Socio-economic impact of alternative spectrum assignment approaches in Latin America

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ABSTRACT

It has been argued that the construction and expansion of broadband networks and the development of broadband-based services generates a positive effect on economic growth as measured by GDP growth, affecting the income of consumers and the productivity of businesses. The essential input to the exploitation of mobile broadband is the radio spectrum. Being a scarce resource, its allocation and eventual assignment by telecommunications regulator and spectrum authorities across the world is of outmost importance. The most popular approach to spectrum assignment is to run an auction where frequency bands get assigned over a fairly large time horizon; this feature of spectrum assignment plays a role in shaping the mobile telecommunications markets and may foreclose the emergence of alternative, plausibly more efficient, new modes of spectrum utilization. The paper's objective is to demonstrate that conventional spectrum assignment processes (based on auctioning of single use licenses) can be enriched with other approaches, such as reserving portion of spectrum to unlicensed use. The methodology explores alternative spectrum assignment scenarios (fully based on licenses and mixed) for a Latin American country, and quantifying their impact in terms of achieving coverage in rural and isolated areas, as well as promoting technological innovation.

KEYWORDS

Mobile broadband; Spectrum; Latin America; Rural coverage

INTRODUCTION

It has been argued that broadband networks and services generate a positive effect on economic development as measured by GDP growth, affecting the income of consumers and the productivity of businesses. Similarly, broadband enables the provision of services that facilitate social inclusion of population, particularly of those residing in rural and remote areas. Research literature provides a fairly large number of cases around the world that empirically support such claim (Katz, 2012; Koutroumpis, 2009; Katz and Koutroumpis, 2013; Katz and Callorda, 2013). Beyond the deployment of fixed networks, worldwide development of broadband wireless networks, mainly 4G infrastructure, greatly enhances the broadband infrastructure that consumers can enjoy and businesses utilize with mobility added as an additional benefit. Thus, it is expected that mobile broadband replicates the same observed positive effect on growth, albeit with its own features, making it hugely attractive to consumers. Again, empirical studies validating this effect are starting to be generated as data comes available (Katz and Koutroumpis, 2014; Center for International Economics, 2014). However, while broadband benefits have already been documented, it is still clear that the digital divide (understood as limited service offering and consequently adoption in rural and isolated geographies of the emerging world) remains a key barrier.

The essential input to the delivery of mobile broadband is the radio spectrum. Being a scarce resource, its allocation and eventual assignment by telecommunications regulators and spectrum authorities across the world is of outmost importance. The most popular approach to spectrum assignment has been, so far, to run an auction by which the spectrum gets assigned to an operator over a fairly large time horizon (typically 10-20 years). This approach plays a role in shaping the mobile telecommunications markets and may foreclose the emergence of alternative, plausibly more efficient, new modes of spectrum utilization that would facilitate tackling the digital divide economic barrier.

The debate over the most effective way of allocating frequency spectrum has been conducted over the past fifty years, in particular since the publication of Coase's seminal paper (1959) on spectrum management. There is a growing body of theory arguing that an approach that combines licensed and unlicensed approaches to spectrum assignment is conducive to maximizing innovation and welfare, while ensuring capital spending in network rollout (Milgrom, 2011; Katz, 2014). In this context, faced with deciding the best route towards efficient spectrum management, regulators and policy makers need to be aware of the balancing game between providing clear signs to markets participants about how spectrum is allocated and assigned on a long term basis and assuring that all sectors of society, specially the most vulnerable in terms of economic opportunities or geographic location, are beneficiaries of its decisions.

This paper argues that spectrum authorities, in addition to assessing the relative importance of income collection (via auction) and mobile broadband coverage in their decisions, need to also factor in the increasing importance of alternative methods of spectrum utilization which are based on either new technologies that improve spectral efficiency and access or management methods that allow for spectrum sharing of various sorts. The paper's objective is to demonstrate that conventional spectrum assignment processes (based on auctioning of single use licenses) can be enriched with other approaches, such as reserving portion of spectrum to unlicensed use.

The methodology will comprise specifying alternative spectrum assignment scenarios (fully based on licenses and mixed) for a Latin American country, and quantifying their impact in terms of achieving coverage in rural and isolated areas, as well as promoting technological innovation. Chapter II outlines the nature of the divide economics in Latin America. Chapter III discusses the theoretical reasoning behind the assessment of alternative spectrum management approaches. Chapter IV explores the international experience supporting said approaches. Chapter V presents a financial model of deployment of a wireless broadband network in Paraguay, using it as a basis to the assessment of how alternative spectrum management approaches might yield different economic profiles.

THE NATURE OF THE PROBLEM: LIMITED BROADBAND COVERAGE IN RURAL AREAS IN LATIN AMERICA

As of the end of 2013, fixed broadband adoption in Latin America had reached a prorated average of 35.46% of households, having grown at a compound annual growth rate (CAGR) of 13.16% since 2009. This average masks wide country divergences between some nations, such as Argentina, Chile, Mexico, and Uruguay with high adoption levels, and others such as Bolivia, Honduras and Paraguay with significantly low penetrations (see table 1).

Country	2009	2010	2011	2012	2013	CAGR (%)
Argentina	31.46	33.03	36.76	45.72	50.56	13
Bolivia	4.19	4.12	2.78	4.60	5.80	8
Brazil	19.59	22.81	28.73	31.18	34.42	15
Chile	36.68	39.32	43.76	46.76	46.44	6
Colombia	17.41	21.36	26.76	31.19	35.48	19
Costa Rica	14.06	30.72	31.60	33.74	35.19	26
Dominican Rep.	10.27	12.73	13.71	14.98	16.07	12
Ecuador	7.97	6.47	19.95	26.03	31.22	41
El Salvador	9.41	10.98	12.83	15.00	17.37	17
Guatemala	4.78	7.75	7.77	7.79	7.73	13
Honduras	…	0.06	3.28	3.43	3.74	296
Mexico	33.28	39.42	41.64	44.10	46.68	9
Nicaragua	7.65	7.03	8.05	9.45	12.10	12
Panama	27.84	30.21	32.59	33.44	33.24	5
Paraguay	0.99	1.74	3.76	4.76	6.33	59
Peru	12.48	13.90	17.95	21.21	23.17	17
Trinidad & Tobago	32.20	36.65	38.61	45.20	47.85	10
Uruguay	22.38	27.24	33.64	41.47	52.82	24

Country	2009	2010	2011	2012	2013	CAGR (%)
Venezuela	21.01	25.01	27.00	29.95	32.67	12
Prorated Average	21.63	25.16	29.45	32.53	35.46	13

Note: the decrease in penetration statistics in certain years is due to changes in broadband speed metrics as defined by the regulator.
Source: Compiled by Katz and Callorda (2014) from regulator and publicly available sources
Table 1. Latin America: Fixed Broadband Adoption (percentage of households)

While lagging penetration can certainly be explained by factors related to the demand gap (for example, affordability, digital literacy, and relevant content) (see Katz and Berry, 2014), service coverage represents a supply barrier. For example, with the exception of specific countries that exhibit favorable topographic conditions and a strong universal service program (such as Uruguay), fixed broadband coverage at the municipal level rarely achieves 100% in the continent (see table 2).

Country	2010	2011	2012	2013
Argentina	95.98	95.98	95.98	95.98
Bolivia	40.27	40.63	41.00	41.37
Brazil	93.60	100.00	100.00	100.00
Chile	98.66	98.66	98.66	98.66
Colombia	…	82.70	88.37	94.42
Costa Rica	94.86	94.86	94.86	94.86
Ecuador	…	86.83	86.83	86.83
Mexico	62.45	66.38	70.56	75.00
Uruguay	100.00	100.00	100.00	100.00

Note: Gray cells indicate that data was compiled from sources below while the remaining ones are either interpolations or inferences by the authors.
Sources: Argentina (TAS, Ministerio de Planeamiento), Bolivia (TAS, Entel), Brasil (Anatel), Chile (TAS, Entel), Colombia (MINTIC), Costa Rica (Plan Nacional de Banda Ancha), Ecuador (Mintel), México (COFETEL), Uruguay (EUTIC).
Table 2. Latin America: Fixed broadband coverage (percentage of population)

The data in table 2 indicate that while coverage has been improving since 2009, countries typically reach a point beyond which fixed broadband coverage does not increase. While it is difficult to assign a single factor to this trend, reasons could range from limited technical feasibility, disadvantaged economics of deployment, limited financial resources, or a combination of all three.

In this context, wireless technology has been posited as the alternative to address the supply gap. However, recognizing that broadband definitions lack definitional consistency, coverage statistics of mobile broadband also indicate the existence of a supply gap (see table 3).

Country	2009	2010	2011	2012	2013
Argentina	…	82.00	84.93	89.00	…
Bolivia	…	29.00	42.30	61.70	90.00
Brazil	64.60	72.60	83.20	87.90	91.30
Chile	…	…	72.47	100.00	100.00
Colombia	…	…	100.00	100.00	100.00
Costa Rica	44.85	64.67	93.25	…	…
Ecuador	62.21	66.29	77.75	87.47	…
Guatemala	…	…	…	53.00	…
Mexico	…	77.29	91.00	…	…
Panamá	…	…	80.00	…	…
Paraguay	…	…	…	…	70.00
Peru	…	55.02	62.51	79.40	…
Trinidad & Tobago	…	…	…	75.00	…
Uruguay	…	32.10	81.00	…	…
Venezuela	…	…	96.08	…	…

Note: Gray cells indicate that data was compiled from sources below while the remaining ones are either interpolations or inferences by the authors.
Sources: Argentina (Personal), Bolivia (Entel), Brasil (Teleco), Chile (UIT), Colombia (Deloitte), Costa Rica (UIT, MINAET), Ecuador (UIT), Guatemala (UIT), Panamá (Deloitte), México (Deloitte, SCT), Trinidad & Tobago (UIT), Uruguay (TAS, Deloitte), Venezuela (TAS).

Table 3. Latin America: Mobile broadband coverage (percentage of population)

As data in table 3 indicates again, while coverage has been increasing over the years, the supply gap persists, indicating that there would appear to be a portion of the population that continues to be excluded from wireless coverage. A second factor which cannot be gleaned out of the data in table 3 is that, in many countries, a portion of the population coverage is achieved through either 2G or 3G technologies which lack the capability to deliver broadband at adequate service levels.

In light of this persistent supply gap, several Latin American governments have been deploying publicly owned backbone networks with the objective of reaching remote locations. Of note, backbone deployment has reached significant levels in Colombia (through its Red Azteca), Peru (by means of its Red Dorsal), and Argentina (supported by its project Argentina Conectada). However, while these networks have reached geographies previously unserved by privately held transport facilities with the ability to significantly reducing backhaul costs, the “last mile” access barrier remains:

- **Argentina**: There are 329 municipal telecommunications cooperatives that would need to develop “last mile” networks. Of these, 169 have an average population of 5,000, and 160 have less than 2,000. Of the 329 cooperatives, it is estimated that only 10% could build a fixed access network that is economically viable, given the resources available to the municipality, revenues and costs. The remainder cannot afford building such a facility[1].
- **Brazil:** Brazil has 5,565 municipalities, subdivided in 10,123 districts. Of these, 9,807 districts have a population of under 100,000, and 1,284 are considered to be urban. The Brazilian government is seeking to deploy last mile fiber optic network to 1,284 urban districts covering a total of 6 million households. The Brazilian Association of Internet Providers and Telecommunications (ABRINT) estimates that deploying a FTTH network in each of these urban districts would require a total investment of US$ 3.8 billion. The Brazilian Ministry of Communications and the Superintendência de Pequenas e Médias Empresas of the Banco do Brasil are searching for funding sources for the above program, but are encountering a number of challenges. The operators, typically fairly small, tend to have a low capitalization rate, with investments funded from their own cash flows. If the operator is able to access credit, it is normally for amounts that are lower that the required investment. Furthermore, credit lines from the BNDES, which could be more suited to this type of funding, are on-lent by commercial banks that are reluctant to lend to these projects due to perceptions of high risk.
- **Colombia**: In 2014, the Colombian government completed the deployment of the *Red Azteca* national fiber optic backbone, linking approximately 1,000 “yet-not-served” municipalities across the country. However, similarly to the Argentina case, the backbone reaches only one point in each municipality and needs to be complemented with “last mile” distribution networks in each municipality. The Colombian Ministry of ICT has not yet quantified the funding that will be required for last mile deployment. Based on the population distribution statistics from the Colombian National Administrative Department of Statistics (DANE), we assume that the newly covered municipalities are those with the lowest population density. In fact, there are 984 municipalities with less than 30,000 population, averaging population density of 5,802 (or 1,450 households). Assuming a fiber cost of US$ 2,000 per household passed[2] for an average municipality of 1,450 households, it would represent an average deployment project cost for each municipality of approximately US$ 2.9 million, which exceeds the funding capacity of both the Universal Fund FONTIC and the financing ability of these municipalities.

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[1] Comisión nacional de Comunicaciones. *Las Cooperativas telefónicas en Argentina*. June 23, 2009.Presentation to the Regional Seminar on the economic and financial aspects of telecommunications for member Countries of the Study Group 3 ITU.
[2] The cost per household depends on potential customer density, measured as “locations per plant mile.” Estimates range between US$ 1,100 and US$ 4,000 per household, although it can be higher if density decreases. We have assumed US$2,000 per household, although this number would have to be further validated. For basis of estimates, see Kim, G. *How much does rural fiber really cost?*

- **Peru**: As in the cases of Argentina and Colombia, the deployment of last-mile fiber optic networks in Peru is now a critical national priority given the ongoing construction of the *Red Dorsal Peruana,* the government-owned national backbone. So far, the Universal Service Fund has identified 6,500 municipalities to benefit from this program. According to the government, 25 small municipalities have already been selected to each receive grants of US$ 3.6 million to cover the full cost of last mile deployment.[3]

A first cut assessment of the funding required to address the rural broadband gap through fixed high capacity facilities would amount to close to US$ 8 billion (see table 4).

Country	Type/Scope of Projects	Number of Projects	Amount per project (US$ million)	Total Funding Required (US$ million)
Argentina	Large municipalities (average: 5,000 pop.)	16	$ 2.5	$ 422.5
	Smaller municipalities (average: 2000 pop.)	160	$ 1.0	$ 160.0
Brazil	Rural municipalities	1,280	$ 3.0	$ 3,843
Colombia	Rural municipalities	1,000	$ 2.9	$ 2,900
Peru	Districts	204	$ 3.0	$ 612
Total				$7,937.5

Sources: Argentina (Comision Nacional de Comunicaciones); Brasil (Brazilian Association of Internet Providers and Telecommunications (ABRINT); Ministry of Communications; Colombia (Ministry of ICT); Peru (FITEL)

Table 4. Latin America: Estimated Funding requirements to Address "Last Mile" Fixed Deployment in rural areas

Here lies the crux of the problem. The construction of fixed broadband networks, even after a national backbone network has reached the rural area is not financially feasible. This situation risks perpetuating the digital divide unless other options are found. Wireless broadband, due to its more advantaged deployment economics could be a potential answer to this problem. However, conventional spectrum management approaches might raise a potential hurdle. It is in this context that alternative approaches need to be tackled. The next chapter explores the theoretical basis for exploring alternative approaches.

THEORETICAL FRAMEWORK AND METHODOLOGY

There appears to be a growing consensus that the approaches to spectrum management that maximize welfare comprise a mix of licenses assigned through auctions and the establishment of rules governing portions of the spectrum as a common pool resource. As a response to the command and control approach that the US government adopted for spectrum management, Coase argued for property rights and a pricing mechanism in spectrum allocation. Although Coase championed the use of auctions, which confer exclusive rights to the auction winners on the assigned frequencies, his proposal was done in the context of spectrum mainly being used for broadcasting services with no technology commercially available yet that would allow other ways of spectrum usage. In an era when sharing the spectrum is not only technically feasible but economically desirable Coase's position gets a renewed perspective by which the focus shifts from whether all spectrum should be allocated on a licensed basis, with corresponding counter arguments for spectrum allocation on an unlicensed basis, to rather questioning what is the optimal mix for the co-existence of the two regimes (Brake, 2015). Some analysts like Milgrom et al. (2011) argue that the reservation of a portion of the spectrum to be free and managed through a set of regulations is particularly attractive in terms of reducing the cost of setting up and deploying networks for local wireless transmission extremely low.

Some examples of this effect already exist. Wireless Internet Service Providers (WISPs) rely primarily on unlicensed spectrum to offer broadband accessibility in rural areas of the United States. In New Zealand the Ministry of Business, Innovation and Employment (MBIE) is the designated spectrum manager for a significant number of spectrum bands. When a provider of communications services seeks to operate on a local or regional but not nationwide the MBIE may grant the operator access to a shared mode of spectrum on a given frequency band, known as Managed Spectrum Park (MSP). In rural Canada, some towns are served by "mini-telcos", relying on Wi-Fi facilities linked to satellite backbones.

[3] See FITEL. *TICs para el desarrollo integral de las comunidades de Candarave*.

We pick up on these examples to raise the following hypothesis. The approach to spectrum management based uniquely on national licenses assigned on the basis of auctions (which include coverage obligations and universal service subsidies) does not maximize consumer welfare for the population located in rural areas.

In this context, if national license spectrum allocation is not the most conducive way to meet social requirements, we explore three potential scenarios, all of which exclude the rural and isolated geographies from the license. Along these lines, two options will be evaluated:

- Unlicensed spectrum: the spectrum in rural and isolated areas is left to be governed by some governance principles, but is opened to unrestricted free use. A municipality would deploy voice and data service only paying for infrastructure deployment. Spectrum access is free, following to some extent the approach proved in the United States for rural wireless ISPs. A slightly modified case would comprise state aid in the form of subsidized backbone access;
- Spectrum parks: a flexible, cooperative, low cost and self-managed approach to allocation of local and/or regional rights to a specified band of spectrum; licenses may be allocated on a "first-come, first-served" basis and spectrum sharing may be strongly encouraged. Licenses fees are paid annually and demand coordination and self-management in a low-cost, cooperative environment.

We will now review the international experience of alternative approaches to spectrum management being utilized to serve rural areas that might represent a solution to this barrier. On this basis, we will present the results of a model used to test the economic implications of alternative approaches to spectrum management. We have three potential spectrum management approaches to tackle the broadband supply gap in rural areas.

NATIONAL LICENSES WITH COVERAGE OBLIGATIONS

Many countries have identified the reduction of the digital divide as an essential policy consideration, particularly in relation to providing broadband service to sparsely populated areas. Coverage obligations may be defined as a percentage of population and/or area of geographic coverage in which service must be available by a set deadline or schedule. This approach, commonly used in the wireless industry, entails including in spectrum auction conditions, the obligation of deploying service in rural areas.

The assignment of national licenses entails a number of frictional costs that stand in the way of fulfilling social objectives. Along these lines, a number of potential failures were identified through interviews with regulatory authorities in Latin American countries:

- The carrier that acquires the national license through an auction never fulfills the deployment of network in remote and rural areas; regulator lacks the technical and enforcement capabilities to ensure that the obligations are fulfilled;
- The national license holder prioritizes in its deployment the areas where it can maximize its rents, postponing the roll-out of the network in the isolated geographies (addressed in the coverage obligations); therefore, while service is finally offered in those areas, it takes place with time delays;
- The national license holder deploys minimal infrastructure (i.e. just one base station with limited capacity per village) to fulfill the obligation, but with considerable quality of service limitations.

WISPS (WIRELESS INTERNET SERVICE PROVIDERS)

The WISP business model, which comprises the organization of a private operator offering local broadband service based on Wi-Fi technology is quite prevalent in the United States. According to a report from the NTIA and the FCC, in 2011 there were 26.2 million US citizens living within 9.2 million households (or 6.99%) unserved by fixed broadband services. As expected, the majority of these households were located in rural and isolated areas of the country. While the FCC report does not track broadband over cellular coverage, the National Broadband Map indicates that 3.2 million households (34% of the unserved number mentioned above) can only gain access to broadband services provided by the so-called Wireless Internet Service Providers (WISPs), which typically operate on unlicensed or lightly licensed spectrum in the 3.65 GHz band.

While some WISPs utilize licensed spectrum (Clear and Digital Bridge), the majority relies on UNII and ISM bands or lightly licensed spectrum in the 3.65 GHz band: 26mhz of unlicensed spectrum just above 900mhz, 50mhz in 2.4ghz and 100mhz in 5.8ghz (Larsen, 2011). According to Wireless mapping.com, the WISP Directory Database compiled by the

WISP Association includes over 1,800 "documented and verified" WISPs. While WISPs initially utilized the 802.11b platform, they have mostly migrated to 802.11n, which allows them to deliver 10 Mbps service or higher to 200 customers from a single four sector base station (Larsen, 2011). As demonstrated by the National Broadband Plan and the corresponding mapping effort, WISPs are critical in providing broadband service in rural areas. In 2008, the National Broadband Map determined that in 21 states with a large rural footprint, 4.93% of households were only served exclusively by a WISP (see Table 5).

State	Total Occupied Households	% of Households passed by WISPs only	Occupied Households Passed by WISP´s only
Michigan	4,009,186	4.34 %	173,834
Oregon	1,516,658	9.41 %	142,760
West Virginia	757,767	0.01 %	107
Texas	8,924,973	23.47 %	2,094,479
Massachusetts	2,615,877	0.10 %	2,489
Wyoming	215,923	4.87 %	10,517
Nebraska	730,577	10.66 %	77,845
Indiana	2,543,090	2.40 %	61,140
Ohio	11,870,733	1.28 %	151,893
Idaho	562,067	9.19 %	51,646
Illinois	4,851,822	2.83 %	137,330
Arkansas	2,942,753	2.36 %	69,319
Colorado	1,959,789	4.88 %	95,698
Arizona	2,336,959	4.21 %	98,382
California	12,764,753	1.40 %	178,743
Maryland	2,202,016	0.25 %	5,529
Montana	394,719	5.55 %	21,916
Nevada	994,992	7.34 %	73,000
Pennsylvania	5,062,337	0.47 %	23,957
South Carolina	1,825,000	0.84 %	15,393
Washington	2,581,680	1.95 %	50,225
Total	71,663,671	4.93 %	3,536,202

Sources: FCC

Table 5. Occupied Households Passed by WISPs only (2008)

Wireless Mapping extended its analysis to the rest of the country and assessed coverage as of 2011. They concluded that WISP coverage grew .43 percentage points from 2008 to 2011 as shown in Table 6.

Total Households	Households with access to a WISP	Households where WISP is only broadband provider
131,704,731	60,147,903 (45.67 %)	3,226,087 (5.36 %)

Source: Wireless Mapping

Table 6 United States: WISP Coverage (2011)

Further developments in the areas of spectrum sensing, dynamic spectrum access, and geo-location techniques (Stevenson et al., 2009) could improve the quality of wireless service based on unlicensed spectrum technologies. For example, as reported by Burger (2011), a new version of the Wi-Fi standard, 802.11af, sometimes called "Super Wi-Fi", can substantially extend the geographic range of conventional 802.11 standard and provide cost-efficient access in rural settings.

There is already some experience in Latin America in relying on Wi-Fi unlicensed spectrum to offer broadband service. It is generally spearheaded by municipalities but rather than relying on Wi-Fi to offer paid service at subsidized prices, the business model is one of free service delivery in public areas. As an example, the municipality of Tandil in Argentina (108,000 population) launched a Municipal Wi-Fi Network at a cost of US$ 140,000 for a total of 83 hot spots, including 16 schools, 22 libraries, 36 municipal offices, and 8 public squares. The investment funds were sourced by the municipality and no revenues will be collected through service provision. This type of model is widely diffused in

Brazil, where approximately 14% of the country's 5,500 municipalities offer some level of free Wi-Fi service, while only 2% (140 municipalities) offer full Wi-Fi coverage.[4]

In a different funding model, the Chilean government provides funding for deployment and operations for a limited amount of regional Wi-Fi Networks (under a program called *Zonas WiFi ChileGob)*. For example, a Wi-Fi Network was launched in 196 hot spots deployed within 49 municipalities in the *Los Rios*, *Lagos* and *Aysen* regions. The investment of US$ 5.62 million for 196 hot spots was provided by two government sources, the Ministry of Transportation and Telecommunications and the regional government. Under the program, users can gain free Internet access limited to 30-minute sessions. In another case, the Chilean government will fund the deployment of 416 hot spots in 104 municipalities located in *Maule, O'Higgins*, and *Araucania*. The company winning the bid has offered free service for a period of five years. The funds to support infrastructure deployment and operations for five years amount to US$ 15.4 million.

In a slight different model from the examples reviewed above, the concept under consideration in this paper would entail relying on Wi-Fi technology but offering paid service potentially at subsidized prices. This offering could be facilitated by technologies such as Super Wi-Fi. This technology operates in the frequency bands between 54 MHz and 698 MHz to deliver broadband up to 10 miles with high penetration at 20 Mbps download and 6Mbps upload speeds. It can extend the range of Wi-Fi and provide broadband in rural areas. Super Wi-Fi relies on empty channels of spectrum (known as white spaces) and uses Dynamic Spectrum Access that optimizes access to available unused bands. Users will predominantly use Super Wi-Fi networks to access smart, radio-enabled devices that report their location to an Internet database. The database will dictate the TV white spaces channels and appropriate power level based on in its current location. The database has a list of all protected TV stations and frequencies across the country, so the devices can avoid interference with TV broadcasts and wireless signals. This technology is truly dynamic – as different TV channels become available, Super Wi-Fi devices can opportunistically switch from one group of channels to another.

LICENSED SPECTRUM PARKS

New Zealand has adopted a unique approach to managing the radio spectrum. The 1989 Radio Communications Act created the Radio Spectrum Manager, a legal entity that allows private firms to manage portions of the spectrum. In New Zealand, the Crown is the spectrum manager overseeing most of the spectrum, and in particular the Ministry of Business, Innovation and Employment is the Manager of the frequency band 2575-2620 MHz (with 5 MHz required for a guard band at the lower boundary reducing the effective bandwidth available for services to 40 MHz), which is operated as a Managed Spectrum Park. In September 2009 80 licences were awarded.

The park concept seeks to encourage "a flexible, cooperative, low cost and self-managed approach to allocation and use" (MBIE, 2010) of the spectrum in the designated frequency band. It intends to allow access to a number of users in a common band of spectrum on a shared basis; also, as the Crown is the manager of the band it also seeks that the shared spectrum, if any, is also self-managed. Other objectives include encouraging efficiency and innovation in the use of spectrum.

The Managed Parks are an alternative to nationwide spectrum rights in that small and medium size firms wishing to specialize in providing services in particular geographical areas can do so without having to resort to paying large amounts of money, typical of spectrum auctions. According to the MBIE the MSP is "intended for local and regional services" (MBIE, 2010) with licensees and services requiring "some coordination or sharing".

Allocation of licences follows a 'first-come, first-served' procedure. Licensees must pay licence administration fees and annual charges; the latter include management charges and a resource rental. MBIE has also imposed a requirement to implement services within two years of allocation. When more than one firm is interested in being licensed for a particular area, MBIE has an arbitration processes in place to decide who gets to use the park. Arbitration has been designed to encourage sharing.

The first instance includes allowing for private negotiations to occur that may lead to shared use of the spectrum; failing that, the arbitration follows random ballot picks that end up in a single licensee being awarded the licence. Essentially, MBIE has shifted the burden of deciding who will use and how it will use the band onto the "competing applicants"; they are supposed to make reasonable efforts to reach an agreement with their competing counterparts on the issues of coordination and modification of specifications on the future conditions of the MSP licence. Conditions to agree upon include issues of interference.

[4] Nowicki, D (2013). *Amenity Wi-Fi: Latin America's biggest wireless network.*

When the applicants involved in negotiating the terms and conditions of using a band in a particular geographical zone reach an agreement one or more Managed Spectrum Park licenses will be granted to those applicants. Lacking an agreement or an explicit announcement by the applicants that an agreement has been reached the Chief Executive eliminates one the applicants in the groups by holding a ballot. Successive ballots will be held to eliminate one applicant if the remaining applicants either fail to agree or send in a solution that does not resolve all the interference issues. The application conditions state that it is the responsibility of applicants to ensure that any MSP Licences for which they apply are suitable for their purposes.

Once MSP licenses are awarded licenses are expected to act in a matter which promotes access to a number of users in a common band of spectrum on a shared basis, encouraging efficient, innovative and flexible use of spectrum; if possible it is also expected that the park be self-managed. Every licensee must negotiate agreements with other, proximal licensees to coordinate frequencies that maximise technical efficiency and minimise interference risks. Interference dispute resolutions are handled following protocols established by the law when licensees are unable to reach an agreement in the issue. In an MSP sharing may take various forms: in some cases it is just two or three companies splitting the available bandwidth between them, while in others it is a geographical split within the licence region.

Currently a number of wireless broadband providers exploit the 2575-2620 MHz band after having successfully applied to be MSP licensees. Some of the names include Gisborne Net, a telecommunications provider for the eastern areas of New Zealand's North Island, mainly around the city of Gisborne, TeamTalk and NetSmarts Ltd. These companies use the band to provide wireless broadband to rural communities; each licensee incurs a cost of about NZD $300 annually per licence.

EVALUATING THE ECONOMICS OF ALTERNATIVE SPECTRUM MANAGEMENT APPROACHES

In order to test the economic implications of each approach discussed in chapter IV we have constructed a model that captures all cost variables of deploying a wireless broadband network in rural areas of specific Latin American country: Paraguay. The model was then adjusted to reflect the various assumptions of three scenarios:

- National license: this is the base case. It assumes conventional business case network deployment assumptions to achieve coverage over the total country
- License exempt (unlicensed): in a slightly modified scenario to the last one, service in rural areas is being provided through unlicensed bands
- Licensed Spectrum Parks: this scenario considers, following the New Zealand model, that rather than assigning a national license with coverage obligations, wireless service in rural areas is made available through managed spectrum parks

Before quantifying each scenario, background on the Paraguay telecommunications demand structure is provided.

THE PARAGUAY MARKET CONTEXT

Paraguay, as a relatively small emerging country at the low tier of income per capita, has been substantially improving its social and economic conditions in the past five years. Its economy has been growing at a fast pace since 2009 (14.4%), the highest in Latin America. That said, the Paraguayan society still remains fair unequal. The country's Gini ratio is 48, which positions it within the higher inequality group of nations in the region. In fact, Paraguay socio-demographic pyramid exhibits a fairly uneven society (see table 7).

	Decil 1	Decil 2	Decil 3	Decil 4	Decil 5	Decil 6	Decil 7	Decil 8	Decil 9	Decil 10
Household Income	$ 145	$ 278	$ 383	$ 497	$ 620	$ 785	$ 984	$ 1,268	$ 1,775	$ 3,852
Individual Income	$ 38	$ 71	$ 99	$ 128	$ 159	$ 200	$ 251	$ 322	$ 441	$ 1,058

Source: Analysis by the authors based on data from "Encuesta Permanente de Hogares 2013" (Dirección General de Estadística, Encuestas y Censos de Paraguay)

Table 7. Paraguay: Average Monthly Income by decil (2013) (in US$)

As indicated in table 7, 70% of Paraguayans have a monthly income below US$ 300. Based on this income distribution, 23.8% of Paraguayan society is under the poverty line. From a geographic standpoint, Paraguay's population is deployed in four tiers: Asuncion (the capital) metropolitan area, second tier cities (Encarnación, Ciudad del Este, Caaguazú, Coronel Oviedo and San Pedro), third tier cities and rural areas. The population and household count in each tier is as follows (see table 8).

Tiers	Population	Households
Asuncion metropolitan area	2,473,443	500,500
Second tier urban centers	912,136	188,106
Third tier urban centers	591,374	127,739
Rural areas	2,695,564	554,276
Total	6,672,517	1,370,195

Source: Analysis by the authors based on data from "Encuesta Permanente de Hogares 2013" (Dirección General de Estadística, Encuestas y Censos de Paraguay)

Table 8. Paraguay: Population distribution (2013)

Income distribution varies by tier with expected higher levels being concentrated in the capital (see table 9).

Tiers	Decil 1	Decil 2	Decil 3	Decil 4	Decil 5	Decil 6	Decil 7	Decil 8	Decil 9	Decil 10
Asuncion metro area	$ 259	$ 474	$ 640	$ 801	$ 976	$ 1,169	$ 1,426	$ 1,770	$ 2,351	$ 4,635
2nd tier urban centers	$ 178	$ 331	$ 431	$ 544	$ 679	$ 840	$ 1,027	$ 1,326	$ 1,824	$ 4,099
3rd tier urban centers	$ 145	$ 323	$ 425	$ 541	$ 681	$ 850	$ 1,021	$ 1,290	$ 1,851	$ 4,418
Rural areas	$ 101	$ 193	$ 261	$ 328	$ 400	$ 492	$ 598	$ 758	$ 1,040	$ 2,411
Total	$ 145	$ 278	$ 383	$ 497	$ 620	$ 785	$ 984	$ 1,268	$ 1,775	$ 3,852

Source: Analysis by the authors based on data from "Encuesta Permanente de Hogares 2013" (Dirección General de Estadística, Encuestas y Censos de Paraguay)

Table 9. Paraguay: Income distribution by household (in US$)

As table 9 indicates, income distribution is quite uniform in all three urban tiers but it drops significantly across deciles in the rural areas. One should consider that the data in table 9 is by household, which is particularly relevant for fixed broadband adoption but less so in mobile (smartphone). For this purpose, individual income distribution was also estimated[5].

Tiers	Decil 1	Decil 2	Decil 3	Decil 4	Decil 5	Decil 6	Decil 7	Decil 8	Decil 9	Decil 10
Asuncion metro area	$ 82	$ 131	$ 164	$ 200	$ 239	$ 286	$ 341	$ 428	$ 573	$ 1,279
2nd tier urban centers	$ 51	$ 85	$ 111	$ 140	$ 174	$ 214	$ 273	$ 339	$ 471	$ 1,114
3rd tier urban centers	$ 50	$ 93	$ 126	$ 151	$ 187	$ 227	$ 297	$ 374	$ 493	$ 1,177
Rural areas	$ 27	$ 47	$ 63	$ 78	$ 97	$ 119	$ 148	$ 192	$ 262	$ 646
Total	$ 38	$ 71	$ 99	$ 128	$159	$ 200	$ 251	$ 322	$ 441	$ 1,058

Source: Analysis by the authors based on data from "Encuesta Permanente de Hogares 2013" (Dirección General de Estadística, Encuestas y Censos de Paraguay)

Table 10. Paraguay: Income distribution by individual (in US$)

As expected, income inequality pervades the Paraguayan socio-demographic pyramid. Individual incomes remain significantly low in rural areas. This is one of the primary drivers of the rural migration to cities.

At 6.33% penetration, the Paraguayan fixed broadband sector is underdeveloped. On the other hand, Paraguay is rapidly moving towards widespread diffusion of wireless broadband (16.3% penetration). Nevertheless, broadband penetration, both fixed and mobile is significantly lower. Table 11 highlights social/geographic segments were fixed and mobile broadband is lower than 30%.

[5] Since data for individuals from the National Household Survey is not available, household income was divided by the average household composition by geographic zone (method used by Paraguay's *Dirección General de Estadística, Encuestas y Censos de Paraguay).*

	Tiers	Decil 1	Decil 2	Decil 3	Decil 4	Decil 5	Decil 6	Decil 7	Decil 8	Decil 9	Decil 10
Fixed Broadband	Asuncion metro area	8.14%	12.19%	15.65%	20.98%	28.42%	33.62%	36.90%	47.38%	43.49%	57.42%
	2nd tier urban centers	6.78%	3.95%	9.22%	10.50%	14.20%	15.82%	23.59%	33.60%	41.45%	53.46%
	3rd tier urban centers	0.00%	10.12%	12.32%	11.15%	23.98%	18.64%	25.52%	31.64%	43.36%	57.96%
	Rural areas	0.33%	1.50%	1.01%	0.26%	1.04%	4.31%	3.03%	5.58%	13.32%	19.50%
	Total	1.80%	1.23%	6.50%	6.64%	9.07%	16.89%	23.62%	28.19%	38.94%	48.40%
Mobile Broadband	Asuncion metro area	18.18%	23.46%	20.74%	29.41%	27.59%	42.27%	33.45%	46.35%	40.83%	49.79%
	2nd tier urban centers	14.43%	17.05%	13.08%	23.86%	19.36%	28.15%	32.97%	27.83%	30.04%	37.92%
	3rd tier urban centers	9.02%	19.38%	16.46%	24.21%	25.07%	23.22%	21.63%	29.71%	22.90%	37.63%
	Rural areas	3.52%	6.33%	4.99%	6.66%	8.25%	11.70%	16.54%	14.31%	21.42%	21.92%
	Total	6.37%	9.13%	13.76%	15.56%	19.87%	23.71%	27.27%	32.54%	34.64%	39.49%

Note: Only population over 9 years old.
Source: Analysis by the authors based on data from "Encuesta Permanente de Hogares 2013" (Dirección General de Estadística, Encuestas y Censos de Paraguay)

Table 11. Paraguay: Household (for fixed) and Population (for Mobile) Adoption of broadband by Income distribution

According to this data, fixed broadband has achieved above 30% penetration in households whose income is in the sixth decile in the Asuncion metropolitan area. However, moving beyond this geography, fixed broadband penetration drops to the eighth decile in the remaining urban centers. Penetration is more skewed for mobile broadband. One should note, however, that there is some embryonic penetration of mobile broadband across demographic segments.

NATIONAL LICENSE SCENARIO

The national license scenario is based on an operator that acquires a 15-year national license of 30 MHz in the 900 MHz spectrum band, devoid of any coverage obligations. Along these lines, the carrier business plan is only driven by commercial considerations: to carve a sustainable position in a market that is already served by four other carriers. For this purpose, the model focuses initially in deploying service in the rural and underserved population outside of the business centers, with a second phase (starting in year 3) focused on extending service to the urban core. The company's plan assumes relying on the LTE platform to offer a mobile and fixed broadband product, initially exploiting the broadband supply gap prevalent in the country. Payment for the license is US$ 40,000,000[6] with an annual use of fee of US$700,000. With this investment in spectrum, the estimated project financials do not appear to be attractive (see table 12).

			2014	2015	2016	2017	2018	2019
Revenues				$525,752	$17,307,893	$43,180,040	$68,565,386	$93,137,043
Cost of Service				$2,301,932	$21,010,134	$24,974,954	$26,466,161	$28,734,489
SG&A			$650,000	$406,093	$10,379,660	$22,362,297	$35,386,030	$46,020,262
EBITDA			$(650,000)	$(2,182,273)	$(14,081,901)	$(4,157,212)	$6,713,195	$18,382,292
Depreciation			$-	$-	$2,983,000	$7,512,286	$7,512,286	$7,512,286
EBIT				$(2,182,273)	$(17,064,901)	$(11,669,497)	$(799,091)	$10,870,007
Taxes	13%			$-	$-	$-	$-	$1,413,101
CAPEX			$40,000,000	$14,915,000	$31,705,000	$-	$-	$4,656,852
Change in Working Cap.				$-	$-	$-	$-	$-
FCF			$(40,650,000)	$(17,097,273)	$(45,786,901)	$(4,157,212)	$6,713,195	$12,312,339
WACC	10.4%							
G	2%							
NPV w/o Terminal Value		$7,789,112						
NPV w/Terminal Value		$181,902,692						
IRR	11.67%							

Source: Analysis by the authors

[6] Price of the license is assumed at US$ 0.20 per POP/per MHz, which at 6,672,000 pops, and 30 MHz results in US$ 40 million.

Table 12. National License Scenario: estimated financials

The model assumes that the new entrant will capture a significant share of the rural subscribers given that it is the only provider. However, considering the CAPEX outlay for spectrum acquisition, the internal rate of return is fairly low (11.36%), while the Net Present Value is only attractive with terminal value, which implies that the value of the business is primarily related to the spectrum holding and the network infrastructure. In other words, the national license scenario unencumbered by coverage obligations of a business primarily focused on the rural population, at least initially, is not attractive.

LICENSE-EXEMPT (UNLICENSED) SCENARIO

Under this scenario, we relied on similar business assumptions but assumed that the operator would be relying on unlicensed spectrum. As a result, three variables in the base case (national license unencumbered by coverage obligations) were adjusted:

- Spectrum costs: given that the model relies on license exempt bands such as Wi-Fi, the spectrum acquisition is reduced to zero
- Infrastructure investment: While the economic advantage of Wi-Fi to cellular infrastructure varies substantially by topography and size of the environment, carrier-grade Wi-Fi sites are considerably less expensive than cellular network equipment with similar capacity. For example, a cellular pico-cell (needed to offer access via conventional cellular service) costs between $7,500 and $15,000[7], while a carrier-grade Wi-Fi access point requires an investment of $2,500[8]. In addition, other capital and operating expense items show a clear advantage to Wi-Fi vis-à-vis an LTE macro cell (see table 13).

	Wi-Fi Site	LTE Macro Cell
New Site acquisition	$ 600	$ 150,000
Collocation	-	$ 50,000
Backhaul	$ 300	$ 5,000
Monthly site rental	$ 20	$ 1,000
Site maintenance/month	$ 10	$ 200

Source: LCC Wireless (2012)

Table 13. Comparative Carrier Grade Wi-Fi and LTE Macro Cell Capex and Opex

As it can be seen, Wi-Fi has significant economic advantages at the unit level. To calculate the CAPEX saving in equipment, we relied on estimates calculated for the United States based on Wi-Fi rerouting of cellular traffic, which estimate a 33% CAPEX savings.

- Operating expenses: However, we must add a caveat here. Site density requirements for Wi-Fi are much higher than for cellular. For example, in a dense urban environment with high traffic, for each cellular site, 23 Wi-Fi hot-spots are required. The difference means that, from a Total Cost of Ownership (CAPEX and OPEX) standpoint, the driver that erodes some of the Wi-Fi economic advantage is OPEX, especially Wi-Fi site rental and backhaul costs. In the case of OPEX savings, the estimates for the United States are 16%.

According to these estimates, the scenario estimates are presented in table 14.

[7] "When Femtocells become Picocells", the 3G4G Blog and Ubiquisys.
[8] Cisco Aironet 1552H Wireless Access Point.

			2014	2015	2016	2017	2018	2019
Revenues				$525,752	$17,307,893	$43,180,040	$68,565,386	$93,137,043
Cost of Service				$2,071,738	$18,909,121	$22,477,459	$23,819,545	$25,861,040
SG&A			$650,000	$406,093	$10,379,660	$22,362,297	$35,386,030	$46,020,262
EBITDA			$(650,000)	$(1,952,080)	$(11,980,887)	$(1,659,716)	$9,359,811	$21,255,741
Depreciation			$-	$-	$2,983,000	$7,512,286	$7,512,286	$7,512,286
EBIT				$(1,952,080)	$(14,963,887)	$(9,172,002)	$1,847,525	$13,743,455
Taxes	13%			$-	$-	$-	$240,178	$1,786,649
CAPEX			$-	$9,843,900	$20,925,300	$-	$-	$3,073,522
Change in Working Cap.				$-	$-	$-	$-	$-
FCF			$(650,000)	$(11,795,980)	$(32,906,187)	$(1,659,716)	$9,119,633	$16,395,570
WACC	10.4%							
G	2%							
NPV w/o Terminal Value		$76,856,431						
NPV w/ Terminal Value		$274,993,427						
IRR	33.48%							

Source: Analysis by the authors

Table 14. License-exempt Scenario: Estimated Financials

Under this scenario, the financials are substantially improved. The model internal rate of return jumps to 33.48%, while the net present value, even without terminal value, yields US$ 76.8 million. Under this case, even a single operator that would attempt to implement a business plan similar to the base scenario but benefitting from unlicensed bands would expect to yield an attractive scenario, which would prove the feasibility of relying on unlicensed bands to achieve coverage of rural areas.

SPECTRUM PARKS SCENARIO

Under this scenario, the only variable to be adjusted from the base scenario is spectrum costs, given that according to the New Zealand case, licenses are assigned for a management fee amounting to NZ$ 300 (or US$ 220) per year.

An alternative approach for estimating spectrum costs under this scenario has been outlined by Shaw et al. (2014). Their analysis considers the population covered by the proposed base station Pop_{SP}, the amount of spectrum, B_{SP}, and time duration T, in years, of the management right, on the one hand. On the other hand, it uses the reserve price of spectrum, p_{RES}, set by a spectrum agency in a - usually – recent spectrum auction aimed to sell an amount B_{WB} MHz of spectrum for wireless broadband, for a license intended to cover Pop_{BW} people. Thus the resulting price p is

$$p = \frac{B_{SP} \cdot Pop_{SP}}{B_{BW} \cdot Pop_{BW}} \cdot p_{RES}$$

If such amount is to be spread over a number of years T, then the annual price p_A to be paid by a MSP licensee will be $p_A = p/T$, in addition to a likely overhead cost incurred. By choosing a suitable interest rate the spread of the price over the time horizon can be calculated more accurately. Under this approach, for example, the 2013 Colombian 4G spectrum auction for 225 MHz in AWS (1700 MHz paired with 2100 MHz), 1900 MHz and 2500 MHz bands was managed with a reserve price of USD $250 million, which yielded a normalized price of 0.0239 $/MHz-pop; this or other similar recent auctions in the region can be used as a proxy to the p_{RES}.

For expediency, this analysis relied on the New Zealand benchmark of US$ 220 per year per base station. Considering that the radio station count in our model is 700, the annual spectrum cost would be US$ 154,000. According to these estimates, the scenario estimates are presented in table 15.

			2014	2015	2016	2017	2018	2019
Revenues				$525,752	$17,307,893	$43,180,040	$68,565,386	$93,137,043
Cost of Service				$2,301,932	$21,010,134	$24,990,354	$26,496,961	$28,780,689
SG&A			$650,000	$406,093	$10,379,660	$22,362,297	$35,386,030	$46,020,262
EBITDA			$(650,000)	$(2,182,273)	$(14,081,901)	$(4,172,612)	$6,682,395	$18,336,092
Depreciation			$-	$-	$2,983,000	$7,512,286	$7,512,286	$7,534,286
EBIT				$(2,182,273)	$(17,064,901)	$(11,684,897)	$(829,891)	$10,801,807
Taxes	13%			$-	$-	$-	$-	$1,404,235
CAPEX				$14,915,000	$31,705,000	$154,000	$154,000	$4,810,852
Change in Working Cap.				$-	$-	$-	$-	$-
FCF			$(650,000)	$(17,097,273)	$(45,786,901)	$(4,326,612)	$6,528,395	$12,121,005
WACC	10.4%							
G	2%							
NPV w/o Terminal Value		$43,166,591						
NPV w/ Terminal Value		$216,415,866						
IRR	21.56%							

Source: Analysis by the authors

Table 15. Spectrum Parks Scenario: Estimated Financials

Under this scenario, the financials are less attractive than in the unlicensed model, but still superior to the national license base case. The model internal rate of return reaches 21.56%, while the net present value, even without terminal value, yields US$ 43.2 million. Under this case, even a single operator that would attempt to implement a business plan similar to the base scenario but benefitting from a spectrum park arrangement would expect to yield an attractive scenario, which would prove its feasibility to achieve coverage of rural areas.

CONCLUSION

In sum, considering the difficulty in fulfilling nationwide mobile broadband coverage in Latin America, the scenarios were tested in terms of their comparative financial attractiveness. Table 16 summarizes the results of all three scenarios.

	National License Scenario	License-exempt Scenario	Spectrum Parks Scenario
CAPEX (over 10 years)	$139,701,354	$65,802,894	$101,087,354
NPV (w/o terminal value)	$7,789,112	$76,856,431	$43,166,591
NPV (w/terminal value	$181,902,692	$274,993,427	$216,415,866
IRR	11.67 %	33.48 %	21.56 %

Source: Analysis by the authors

Table 16. Comparative Spectrum management Scenarios: Estimated Financials for achieving rural coverage in Paraguay

The results indicate the convenience for policy makers and regulators to explore alternative spectrum management approaches to address this market failure. Further research should be conducted in refining these estimates, particularly with regards to equipment costs, and regulatory feasibility.

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