 (NERC 1999).[15] Telgua was sold to investors with a license to provide nationwide wireless phone service, initiating competition in the sector.

The *Ley General de Telecomunicaciones*, adopted in November 1996, significantly revamped Guatemala's spectrum policies. The result is perhaps the most liberal spectrum regulatory policy in the world. [16] There are two essential features of this regime. The first is that the law establishes a presumption that radio waves are to be available for the use of those who request them, and for the purposes requested. As Pablo Spiller and Carlo Cardillo observe, "[t]he basic building block of Guatemala's approach to the spectrum is that all spectrum not currently assigned to [users]… can be requested by any person" (Spiller & Cardillo 1999). This inverts the standard, top-down administrative allocation process, where high level trade-offs between alternative uses for radio spectrum are made by government regulators.

The second key aspect is that *usufructory* rights are issued, entitling holders to exercise exclusive control over the use of the radio spectrum in question. This includes the right to change spectrum uses over time, and to subdivide and transfer rights, subject only to minimal technical limitations (designed to prevent interference) and international agreements to which Guatemala is a signatory. This has the effect of delegating broad discretion to private parties in determining how radio spectrum is used, including the selection of services, technologies, and business models.

In the Guatemalan Civil Code the usufructory right carries the right to use and enjoy the property of another to the extent that such use and enjoyment does not destroy or diminish its essential substance.[17] Since electromagnetic waves are infinitely reusable and are not "destroyed or diminished" when employed, these rights are a close approximation of private property rights in radio spectrum.[18] The 1996 law defines these

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[15] Portions of Guatel's assets, mostly wireline local exchange operations in rural areas, were not privatized and continue to operate under the name Guatel (NERC 1999).

16 Giancarlo Ibarguen S. 1995 monograph detailed the essential logic of spectrum reform. See also Ibarguen, Privatizar Las Ondas de Radio (Guatemala City: CEES, Feb. 15, 1992). In 1996, Prof. Hazlett was retained, as was Prof. Pablo Spiller of U.C. Berkeley, by the governments of both Guatemala and El Salvador to advise on pending telecommunications reform legislation. The liberalization of wireline telecommunications in Guatemala is described in Spiller & Cardillo (1997). See also: Spiller and Cardillo (1999); Hazlett (2001); Giancarlo Ibarguen (2003).

[17] República de Guatemala. Código Civil, Libro II, De los Bienes, de la Propiedad y demás Derechos Reales, Título III, Usufructo, uso y habitación.

[18] Ownership of spectrum itself was barred by Article 121 of the Guatemalan Constitution of 1985, which assigns the property of the radio waves to the State. The framers of the Constitution argued that the radio spectrum, along with water masses (underground or above), ocean and river shores, air space,

rights as *TUFs – título de usufructo de frecuencia* – and specifically states that the *TUF* may be leased, sold, subdivided or consolidated for a limited period (fifteen years).[19] The *TUF* may be used as equity or collateral. The usufruct term can be extended for an additional 15 years by a simple request (no payment by *TUF* owners.)[20]

The distinction between a usufruct title and a standard wireless authorization is key. In other countries, wireless licenses (including those auctioned in the United States, United Kingdom, Europe, and Asia over the past decade) regulate the use of radio frequencies. Licensees are generally prohibited from redeploying frequencies from one service (or technology) to another as per economic incentives. Hence, a market for radio spectrum is excluded by regulatory restrictions. In contrast, Guatemala's reforms enable such a market to emerge

B. Key Elements of Spectrum Reform

The 1996 *Ley General de Telecomunicaciones* established foundational elements for a property regime, most (but not all) of which were subsequently implemented. First, an independent regulatory body was established, the Superintendent of Telecommunications (*SIT*). Under the previous state telecommunications monopoly, there were no private firms to regulate. The newly created body was conceived as an administrator to enforce specified rules. The broad political discretion embedded in the public interest standard was rejected in favor of specific mandates. Essentially, the *SIT* is empowered to respond to private claims for spectrum access (*TUFs*), and to adjudicate disputes over airwave rights. It may also engage in related activities, such as spectrum monitoring.

Nonetheless, the *SIT* is subject to political pressure, and this produces some consequences unanticipated in the law (see discussion in Section VII). The issue of how to shield dispute resolution from political pressures is a difficult one, with implications far beyond telecommunications policy. It is left for future research.

Second, existing commercial users were granted flexibility in the use of radio waves. These commercial users received *TUF*s, referred to as "regulated" spectrum in the 1996 act. Two other general categories of users also were established. Government and amateur users received authorizations (*AUF*s), while international satellite operators received licenses. Ironically, while *TUF*s exist within "regulated" bands, they are some of the least regulated frequency bands in the world. These "regulated" bands may be employed according to market conditions so long as technical parameters associated with the *TUF* are met. The former state telecommunications monopoly, Guatel (now largely

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subsurface (including minerals), natural gas and oil, was inherently scarce and, thus, "strategic." Previous Constitutions had also nationalized these resources.

[19] *Ley General de Telecomunicaciones*, Art. 58.

[20] *Ley General de Telecomunicaciones*, Art. 59. The government may refuse to renew a TUF only in the event that evidence is submitted by an accredited party that the spectrum was in no way used during the usufructory period, and "use" is not defined.

privatized under the name Telgua), was grandfathered with over 900 frequency rights, as were radio and television broadcasters and the erstwhile cellular monopolist, ComCel.

Third, parties wishing to access frequencies are allowed to petition the *SIT* for the right to use any unoccupied bandwidth. The 1996 reform does not prohibit foreign entities from acquiring and using these frequencies. The process for providing access to spectrum is contained in Article 61 and has been implemented as follows:

1) An interested party applies to the *SIT* for the right to use a frequency band under the terms of a *TUF*.
2) The application is evaluated by the *SIT*, which deems it accepted, incomplete, or rejected. The *SIT* is required to answer within 3 days. Grounds for rejection include technical interference, violation of international agreements to which Guatemala is a signatory, or request of reserved or radio amateur bands. Reserved bands are for government use only.[21]
3) If the application is accepted, public notice is issued. Parties objecting to the new use file formal complaints. Grounds for opposition are limited to technical interference and must be filed within five days of the public announcement.
4) Complaints are adjudicated by the *SIT*, and the adjudication process cannot exceed 10 days.
5) Other interested parties are allowed to file competing claims to requested spectrum rights.
6) If no competing claims are filed, then the petitioner receives rights *gratis*.
7) If competing claims are filed, the *SIT* must schedule an auction within 35 days of the close of the opposition period.[22]

A principal result of this law is observed in the *TUF* itself.[23] Instead of authorizing particular "radio stations," as in the U.S. license, the Guatemalan wireless operator explicitly controls the spectrum resource for a specified time period. The *TUF* is defined in a one-page form listing six basic variables:

1) frequency band
2) hours of operation
3) maximum power transmitted
4) maximum power emitted at the border of adjacent frequencies
5) geographic territory
6) duration of right (beginning and ending)

The back of the *TUF* contains spaces for endorsements, required whenever the instrument is transferred to a new owner.

[21] The law stipulates that the government may at any moment request the SIT to transform reserved bands into regulated bands.
[22] *Ley General de Telecomunicaciones*, Art. 61.
[23] A picture of the actual TUF form is found in Hazlett (2001, p. 447).

Guatemala's 1996 telecommunications law also mandated elements that have been implemented less successfully. For example, the law requires the *SIT* to create a registry of all users of the communications spectrum, including government users, private holders of *TUF*s, and amateur radio operators, with the registry available to the public without charge.[24] The *SIT* is developing an online database but it has not, as yet, been made available for public access. Interested parties may request in writing information about available spectrum bands, which the *SIT* will provide for a nominal fee.[25]

The *Ley General de Telecomunicaciones* also specifies the government's role in protecting the rights of *TUF* holders and other legal users of the spectrum. Article 53 of this law establishes the rights of *TUF* holders to file a formal complaint before the *SIT* in the event of interference caused by a third party.[26] While in most spectrum bands the dispute resolution process works effectively, the FM radio band hosts considerable "pirate radio" activity. For political reasons, however, the *SIT* has been reluctant to enforce FM band TUFs from interference, as discussed in Section VII.

IV. EL SALVADOR'S REFORMS

A. The 1997 Statute and Its Antecedents

Prior to its reform in 1997, El Salvador's telecommunications were provided by a state-run monopoly, Antel. Wireline service was entirely controlled by this company and service generally was poor. The right to provide commercial mobile telephone service was granted to a private company, Telemovil, in 1991, and service was initiated in 1993. Competition in mobile telephony did not appear until after 1997, when El Salvador adopted the *Ley de Telecomunicaciones*.[27] Several key elements make this reform similar to Guatemala's deregulatory experience.

First, a wide array of license limitations were eliminated, with interference contours forming the constraints imposed on wireless operators. Second, requests to use unoccupied radio spectrum must be granted by the regulator. Hence, the regime permits market allocation of frequencies. Salvadoran property rights are not explicitly defined as privately owned, however; liberalization is achieved by a statutory provision permitting license holders full flexibility in the use of allocated frequencies. This results in a situation where, despite issuing wireless licenses similar to those in other countries, the licensee exercises broad control of assigned airwaves. The Salvadoran regime, while technically distinct from Guatemala's, yet yields a similar set of spectrum property rights.

[24] *Ley General de Telecomunicaciones*, Art. 23.
[25] The *SIT* charges 500 Quetzales, or approximately US $66.00, for this information. Pricing data provided to authors in correspondence with *SIT* representatives on November 21, 2005.
[26] *Ley General de Telecomunicaciones*, Art. 53.
[27] *Ley de Telecomunicaciones*, Decreto Legislativo No. 142, 6 de noviembre de 1997, Diario Oficial No. 218, Tomo 337 del 21 de noviembre de 1997 (El Salvador).

B. Key Elements of Spectrum Reform

El Salvador also established an independent regulatory body, the General Superintendent of Electricity and Telecommunications, or *SIGET*. Like the *SIT*, the *SIGET* in El Salvador has limited discretion. While the agency engages in spectrum monitoring and other activities to help detect and limit illegal use of the spectrum, its operations are largely passive, responding to complaints and petitions.

Spectrum is divided into three general categories: official use, free use, and regulated (or commercial) use.[28] Official use refers to bandwidth reserved for government entities or set aside by international treaties. Parties must receive an authorization to use this spectrum. A small amount of spectrum is dedicated for "free" use by the public, although *SIGET* may require users to be licensed. As in Guatemala, the most liberal rules apply to "regulated" bands, which is where commercial services (such as mobile telephony) are provided. Parties operating in these bands received concessions. Existing commercial users rights were grandfathered.

New users of spectrum are accommodated much as in Guatemala. Interested parties, including foreigners, can petition the *SIGET* to receive a concession. The adjudication process is found in Articles 78-82 of the 1997 law:

1) An interested party may petition the *SIGET* for the right to a concession.
2) The *SIGET* must consider the application. Grounds for rejecting a petition are specific and limited, including: The spectrum is granted to another party and there is no compatibility in use. The spectrum requested does not require a concession for use (*e.g.*, free use spectrum). The requesting party has an outstanding sanction related to the existing telecom law. The requesting party is not eligible to receive a concession under the existing law.
3) Upon receipt of a request for concession, the *SIGET* must publish this request, and other parties have 20 days to respond.
4) Opposing parties must receive a hearing within ten days of their response.
5) During the response period, *SIGET*'s Manager of Telecommunications must produce a technical evaluation of the request.
6) In the event the Manager of Telecommunications provides a favorable report and there are no parties opposing the request, the concession is granted as requested. If the Manager of Telecommunications provides a favorable report and there are additional spectrum claimants, the *SIGET* must hold an auction within 60 days. [29]

In contrast to Guatemala, in El Salvador all parties receiving a concession must pay an annual fee for use. The fee is based on the spectrum band in question, the amount

[28] *Ley de Telecomunicaciones*, Art. 12.
[29] *Ley de Telecomunicaciones*, Art. 78-82.

of spectrum used, etc.[30] Further, El Salvador's telecommunications law does not require a spectrum registry.

V. ADMINISTRATIVE RESULTS

A. Guatemala

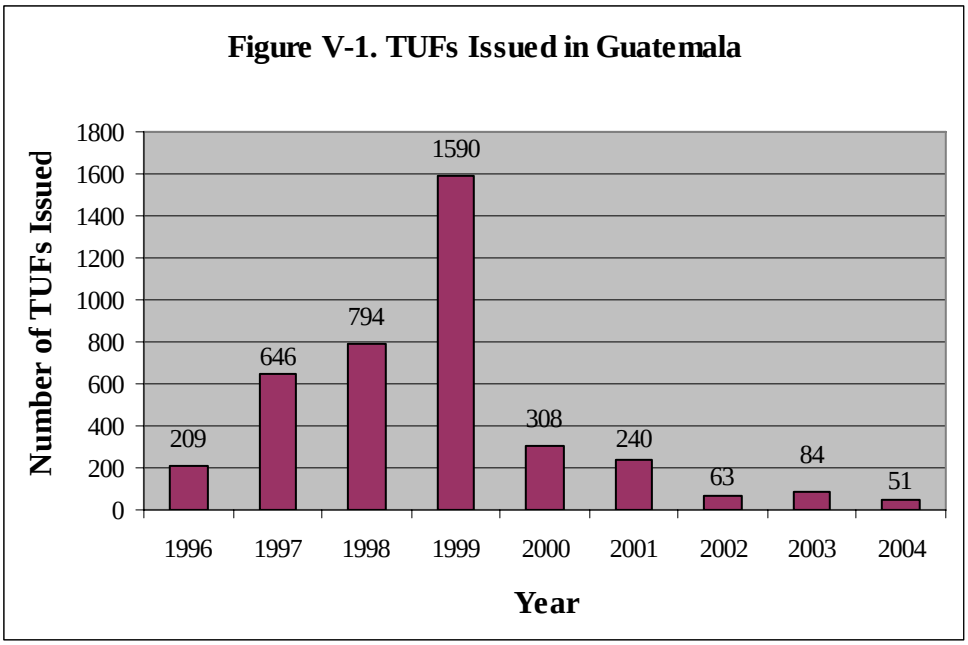
Despite political pressures to protect incumbent interests in Guatemala, including government efforts to delay competition in mobile telephone markets while Guatel was being privatized (new entry would reduce bids for state assets), requested *TUF*s have generally been issued. All told, 3,985 *TUF*s have been awarded since the beginning of the reform process through June 2005, along with approximately 1,000 licenses for satellite and other uses, and 880 authorizations for government and amateur users. See Table V-1 and Figure V-1. Of the 3,985 *TUF*s issued following reform, 930 went directly to the former state telecommunications monopoly, 918 went directly to other incumbents, and 2,137 were awarded by auction.

Table V-1. Spectrum Rights Issued by Guatemalan Government

Type of Right	*TUFs*	*Authorizations*	*Licenses*
Approximate Number of Rights Issued	3,985	290 (government) 590 (amateurs)	1,000

Sources: "The Role of the Government in Protecting Rights and Overseeing Disputes," Marco Antonio Escalante, Superintendencia de Telecomunicaciones, presentation made at the telecommunications conference: "Convergence or Competition: Radio Spectrum Management in Guatemala and Latin America," Francisco Marroquín University, Guatemala, June 9, 2005, Available at http://www.cadep.ufm.edu.gt/telecom/ingles/default.htm. Also, email correspondence with Mr. Escalante on July 6, 2005 and September 12, 2005.

[30] *Ley de Telecomunicaciones*, Art. 13. The fee is a base rate multiplied by the bandwidth, multiplied by a measure of the transmission power, multiplied by a service factor (based on location within the spectrum band).



Source: Escalante (2005).

B. El Salvador

Since its 1997 reform, El Salvador has granted 1,311 concessions, 80 authorizations, and 56 licenses. See Table V-2. Of the 1,311 concessions granted, 152 were assigned via auctions.[31] The number of concessions in El Salvador is considerably smaller than the number of *TUF*s in Guatemala, though this is largely explained by the Salvadoran regulator's practice of grouping many frequencies into a single concession. For example, the 152 concessions that have been auctioned in El Salvador represent 564 distinct frequency bands. A single concession may grant rights to use several megahertz in the 800 MHz band, several megahertz in the 900 MHz band, etc. As a result, direct comparisons with other countries can be misleading. But as demonstrated in Section VI, sufficient spectrum is available for the most highly valued services. Moreover, as in Guatemala, the issuance of licenses has proceeded without evident administrative confusion or corruption. This is despite an exceptionally large shift in the law and a dramatic transformation in the nature of the rights being issued.

[31] Data provided to authors by SIGET representatives in email correspondence on September 14, 2005. Much of this data also is available on the agency's website under the title "Registro de Electricidad y Telecomunicaciones," at www.siget.es.gov.

Table V-2. Spectrum Rights Issued by Salvadoran Government

Type of Right	*Concessions*	*Authorizations*	*Licenses*
Approximate Number of Rights Issued	1,311	80	56

Source: Registry of the Superintendencia de Electricidad y Telecomunicaciones (SIGET), available at www.siget.gob.es. Also, email correspondence with author on August 29, 2005.

VI. ECONOMIC RESULTS

Spectrum is an input into the production of all wireless services. As such, the regulatory model used to allocate spectrum may yield significant consumer welfare implications. The analysis presented here concentrates on wireless telephone service, as this is the dominant market in terms of economic benefit,[32] and radio spectrum has considerable value at the margin (Hazlet and Muñoz 2004). Moreover, the regimes we are attempting to study were instituted in 1996 and 1997, just as mobile telephone service was beginning to emerge as an important, mass consumer market throughout Latin America (and elsewhere). This affords an opportunity to observe the results of policy changes in terms of their actual effects on consumers.

We do not systematically examine the broadcasting industry. While Guatemala and El Salvador grant rights to broadcast frequencies that, in a technical sense, more closely resemble private property rights than in other countries, spectrum reforms have – as a practical matter – been largely confined to common carrier communications. This reflects a standard pattern in spectrum policy. In the United States, for instance, the intense political interest in broadcast media has been shown to drive non-market allocation methods (Hazlett 1998). Interesting issues arise out of this divergence, as are discussed in Section VII.

A. A Simple Model

Our general hypothesis is that, as compared to other countries in Latin America, the liberal reforms in Guatemala and El Salvador produce consumer welfare gains. Specifically, such reforms reduce barriers to the productive use of bandwidth, thus improving efficiency in the mobile telephone sector. The theory is joint with the hypothesis that the property rights reforms do not result in transaction costs sufficient to offset welfare gains.

[32] Ofcom, the UK radio spectrum regulatory authority, produces estimates of the social value of wireless services by sector. These estimates place mobile telephone service as the most valuable sector, with broadcasting in second place. Both are well ahead of other categories. This ranking is likely to be skewed even more in the direction of mobile telephony in developing countries. (Ofcom 2005, Waverman et al. 2005)

This conjecture stems from the logic put forward in Coase (1959), namely that decentralized decisions by spectrum owners will produce superior economic outcomes to administrative allocations. This is further developed in Hazlett & Muñoz (2005), which considers bandwidth as an input into the production of mobile phone services. Incremental bandwidth lowers the opportunity cost of delivering a phone call, ceteris paribus. In addition, given that capital (network infrastructure) and spectrum can be used as substitutes, incremental bandwidth in the market lowers fixed costs for entrants, potentially intensifying competition. Either effect tends to increase efficiency.

Empirically, we wish to test the proposition that liberally extending exclusive property rights to radio spectrum has resulted in lower prices and expanded outputs in mobile telephone markets.[33] Formally, we can think of the structural relationship between liberal policies and retail market outcomes as defined by a system of equations:

(E1) $PRICE = f_1(SPECTRUM, HHI, QUANTITY, Z_1)$;

(E2) $QUANTITY = f_2(SPECTRUM, HHI, PRICE, Z_2)$;

(E3) $SPECTRUM = f_3(LIB, Z_3)$;

(E4) $HHI = f_4(SPECTRUM, LIB, Z_4)$.

where Z_1, Z_2, Z_3, and Z_4 are vectors of explanatory variables.

The prediction we make is that liberalization is associated with an increased utilization of *SPECTRUM* and a market structure characterized by a decreased *HHI*,[34] such that *PRICE* declines and *QUANTITY* increases. Formally, the prediction can be stated as two joint propositions given by:

(E5) $(\partial PRICE/\partial SPECTRUM)(\partial SPECTRUM/\partial LIB) < 0$, and
(E6) $(\partial QUANTITY/\partial SPECTRUM)(\partial SPECTRUM/\partial LIB) > 0$.

(E7) $(\partial PRICE/\partial HHI)(\partial HHI/\partial LIB) < 0$, and
(E8) $(\partial QUANTITY/\partial HHI)(\partial HHI/\partial LIB) > 0$.

One empirical framework for evaluating these hypotheses would involve simultaneous estimation of both the market structure variables (*SPECTRUM* and *HHI*)

[33] The opportunity cost of radio spectrum would be an issue if spectrum were fully utilized in the provision of alternative services. In fact, radio spectrum is characterized by widespread under-employment. See Hazlett (2001).

[34] This metric conforms to standard notions of market competitiveness. It should be noted, however, that concentration ratios based on existing market share data are problematic proxies for the underlying variable, which is *degree of competitiveness*. In a market with free entry, potential rivalry may serve as an important constraint on firm behavior, and these constraints may not be highly (or even positively) correlated with market share data. This has been seen in the market prices paid for wireless licenses, where investors are keenly sensitive to the possibility of future competitive entry (Hazlett 2004.). Market share data are observable, however, whereas other measures of degree of competitiveness are not.

and the retail market outcome variables (*PRICE* and *QUANTITY*). This is similar to the approach in Hazlett-Muñoz (2004), where price and output data for mobile phone markets in 29 countries are examined. Given the concentrated nature of wireless markets, this method simultaneously estimates Demand and Mark-Up equations, using an instrument for output. This, however, requires data on the operating costs of wireless carriers (mark up margins). Such data are not available for our cross section of Latin American countries.

Hence, we here attempt a more modest empirical test. Using a pooled dataset for 16 Latin American mobile phone markets with annual data 2000-2004, we estimate four reduced form equations to test each of the separate propositions our theory suggests. Specifically, we run the following regressions:

(E9) $SPECTRUM_{it} = f(LIB_i, Z_{1i})$, where *SPECTRUM* = bandwidth, in MHz, available to mobile phone operators in country *i* during period *t*; *LIB* is a dichotomous variable = 1 if Guatemala or El Salvador, 0 otherwise; and Z_i = a vector of explanatory variables;

(E10) $HHI_{it} = f(LIB_i, Z_{2i})$, where HHI_{it} = Herfindahl-Hirschman Index for mobile phone sector in country *i* during period *t*.

(E11) $PRICE_{it} = f(SPECTRUM_{it}, HHI_{it}, Z_{3i})$, where $PRICE_{it}$ = average revenue per minute of use for mobile telephone service in country *i*, period *t*; Y_i is a vector of explanatory variables.

(E12) $MOU_{it} = f(SPECTRUM_{it}, HHI_{it}, Z_{4i})$, where MOU_{it} = average monthly minutes of use per person in country *i* during period *t*.

The explanatory variables used across the four equations are listed in Table VI-1, with predicted signs. Each specification is estimated using natural logs of dependent and independent variables, with the exception of dichotomous variables. Data sources and methodology are discussed in the Appendix.

The implications of the estimated equations are straightforward. The liberal reforms in Guatemala and El Salvador should lead to the following outcomes:

(1) Deployment of a relatively generous amount of spectrum.

(2) A relatively high level of competitiveness.

(3) Relatively low retail prices.

(4) Relatively large quantities of output (minutes of use).

We note that the implications (3) and (4) are largely cross-checks on the more direct implications of the theory, (1) and (2). That is because reforms that produce more

generous resource inputs and greater competitiveness will, by microeconomic theory, produce consumer welfare gains. We also note, as above, that the issue of transactional efficiency is embedded in these predictions, as reforms that increased uncertainty over property rights or otherwise limited productive activities would lower consumer welfare gains as evidenced by lower prices and higher outputs.

B. Data

We focus on cross-country comparisons in Central and Latin America, attempting to distinguish the spectrum policies in Guatemala and El Salvador from other similar countries. The data examined are for 16 Latin American nations, annual 2000-2004, and were collected from the International Telecommunications Union, the World Bank, the CIA World Factbook, and Pyramid Research.[35] Pooling these data yield up to 80 observations (16 X 5). All Latin American countries for which data are available were included, except Costa Rica, which has a government monopoly mobile phone supplier, making pricing data problematic to interpret. Caribbean nations are also excluded. When focusing on Central America, five countries are analyzed: Guatemala, El Salvador, Honduras, Nicaragua, and Panama. The Latin American sample adds these eleven markets: Mexico, Bolivia, Ecuador, Peru, Venezuela, Columbia, Brazil, Chile, Argentina, Uruguay and Paraguay.

C. Specifications and Results

1. *Spectrum*

We estimate the amount of spectrum utilized, as in (E9), with explanatory variables *POP*, *DENSITY*, *GDPPC*, and *FRASER*, an economic freedom index measuring security of overall (as opposed to spectrum) property rights. We expect the coefficients on *GDPPC* and *FRASER* to be positive, while the signs of the coefficients on *POP* and *DENSITY* are theoretically ambiguous.

[35] See the Appendix for details of the data and sources.

TABLE VI-1: REGRESSION VARIABLES

Dependent Variables	**E9**	**E10**	**E11**	**E12**
SPECTRUM (MHz available to mobile phone operators)	**x**			
HHI (concentration by revenues, 0-10,000, for mobile telephone sector)		**x**		
PRICE (average revenue per minute of use, pre-paid and post-paid)			**x**	
MOU (average monthly minutes of use per capita)				**x**
Independent Variables	**Expected Coefficient Signs**			
SPECTRUM [*SPEC*] (defined as above)			-	+
HHI [*HHI*] (defined as above)			+	-
LIBERAL DUMMY [*LIB*] (1= Guatemala or El Salvador, 0= otherwise)	+	-		
POPULATION [***POP***] (total population of a country)	+/-	-	+/-	+/-
POPULATION DENSITY [*DENSITY*] (number of people per square kilometer)	+/-	-	+/-	+/-
GDP PER CAPITA [*GDPPC*] (per-capita GDP, in US dollars and at PPP)	+	-	+/ -	+
FRASER INDEX [*FRASER*] (Index value, 1-10, measuring general security of property rights)	+	-	+/ -	+/-
INDUSTRIALIZATION [*INDUSTRY*] (ratio of GDP associated with industry)		+/-		
COST OF HIRING [*LCOST*] (cost of hiring workers)		+/-		
FIXED LINES [***FLINE***} (number of fixed lines per 100 persons)			+/-	+/-
FIXED LINE PRICE [***FPRICE***] (percentage of population that is literate)			+/-	+/-

Regression results displayed in Table VI-2 yield coefficient estimates for the Latin American sample (16 countries) and the Central American sample (5 countries). Results for three alternative specifications are given using either sample. Multicollinearity is a problem in Specifications A and B using the Central American sample; with *POP* and *DENSITY* very highly correlated (simple correlation = .972), density is dropped for Specification C.

TABLE VI-2. SPECTRUM REGRESSION RESULTS

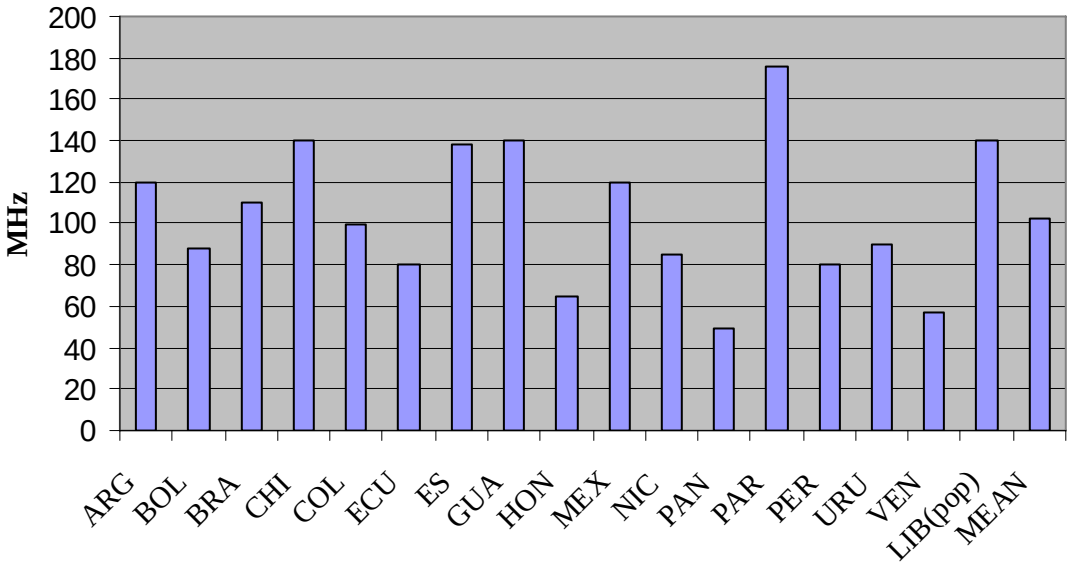
	Latin America			**Central America**		
Variable	**A**	**B**	**C**	**A**	**B**	**C**
LIB	1.493 (9.61) [0.00]	1.447 (9.36) [0.00]	0.669 (4.97) [0.00]	2.762 (19.78) [0.00]	2.751 (24.76) [0.00]	3.405 (10.29) [0.00]
GDPPC	0.369 (4.79) [0.00]	4.892 (2.02) [0.05]	0.429 (4.34) [0.00]	-0.187 (-0.71) [0.49]	-9.914 (-3.07) [0.01]	-1.525 (-2.51) [0.02]
GDPPC-squared		-0.264 (-1.87) [0.07]			0.596 (3.02) [0.01]	
FRASER	0.487 (1.43) [0.16]	0.615 (1.8) [0.08]	0.647 (1.48) [0.14]	4.648 (3.08) [0.01]	3.781 (3.06) [0.01]	1.315 (0.33) [0.74]
POPULATION	0.112 (3.09) [0.00]	0.107 (2.98) [0.00]	0.107 (2.3) [0.02]	1.177 (3.37) [0.01]	1.164 (4.19) [0.00]	-2.096 (-8.26) [0.00]
DENSITY	-0.419 (-7.15) [0.00]	-0.434 (-7.45) [0.00]		-2.808 (- 9.73) [0.00]	-2.697 (- 11.60) [0.00]	
CONSTANT	-0.173 (-0.18) [0.86]	-19.559 (1.88) [0.06]	-2.281 (-1.91) [0.06]	-10.912 (- 1.74) [0.10]	30.100 (2.08) [0.06]	45.847 (7.41) [0.00]
R-squared	0.6837	0.6982	0.4654	0.9949	0.997	0.9605
Observations	80	80	80	20	20	20

Coefficient estimates with t-statistics in parentheses and p-values in brackets.

For the full sample, *GDPPC* appears positively related to *SPEC*, although the second specification, which adds a *GDPPC-squared* term, suggests that the relationship may be non-linear (the squared term coefficient having p=0.07). The Central American regression is not as predicted, with a negative coefficient (p=0.02). Across both samples, the economic freedom index appears positively correlated with *SPEC*, but not significant at the standard 95% level. *POP* is found to be positively related to *SPEC*, and *DENSITY* to be negatively related (although the latter term is dropped in the Central American regression to avoid multicollinearity).

The key empirical issue concerns the estimated coefficient on the *LIB* dummy. Across all specifications this term is predicted to be positive and statistically significant. This is a straightforward outcome in that the two liberal regimes have deployed 140 MHz (Guatemala) and 137.8 MHz (El Salvador) in the provision of wireless phone networks. This is substantially above the unweighted 16-country Latin American average of 102.4 MHz. Excepting Paraguay (with 170 MHz) and Chile (140 MHz), these are the highest deployments in the region. See Fig. VI-1, which lists each country's mobile spectrum allocation, the mean value for Latin America, and the population-weighted mean for the two-country liberal sample.

Fig. VI-1. Latin American Mobile Spectrum Deployment (2004)



The relatively generous use of bandwidth in Guatemala and El Salvador is not explained by other variables, such as *GDPPC* or *FRASER (economic freedom).* Guatemala and El Salvador are associated with relatively low incomes and low levels of (overall) economic freedom, the above average utilization of radio spectrum suggests that the specific liberalization in wireless telecommunications has achieved a fundamental policy goal.

2. Market Structure

A measure of market concentration, *HHI*, is regressed against a vector of explanatory variables and the *LIB* dummy (E10). The independent variables include *POP*, *GDPPC*, *DENSITY*, *FRASER*, *INDUSTRY*, and *LCOST*. Predicted values are as given in Table VI-1; results are displayed in Table VI-3. The industrialization and labor

cost variables add little explanatory power, and the preferred Latin American specification is A. Here it is suggested that the concentration ratio in the mobile telephony sector declines (becomes more competitive) as *per capita income* rises, as *population* rises, and as *density* declines.

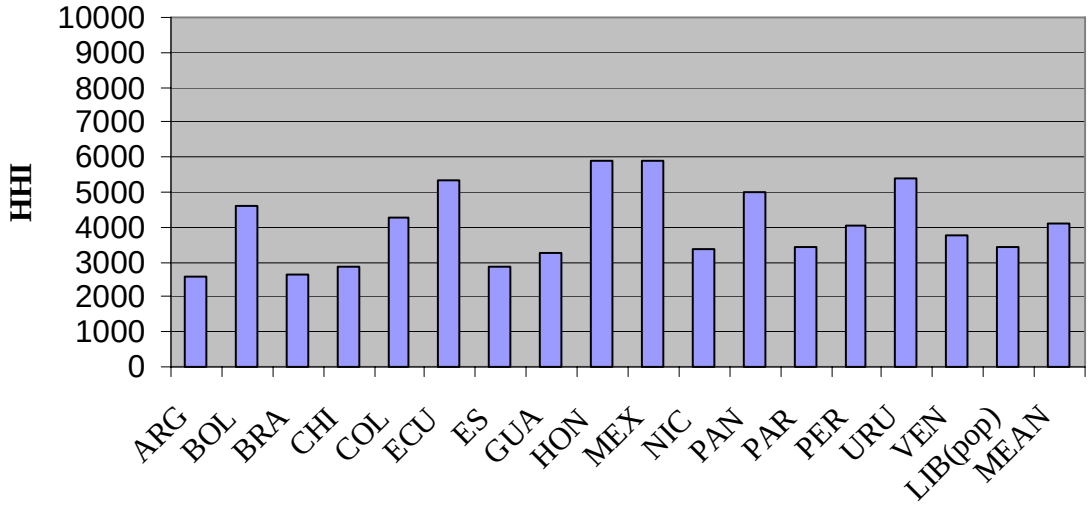
The *LIB* dummy coefficient is positive and highly significant, both in the Latin American and the Central American samples. This empirical relation suggests that the spectrum property reforms in Guatemala and El Salvador have not only opened the possibility of future competition (potential entry), but have already produced more competitive markets by reducing barriers for additional wireless phone operators. Again, this result is seen in the aggregate data for Latin America. The unweighted mean for 16 Latin American markets is 4702; the population-weighted mean for Guatemala and El Salvador is 3394, or 28% below the average. Again, this difference does not appear to be accounted for other economic variables. Indeed, the only countries to feature lower HHIs, Chile, Brazil, and Argentina, feature much larger economies and per capita incomes. Among small, relatively poor countries, the two markets in the *LIB* sample achieve remarkably high levels of deconcentration. Fig. VI-2 displays the concentration ratios across Latin American countries, with mean values for the entire sample and the two-country liberal sub-sample.

TABLE VI-3. HHI REGRESSION RESULTS

	Latin America			Central America		
Variable	**A**	**B**	**C**	**A**	**B**	**C**
LIB	-0.990 (-7.78) [0.00]	-1.007 (7.63) [0.00]	-0.954 (-6.78) [0.00]	-2.488 (-3.2) [0.01]	-0.751 (-0.49) [0.63]	8.781 (3.32) [0.01]
GDPPC	-0.233 (3.70) [0.00]	-0.219 (-3.27) [0.00]	-0.213 (-3.01) [0.00]	2.890 (1.96) [0.07]	2.632 (1.82) [0.10]	2.086 (2.10) [0.06]
FRASER	0.210 (0.75) [0.45]	0.080 (0.25) [0.81]	0.235 (0.83) [0.41]	-16.201 (-1.93) [0.07]	-10.386 (-1.12) [0.29]	3.717 (0.52) [0.62]
POP	-0.070 (-2.36) [0.02]	-0.073 (-2.38) [0.02]	-0.067 (-2.21) [0.03]	1.322 (0.68) [0.51]	0.8167 (0.42) [0.68]	-16.344 (3.84) [0.00]
DENSITY	0.288 (5.99) [0.00]	0.297 (5.83) [0.00]	0.279 (5.54) [0.00]	-0.289 (-0.18) [0.86]	-1.058 (-0.63) [0.54]	10.390 (3.88) [0.00]
INDUSTRY		-0.096 (-0.72) [0.48]			1.980 (1.31) [0.21]	
LCOST			-0.067 (-0.63) [0.54]			-13.253 (3.04) [0.00]
CONSTANT	10.274 (12.90) [0.00]	10.735 (10.48) [0.00]	10.305 (12.68) [0.00]	-3.264 (-0.09) [0.93]	-7.716 (0.23) [0.83]	246.563 (61.92) [0.00]
R-squared	0.563	0.5681	0.5651	0.6933	0.7292	0.8751
Observations	80	80	80	20	20	20

Coefficient estimates with t-statistics in parentheses and p-values in brackets.

Fig. VI.-2. Latin American Mobile Sector HHIs (2004)



3. Price

In the reduced form price equation (E11), retail prices are proxied by average revenue per minute. This measure helps simplify complications associated with non-linear pricing, commonly used in the provision of cellular services. The data are reported as average revenue per month (ARPM), per subscriber for three categories: pre-paid, post-paid, and an average for all subscribers. Explanatory variables include *SPEC, HHI, GDPPC, POP, DENSITY, FRASER, FLINE*, and *FIXPR*. *SPEC* is predicted, in standard theory, to be negatively related to price; *HHI* positively. The other coefficient signs are theoretically ambiguous. Income might drive demand so as to increase prices, while also being related to infrastructure or scale economies that reduce the cost of supply. Similar arguments apply to *POP*, *DENSITY*, and *FRASER*. *FLINE*, measuring the number of fixed lines per 100 persons, may influence retail phone prices either due to substitution or complementarities, as may *FIXPR*, the price of a 3-minute peak period phone call via a fixed line.

The variables of interest are *SPEC* and *HHI*, with coefficients on either variable carrying the expected sign (and statistical significance) across alternative specifications in the Latin American sample. Within Central America, however, the result is not significant for *SPEC*, but continues to be significant for *HHI*. The price results can, again, be anticipated in the raw data. Guatemalan prices per minute of use are among the very lowest in Latin America (the exact rank depending on the year). Prices in El Salvador are about average, however. Given that the population of Guatemala is about twice that of El Salvador, a pop-weighted average of the prices is well below the Latin American (or Central American) means. This data can be used to produce first approximation welfare results, which we do just below.

TABLE IV-4. RETAIL PRICE REGRESSIONS

	Latin America				Central America
Variable	**A**	**B**	**C**	**D**	**A**
LIB	-0.394 (-3.11) [0.00]	-0.531 (-3.93) [0.00]	-0.426 (-3.30) [0.00]	-0.395 (-3.3.) [0.00]	0.184 (0.85) [0.41]
HHI	0.344* (1.97) [0.05]	0.133 (0.68) [0.05]	0.253 (1.42) [0.16]	0.335 (1.53) [0.06]	0.677 (2.53) [0.02]
GDPPC	5.054 (1.6) [0.12]	5.802 (1.69) [0.10]	0.285 (1.45) [0.15]	4.299 (1.13) [0.20]	-80.027 (-5.46) [0.00]
GDPPC-squared	-0.295 (-1.6) [0.11]	-0.328 (-1.63) [0.11]		-0.250 (-1.51) [0.20]	4.851 (5.48) [0.00]
FLINE		-0.177 (1.25) [0.22]	-0.236 (-1.60) [0.10]		
FPRICE		0.114 (1.22) [0.23]			
FRASER		0.542 (1.00) [0.32]			
POP		0.021 (0.42) [0.68]			
DENSITY		0.055 (0.89) [0.38]	0.075 (1.39) [0.17]		
CONSTANT	-24.296 (-1.77) [0.08]	-26.656 (-1.79) 0.08	-3.929 (-1.81) [0.07]	-21.181 (-1.48) [0.15]	321.459 (5.41) [0.00]
R-squared	0.351	0.417	0.365	0.355	0.8054
Observations	80	80	80	80	20

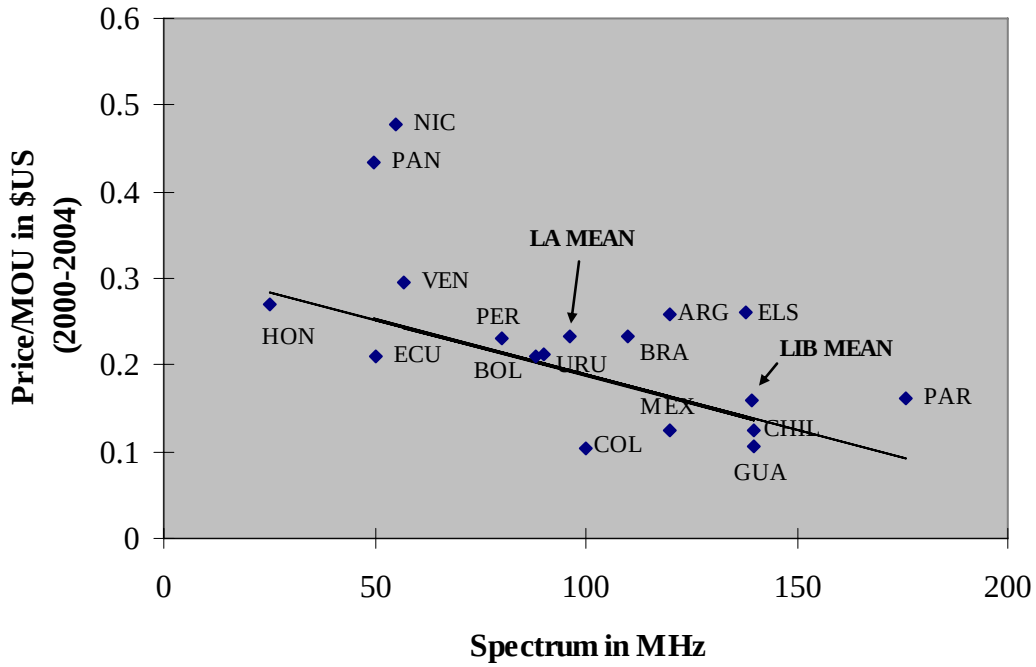
Coefficient estimates with t-statistics in parentheses and p-values in brackets.

A scatter diagram showing the relationship between spectrum allocation and retail prices is informative. See Fig. VI-3. The simple OLS line is downward sloping, with a statistically significant coefficient.[36] Countries with greater bandwidth deployed by mobile operators generally enjoy lower retail prices, consistent with economic theory. The mean values for the entire Latin American sample, excluding Guatemala and El

[36] The slope coefficient of the line in Fig VI-3 = - 0.00128 and has a p-value = 0.0092**.** This implies that a 10 MHz increase in spectrum is associated with a per minute price decrease of $0.013.

Salvador, are 19.6 cents for per minute and 90.0 MHz.[37] Mean values for the liberal sub-sample (Guatemala and El Salvador), are 14.5 cents per minute and 139.3 MHz.[38] This suggests that there is about a 26% lower price in the liberal sample, simply comparing means. Alternatively, predicting prices based on spectrum (MHz) available to mobile carriers, yields a differential (*LIB* discount) equal to 31.3% (using 90.0 MHz for the non *LIB* sample and 139.3 MHz for the LIB sample).

Figure VI-3: Mobile Prices and Spectrum Allocation in Latin America



Source: Pyramid Research (2005).

4. Output

In the output regression (E12), the dependent variable is the total minutes of mobile phone use in the market. This measure includes pre-paid and post-paid minutes. We expect this quantity to be positively related to *SPEC*, negatively related to *HHI,* and positively related to *GDPPC*. Other relationships are ambiguous.

[37] These data are for the most recent year of the series, 2004, and each country is weighted equally. Averaging over the five years of data, 2000-2004, yields mean values of 23.9 cents per minute and 90 MHz (mobile spectrum allocations do not materially change).

[38] These are 2004 data, population weighted. Guatemala's population exceeds El Salvador's by 90 percent.

Results are given in Table VI-5. Coefficient estimates for *HHI* and *GDPPC* carry the expected signs, although the *GDPPC* estimate becomes insignificant when *FLINE* is added to the regression. When included as a linear term, the *SPEC* coefficient is estimated to be negative, but is statistically insignificant. When *SPEC*-squared is added to the regression, however, the combined effect of bandwidth is highly significant and, through the interval which the data run (roughly, 25-175 MHz), positively correlated with *MOU*. (The minimum of the function occurs where *SPEC* = 67.76 MHz.)

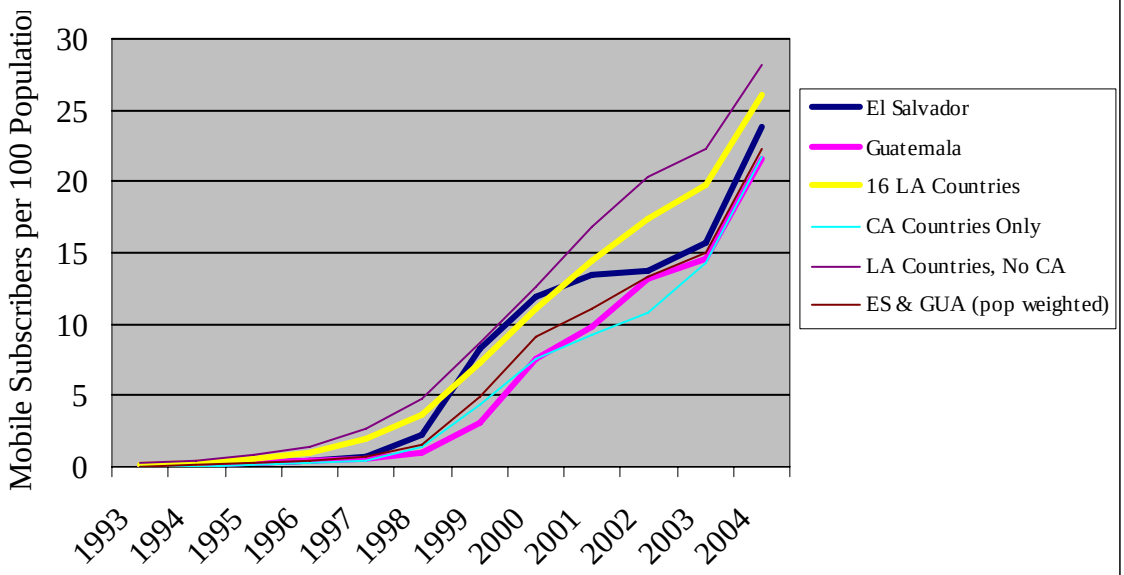
TABLE VI-5. OUTPUT (MOU) REGRESSIONS

	Latin America			Central America		
Variable	**A**	**B**	**C**	**A**	**B**	**C**
SPEC	-3.523 (-2.36) [0.02]	-0.004 (-0.03) [0.98]	-4.275 (-3.00) [0.00]	-6.957 (-4.95) [0.00]	-0.099 (-0.43) [0.68]	-7.019 (-2.9) [0.01]
SPEC-squared	0.407 (2.37) [0.02]		0.507 (3.07) [0.00]	0.831 (4.90) [0.00]		0.837 (3.25) [0.01]
HHI	-1.132 (-5.89) [0.00]	-1.071 (-5.45) [0.00]	-1.021 (-5.53) [0.00]	-1.235 (-5.66) [0.00]	-1.257 (-3.69) [0.00]	-1.252 (-2.15) [0.05]
GDPPC	0.771 (6.78) [0.00]	0.725 (6.28) [0.00]	0.227 (1.14) [0.26]	1.778 (9.94) [0.00]	1.544 (5.74) [0.00]	1.819 (1.38) [0.19]
FLINE			0.470 (3.22) [0.00]			-0.034 (-0.03) [0.98]
CONSTANT	6.090 (1.55) [0.13]	-1.519 (-0.65) [0.52]	10.021 (2.57) [0.01]	5.594 (1.44) [0.17]	-6.129 (-1.28) [0.29]	5.613 (1.38) [0.19]
R-squared	0.6862	0.6627	0.7248	0.9466	0.861	0.9466
Observations	80	80	80	20	20	20

Coefficient estimates with t-statistics in parentheses and p-values in brackets.

These results are not as easily anticipated from the raw data. The growth in mobile phone usage across all Latin American countries has been strong over the past decade, as in the rest of the world. The *LIB* sub-sample has slightly outperformed its Central American peer group (which consists of Honduras, Nicaragua, and Panama), but has lagged overall regional growth in Latin America. See Fig. VI-4.

Figure VI-4. Mobile Phone Subscribers in Latin America, 1993-2004



Source: World Telecommunications Indicators 2005, International Telecommunications Union (2004).

5. *Summary of Empirical Estimates*

The empirical evidence gleaned across the four estimated equations is consistent with the hypothesis that spectrum reforms in Guatemala and El Salvador have resulted both in expanded deployment of radio spectrum and in less concentrated markets.[39] The connection between these two findings is clear. Given critical mass (or minimum efficient scale), mobile network operators typically utilize blocks of frequencies of at least 20 MHz. Scope economies (as when existing base stations and other network infrastructure is complementary to the use of additional MHz) imply substantial scale efficiencies (in bandwidth) even above this lower bound. Hence, where only 50 MHz are allocated to the service, monopoly or duopoly is the likely result, whether the market structure is imposed by regulators (in creating licenses) or by secondary market transactions. With more generous spectrum availability, the entry of additional networks is facilitated. Given that Guatemala and El Salvador have succeeded in having much more bandwidth deployed by operators than in the average Latin American regime (approximately 139 MHz to 90 MHz), competition has been enabled.

[39] We note that, in addition to the independent variables listed in Table VI-1, we tested a number of other explanatory factors as regressors. These included the level of urbanization, the literacy rate, and the extent of services as proportion of GDP. These variables were not found to have statistically significant coefficients.

The effect of larger bandwidth and less concentration are also seen to have the predicted effects on prices and outputs. This is consistent with economic theory. It also permits us to make preliminary estimates of the value of the liberal policies adopted in Guatemala and El Salvador.

6. *First Approximation Welfare Estimates from Liberalization*

The evidence suggests that liberal property rights have expanded spectrum use and competition in mobile markets in Guatemala and El Salvador, and that these factors have in turn led to reduced retail prices. We offer a simple first approximation of the welfare gains realized from this change to obtain an idea of the order of magnitude of the impact such liberalization policies may have.

In the data displayed in Fig. VI-3 we observed a negative relationship between *SPEC* and *PRICE*, and the regression estimates of E11 suggest that this relationship is not explained by other variables. There is also a positive relationship between *HHI* and *PRICE*, as suggested by E11. From the estimated coefficients in E9 and E10, there is additional empirical evidence to suggest that liberal spectrum regimes are associated with higher levels of spectrum utilization and lower market concentration.

We use these results as the basis for a simple exercise, which assumes that the price difference in the liberal sub-sample – about 26% to 31% – is due to the impact of liberalization. This allows us to estimate the social gains from the policies by using demand elasticity estimates available elsewhere in the economic literature. In general, estimated elasticities range from -1.1 to -1.5.[40] Assuming that elasticity of demand over the relevant interval equals -1.2, a price reduction of 26% implies that consumer surplus would increase by a sum equal to about 29% the size of initial industry revenues. This suggests that the magnitude of the gains associated with liberalization is substantial.

VII. TRANSACTION COSTS

With any policy reform, the possibility arises that transitional difficulties will dominate gains. This prospect is particularly important in wireless telecommunications for two reasons. First, the centralized spectrum allocation regime has been historically supported with arguments concerning the transactions costs of private ownership. Second, global markets for manufactured wireless equipment (handsets, base stations, and other cellular network infrastructure) exhibit pronounced economies of scale. Such economies may fundamentally impact the success of policy reforms, although it is not clear in which direction.[41] In any event, we here examine how the costs of allocating

[40] Ingraham and Sidak (2004) have estimated that the elasticity of demand in the US for wireless services is between –1.12 and –1.29, while Hazlett and Munoz (2006) estimated that the same elasticity is approximately -1.2.

[41] Global standards may facilitate experimentation with liberal regimes in small economies, providing private market coordination without government regulation. Alternatively, small markets may not capture many of the advantages of free entry (due to liberalization) because scale economies are not available.

radio spectrum appear to be impacted, in both the private and public sectors, under the liberal spectrum regimes being evaluated.

A. Private Sector

1. Guatemala

It has been shown that liberal regimes are relatively successful in assigning wireless property rights, and that liberalized mobile phone markets demonstrate a high degree of efficiency relative to other Latin American markets. These findings imply that transactions costs are not offsetting social gains. Here we focus on the issue of radio interference. The inability of private property rules to adequately police spectrum use, leading to tragedy of the commons, has traditionally been a stated concern of regulators.

In Guatemala, *TUF* holders may file a formal complaint to the *SIT*, accompanied by a technical report produced by an accredited expert, in response to radio interference.[42] The *SIT* then informs the party alleged to be creating the reported conflicts, with that party given ten days to file its own expert technical report. Following this reply, the *SIT* must issue a decision within ten days. If the accused has violated *TUF* rights, the party must cease interfering activities and pay any fines imposed by the *SIT*, which range from $10,000 to $100,000,[43] within five days.[44]

Within the mobile telephony sector, there have been almost no problems with interference. For example, the largest mobile telephony provider, Telgua, reports little difficulty in coordinating use with other *TUF* holders and has encountered virtually no illegal use of their frequencies. On one occasion, however, Telgua was the cause of interference when, after the 1996 reform, it continued to use a point-to-point transmitter in a band for which it did not have a *TUF*. The *SIT* issued a $50,000 fine; Telgua paid the fine and ceased operations in the band.[45]

This episode illustrates how the resolution process is designed to work. The band that Telgua used illegally was reserved for governmental use. In 2001, the U.S. government intended to use these frequencies in conjunction with security during a visit by former U.S. President Bill Clinton. Testing the band prior to the official event, American authorities experienced interference and complained to the *SIT*, which promptly investigated and enjoined Telgua.

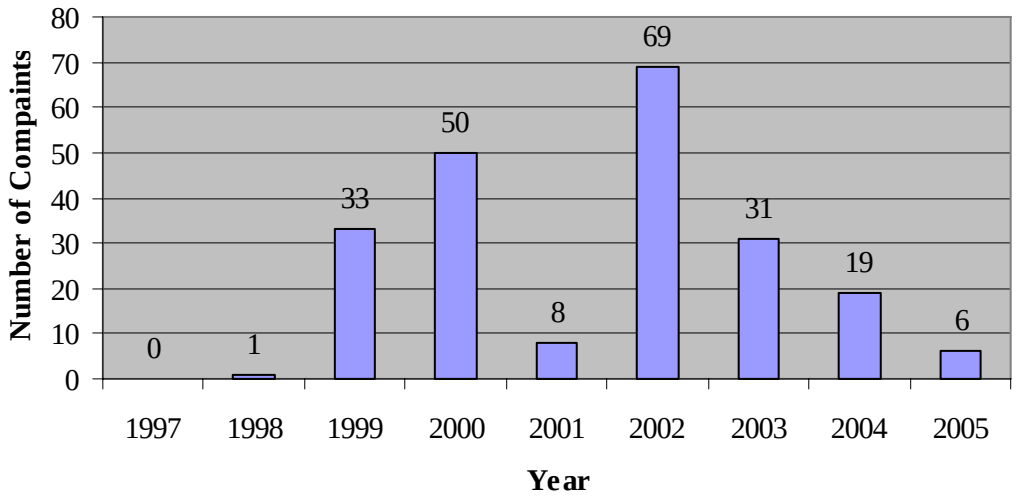
As elsewhere, broadcast spectrum in Guatemala receives special treatment. The relevant regulations were largely established in the Radio Communications Law of 1966.[46] This law established the General Directorate for Broadcasting, which allocated spectrum until the telecommunications reform in 1996, and which was managed by the

[42] *Ley General de Telecomunicaciones*, Art. 53.
[43] *Ley General de Telecomunicaciones*, Art. 81.
[44] *Ley General de Telecomunicaciones*, Art. 84.
[45] Interview with Belisario Montepeque, Chief Counsel, Telgua. Guatemala City (June 8, 2005).
[46] *Ley de Radiocomunicaciones*, Decreto-Ley Número 433, March 10, 1966.

Guatemalan military. The General Directorate for Broadcasting was retained following the Telecommunications Law of 1996, although it now shares responsibility for spectrum regulation with the *SIT* and the Ministerio Público (Ministry of Justice).[47]

From 1997 to mid-2005, the *SIT* reports that it has received a total of 217 formal complaints of interference (Escalante 2005). See Figure VII-1. Of these, 181 cases (84 percent) pertain to the VHF band, and 158 of these (72.8 percent of all interference complaints) pertain to the FM radio bands. With the exception of only seven cases, the remaining interference complaints pertain to use of the UHF bands (29 complaints) (Escalante 2005). Not only are the reported cases concentrated in the FM radio band, some *TUF* holders with FM frequencies claim that the post-2002 decrease in the number of *SIT* complaints is a result of their lack of faith in the government's commitment to rights enforcement (Liu 2005).

Figure VII-1. Interference Complaints in Guatemala



Source: Escalante (2005).

According to the Guatemalan broadcasting association, illegal use of FM channels is widespread but is generally tolerated by the authorities.[48] Many of the illegal stations have been affiliated with religious organizations, including evangelical Christian churches. In early 2003, the Guatemalan National Radio Broadcast Chamber

[47] The Ministerio Público in Guatemala is the administrative home of prosecutors serving at the national level and includes the Procuraduría General, approximately equivalent to the U.S. Attorney General. In this sense, the Ministerio Público is similar to the U.S. Department of Justice.

[48] Unless otherwise cited, the information pertaining to the Guatemalan broadcasting industry is based on an interview with Mario F. Valderramos, President, Guatemalan Chamber of Broadcasters. Guatemala City (June 1, 2005).

waged a media campaign against the "pirates" and filed a lawsuit demanding that 341 unauthorized stations be closed by the government for operating illegally.[49]

In 2004, the Ministerio Público announced that it intended to prosecute illegal users of spectrum; some unauthorized users responded by suing the government for the violation of their constitutional rights to private property and freedom of expression.[50] These arguments were accepted by some lower courts**,** but the highest court in Guatemala, the Corte de Constitucionalidad, heard two of these cases and overturned both, freeing the Ministerio Público to shut down users not possessing *TUFs*.[51] The decisions support property rights holders, even as many illegal users continue to operate.

Weak property rights enforcement is suggested by the highly political nature of broadcast content. Whereas standard regimes vest great discretion in regulators, and allow policy makers to thereby engage in rent-seeking via "public interest" spectrum allocations, Guatemalan law formally constrains regulators. This tends to lessen support for the standard pro-incumbent policies exhibited.

2. El Salvador

In El Salvador, the process for resolving interference is not as well-defined as it is in Guatemala.[52] The 1997 law does not specify how rights holders may bring a complaint against illegal encroachment. However, the Act does establish the *SIGET*'s authority to regulate spectrum,[53] and specifies "less serious," "serious" and "very serious" violations.[54] The use of "regulated" (*i.e.*, commercial) or official spectrum bands without the relevant authorization is considered a "serious" infraction, with substantial fines assessed on a per-day (of violation) basis.

As in Guatemala, El Salvador experiences little or no illegal interference problems involving mobile telephony. Moreover, *SIGET* reports that illegal use of spectrum is rare in all bands.[55] The lack of illegal use in the broadcasting bands is

[49] "Community Radio Asks for Solidarity," (May 5, 2003); http://www.fhrg.org/news/ghrc_march_2003.html

[50] See, Ref. Amparo 1377-2004, Juzgado de Primera Instancia Penal, Narcoactividad y Delitos contra el Ambiente, Coban, Alta Verapaz. January 31, 2005. This case involved a community radio station, Radio Libre, operating illegally at 90.7 FM. See also, Ref. Amparo 1376-2004, Juzgado de Primera Instancia Penal, Narcoactividad y Delitos contra el Ambiente, Coban, Alta Verapaz. January 31, 2005. This case involved another community radio station, Stereo Tiempo, operating illegally at 98.3 FM.

[51] See, Expediente No. 1987-2004, Corte de Constitucionalidad, Republica de Guatemala (Nov. 12, 2004). See also, Expediente No. 1664-2004, Corte de Constitucionalidad, Republica de Guatemala (March 27, 2005).

[52] See Art. 76-82.

[53] *Ley de Telecomunicaciones y su Reglamento*, Art. 50.

[54] *Ley de Telecomunicaciones y su Reglamento*, Art. 33.

[55] Interview with Victor Artiga, Director of Telecommunications, SIGET, in San Salvador, El Salvador (Feb. 7, 2005).

corroborated by representatives from that industry.[56] This contrasts with the pre-democracy period. In a peace accord signed in 1990, guerrillas were given licenses to frequencies that they previously had used illegally. In subsequent years, some illegal broadcast users again emerged.

Salvadoran government and industry representatives observe that, since its reform in 1997, the country has had few if any problems with the illegal use of spectrum.[57] This success in avoiding continued pirate-radio problems may be due to the fact that, prior to its reforms, the country brought its largest and most powerful illegal users into the legal framework. By doing so, these parties were given a stake in the new system and a strong incentive to support government protection of their rights. However, this does not offer a full explanation as to why new illegal users have not emerged.

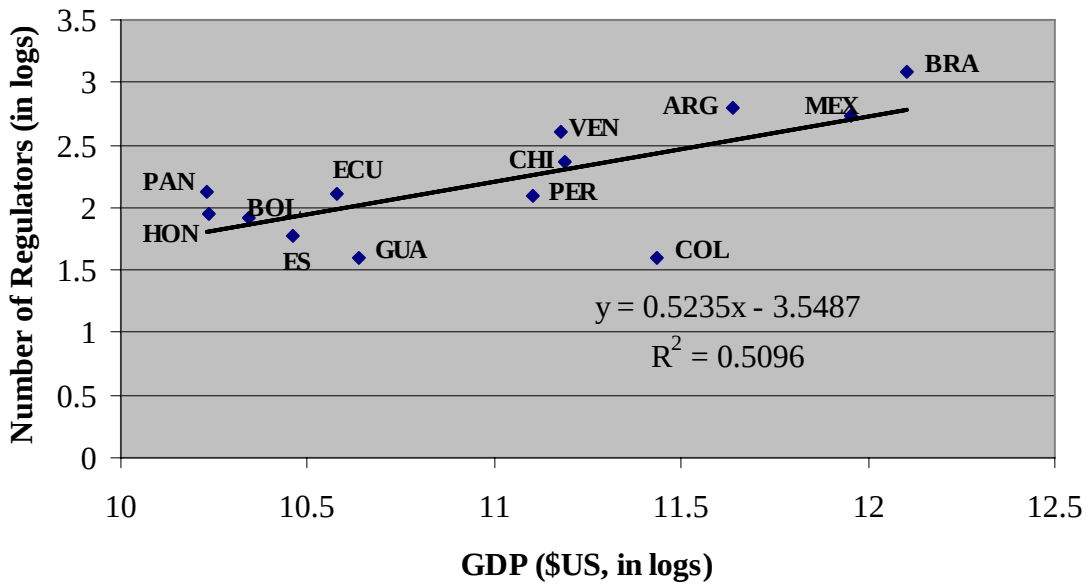
B. Public Sector

To compare the transaction costs incurred in the public sector, we hypothesize that the number of employees in the relevant regulatory agency serves as a cost proxy. Hence, we test the prediction that Guatemala and El Salvador have significantly greater spectrum regulatory agency workers than other countries, adjusting for GDP (conflating income per capita and population). These regulatory data are available as per a survey conducted by the World Bank in 2004 (Wallsten et al., 2004).

A scatter diagram is plotted in Fig. VII-2. Guatemala and El Salvador have fewer regulatory employees per GDP size than other countries for which data are available in the survey (these countries extend beyond Latin America). This simple analysis suggests that transaction costs in the public sector are not increased by the switch to a liberal spectrum regime. This supports the evidence presented above, consistent with the view that the administrative process of rights definition has – with an interesting exception in the case of Guatemala's governmental support for illegal FM radio broadcasters – worked relatively smoothly under liberal spectrum reforms in Guatemala and El Salvador.

[56] Interview with Ana Maria Urrutia de Lara, Executive Director, Broadcasters Association. San Salvador, El Salvador (Feb. 7, 2005).
[57] Interview with Victor Artiga, op. cit. Interview with Ana Maria Urrutia de Lara, op. cit.

Figure VII-2. Number of Regulators vs. GDP



VIII. UNLICENSED BANDS

In the U.S. and most other countries, particular bands are set aside for the operation of unlicensed devices. Standard allocations, pursuant to international coordination, include the 902-928 MHz and 2.4-24835 GHz frequencies.[58] In these bands, usage is limited not by licensing, but by regulation of devices, including power limits, technologies, and (in some cases) business models.[59] Short range communications, or wireless links in rural areas with limited demand for airwaves, are commonly provided by these regulated but unlicensed devices. Examples include cordless phones, Wi-Fi routers, and baby monitors.

In El Salvador, the management and use of these bands closely parallel the experience seen elsewhere.[60] In both the 900 MHz and 2.4 GHz bands, license-exempt use is authorized, with the standard caveat that such operation is not protected against

[58] See Carter, et al. (2003); Hazlett & Spitzer (2006). Several other bands are commonly used for unlicensed allocations, including at least 300 MHz in the 5 GHz band.

[59] In Mexico, for instance, the use of unlicensed bands for commercial purposes (such as wireless hotspot service) is illegal.

[60] Information pertaining to the regulation and use of the 900 MHz and 2.4 GHz bands in El Salvador is taken from the Cuadro Nacional de Atribución de Frecuencias (National Table of Allocations), *Superintendencia General de Electricidad y Telecomunicaciones (SIGET)*, available at www.siget.gob.sv (visited on January 20, 2006).

harmful interference by other parties in the band. Users are mandated to employ "spread spectrum" systems and to operate at low power.[61]

In contrast, private parties transmitting wireless communications in Guatemala must hold a TUF, and there are no specific allocations for unlicensed use on any band in this country.[62] Rights for the 2.4 GHz band are held by nine TUF holders, which engage in a variety of uses. The TUF representing the largest amount of spectrum in this band is held by a banking consortium, which uses the band to provide point-to-multipoint connections between its main office in Guatemala City, 200 branch locations, and 150 automatic teller machines (ATMs) located around the country.[63]

Due to the availability of low-cost devices, Guatemalans extensively use the 2.4 GHz band for "unlicensed" operations. Absent permission from TUF holders, such users have no rights to be in the band. Some parties seek and receive permission. For example, Francisco Marroquín University, maintains a private wireless Internet network on its campus in the heart of Guatemala City, which it operates with permission from *Bancared*. Other businesses, such as restaurants and cafes, provide wireless Internet access to patrons, using 2.4 GHz Wi-Fi devices as elsewhere. The most common use is for wireless networking within private residences.

The TUF holders in the 2.4 GHz band take little action against these unlicensed users. Costs of enforcing their rights are relatively high, and tend to outweigh the benefit from enforcement which is of limited value because the harm caused is modest. By design, equipment for unlicensed band use operates at low power. When TUF holders experience interference from low-power devices, they can typically increase power at low cost, eliminating (or dominating) the conflict.

The 900 MHz band is also used by unlicensed operators in Guatemala. While some TUFs in this band are held by paging companies, among others, the Guatemalan government withheld the majority. This reflected a policy decision to use the state's regulatory powers to procure frequency space for the use of unlicensed devices.

Recently, the Guatemalan regulator (*SIT*) has begun negotiations with TUF holders in the 900 MHz and 2.4 GHz bands in an attempt to encourage them to move to other frequencies, for which they would be compensated. The *SIT* has authority to purchase these privately held TUFs, making them available for unlicensed access (as with 900 MHz TUFs). Such a policy may allow more unlicensed use, free from contention by private TUF holders, in bands used for this purpose across the world and for which global equipment markets supply a wide range of low-cost devices.

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[61] These technical rules and the authorization for "free" use apply specifically to the 902-928 MHz and 2.4-2.4835 GHz bands. *Id.*

[62] Information pertaining to Guatemala's use of TUFs and regulation of the 900 MHz and 2.4 GHZ bands, as reported in this section, is based on an interview with Marco Antonio Escalante of the *Superintendencia de Telecomunicaciones* (Jan. 20, 2006), and subsequent correspondence (March 2, 2006).

[63] Information pertaining to this firm is based on an interview with Ramiro Morales, Manager of Communications, Bancared (Guatemala City, June 8, 2005).

The allocation of privately owned spectrum rights for access by device users or their agents (presumably, device manufacturers) would constitute an interesting addition to the analysis of property rights. It will be interesting to see how market structures mimic, or differ, from the organization of mobile phone markets where wireless operators offer relatively complex contracts entitling subscribers to access radio spectrum and complementary network infrastructure.

IX. CONCLUSION.

Ronald Coase's normative conclusion that private property rights in spectrum would yield incentives for efficient use has been widely embraced by economists (Rosston et al., 2001). Yet, public policy has been slow to catch up. While many countries use auctions to assign wireless licenses, administrative fiat remains the standard mechanism to allocate radio spectrum itself.

The experience in Guatemala and El Salvador provides an important natural experiment. Liberal reforms in these countries a decade ago have permitted market mechanisms to distribute bandwidth across wireless services, technologies and operators. Performance indicators from the dominant industry within the sector, mobile telephony, suggest that economic benefits have obtained. Consumer welfare is roughly estimated to increase about 17% of total industry revenues, with much larger gains being transferred to consumers as a class (about 45% of initial revenues).

These gains result because Guatemala and El Salvador feature relatively abundant spectrum utilization and market competitiveness. We also find that the asserted transaction costs of liberal reform, or markets governed by private property rules, are not yet in evidence, although the shifting political allegiances of policy makers (in Guatemala) have led to rights enforcement problems within the FM radio band.

Guatemala and El Salvador offer a relatively challenging venue for the policy experiment conducted, with relatively low incomes, small populations, and poor ratings in terms of "economic freedom." Larger countries, which may capture higher returns to scale in entrepreneurial use of spectrum, as well as countries with better developed capital markets and judicial systems, may well experience greater benefits from Coasean spectrum reforms. Research on the political dynamics enabling such further experimentation could prove highly beneficial for lawyers, economists, technologists, and policy makers.

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Appendix
Description of Data and Sources

The following 16 Latin American countries were considered in this analysis: Argentina, Bolivia, Brazil, Chile, Columbia, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela. Costa Rica was excluded because it featured a state monopoly provider of mobile telephony throughout the sample period, which makes it difficult to interpret price data given the potential for cross-subsidization of services.

Dependent Variables:

HHI = the Hirschman-Herfindahl Index score based on subscriber data. 2000-2004 data from "Latin America Mobile Data," Pyramid Research, Cambridge, MA (2005)

MOU = minutes of use for voice mobile telephone service, per capita. 2000-2004 data from "Latin America Mobile Data," Pyramid Research, Cambridge, MA (2005). MOU per subscriber reported as a blend of pre-paid and post-paid use for, and then adjusted for overall population.

PRICE = average revenue per minute of mobile telephone service. 2003 data. Source: "Latin America Mobile Data," Pyramid Research, Cambridge, MA (2005). The data are averaged across pre-paid and post-paid subscribers.

SPECTRUM = the amount of spectrum within a country that is available for mobile telephony service. 2003 data. Source: Country regulator websites.

Independent Variables:

DENSITY = the population density of a country (in terms of number of people per square kilometer). 2000-2004 data. Source: World Telecom Indicators 2005, International Telecommunications Union, Geneva, Switzerland: http://www.itu.int/publications/template.aspx?lang=e&menu=main&media=download&target=/publications/EBookshop.html

FIXED LINES = the number of fixed lines per 100 persons. 2000-2004 data. Source: World Telecom Indicators 2005, International Telecommunications Union, Geneva, Switzerland: http://www.itu.int/publications/template.aspx?lang=e&menu=main&media=download&target=/publications/EBookshop.html

FIXED LINE PRICE = the price of a three-minute phone call on the wireline network, peak rate. 2000-2004 data. Source: World Telecom Indicators 2005, International Telecommunications Union, Geneva, Switzerland:

http://www.itu.int/publications/template.aspx?lang=e&menu=main&media=download&target=/publications/EBookshop.html

GDP PER CAPITA = the per-capita GDP, by country, in US dollars and on a PPP basis. 2000-2004 data. Source: World Development Indicators, World Bank: http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,menuPK:232599~pagePK:64133170~piPK:64133498~theSitePK:239419,00.html

GDP SERVICES = the percentage of a country's GDP that is tied to the service sector. 2003 data. Source: World Development Indicators 2005, World Bank. Available at http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,menuPK:232599~pagePK:64133170~piPK:64133498~theSitePK:239419,00.html

HIRING = a composite score representing the costs of hiring workers within a country. 2003 data. Source: The World Bank Group (as reported by Nationmaster.com). The original methodology and data are from Juan Botero, Simeon Djankov, Rafael La Porta, Florencio Lopez-de-Silanes, and Andrei Shleifer, "The Regulation of Labor."

LITERACY = the percentage of a country's population that is literate. 2003 data only. Source: The World Almanac and Book of Facts 2004.

POPULATION = the total population of a country. 2000-2004 data. Source: CIA World Factbook, 2001-2005: http://www.theodora.com/wfb/abc_world_fact_book.html

URBAN = the percentage of a country's population that lives in urban areas. 2003 data only. Source: The World Almanac and Book of Facts 2004.