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LATIN AMERICAN TELECOMMUNICATIONS AT THE CROSSROADS OF PASSIVE INFRASTRUCTURE SHARING

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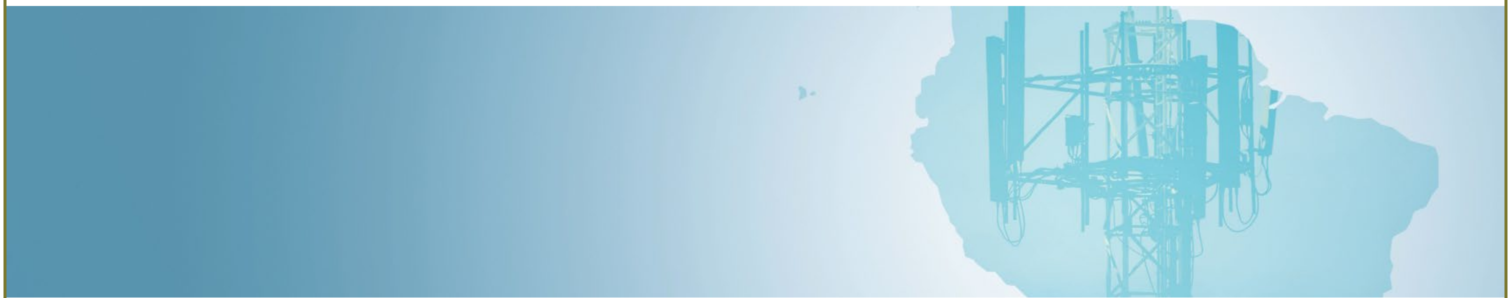

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Table of Contents

Executive Summary

The development of the Latin American wireless industry over the past twenty years has been remarkable. Coverage of 3G and 4G is almost ubiquitous. Service quality, as measured by speed and latency, has also improved significantly in recent years. Accordingly, the gap that separates the region from the most advanced world economies has considerably reduced in the past decade. One of the factors that have been instrumental in propelling such progress is the ability of the industry to start promoting its ability and willingness to share infrastructure across operators while preserving competition.

That said, the industry is still confronted with important challenges. Coverage gaps remain significant in rural areas, in key transportation highways, and even in some of parts of the biggest cities in the region. While 5G service has been officially launched in many countries and spectrum is becoming available in most countries, this technology remains a future possibility for most countries. While wireless broadband adoption is widespread, affordability is also a key factor limiting access for the base of the socio-demographic pyramid. Finally, while certain structural conditions, such as low ARPUs, still constrain the level of capital spending, the Latin American lag with respect to OECD countries in terms of capital investment remains a worrying factor considering the future development challenges. In this context, as stated by the International Telecommunication Union, passive infrastructure sharing is critical to address the wireless industry forward-looking capital spending challenges, and far less complex to agree upon than active sharing since it requires greater collaboration.

In fact, econometric analysis conducted in this study validate the positive effects of passive infrastructure sharing. For example, a country with an initial 4G coverage of 80% and an adoption of unique mobile broadband users equal to 60% (a common feature in the region) would undergo the following effects as a result of introducing best practices infrastructure sharing regulation:

- 4G coverage level would increase from 80.00% to 93.03%
- As a result of the increase in 4G coverage, unique mobile broadband users would increase from 60.00% to 61.55%
- The increase in unique mobile broadband users would generate in turn an increase in GDP per capita of 0.41%

In this context, the contribution of the tower industry is particularly relevant. As of 2022, in the twelve largest Latin America countries, wireless tower deployment reached over 191,330. In parallel with the growth in the installed base, the sector has been gradually evolving toward an increased share of independent players and MNO-owned companies. When compared against other regions, Latin America is a fairly developed tower company market, only behind South Asia. A view of the tower industry structure by Latin American country indicates that, on average, half of the installed base is run by independent companies. The gradual divestiture of MNOs of most of their tower infrastructure and the combined development of MNO-owned and independent tower companies in Latin America raise the question of the impact of tower ownership on future industry development. In other words, is the share of independent tower "specialists" associated with industry performance, as measured by capital efficiency, network deployment, service adoption and quality?

The empirical evidence conducted in this study provides a positive answer to this question, supported both by correlational and econometric analyses. From a correlational standpoint, Latin American countries with a larger independent tower industry (measured by its market share and its tower deployment) exhibit higher wireless performance metrics than the rest. Countries with a higher share of independent towers are associated with:

- Higher 4G coverage than the rest of countries (97% of the population vs. 90%)
- Wireless broadband is 12% faster than the rest (33 Mbps vs. 29 Mbps)
- Capital spending is 31% higher in country leaders (USD 21 per capita vs. USD 16 per capita)
- Wireless broadband services represent 1/3 of costs in terms of per capita income in country leaders relative to the rest of countries
- Consequently, country leaders exhibit higher broadband adoption than in the rest of the region (65% vs. 58%)
- Wireless competition is more intense in countries with higher share of independent tower deployment (wireless broadband of HHI= 2,440 vs. 4,135); by reducing the pressure on capital spending, telecommunications operators can focus on better and differentiated services

From an econometric standpoint, the causality between independent tower companies and wireless industry development has also been proven in this study. An increase in the number of independent towers by 10% in any Latin American country:

- Leads to, at least, an increase in 4G coverage levels of 0.96%
- Is causally linked to an increase in wireless broadband adoption levels of 0.51%
- Is associated with an increase in service quality levels (measured as mobile broadband download speed) of 2.05%
- Leads to an increase in mobile market competition levels (measured as a decrease in the Herfindahl Hirschman Index that measures industry concentration-a lower index depicts more intense competition) of 0.46%
- Results in an improvement in the level of mobile affordability (measured as a decrease in service price relative to the monthly GDP per capita) of 3.18%; this is because more intense competition drives down prices, which in turn increases affordability

Given this robust evidence, it would be important for Latin American countries – governments and regulators - to support the development of the independent tower industry. This effect is, however, contingent upon several regulatory and public policy initiatives. In other words, the regulatory and policy variables play an important role in the development of the independent tower company sector beyond the willingness of the private sector to invest, notably facilitating their investment leverage and returns to both the public and private sectors.

A review of the research literature and interviews of regulators and policymakers have led to the identification of seven types of initiatives that can contribute to the development and sustainability of an independent tower sector:

- **No need for service concession**: The construction of a cell tower does not rely on a public good, as is the case of spectrum. Therefore, it should not be ruled by a concessionary framework. Furthermore, the tower industry is not a natural monopoly requiring a concessionary regime, like in the case of power transmission, and railways. This concept supports the need to provide public right of way access at market rates. As a caveat, considering that the tower industry is not unlike other forms of private real estate, regulation should be limited to over-deployment, as determined by environmental reasons (see below).

- **Need for fast permit approvals driven by consistent and reasonable timeframes**: At present, many Latin American municipalities have constitutional autonomy to grant installation permits for antennas and rights of way for fiber rollout. Accordingly, they can interfere with the provision of telecommunications/internet services that are under federal authority. Frequently, in many countries of the region, local regulations have been imposed over federal authority, becoming very restrictive, not transparent, bureaucratic, and even irrational for obtaining municipal permits. These barriers increase the opportunity cost for deploying passive infrastructure, enhancing the cost of deployment.

- **Regulations to prevent over-deployment**: Tower over-deployment, in many cases driven by straight financial speculation, is a frequent feature in Latin America. The negative consequences of this situation are environmental and economic. Focusing on the latter, a simplified financial model developed for this study indicates that, on average, unless a single tower is not supporting the radios of more than one operator (preferably three), its profitability is questionable, especially in suburban and rural settings over a ten-year time horizon.[1] On this basis, governments should promote policies and regulatory frameworks preventing over-deployment while fostering sharing especially in rural areas.

- **Establishment of a cap on fees and taxes, and rights of construction**: Fees and taxes, also referred to as the "cost of compliance", have an impact on the tower business case. In general terms, most macroeconomic research literature has found that taxation regimes play an important role in driving capital flows, when controlling for economic development, and currency fluctuations. In this context, tower deployment is affected by the fiscal burden imposed by municipalities in the form of

[1] As an exception, low-cost poles can be designed to profitably support a single operator.

specific fees with the purpose of either limiting deployment of infrastructure or increasing revenues. Sometimes these fees become recurrent and even subject to annual increase defined on an ad-hoc basis. Without making any judgement about the need of municipalities to collect revenues to support the delivery of public services, it is also the case that by increasing the pre-tax cost of tower deployment, local authorities limit the capacity for the wireless industry to support the connectivity needs of their population.

- **Implement policies to promote development of infrastructure to be shared for deployment of 5G**: The deployment of 5G will require significant expansion of the level of densification of radios and antenna arrangements at street level to achieve useful coverage in some high data traffic spaces. Considering the layered architecture of wireless networks that necessitates both macro sites and small cell sites. it is estimated that by 2030 between 2 and 3 times the current number of sites will be required. In the context of these deployments, zoning regulation will become critical to address over-deployment, reduce permit approval process, and access to public buildings and right-of-way at market prices.

- **Do not impose price regulation of tower company contracts with service providers:** In economic terms, price regulation is normally justified when markets fail to produce competitive prices. In the past, price regulation has been applied in the telecommunication sector to meet efficiency (under scarcity conditions) and equity objectives (fair access to an essential service). Similarly, interconnection prices have been regulated at times to ensure anti-competitive behavior of incumbent carriers at times of market liberalization. None of these conditions apply to contracts between a provider of infrastructure and a service provider. Prices to be charged between an independent tower company and wireless operators should not be regulated because: (i) they reflect contracts between private parties based on agreed upon prices; (ii) they do not reflect excessive or unconscionable pricing of an essential good (also called "price gouging"[2]); and (iii) they would represent a disincentive to invest in infrastructure.

- **Define long-term guarantees in regulations and permits**: Heavy initial CAPEX for tower deployment should be accompanied by relatively stable and predictable rules to ensure profitability and re-investment. While the financial profile developed in the context of this study is calculated over a ten-year timeframe, stability and predictability of regulatory frameworks are a critical industry requirement.

These policy and regulatory prescriptions have been undertaken by countries that could be considered as benchmarks of good practices when it comes to development of the

[2] Price gouging is a term referring to when a seller spikes the prices of goods, services, or commodities to a level much higher than is considered reasonable or fair and is considered exploitative, potentially to an unethical extent.

telecommunications and passive infrastructure sharing industries: South Korea, United Kingdom, and the United States. As such, these countries:

- Have specific laws to regulate the deployment of passive infrastructure.
- Do not require independent tower companies to register with the regulatory authorities to begin operations
- Have enacted laws that are in harmony with local ordinances, light procedures for construction permits, and references to construction fees that are known to infrastructure operators.
- Do not have pricing regulations for shared infrastructure.
- Present information that promotes the deployment of networks for new technologies such as 5G and small cells.
- Have plans or manuals of good practices that make it possible to supplement or complement the regulatory frameworks that promote the orderly construction of shared telecommunication infrastructure.

While some Latin American countries have already adopted most of these prescriptions, some currently lag:

- All countries except for Colombia, El Salvador and Guatemala include the passive infrastructure provider in their regulations, even though many lack a specific law on the subject. Similarly, the same countries lacking a specific law, do not have rules (laws, regulations, or technical standards) on passive infrastructure deployment.
- In most countries except for Ecuador and Chile, tower companies are not required to apply for some type of registration to obtain a passive operator's license from the telecommunications regulator.
- Only Chile can be considered to have national standards that are harmonized with local ordinances. In most countries there are general laws that establish the technical mechanisms of deployment (distance, height, sharing, co-location) coexisting with ordinances that exclusively govern the civil construction field of building (building permit, land charges, landscape environment). In Costa Rica, El Salvador and Guatemala local ordinances are free from any national constraints.
- Only Chile, Peru and Panama have implemented “light” regulatory processes for deployment and operation of passive infrastructure.
- Only Chile and Costa Rica have clearly established parameters or reference tables that determine fees for consideration for the use of space or land use for the deployment of towers.
- In all countries, it is preferred that infrastructure lease prices be established between the parties; however, Costa Rica, Ecuador and Colombia partially define some type of bands or ranges within which prices should be set.
- Only Brazil, Colombia and Chile have clear plans focused on the development of passive infrastructure for new technologies such as 5G. In addition, Peru and Panama have already defined regulations for the deployment of microcells (low power stations) or urban attachments.

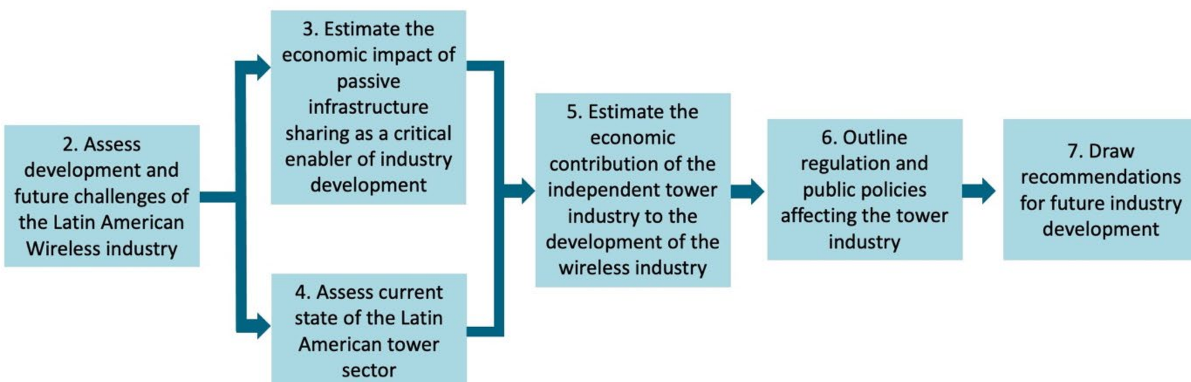
In summary, as economically corroborated in this study, the development of a vibrant, sustainable independent tower industry is critical for future development of Latin American wireless telecommunications. Furthermore, given the expanded potential for tower sites for supporting edge computing, network distribution nodes for both fiber and wireless networks, and future generation of alternative energy, it is imperative that governments upgrade policies and regulations to generate the right kind of incentives for sector development. The successful development of the wireless and independent tower industries are intrinsically linked. Regulators and policy makers should recognize this and support their development.

1. INTRODUCTION

The development of the Latin American wireless industry over the past twenty years has been remarkable. Progress across technology deployment, adoption, and affordability are some of the indicators of the positive trend. One of the factors that have been instrumental in propelling such progress is the ability of the industry to start promoting its ability and willingness to share infrastructure across operators while preserving competition. This study explores these trends and the underlying economics that make this possible. On this basis, it develops a range of recommendations to continue building on infrastructure sharing, based on the development of the independent tower sector to accelerate innovation, propel capital spending in new technologies, and tackle the digital divide.

The analytical structure of this study is organized around six central chapters *(see Figure 1-1).*

Figure 1-1. General study framework



Chapter 2 provides an analysis of the current development of the Latin American wireless industry, comparing it with selected advanced economies along variables such as capital spending, network deployment, service affordability, and quality. While highlighting the advances in the sector, the assessment also depicts areas where wireless services still show significant gaps. In this context, Chapter 3 brings into focus the contribution of infrastructure sharing to industry development and presents econometric analyses proving its impact to the development of telecommunications.[3] Drilling down on the infrastructure sharing stage of the telecommunications value chain, Chapter 4 examines the state of development of the Latin American tower industry, examining its deployment, and industry structure, in particular its ownership structure. This assessment serves as a backdrop to understand whether ownership of tower companies matters in terms of its contribution to the

[3] All econometric models are included in the Appendix for reference.

performance of the telecommunications sector, which is addressed in Chapter 5. This is supported by a correlational analysis and through econometric demonstrating the causal relationship between an increase in the number of independent tower companies and several mobile industry indicators (increase in 4G coverage, mobile broadband adoption growth, service quality enhancement, the increase in mobile competition in the mobile market and the improvement in the affordability levels of mobile service). The empirical analyses of Chapters 3 through 5 set the stage for outlining regulatory and policy prescriptions – in other words, what needs to happen in the policy arena to maximize the development and sustainability of an independent tower industry? This is the topic of Chapter 6, which builds on an assessment of the state of regulation in the region and a compilation of best practices in this domain in advanced economies. Chapter 7 complements this analysis with a brief forward-looking view if the tower industry, and how regulators could enrich the eco-system with the emergence of a green and digital player. Finally, Chapter 8 draws the study conclusions, recommendations, and some lines for future research.

2. DEVELOPMENT AND FUTURE CHALLENGES OF THE LATIN AMERICAN WIRELESS INDUSTRY

The Latin American wireless industry has shown remarkable advances in the last two decades. Coverage of 3G and 4G is almost ubiquitous. Service quality, as measured by speed and latency, has also improved significantly in recent years. Accordingly, the gap that separates the region from the most advanced world economies has considerably reduced in the past decade.

That said, the industry is still confronted with important challenges. The lack of coverage remains significant in rural areas, in key transportation highways, and even in some of parts of the biggest cities in the region. While 5G service has been officially launched in many countries and spectrum is becoming available in most countries, this technology remains a future possibility for many countries. While adoption is widespread, affordability is also a key factor limiting access to broadband and digital mobile services for the base of the socio-demographic pyramid. Finally, while certain structural conditions such as low ARPUs, still constrain the level of capital spending, the Latin American lag with respect to OECD countries in terms of capital investment remains a worrying factor considering the development challenges.

This mixed view of progress and future challenges will be explained in detail in this chapter and serve as background to emphasize in following chapters the importance of infrastructure sharing, more particularly the development of a healthy and thriving tower industry. The assessment comprises an aggregate regional view, a disaggregated perspective at the country level, and a comparison of indicators with a list of benchmark countries or group of countries.

2.1. The gap with advanced economies is closing down

The Latin American wireless industry has, in the aggregate, reached a level of development surpassing the world average. In 2021, broadband wireless adoption (as measured by unique mobile subscribers rather than connections) reached 58.49% (compared to the world average of 56.84%) while 4G population coverage[4], a metric assessing mobile broadband footprint, amounted to 89.84% of the population (while the world prorated average is 87.95%) (see table 2-1).

[4] We consider 4G as the technology providing reliable mobile broadband service. For reference, Latin American 3G population coverage has reached 97%.

Table 2-1. Mobile broadband adoption and 4G coverage

	Mobile broadband adoption (*)					4G Coverage (**)				
	2018	2019	2020	2021	CAGR (2018-21)	2018	2019	2020	2021	CAGR (2018-21)
World	49.06%	51.78%	54.34%	56.84%	5.03%	84.63%	85.96%	86.91%	87.95%	1.29%
Sub-Saharan Africa	26.16%	28.68%	31.25%	33.95%	9.07%	52.75%	53.58%	53.70%	53.62%	0.55%
Latin America and Caribbean	52.51%	54.68%	56.55%	58.49%	3.66%	81.92%	85.08%	87.42%	89.84%	3.13%
North America	75.13%	76.59%	77.86%	79.45%	1.88%	98.10%	99.00%	99.00%	99.00%	0.30%
Asia Pacific	45.69%	48.98%	52.10%	55.05%	6.41%	88.82%	89.64%	90.26%	91.31%	0.93%
Western Europe	70.46%	71.60%	72.64%	73.67%	1.49%	96.40%	96.44%	96.52%	96.64%	0.08%
Eastern Europe	64.70%	67.33%	69.77%	72.14%	3.69%	75.88%	77.05%	78.70%	79.49%	1.56%
Arab States	46.48%	48.72%	50.79%	52.86%	4.38%	69.11%	79.77%	88.10%	93.42%	10.57%
BENCHMARKS										
OECD	70.69%	72.30%	73.73%	75.16%	2.07%	96.65%	97.32%	97.70%	97.93%	0.44%
United States	76.01%	77.50%	78.81%	80.45%	1.91%	98.00%	99.00%	99.00%	99.00%	0.34%
Canada	67.36%	68.64%	69.63%	70.79%	1.67%	99.00%	99.00%	99.00%	99.00%	0.00%
United Kingdom	74.19%	75.67%	77.03%	78.36%	1.84%	99.00%	99.00%	99.00%	99.00%	0.00%
South Korea	82.56%	83.18%	83.83%	84.56%	0.80%	100.0%	100.0%	100.0%	100.0%	0.00%

(*) Measured as unique mobile broadband subscribers
(**) Measured as percent of the population
Sources: GSMA Intelligence; Telecom Advisory Services analysis

As shown in table 2-1, the distance separating Latin America from the prorated average of OECD countries (the community of advanced economies) regarding adoption has diminished from 18.18 in 2018 to 16.67 in 2021, while the same ratio in terms of 4G coverage has decreased from 14.73 in 2018 to 8.09 in 2021. As expected, the distance separating the region from high-income benchmark economies remains still very wide, although structural factors, such as economic development explain a large portion of the gap.

In parallel with the increase of mobile broadband adoption and 4G coverage, the region has achieved substantial progress with regards to mobile broadband service quality, as measured by average download speed and service latency (see table 2-2). As indicated in table II-2, wireless broadband average download speed has increased at a 16.57% rate since 2018, and latency has decreased by a 19.64% rate. These values indicate that, despite the significant progress in the region, the wireless broadband speed difference in relation to the OECD countries has widened in recent years, while the region has somewhat closed the gap regarding latency.

Table 2-2. Wireless service quality

	Mobile broadband average download speed (in Mbps)					Mobile broadband Latency (in Ms)				
	2018	2019	2020	2021	2018-21 CAGR	2018	2019	2020	2021	2018-21 CAGR
World	20	24	41	62	45.64%	52	38	32	30	-16.52%
Sub-Saharan Africa	12	16	17	22	23.69%	47	38	33	29	-14.58%
Latin America and the Caribbean	18	21	25	29	16.57%	61	40	34	32	-19.64%
North America	30	37	47	90	45.02%	48	39	36	32	-12.42%
Asia Pacific	19	23	49	73	56.54%	52	39	32	30	-16.69%
Western Europe	32	37	42	66	27.10%	45	35	32	30	-12.10%
Eastern Europe	22	26	29	38	18.74%	47	34	32	30	-13.81%
Arab States	19	24	34	53	41.29%	66	35	30	28	-24.96%
BENCHMARKS										
OECD	30	38	44	74	34.76%	47	37	33	31	-12.56%
United States	27	35	44	91	49.20%	49	40	37	33	-12.47%
Canada	50	61	68	86	20.01%	38	30	28	26	-11.66%
United Kingdom	27	31	35	79	43.91%	45	39	37	36	-7.75%
South Korea	37	97	109	189	72.84%	44	32	34	28	-14.42%

Sources: Ookla Speedtest; Telecom Advisory Services analysis

Finally, while wireless broadband affordability gap between the region and the OECD countries, measured as the price of standard plan as percentage of the monthly gross national income per capita, has remain three times higher than that of OECD countries, in absolute values, the situation has improved since 2018 to reach 1.87% of GNI per capita[5] despite the COVID-induced economic contraction (see table 2-3).

Table 2-3. Wireless broadband affordability (*)

	2018	2019	2020	2021	2018-21 CAGR
World	2.36	1.48	1.43	1.43	-15.25%
OECD	0.92	0.60	0.63	0.63	-11.61%
Sub-Saharan Africa	10.81	6.11	5.03	5.01	-22.60%
Latin America and the Caribbean	2.89	2.09	1.87	1.87	-13.56%
North America	0.75	0.44	0.42	0.43	-17.42%
Asia Pacific	1.51	0.95	1.07	1.07	-10.81%
Western Europe	0.81	0.54	0.56	0.56	-11.52%
Eastern Europe	1.03	0.92	0.83	0.83	-6.89%
Arab States	1.45	1.27	1.06	1.05	-10.01%

(*) Price of a 500 Mb basket for smartphone service as percent of monthly Gross National Income
Sources: International telecommunication Union; Telecom Advisory Services analysis

[5] The Broadband Commission for Sustainable Development considers that by 2025, the target affordability metric should be 2% of monthly GNI per capita. See Broadband Commission for Sustainable Development (2022). *2025 Targets: Connecting the other half.* Retrieved in: https://www.broadbandcommission.org/broadband-targets/

In sum, the wireless industry in Latin America has dramatically increased 4G population coverage, mobile service adoption, network service quality, while keeping affordability at stable level despite the economic contraction.

2.2. Forward-looking challenges remain

The advances highlighted above notwithstanding, the lag between Latin America and the prorated average of OECD countries as of 2021 remains significant. As of 2021, the wireless adoption gap of Latin America with the OECD nations is 16.67 percentual points, while the 4G coverage gap remains at 8.09 percentual points. Furthermore, while Latin American average wireless speed has closed to double in the last four years reaching 29 Mbps, the OECD average has also increased but at a higher rate (reaching 74 Mbps). Finally, while the region has achieved an important progress with regards to service affordability, the gap with advanced economies remains substantial. The following section reviews the challenges still facing the wireless industry in the region.

Uneven wireless broadband coverage and service quality

Despite the narrowing gap with advanced economies in terms of coverage and service quality, the level of development of the Latin American wireless industry by country depicts wide divergences. As an example, the level of wireless broadband coverage varies greatly across nations (see table 2-4)

Table 2-4. Latin America: 4G coverage

	2018	2019	2020	2021	CAGR 2018-21
Latin America and Caribbean	81.92%	85.08%	87.42%	89.84%	3.13%
Argentina	88.00%	92.00%	91.58%	93.43%	2.02%
Bolivia	80.00%	80.00%	80.00%	80.00%	0.00%
Brazil	93.00%	94.00%	95.00%	96.96%	1.40%
Chile	94.00%	96.00%	98.00%	98.00%	1.40%
Colombia	67.64%	71.00%	74.76%	78.73%	5.19%
Costa Rica	89.00%	89.00%	89.00%	89.00%	0.00%
Ecuador	71.04%	86.35%	88.00%	88.00%	7.40%
El Salvador	64.00%	73.63%	89.50%	90.00%	12.04%
Guatemala	78.32%	86.35%	88.00%	88.00%	3.96%
Mexico	86.00%	90.00%	93.65%	96.00%	3.73%
Nicaragua	46.00%	49.00%	71.44%	86.84%	23.59%
Panama	76.54%	90.00%	90.00%	90.00%	5.55%
Paraguay	80.80%	84.08%	87.49%	91.05%	4.06%
Peru	74.00%	77.00%	80.00%	82.63%	3.75%
Uruguay	88.00%	88.00%	88.00%	88.00%	0.00%
Venezuela	88.00%	88.00%	88.00%	88.00%	0.00%

(*) Measured not as connections but as unique mobile broadband subscribers
(**) Measured as percent of population
Sources: GSMA Intelligence; Telecom Advisory Services analysis

Bolivia, Colombia, Costa Rica, Ecuador, Guatemala, Nicaragua, Peru, Uruguay, and Venezuela are all countries where 4G coverage is under the regional average. Furthermore, in some countries (Argentina, Bolivia, Brazil, Chile, Costa Rica, Uruguay, and Venezuela), 4G deployment has increased less than the average growth rate. As indicated in figure 2-1, lagging 4G coverage is prevalent in Bolivia, Ecuador, and Central American countries.

Figure 2-1. Latin America. 4G Coverage Levels

Sources: GSMA Intelligence; Telecom Advisory Services analysis

Beyond divergent paths in network deployment, the difference in service quality across countries, when measured by average wireless broadband speed, remains also important (see table 2-5).

Table 2-5. Latin America: Average Wireless Broadband Speeds (in Mbps) (*)

Countries	Download speed				Upload speed			
	2018	2019	2020	2020	2018	2019	2020	2021
Latin America and Caribbean	**18**	**21**	**25**	**29**	**9**	**10**	**11**	**11**
Argentina	16	21	28	30	8	10	9	10
Bolivia	18	17	19	22	11	12	11	12
Brazil	19	23	28	33	8	10	10	11
Chile	17	20	19	20	9	12	12	12
Colombia	16	17	18	18	9	10	9	10
Costa Rica	16	18	27	33	7	8	9	10
Ecuador	21	21	23	25	8	11	11	11
El Salvador	9	10	17	23	4	6	8	10
Guatemala	14	17	25	29	10	13	16	16
Mexico	22	25	31	34	12	12	13	13
Nicaragua	21	22	21	23	8	12	11	11
Panama	14	13	17	19	9	10	11	12
Paraguay	14	15	15	20	8	10	9	10
Peru	22	23	23	24	13	14	12	13
Uruguay	24	28	32	34	11	13	14	14
Venezuela	8	7	8	8	5	4	5	4

Countries	Download speed				Upload speed			
	2018	2019	2020	2020	2018	2019	2020	2021
BENCHMARKS								
OECD	30	38	44	74	11	12	12	14
United States	27	35	44	91	8	10	9	13
Canada	50	61	68	86	11	14	11	12
United Kingdom	27	31	35	79	11	11	10	12
South Korea	37	97	109	189	14	16	18	21

(8) Data for July of each year

Sources: Ookla speedtest; Telecom Advisory Services analysis

The average broadband download speed, 29 Mbps in Latin American countries in 2021, is three times lower than the average in high-income economies (e.g., 91 Mbps in the United States, 189 Mbps in South Korea or 74 Mbps in the OECD) and has diverged from all high-income benchmark economies since 2016. In addition, lower download broadband speed is apparent in Bolivia, Chile, Colombia, Ecuador, El Salvador, Nicaragua, Panama, Paraguay, and Peru (see figure 2-2).

Figure 2-2. Latin America. Average Wireless Broadband Download Speed

Sources: Ookla speedtest; Telecom Advisory Services analysis

Slow 5G deployment

While ongoing availability of spectrum is proceeding at a fast pace, 5G remains still a future possibility in Latin America, with the notable exception of Brazil where the 17% of the population was already covered in 2022. Beyond Brazil, some advance in 5G deployment in Brazil and service launch has taken place in Chile, Mexico, Peru, and Guatemala *(see table 2-6).*

Table 2-6. State of 5G deployment (August 2022)

Countries	2021 coverage	Spectrum auctioned	Service launched	Cities/Areas with 5G service
Argentina	0.00%	Not available yet. Used to test only (5G through DSS)	Telecom	Buenos Aires (5 sites), Rosario (5 sites), Mar del Plata (5 sites), Pinamar (5 sites) and Cariló (1 site)
Bolivia	0.00%	Not available yet. They are in the process of implementing the National Integrated Radio Spectrum System and this will allow planning the arrival of 5G technology by 2023-2024	-	-
Brazil	17.00%**	Bands in 700 MHz, 2.6 GHz, 3.5 GHz y 26 GHz	Algar, Claro, Telefonica (Vivo), TIM. Regional lots: Sercomtel, Brisanet, Consorcio 5G Sul, Cloud2U	Brasilia and 26 regional capitals. Until September it is planned to have 5G in all the capitals of the country
Chile	Signal coverage is present in at least 70%** of urban locations and 5G connections already represent 5.8%* of the total	Bands in 700 MHz, AWS, 3.5 GHz y 26 GHz	Claro, Telefonica, Entel, WOM	Región Metropolitana, Tarapacá, Antofagasta, Valparaíso, OHiggins, Maule, Bío Bío, La Araucanía, Atacama, Conquimbo, Los Lagos and Los Ríos
Colombia	0.00%	Used to test only. Not available yet (in 3.5GHz and 28GHz)	DirecTV (fixed internet), Claro	Bogotá, Medellín, Cali and Barrancabermeja
Costa Rica	0.00%	Not available yet. In the process of recovering the 3.5GHz band from ICE. In allocation plans for 2023-2024	-	-
Ecuador	0.00%	Used to test only. Not available yet (in 3.5GHz) In the process of cleaning and valuing the band	CNT, Claro and Movistar	Quito and Guayaquil
El Salvador	0.00%	Not available yet. Tigo is in plans but did not define a date	-	-
Guatemala	17.5% **(Calculated based on the number of inhabitants in the capital city)	Tigo and Claro are developing a 5G NSA network with the 700MHz, 3.5GHz and AWS to enhance the 4G service	Tigo, Claro	Initially in the capital city and later it will be extended to 22 departments

Countries	2021 coverage	Spectrum auctioned	Service launched	Cities/Areas with 5G service
Mexico	31.00% **(Calculated based on the number of inhabitants in the signal coverage)	Bands in 2.5GHz and 3.5GHz	Telcel, ATT	In at least 18 cities (Hermosillo, Ciudad Juárez, Chihuahua, Torreón, Tijuana, Monterrey, San Luis Potosí, Saltillo, Querétaro, Culiacán, Querétaro, Mazatlán, Durango, Puebla, Guadalajara, León, Toluca, Ciudad de México y Mérida). By the end of 2022, 120 cities are expected
Nicaragua	0.00%	Not available yet. TELCOR is in plans to promote a transition between 4G and 5G	-	-
Panama	0.00%	Not available yet. CAF is collaborating with the authorities (AIG, ASEP) to develop a roadmap towards 5G	-	-
Paraguay	0.00%	Not available yet. National Telecommunications Plan stipulates that by 2024, 30% of the population will has access to 5G in 511 locations	-	-
Peru	21.00%** (Calculated based on the population in the signal coverage)	3.5GHz to fixed internet services, but MTC plans to hold a spectrum auction in the 3.5 GHz and 26 GHz bands for mobile services	Claro, Entel, Telefonica	Lima, Trujillo, Piura, Arequipa, Ancash, Oca, Lambayeque, La Libertad, Tacna, Callao
Uruguay	5.25%	In 28GHz band and 3.5GHC to test 5G	Antel, Claro, Movistar	Barra de Maldonado, Colonia, Montevideo
Venezuela	0.00%	Not available yet. In test	Movilnet	Caracas

(*) Measured not as connections but as unique mobile broadband subscribers
(**) Measured as percent of population
Sources: GSMA Intelligence; DPL; Telecom Advisory Services analysis

According to GSMA Intelligence estimates[6], Latin America has a 4/5-year lag with respect to the OECD countries in the expansion of 5G. For instance, average coverage in 2025 is expected to reach 37%, a level similar to the OECD countries in 2022. This development will be led by Chile (projected 2025 penetration of 57%), Brazil (estimated 2025 penetration: 48%) and Mexico (projected 2025 penetration of 54%), (see table 2-7).

[6] GSMA Intelligence (2021), *La Economía Móvil en América Latina 2021*, 2021 GSM Association.

Table 2-7. 5G Population Coverage (2021-2025)

	2021	2022	2023	2024	2025
Latin America and Caribbean	4.23%	10.21%	18.42%	27.87%	36.99%
Argentina	0.00%	0.00%	23.03%	27.56%	34.94%
Bolivia	0.00%	0.00%	0.00%	16.26%	16.55%
Brazil	11.00%	22.00%	34.00%	42.00%	48.00%
Chile	0.00%	9.20%	20.83%	38.79%	56.74%
Colombia	0.00%	0.00%	0.00%	12.63%	30.33%
Costa Rica	0.00%	0.00%	0.00%	7.61%	20.08%
Ecuador	0.00%	0.00%	0.00%	19.09%	40.44%
El Salvador	0.00%	0.00%	0.00%	0.00%	0.00%
Guatemala	0.00%	0.00%	0.00%	0.00%	0.00%
Mexico	3.00%	13.51%	24.07%	39.15%	54.24%
Nicaragua	0.00%	0.00%	0.00%	0.00%	0.00%
Panama	0.00%	0.00%	0.00%	0.00%	0.00%
Paraguay	0.00%	0.00%	0.00%	16.11%	30.12%
Peru	0.00%	0.00%	3.13%	14.55%	27.18%
Uruguay	5.25%	9.18%	16.05%	25.00%	25.00%
Venezuela	0.00%	0.00%	0.00%	0.00%	0.00%
BENCHMARKS					
OECD	52.18%	62.21%	70.40%	77.82%	83.61%
United States	86.00%	93.64%	96.52%	98.00%	98.00%
Canada	66.18%	83.49%	90.72%	97.95%	98.00%
United Kingdom	45.90%	57.94%	68.21%	76.48%	83.26%
South Korea	97.00%	97.00%	97.00%	97.00%	97.00%

Sources: GSMA Intelligence; Telecom Advisory Services analysis

Some countries lag in wireless adoption

Consistent with the divergence in network deployment, the rate of wireless adoption, both in telephony and broadband, varies across countries in the region. Bolivia, Colombia, Ecuador, El Salvador, Guatemala, Nicaragua, Paraguay, Peru, and Venezuela lag the Latin American average in wireless telephony while Bolivia, Colombia, Ecuador, Guatemala, Nicaragua, Peru, Uruguay and Venezuela do so in wireless broadband (see table 2-8).

Table 2-8. Latin America: Wireless adoption

Countries	Wireless Telephony (*)				Wireless Broadband (**)			
	2018	2019	2020	2021	2018	2019	2020	2021
Latin America and Caribbean	109.32	109.06	109.28	113.10	52.51%	54.68%	56.55%	58.49%
Argentina	136.66	132.31	126.95	130.59	59.58%	61.41%	63.78%	66.08%
Bolivia	101.48	102.97	110.78	114.37	42.58%	44.12%	45.29%	46.41%
Brazil	109.82	109.38	113.38	119.31	58.43%	60.71%	62.71%	64.48%
Chile	150.80	148.50	142.62	146.37	68.64%	69.62%	70.16%	71.08%
Colombia	125.15	125.70	127.12	132.76	50.71%	52.77%	54.67%	57.19%
Costa Rica	174.50	175.57	154.45	158.03	57.80%	59.64%	61.36%	63.13%
Ecuador	94.98	94.43	91.30	95.02	46.35%	48.34%	50.07%	51.54%
El Salvador	148.86	149.13	148.76	150.27	44.70%	46.39%	47.96%	49.59%
Guatemala	119.07	118.98	114.40	111.39	41.06%	43.22%	44.44%	45.99%
Mexico	97.75	98.80	98.20	99.86	53.42%	55.98%	58.30%	60.64%
Nicaragua	116.43	117.27	121.09	125.39	36.10%	38.92%	42.16%	44.84%

Countries	Wireless Telephony (*)				Wireless Broadband (**)			
	2018	2019	2020	2021	2018	2019	2020	2021
Panama	117.47	118.53	118.01	127.20	61.61%	63.74%	65.46%	67.45%
Paraguay	100.84	102.05	100.00	99.43	40.35%	41.90%	43.26%	44.44%
Peru	124.47	116.56	112.33	115.82	50.39%	51.54%	53.07%	54.45%
Uruguay	160.54	174.78	168.63	163.17	61.91%	63.68%	65.16%	66.46%
Venezuela	84.51	85.56	83.67	86.37	43.63%	45.06%	45.06%	46.72%

(*) Number of connections/Population
(**) Unique subscribers (Percent Population), Mobile internet
Sources: GSMA Intelligence; Telecom Advisory Services analysis

When assessed in a comparative manner, Argentina, Brazil and Mexico remain wireless broadband adoption leaders, while Bolivia, Ecuador, Colombia, Peru and the Central American countries remain the laggards (see Figure 2-3).

Figure 2-3. Latin America: Wireless Broadband Adoption

Sources: GSMA Intelligence; Telecom Advisory Services analysis

The affordability barrier

Despite significant regional progress since 2013 (driven notably by Brazil), affordability emerges as a key factor limiting access to broadband and digital mobile services. As a percentage of per capita income, broadband and wireless telephones represent 1.8% and 2.1% on average in Latin America in 2021, between two and three times that of high-income countries making it an additional barrier to close adoption gaps (Table 2-9).

Table 2-9. Latin America: Wireless affordability

	Wireless telephony (*)		Wireless broadband (**)	
	2021	CAGR (2013-2021)	2021	CAGR (2013-2021)
Latin America and Caribbean	2.1 %	-8.5 %	1.8 %	-7.2 %
Argentina	2.1 %	- 0.7 %	1.4 %	-0.3 %
Bolivia	3.2 %	7.8 %	2.5 %	-14.9 %
Brazil	1.0 %	-3.7 %	0.6 %	- 2.4 %
Chile	0.6 %	-1.4 %	0.5 %	-1.1 %
Colombia	1.1 %	-2.1 %	1.9 %	-0.6 %
Costa Rica	0.5 %	0.0 %	0.7 %	-1.0 %
Ecuador	2.8 %	-0.7 %	2.2 %	-2.2 %
El Salvador	3.4 %	-2.2 %	4.9 %	0.6 %
Guatemala	3.4 %	-4.5 %	3.4 %	-3.3 %
Mexico	0.5 %	-0.9 %	0.6 %	-0.9 %
Nicaragua	19.5 %	1.0 %	6.6 %	-2.6 %
Panama	0.9 %	-0.5 %	2.1 %	1.0 %
Paraguay	2.3 %	-3.7 %	3.0 %	-5.8 %
Peru	0.9 %	-0.8 %	1.7 %	-2.5 %
Uruguay	1.2 %	-5.2 %	1.0 %	2.6 %
BENCHMARKS				
OECD	0.7 %	-8.4 %	0.6 %	-6.5 %
United States	0.6 %	-4.0 %	0.4 %	-2.8 %
Canada	0.6 %	-6.6 %	0.7 %	-8.6 %
United Kingdom	0.5 %	-12.4 %	0.6 %	2.0 %
South Korea	0.8 %	-1.2 %	0.4 %	-12.3 %

(*) Mobile cellular low usage basket (70 minutes + 20 SMS) connection
(**) Data-only mobile broadband basket (2 GB) connection
Sources: International Telecommunication Union; Telecom Advisory Services analysis

Figure 2-4 provides an affordability comparison between wireless telephony and wireless broadband indicating how the latter remains a bigger obstacle for adoption in the region.

Figure 2-4. Latin America: Wireless Telephony and Wireless Broadband Affordability

Affordability broadband

Affordability Wireless Telephony

Sources: International Telecommunication Union; Telecom Advisory Services analysis

The affordability barrier to broadband adoption is concentrated at the base of the socio-demographic pyramid. Indeed, although on average, costs are in line to the expected range for developing regions, the high level of income inequality explain that access represent an unbearable charge for the most vulnerable population. Even focusing on the most affordable mobile services, mobile broadband in 2020 represented 1.8% of GNI per capita on average for the whole population, but as much as 10.2% for decile 1 (i.e., the 10 percent population with the lowest income) as shown in Table 2-10.

Table 2-10. Price of broadband service as a percentage of GNI per capita by decile for Latin America and the Caribbean (2020)

Country	Average	Decile 1	Decile 2	Decile 3
Fixed Broadband	3.6%	20.8%	11.9%	8.8%
Mobile Broadband	1.8%	10.2%	5.8%	4.4%

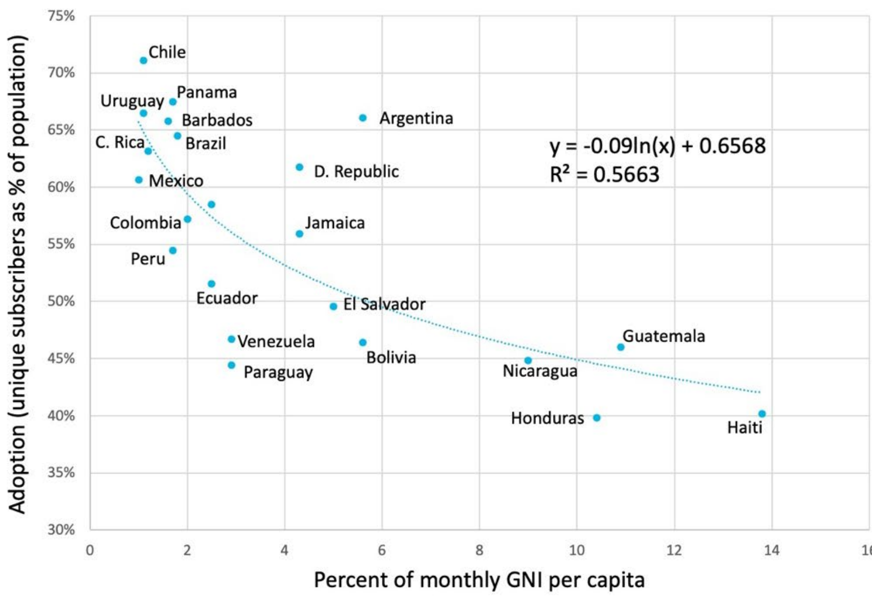
Sources: SEDLAC (CEDLAS and World Bank) based on microdata from Household Surveys, Katz, R. and Jung, J. (2021) The economic impact of broadband and digitization through the COVID-19 pandemic: Econometric Modelling. Geneva: International Telecommunication Union; analysis by Telecom Advisory Services.

Even for decile 3, close to the so-called *vulnerable middle-class*, mobile broadband cost reached 4.4% of their income, well above the International Telecommunication Union's 2%

affordability threshold[7]. In addition, the cheapest basic smartphone available costs between 4 and 12% of average household income in much of the region, and as much as 31-34% for people in Guatemala and Nicaragua or even 84% for people in Haiti (Drees-Gross and Zhang, 2021[8]).

The reason why there is no total correlation between coverage and adoption is because, given the level of development of the Latin American wireless industry and the region's income distribution, affordability becomes the key explanatory driver of future growth in wireless broadband service penetration (see Graphic 2-1).

Graphic 2-1. Latin America and the Caribbean: Affordability versus wireless broadband adoption



Source: World Bank; GSMA Intelligence; Telecom Advisory Services analysis

As graphic II-1 indicates, the higher the cost of wireless broadband service as percent of the monthly GNI per capita, the lower the service adoption is.

The urban/rural dichotomy

While representing pockets of limited affordability, rural areas in Latin American countries generally exhibit a lower network coverage. Both variables have an impact on the lower adoption of broadband in rural geographies (see graphic 2-2).

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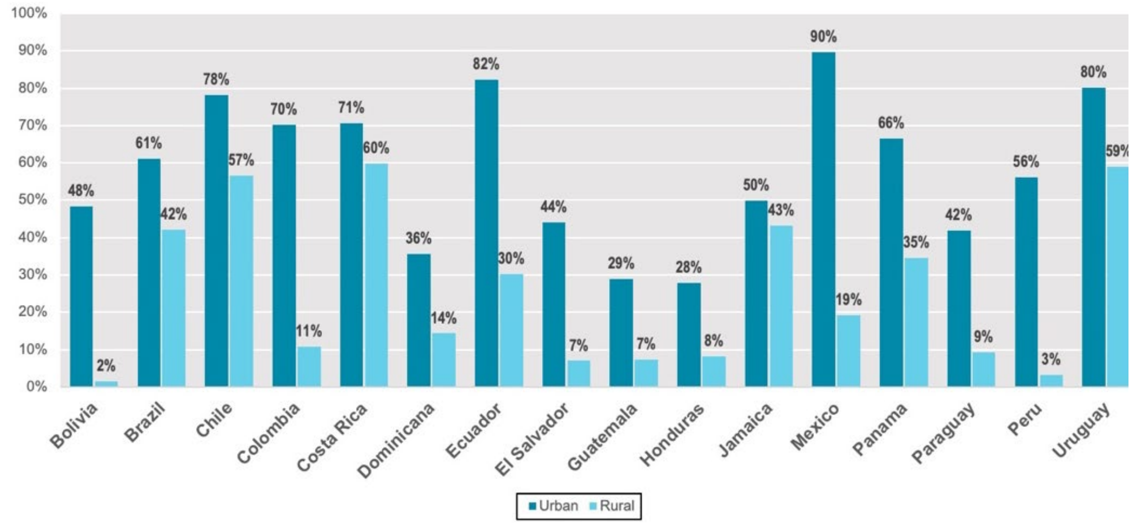
[7] https://a4ai.org/news/un-broadband-commission-adopts-a4ai-1-for-2-affordability-target/

[8] Drees-Gross, F. and Zhang, P. (2021), "Poor digital access is holding Latin America and the Caribbean back. Here's how to change it", *World Bank Blogs,* August 12.

Graphic 2-2. Latin America: Broadband adoption (percent of households)



NOTE: Urban/Total and Rural/Total ratios from previous years (2018 and 2019) are applied to ITU national penetration data for 2020.
Source: ITU, Household Surveys, IDB, Telecom Advisory Services analysis.

The statistics in graphic 2-2 are at the core of the importance of infrastructure sharing. Governments and civil society in the region are cognizant of the urgent need to bridge the digital divide, particularly considering the pandemic. In fact, the ongoing dialogue with governments and regulators, not only in the region but around the world, indicate that there is a wide understanding that the region cannot afford another pandemic cycle with the current level of development of wireless infrastructure.

Lagging capital spending

Latin America and the Caribbean invests a weighted USD 33.8 per capita in telecommunications, which is below the world average and significantly lower than in advanced economies (see Table 2-11).

Table 2-11. Investment in telecommunications per capita (in US$)

Region	2019	2020	Delta 2019-20	2021
World	$ 51.3	$ 51.7	0.9%	$ 52.3
Sub-Saharan Africa	$ 8.5	$ 7.6	-11.0%	$ 7.4
Latin America and the Caribbean	$ 36.4	$ 33.7	-7.4%	$ 35.2
North America	$ 345.6	$ 338.1	-2.2%	$ 352.3
Asia and Pacific	$ 26.2	$ 28.0	7.0%	$ 27.8
Western Europe	$ 121.6	$ 121.6	0.0%	$ 121.1
Eastern Europe	$ 38.8	$ 40.5	4.3%	$ 40.5
Arab States	$ 39.7	$ 43.6	10.0%	$ 43.0
OECD	$ 177.4	$ 174.6	-1.5%	$ 178.7

Source: ITU World Telecommunication/ICT Indicators (WTI) Database 2021 & GSMA Intelligence; Telecom Advisory Services analysis

The need to accelerate wireless network deployment is extremely relevant under the current circumstances: capital spending by country varies significantly (see figure 2-5).

Figure 2-5. Latin America: CAPEX per capita

Sources: ITU World Telecommunication/ICT Indicators (WTI) Database 2021 & GSMA Intelligence; Telecom Advisory Services analysis

As indicated, many countries in the region depict a consistent reduction in capital spending only accelerated with a lag by the "COVID effect", as depicted in Table 2-12 with annual wireless investment per capita (see table 2-12).

Table 2-12. Wireless CAPEX per capita (2011-2021) (in USD)

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Latin America and Caribbean	17.06	19.76	19.46	18.98	19.33	21.24	17.78	18.41	19.29	17.76	18.33
Argentina	4.66	4.08	4.04	3.84	5.80	6.78	6.40	6.68	9.01	7.92	8.38
Bolivia	7.71	9.58	10.91	12.80	14.81	16.60	23.14	29.69	34.92	38.89	42.88
Brazil	12.46	14.39	14.09	14.39	16.23	15.77	14.62	15.16	16.40	15.77	16.88
Chile	57.08	57.11	48.64	50.90	47.91	53.24	48.90	46.92	44.58	40.98	50.66
Colombia	20.43	20.43	19.37	20.30	19.88	18.22	18.05	15.40	18.02	17.61	17.50
Costa Rica	22.87	31.87	42.83	45.31	50.36	54.24	54.48	54.19	47.64	43.01	41.12
Ecuador	21.29	23.65	24.72	25.58	22.88	24.29	21.60	20.93	18.59	14.07	13.23
El Salvador	37.32	33.44	39.11	42.22	42.29	39.54	32.74	32.30	32.71	33.01	31.87
Guatemala	19.82	22.66	22.00	19.62	23.01	25.00	25.21	25.78	29.35	23.29	19.99
Mexico	10.92	17.59	16.99	14.30	11.28	13.99	7.07	13.85	14.23	13.92	14.19
Nicaragua	15.47	18.68	21.30	22.12	25.33	32.67	36.30	36.12	35.67	30.65	24.74
Panama	104.27	86.89	84.05	90.61	88.82	72.00	71.33	64.09	58.32	59.70	57.54
Paraguay	10.84	12.34	14.30	16.01	17.01	19.67	20.94	22.41	23.52	24.42	23.28
Peru	18.79	18.97	20.82	25.40	30.78	49.71	31.91	31.25	29.04	21.76	24.96
Uruguay	19.79	18.97	18.31	18.09	18.65	21.02	22.50	23.82	25.47	23.72	22.10
BENCHMARKS											
OECD	60.87	64.56	68.39	72.42	73.74	72.30	69.41	67.37	67.37	69.43	72.24
United States	85.68	96.79	105.50	102.51	101.32	98.71	106.24	116.82	138.13	134.69	139.45

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Canada	79.18	77.54	71.90	76.81	75.44	71.76	72.02	73.74	76.78	74.29	83.90
United Kingdom	47.94	48.64	49.93	54.39	55.46	55.74	55.58	54.72	51.98	50.10	49.46
South Korea	62.67	72.50	75.54	79.57	77.15	73.66	64.11	60.62	64.37	70.70	74.81

	Countries year-on-year reduction

Sources: GSMA Intelligence; Telecom Advisory Services analysis

When smoothed out to limit data volatility, the time series indicate that telecommunications capital investment in the region has been consistently declining in the past four years (see Table 2-12).

Table 2-13. Latin America: Annual wireline/wireless telecommunications investment per capita (USD current prices five-year average)

	2018	2019	2020	2021
Latin America and the Caribbean	37.55	36.80	36.06	34.84
Argentina	72.34	70.45	62.53	55.99
Barbados	125.30	126.43	117.89	95.11
Bolivia	34.92	39.63	42.95	45.66
Brazil	30.53	31.19	32.49	33.16
Chile	88.24	82.54	80.58	83.13
Colombia	40.93	37.74	37.42	37.19
Costa Rica	95.29	96.54	86.74	74.74
Ecuador	54.01	50.00	46.50	36.35
Jamaica	43.53	41.29	38.50	36.28
Mexico	33.93	32.93	33.06	32.76
Panama	60.51	61.60	63.23	66.61
Paraguay	30.26	31.76	32.98	31.44
Peru	39.47	37.10	35.20	30.09
Dominican Republic	29.59	30.28	30.95	28.09
Trinidad & Tobago	42.68	42.10	43.25	43.99
Uruguay	70.35	65.88	57.48	53.56
Venezuela	18.03	12.41	7.18	2.76
BENCHMARK				
OCDE	152.52	156.62	162.64	168.68

Sources: ITU World Telecommunication/ICT Indicators (WTI) Database 2021 & GSMA Intelligence; Telecom Advisory Services analysis

The CAPEX per capita values in table 2-12 present a five-year average used to smooth out the normal volatility in telecommunications CAPEX and compare the prorated value of OECD countries with Latin America and the Caribbean as well as each country in the region for the last four years.

First, the region invests one fifth of telecommunications capital of advanced economies. This is partly, but not completely, justified by lower ARPUs in the region, which puts a structural lid on the sector's ability to spend capital (see figure 2-6).

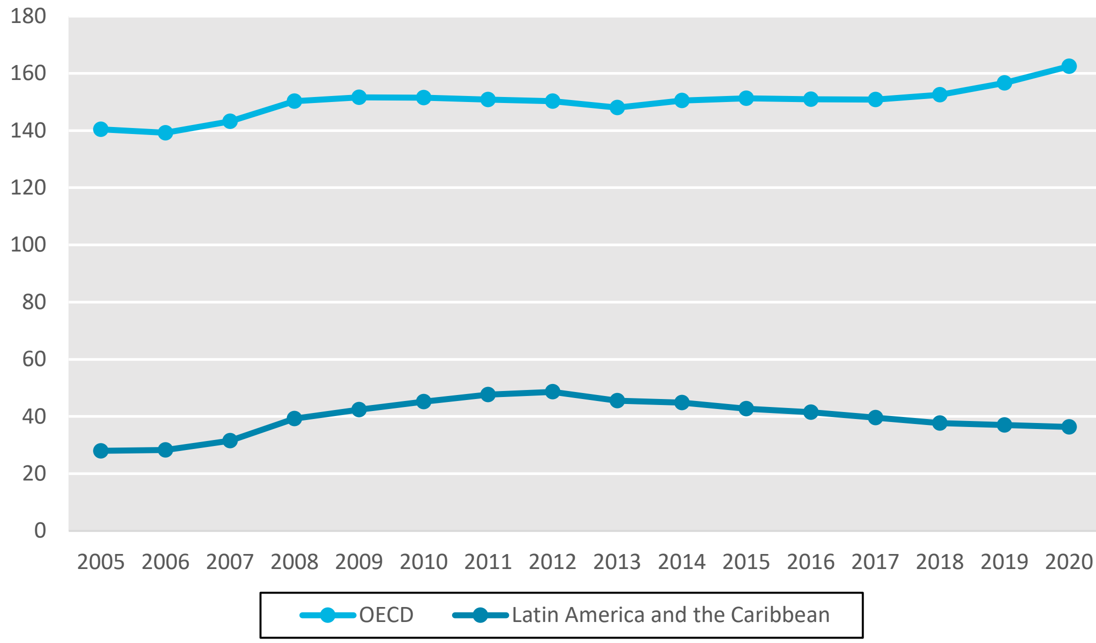
Figure 2-6. Latin America: Average Wireless Revenue per User

Source: GSMA Intelligence; Telecom Advisory Services analysis

Indeed, there are certain environmental conditions that make it natural for investment levels in the OECD to be higher. This is explained by the fact that these are countries with higher per capita incomes, where income per user is considerably higher and companies therefore have a greater capacity to finance and make investments profitable.

Second, the spending gap between Latin America and the OECD is widening rather than narrowing. And the trends are moving in opposite direction: OECD countries are investing more in telecommunications infrastructure while Latin America invests less *(see Graphic 2-3).*

Graphic 2-3. Investment in telecommunications per capita (average 5 years)



NOTE: the annual investment has been averaged over five years to reduce the volatility that characterizes the annual CAPEX.
Source: ITU and GSMA Intelligence, Telecom Advisory Services analysis.

Third, the region is, therefore, confronted with a network deployment imperative while dealing with the pressure on CAPEX. Considering the need to support the deployment of advanced technologies such as 5G -when 4G penetrations allow it- and fiber optics, Latin America's lag with respect to the OECD in terms of capital investment is a worrying factor. According to estimates by the Inter-American Development Bank[9], the investments needed in the telecommunications sector for the region to meet the targets of the Sustainable Development Goals by 2030 amount to USD 293,675 million.

Uneven progress toward sustainable competition

Economic analysis has shown that in capital-intensive industries such as telecommunications there is an optimal degree of industrial concentration that generates benefits for consumers while ensuring sector sustainability. This postulate is supported for three reasons:

- Significant economies of scale of service providers
- Operational efficiency of large operators
- Increased infrastructure investment and deployment capacity

[9] Brichetti, J.P., Mastronardi, L., Rivas Amiassorho, M.E., Serebrisky, T. and Solís, B. (2021), *The infrastructure gap in Latin America and the Caribbean: estimation of in - version needs until 2030 to progress towards meeting the Sustainable Development Goals.* InterAmerican Development Bank.

In this sense, *sustainable competition* allows increasing the stimulus to capital investment to the extent that, in contrast to the open and unrestricted competition model, permits operators to benefit from an adequate rate of return. The argument is based on the premise that a certain level of market power is necessary to stimulate an adequate level of investment and innovation, beyond which the incentives to invest and innovate decline.[10] The degree of industry concentration can be measured through the Herfindahl Hirschman Index. [11]

In general terms, the wireless industry in the region has moved towards *sustainable competition* during the last decade, closing the gap vs high-income economies. When measured by the Herfindahl Hirschman index, Brazil, Chile, or Peru show higher competition than the US, UK, or OECD average. The main regional outliers, despite significant progress, remain Ecuador, Mexico, and Nicaragua, where concentration remains high (see table 2-14).

Table 2-14. Wireless services competition and returns

	Competition in wireless broadband (HHI)		ARPU USD by subscriber	
	2021	Difference (2011-21)	2021	Difference (2011-21)
Latin America and Caribbean	3,658	-866	10.8	-3.2
Argentina	3,716	256	7.2	5.6
Bolivia	4,026	-6	9.7	1.1
Brazil	2,361	-824	7.5	-1.9
Chile	2,847	-682	19.8	0.8
Colombia	3,980	-1,333	6.4	-1.8
Costa Rica	3,567	-658	14.23	11.7
Ecuador	5,754	-1,242	10.5	-6.9
El Salvador	2,899	-1,289	20.9	-5.9
Guatemala	3,632	-1,485	19.7	-4.0
Mexico	4,635	-1,049	9.1	-4.0
Nicaragua	4,544	-1,176	36.5	17.3
Panama	3,084	-285	19.4	-13.4

[10] This is the same argument that underlies the need for the system of intellectual protection through patents to secure investment and stimulate innovation.

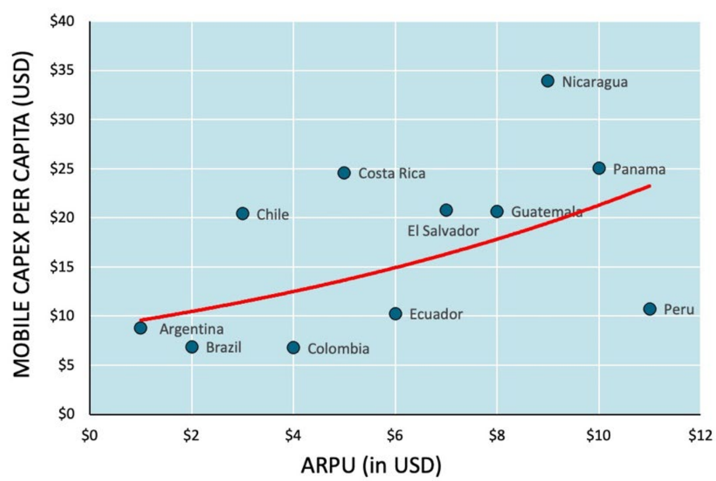
[11] The Herfindahl-Hirschman Index (HHI) is calculated based on the sum of the market shares of each operator squared. The closer it is to the value of 10,000, the presence of a monopolistic market, while a value below 10,000 indicates a certain market fragmentation. The U.S. Horizontal Concentration Guide considers a market to be highly concentrated when the HHI is above 2,500 points. These metrics are based on competition models of advanced economies whose exclusive application does not consider one of the most important principles that should guide the supervision of competition models in emerging countries. The competition model to be defined in the telecommunications industry in emerging countries should aim to maximize the objectives of economic development and equity. Thus, effects such as increased coverage and quality of service, increased affordability for vulnerable populations, and support for the digitization of productive processes should be considered in the definition of an optimal level of the HHI index, which should be higher than that defined in advanced nations.

	Competition in wireless broadband (HHI)		ARPU USD by subscriber	
	2021	Difference (2011-21)	2021	Difference (2011-21)
Paraguay	3,563	-534	10.0	0.2
Peru	2,611	-2,136	9.9	1.4
Uruguay	3,849	-54	12.4	0.4
Venezuela	3,914	-307	5.2	-8.1
BENCHMARKS				
United States	2,736	-376	58.0	-9.5
Canada	2,735	-218	46.7	-6.2
United Kingdom	2,776	167	22.0	-2.7
South Korea	5,197	441	29.9	-3.8
Philippines	5,000	-664	2.6	-0.3
OECD	3,548	21	---	---

Sources: IMF & GSMA Intelligence; Telecom Advisory Services analysis

This intense competition, which resulted in the greater affordability of services mentioned before, has also driven down the already low ARPUs for operators. In 2021, ARPUs for a sample of Latin American markets fell to USD 9.5 per subscriber, five times lower than the ones in the US or Canada. There are, again, significant differences among countries, as Central America (especially Nicaragua, El Salvador) and Chile keep relatively higher revenues per subscriber (over USD 20 per subscriber). Increasing competition and falling ARPUs are two of the ingredients of the low investment (measured by operators CAPEX) in the wireless industry in Latin America (see graphic 2-4).

Graphic 2-4. Wireless Broadband ARPU vs. Mobile CAPEX (2021)



Sources: GSMA Intelligence; Telecom Advisory Services analysis

Not only investment in the US is seven times higher than on the average of the 11 Latin American economies (USD 135.9 per subscriber vs USD 21.5 in 2021), but it has increased significantly since 2013, in line with a more intense use and uses of connectivity in the US (while it remained at very low levels in Latin America).

2.3. Conclusion

To conclude, despite the remarkable progress, it is key to highlight the high degree of heterogeneity of Latin America in terms of the development of its wireless industry. Among the positive trends, we should highlight:

- Nearly total deployment of 3G
- High coverage of 4G in most countries, closing the gap with advanced economies
- Some advances in 5G deployment in Brazil and service launch in Chile, Mexico, Peru and Guatemala
- High service adoption fueled by affordability in high-income countries
- Increasingly competitive sector

Regarding the challenges:

- Remaining coverage gaps in Colombia, Costa Rica, Ecuador, Guatemala, Nicaragua and Peru
- Embryonic development of 5G with several investment constraints
- Lack of connectivity in Central America reaches 5 out 10 citizens
- Limited coverage and wireless broadband adoption in rural areas
- Low service penetration driven by limited affordability principally in central American countries
- Diminishing capital investment constrained by low ARPUs

Along these lines, a factor that has been instrumental in the positive developments of the industry has been passive infrastructure sharing as a way of controlling capital spending and operating expenditure. The following chapter will analyze econometrically the casual relations and correlations between passive infrastructure and the different market indicators.

3. PASSIVE INFRASTRUCTURE SHARING: A CRITICAL ENABLER OF WIRELESS TELECOMMUNICATIONS INDUSTRY DEVELOPMENT

Passive infrastructure sharing comprises multiple models.[12] In the wireless segment, at its most basic level, it entails the sharing of the geographic location of stations, whereby all network components at the site belong to each operator. This model essentially saves the cost of leasing or purchasing a site, although it is difficult sometimes to find a fixed location that suits all operators. The next level of wireless passive sharing involves towers, where each operator deploys its own equipment and has control over it. In this case, while the sharing agreement is signed between two or more operators, they might include third-party independent companies acting as neutral hosts. In this model, costs can be significantly reduced when operators share physical assets and transport networks. In this scenario, sharing can be managed by the site owner, who acts as a landowner for the operators who lease the site. The owner may be an operator sharing the site or an independent tower company that provides the infrastructure. In the wireline sector, passive sharing could include the use of ducts provided by an infrastructure operator (electric utility, water company, subways, etc.) or a pole from an electric utility that charges a fixed amount by pole attachment.

The rational for infrastructure sharing Is quite straightforward. The justification has already been validated by some empirical research. For example, Caussen et al (2012) examined how outsourcing of a core service affects firm performance in the context of the mobile telephony industry, covering 50 mobile network operators in 28 countries during 2000-2009. The authors found that mobile network operators decrease costs, increase revenues, and improve their profitability by outsourcing mobile network operation services. In cumulative terms up to four years after the outsourcing agreements were implemented, the ratio of EBITDA to revenues increases by about eight percentage points. In the review of empirical literature on outsourcing IT management and its impact on telecom operations – a concept more akin to active infrastructure sharing - , Patil and Patil (2014) confirm evidence on the impact of infrastructure sharing on savings in operating expenditures, investment, competitive position and risk and returns (among many others). GSMA (2012) added to

[12] Active sharing extends to the electronic components of the network and the radio spectrum, according to different models. Under the RAN model, the shared equipment includes base stations, Node B, base station, and radio network controllers, and may extend to feeder cables and antennas, leaving the transmission network and the core network to be operated independently. Under this model, operators control the cells in their core network and have a separate operation. The backhaul sharing model, adds to the shared RAN infrastructure the transmission channel. This approach is useful to accelerate deployment and focus on providing quality services. Under the backhaul sharing scenario, several options exist: the backhaul can be deployed by a joint venture of the participating mobile operators or by a third-party that would deploy and operate the infrastructure and offer it to the operators through a "platform as a service" model. The highest level of sharing is that of core network sharing, where the Home Location Register, the billing platform, and the value-added systems can be shared.

these same strategic and commercial effects, a positive contribution to environmental sustainability.

More recently, Houngbonon et al. (2020) put forward an analysis showing how infrastructure sharing can accelerate digital connectivity at lower cost (especially in the least developed markets where returns to investment can be limited), reduce investment costs and operating expenses for investors and operators, and increase their balance sheet sustainability, while also benefitting consumers by enhancing competition, lowering prices, and raising service quality.[13] Similarly, Cabello et al. (2021) even projected that infrastructure sharing would increase by up to 16 percentage points by 2030, driven on the one hand by the growing market share of infrastructure companies (naturally more prone to sharing than mobile network operators), which is expected to reach over 67% for total sites; and on the other hand by a higher level of network sharing as public spaces become more easily available and agreements are made with other sectors, such as utilities.[14] Along those lines, Wang and Sun (2022), focusing on the China's mobile telecommunications industry showed that the telecommunication infrastructure sharing promotes the total industry network investment.

The focus of this chapter is to add to the empirical literature, demonstrating that passive infrastructure regulation has an impact on the development of the wireless industry in Latin America and, in turn, to economic development. We first introduce the theoretical framework and describe the data upon which the analysis will be based on. Following this, we present the results of the empirical modelling and, on these bases, discuss the implications.

3.1. Theoretical framework

As mentioned above, the objective of this analysis is to demonstrate the relationship between improved infrastructure sharing regulation and ultimately economic performance (see figure 3-1).

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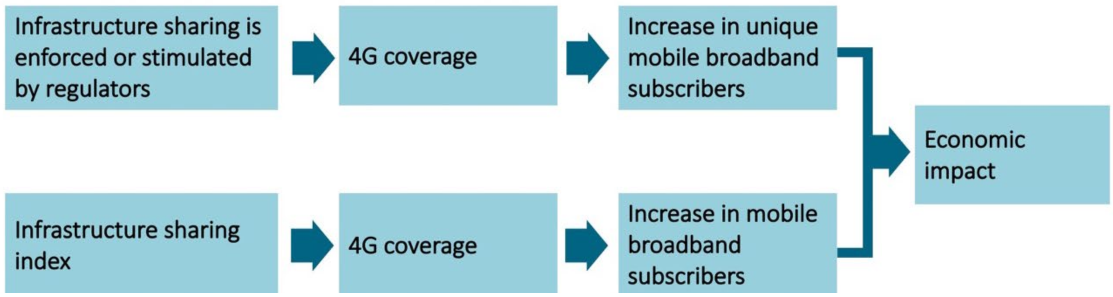
[13] Houngbonon, G; Rossotto, C., and Strusani, D. (2021). *Enabling a competitive mobile sector in emerging markets through the development of tower companies*. EM Compass Note 104 (June); Washington, DC: International Financial Corporations.

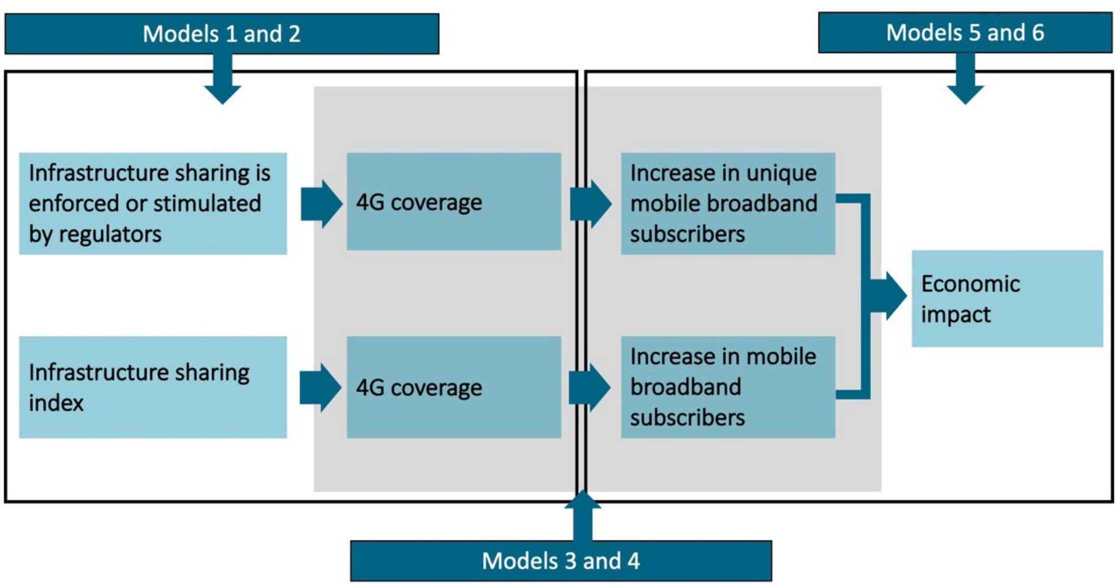
[14] Cabello, S., Rooney, D. y Fernandez, M. (2021). *Nuevas dinámicas de la gestión de infraestructura en América Latina*. SMC+

Figure 3-1. Focus of the analysis



In order to show the aforementioned relationship, it is considered that the most appropriate approach to the analysis is to divide the problem into stages. First, we analyze the relationship between a regulation that forces or proactively encourages site sharing and the level of 4G coverage. [15] At the same time, we test the relationship between an index that quantifies how proactive the country's regulation is in relation to infrastructure sharing beyond site co-location and the level of 4G coverage will be analyzed. Then, in a second stage, the relationship between an increase in 4G coverage and an increase in unique mobile broadband users will be quantified. Finally, the relationship between an increase in the number of unique mobile broadband users and an enhancement in economic indicators will be estimated (See figure 3-2).

Figure 3-2. Stages of analysis



[15] Site sharing is defined as co-location.

The models will rely on information published by the International Telecommunication Union (ITU) in the "ICT Regulatory Tracker". This database presents information from 2007 to 2020, compiled on the basis of questionnaires sent annually to regulators in each country on various regulatory issues. Based on the responses to these questionnaires, the ITU codes the results for each question at two levels:

- No: 0
- Yes:1

Out of the universe of available questions, only three are considered here, those that cover the subject of infrastructure sharing:

1. Is infrastructure sharing (towers, radio bases, poles, ducts, etc.) mandated or proactively encouraged
2. Is co-location/site sharing forced or proactively stimulated?
3. Is local loop unbundling mandatory?

The first of these questions refers to the presence or not of infrastructure sharing, which is a step ahead of operators who simply share their sites and involves sharing more passive components, such as towers, base stations, poles, ducts, etc. facilities maintenance, as well as increasing the productivity of resource use.

The second of the questions refers to co-location / site sharing, which is the simplest form of sharing, and refers to the allocation of some passive network equipment at the same site. As a result, telecom operators share the same physical complex, but install masts, antennas, cabinets and backhaul at separate sites.

Finally, the third question refers to local loop unbundling, which refers to the regulatory process in which incumbents lease, in whole or in part, the local segment of their telecommunications network to competitors, and then allow multiple operators to use connections from the telephone exchange to the user's premises.

In terms of quantitative analysis, we chose to work with two alternative mechanisms:

- Only using the second question since it is the most comprehensive of all the questions available regarding wireless infrastructure sharing.
- Build an index that takes the value 100 if all answers to the three questions are affirmative; 66.66 if two are affirmative; 33.33 if only one is affirmative; and 1 if all three answers are negative.

The countries included in the analysis are all those in Latin America and the Caribbean for which the ITU publishes information, provided they have more than one million inhabitants. This decision was made to avoid bias in the results due to the presence of small countries. Thus, the countries considered are Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago and Uruguay. The analysis period covers the period from 2010 to 2020[16] . Thus, the models rely on a total of 209 observations over 19 countries and 11 years.

Based on these data, the first econometric model proposes to evaluate the relationship between the answer to the question of whether co-location/site sharing is forced or proactively encouraged and the level of 4G coverage in each country (based on GSMA Intelligence data). In this context it is possible to perform a simple regression that determines the effect on the level of 4G coverage of residing in a country with co-location/sharing (treatment):

$$Coverage\ 4G = \beta_0 + \beta_1 . Treatment_{it} + \beta_2 . Year_t + \beta_3 Area_i + \beta_4 . X_{it} + \mu_{it} \ (1)$$

Where,

- 4G Coverage: Percentage of population with 4G coverage (Source: GSMA)
- Treatment: This is the variable that distinguishes each country on the basis of
    - 1 where there is forced or proactively stimulated co-location/site sharing (Source: ITU Regulatory Tracker)
    - 0 otherwise
- Year: Corresponds to a fixed effect for each year between 2010 and 2020.
- Area: Corresponds to a fixed effect for each country in the regression.
- X: is a matrix of other independent variables that are used as controls, in particular GDP per capita.

The second econometric model estimates the relationship between an index constructed from all the ITU questions (presented above) and the level of 4G coverage in each country (according to GSMA Intelligence data). Based on these data it is possible to perform a simple regression that determines the effect on the level of 4G coverage related to an increase in the index:

$$Coverage\ 4G = \beta_0 + \beta_1 .\ Index_{it} + \beta_2 . Year_t + \beta_3 Area_i + \beta_4 . X_{it} + \mu_{it} \ (2)$$

Where,

- 4G Coverage: Percentage of population with 4G coverage (Source: GSMA)
- Index: An index that takes the value 100 if all 3 answers are affirmative; 66.66 if 2 are affirmative; 33.33 if only one is affirmative; and 1 if all 3 answers are negative (Source: ITU Regulatory Tracker).
- Year: Corresponds to a fixed effect for each year between 2010 and 2020.

[16] Despite the existence of data since 2007, only data from 2010 are considered, as inconsistencies were found in the database in the first years.

- Area: Corresponds to a fixed effect for each country in the regression.
- X: is a matrix of other independent variables that are used as controls, in particular GDP per capita.

Moving on to the second module of analysis, which seeks to quantify the relationship between an increase in 4G coverage and an increase in unique mobile broadband users, the following regression model is proposed:

$$Unique\ mobile\ broadband\ users_{it} = \beta_0 + \beta_1.\ Coverage\ 4G_{it} + \beta_2.Year_t + \beta_3 Area_i + \beta_4.X_{it} + \mu_{it}\ (3)$$

Where,

- Unique mobile broadband users: Percentage of the population that is a mobile broadband user (Source: GSMA)
- 4G Coverage: Percentage of population with 4G coverage (Source: GSMA)
- Year: Corresponds to a fixed effect for each year between 2010 and 2020.
- Area: Corresponds to a fixed effect for each country in the regression.
- X: Is a matrix of other independent variables that are used as controls, in particular the treatment variable of model 1, and the Index of model 2.

Finally, to estimate the relationship between an increase in the number of unique mobile broadband users and an improvement in economic indicators, the results of Katz and Jung (2021) are used.

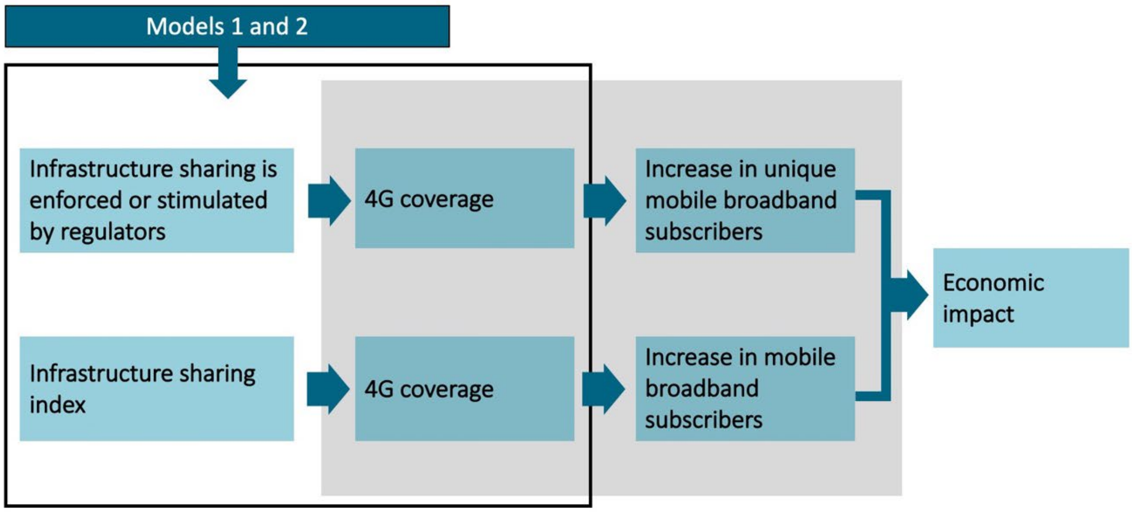
3.2 Econometric modelling results

This section presents the results of the econometric models presented above in a sequential fashion.

Impact of infrastructure sharing on 4G coverage

We first present the results of the econometric regressions that analyze the relationship between a regulation that proactively forces or stimulates site sharing and the level of 4G coverage. At the same time, the link between an index that quantifies how proactive the country's regulation is in relation to infrastructure sharing and the level of 4G coverage is analyzed (see figure 3-3).

Figure 3-3. First analysis module



Source: Telecom Advisory Services, LCC

The first econometric model indicates that the introduction of treatment (understood as the regulation that forces or stimulates the co-location or sharing of sites) generates an increase in 4G coverage levels of 13.02 percentage points (i.e., going from 80% coverage of the population to 93.02%). The second econometric model estimates that a 10-point increase in the sharing regulation index (as described in the previous section) increases 4G coverage level by 1.54 percentage points. This result implies that with each additional measure in favor of sharing (out of the 3 considered), the index increases by 33 points, which generates in turn an increase in 4G coverage of 5.08 percentage points (See Table 3-1).

Table 3-1. Econometric models with 4G coverage as dependent variable

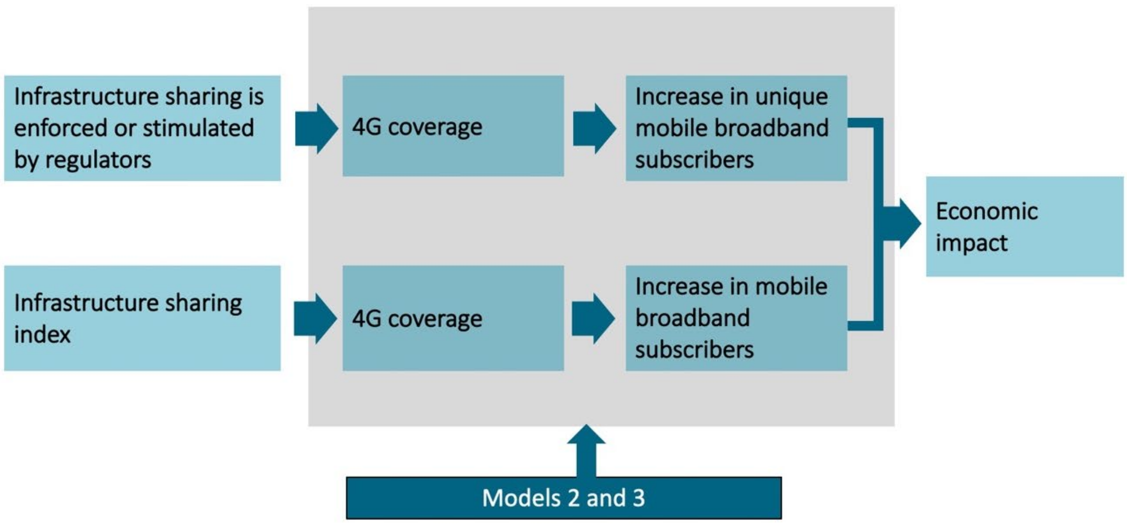
4G Coverage	**Results**	
	(1)	**(2)**
Ln (GDP pcap)	-0.0094265	-0.0093197
	(0.0813132)	(0.0821491)
Treatment	0.1302603***	-
	(0.0452936)	-
Index	-	0.0015407**
	-	(0.0006526)
E.F.	Country and Year	Country and Year
Years	2010-2020	2010-2020
Countries		
Remarks		
R^2	0.8471	0.8338

NOTE: ***, **, * significant at 1%; 5% and 10% respectively.

Impact of 4G coverage on mobile broadband adoption

This section presents the results of the econometric regressions that analyze the relationship between an increase in 4G coverage and an increase in unique mobile broadband users (that is, adoption) (see figure 3-4).

Figure 3-4. Second analysis module



Source: Telecom Advisory Services, LCC

The third econometric model estimates that a 10-percentage point increase in 4G coverage is linked to an increase in the percentage of the population that is a unique mobile broadband user of 1.19 percentage points. This implies that, if coverage increases from 80% of the population to 90% of the population, then the number of unique users will increase from 60% (assuming that this is their initial level) to 61.19%. From this result it is also important to note that the treatment only has an effect through the increase in 4G coverage (effect shown in Table 4) but has no additional direct effect on the percentage of unique users. Then, in a variant of model 3 (Model 4), where instead of controlling for treatment we control for the sharing regulation index, similar results are found (see Table 3-2).

Table 3-2. Econometric models with dependent variable 4G coverage

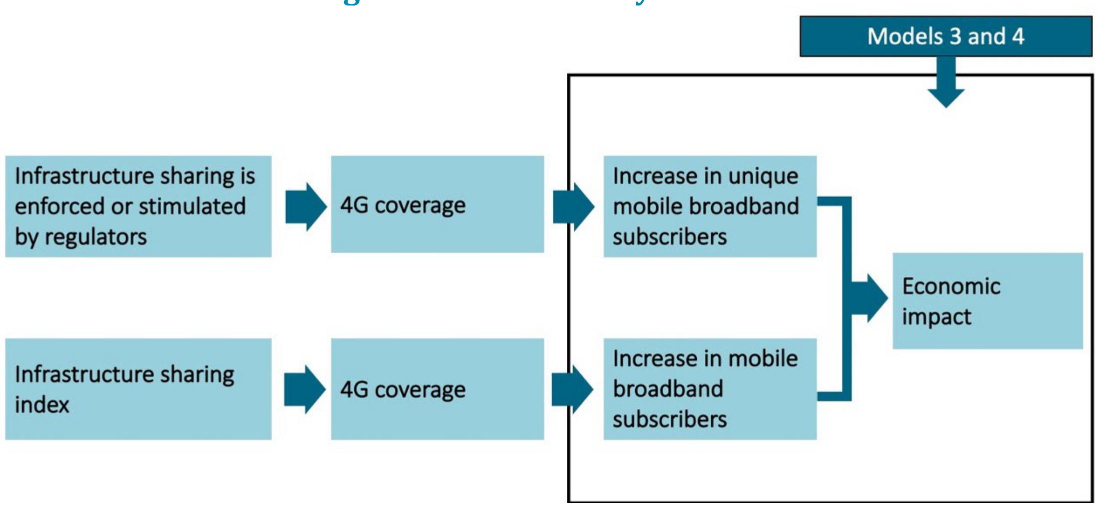
Unique BAM users (% population)	Results (3)	Results (4)
4G Coverage	0.1186981 ***	0.110544 ***
	(0.0240667)	(0.0238254)
Ln (GDP pcap)	0.0343244	0.040168
	(0.0261098)	(0.0261137)
Treatment	-0.0095116	-
	(0.0148774)	-
Index	-	0.0002492
	-	(0.0002107)
E.F.	Country and Year	Country and Year
Years	2010-2020	2010-2020
Countries		
Remarks		
R^2	0.7483	0.7690

NOTE: ***, **, * significant at 1%; 5% and 10% respectively.

Impact of mobile penetration and economic growth

This section will present the results of the econometric regressions that analyze the relationship between an increase in the number of unique mobile broadband users and an improvement in economic indicators (See Figure 3-5).

Figure 3-5. Third analysis module



Source: Telecom Advisory Services, LCC

For this module we rely on the coefficients of the Katz and Jung (2021) model, which show that a 1% increase in mobile broadband adoption generates a 0.16% increase in GDP per capita (see Table 3-3).

Table 3-3. Econometric model of the impact of an increase in mobile broadband subscribers on GDP per capita

GDP per capita (PPP)	***Results***
Penetration of mobile broadband subscribers	0.160***
Gross fixed capital formation	0.137***
Education	0.048***
Penetration of mobile broadband subscribers	
Mobile adoption	1.694***
Rural Population	-0.052***
GDP per capita	0.046***
Mobile broadband pricing	-0.012
Mobile broadband competition	-0.331***
Mobile broadband revenues	
GDP per capita	0.517***
Mobile broadband pricing	0.129***
Mobile broadband competition	-1.547***
Growth in mobile broadband adoption	
Mobile broadband revenues	-0.008***
Remarks	5,227
Number of countries	
Country fixed effect	Yes
Fixed effects by year and country	Yes
Years	2010-2020
R^2	0.993

NOTE: ***, **, * significant at 1%; 5% and 10% respectively.
Source: Katz and Jung (2021)

3.3. Conclusions

Based on the previous results, we estimate the positive effects of site co-location and infrastructure sharing. A country with an initial 4G coverage of 80% and an adoption of unique mobile broadband users equal to 60% would undergo the following effects as a result of introducing site-colocation:

- 4G coverage level would increase from 80.00% to 93.03% (applying coefficient of econometric model 1).
- As a result of the increase in 4G coverage, unique mobile broadband users would increase from 60.00% to 61.55% (applying the coefficient of econometric model 3).
- The increase in unique users would generate in turn an increase in GDP per capita of 0.41% (applying the coefficient of the model in Table 8 to the previous result).

Similarly, having one more affirmative answer out of the three that make up the sharing regulation index described above generates the following effects:

- 4G coverage level would increase from 80.00% to 85.08% (applying coefficient of econometric model 2).

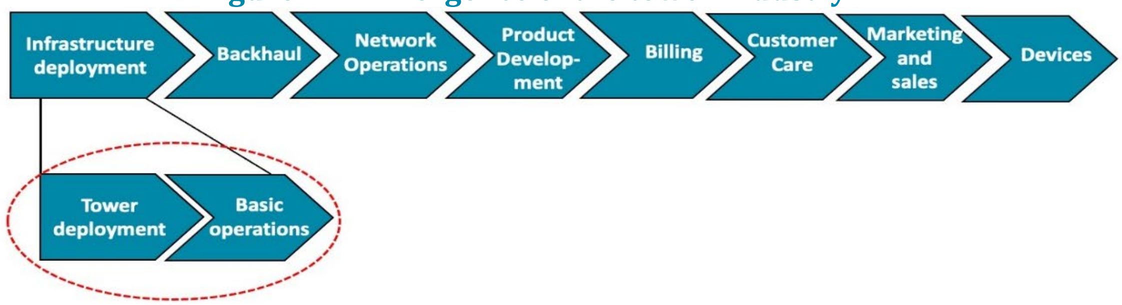
- As a result of the increase in 4G coverage, unique users would increase from 60.00% to 60.56% (applying the coefficient of econometric model 3*).
- The increase in unique users would generate an increase in GDP per capita of 0.15% (applying the coefficient of the model in Table 8 to the previous result).

In conclusion, these first econometric models have provided empirical evidence of the positive impact of infrastructure sharing on the development of the wireless industry, service adoption and economic development. We will now focus on a particular segment of infrastructure sharing: wireless towers.

4. THE CURRENT STATE OF THE LATIN AMERICAN TOWER INDUSTRY

In the past fifteen years, the wireless telecommunications industry has witnessed the emergence of what in economic terms is labeled as "value chain specialists": wireless towers. The study of value chains across industry life cycles indicates that at the early stage of industry development, young firms need to manufacture their own inputs, they must persuade customers to shift purchases to their own products, and they must design specialized equipment. This leads to value chain integration, where firms control all stages. However, over time, as independent middlemen become more knowledgeable of the technology and as reliability increases, the incentive to maintain a forward market presence decreases. With this, value chain fragmentation emerges around scale efficient specialists. Such has been the case in the wireless telecommunications sector (see figure 4-1).

Figure 4-1. Emergence of the tower industry



This trend has also been prevalent in Latin America. As of 2022, in the twelve largest Latin America countries, wireless tower deployment reached over 191,330[17] (see table 4-1).

Table 4-1. Latin America: Tower deployment

	2016	2017	2018	2019	2020	2021	2022	CAGR (16-22)
Argentina	- - -	- - -	- - -	17,279	17,399	17,577	17,683	- - -
Brazil	58,358	56,957	59,778	64,790	68,542	67,903	68,325	2.66%
Chile	8,640	8,926	8,968	9,164	9,029	9,441	9,950	2.38%
Colombia	15,359	15,448	16,442	17,552	17,473	17,943	17,972	2.65%
Costa Rica	3,055	3,302	3,926	3,999	3780	42,55	4,286	5.81%
Ecuador	- - -	- - -	- - -	- - -	- - -	5,930	5,852	- - -
El Salvador	1,264	1,267	1,683	1,728	1,760	2,850	2,851	14.52%
Guatemala	3,638	3,676	3,742	4,002	4,002	6,571	6,518	10.21%
Mexico	26,069	29,797	31,548	33,874	34,835	37,060	39,038	5.04%
Nicaragua	1,025	1,155	1,231	1,364	1,364	1,785	1,789	9.73%
Panama	1,577	1,639	1,656	1,726	1,726	2,211	2,198	5.69%
Peru	9,167	10,604	11,121	12,452	14,656	14,765	14,868	8.39%
Total	131,152	132,771	139,796	167,931	174,566	188,291	191,330	6.50%

Source: TowerXchange; Telecom Advisory Services analysis

[17] We do not distinguish between types of towers. Ground-based towers are typically freestanding structures and are more prevalent in less densely populated areas. Rooftop towers are (usually) set up on pre-existing buildings and are typically located on the roof, roofing pavement or high windows. EY-Parthenon and European Wireless Infrastructure Association, EWIA (2019).

Notwithstanding the missing values across the time series, the growth in the wireless industry, cell towers grew from 128,152 in 2016 to 191,330 in 2022 (a compound annual growth rate of 6.91%) supporting the growth in the wireless industry. In this context, middle-income Central America (El Salvador (14.52%), Guatemala (10.21%), and Nicaragua (9.73%)) and Peru (8.39%) show the greatest dynamism with the highest growth rates of installed towers since the mid 2010s. In the rest of Latin American economies tower deployment has grown at a compound rate ranging between 2.69% and 6.96%.

A comparative assessment of tower density provides an indication of different deployment patterns across countries: Panama exhibits 775 towers per million wireless subscribers, Costa Rica depicts 520, while, at the other end of the distribution, Brazil has 268 and Chile 327. This could indicate a potential over-deployment in some countries, an issue that will be addressed in subsequent chapters (see table 4-2).

Table 4-2. Latin America: Tower density (2022)

Country	Towers	Towers per million population	Towers per million wireless subscribers	Towers per square kms of land area
Argentina	17,683	382	294	0.65
Brazil	68,325	319	268	0.82
Chile	9,950	479	327	1.34
Colombia	17,972	351	265	1.62
Costa Rica	4,286	821	520	8.39
Ecuador	5,852	334	351	2.36
El Salvador	2,851	437	291	13.76
Guatemala	6,518	358	322	6.08
Mexico	39,038	300	295	2.01
Nicaragua	1,789	271	218	1.49
Panama	2,198	500	775	2.96
Peru	14,868	435	377	1.16
Total/average	191,330	344	286	1.14

Higher than average
Source: TowerXchange; Telecom Advisory Services analysis

A view of tower density over time allows placing specific timing and countries when a particular jump in deployment emerges (see table 4-3).

Table 4-3. Latin America: Towers per million population (2016-2022)

Country	2016	2017	2018	2019	2020	2021	2022
Argentina	- - -	- - -	- - -	384	383	383	382
Brazil	284	275	287	308	324	319	319
Chile	476	485	478	480	464	479	499
Colombia	328	326	341	355	347	351	348
Costa Rica	622	665	- - -	788	737	821	819
Ecuador	- - -	- - -	- - -	- - -	- - -	334	325
El Salvador	199	198	262	268	271	437	435
Guatemala	219	217	217	227	223	358	348
Mexico	237	240	252	268	273	287	300
Nicaragua	162	181	191	209	210	273	271
Panama	391	400	398	409	403	510	500
Peru	291	333	346	376	438	436	435
Average	284	284	291	321	330	342	344

Rapid increase in deployment

Source: TowerXchange; Telecom Advisory Services analysis

In parallel with the growth in the installed base and confirming the value chain trend towards the emergence of "specialists", the sector has been gradually evolving toward an increased share of independent players and MNO-owned companies. In fact, following transitions in more mature markets as Europe or the United States, tower divestiture by MNOs is apparent. That said, the stable share of independent tower companies exists in parallel with the spin-off by a major regional telecommunication player, who created an MNO-owned towerco from its foreign operations in 2021 (see table 4-3).

Table 4-3. Latin America: Tower ownership by operators

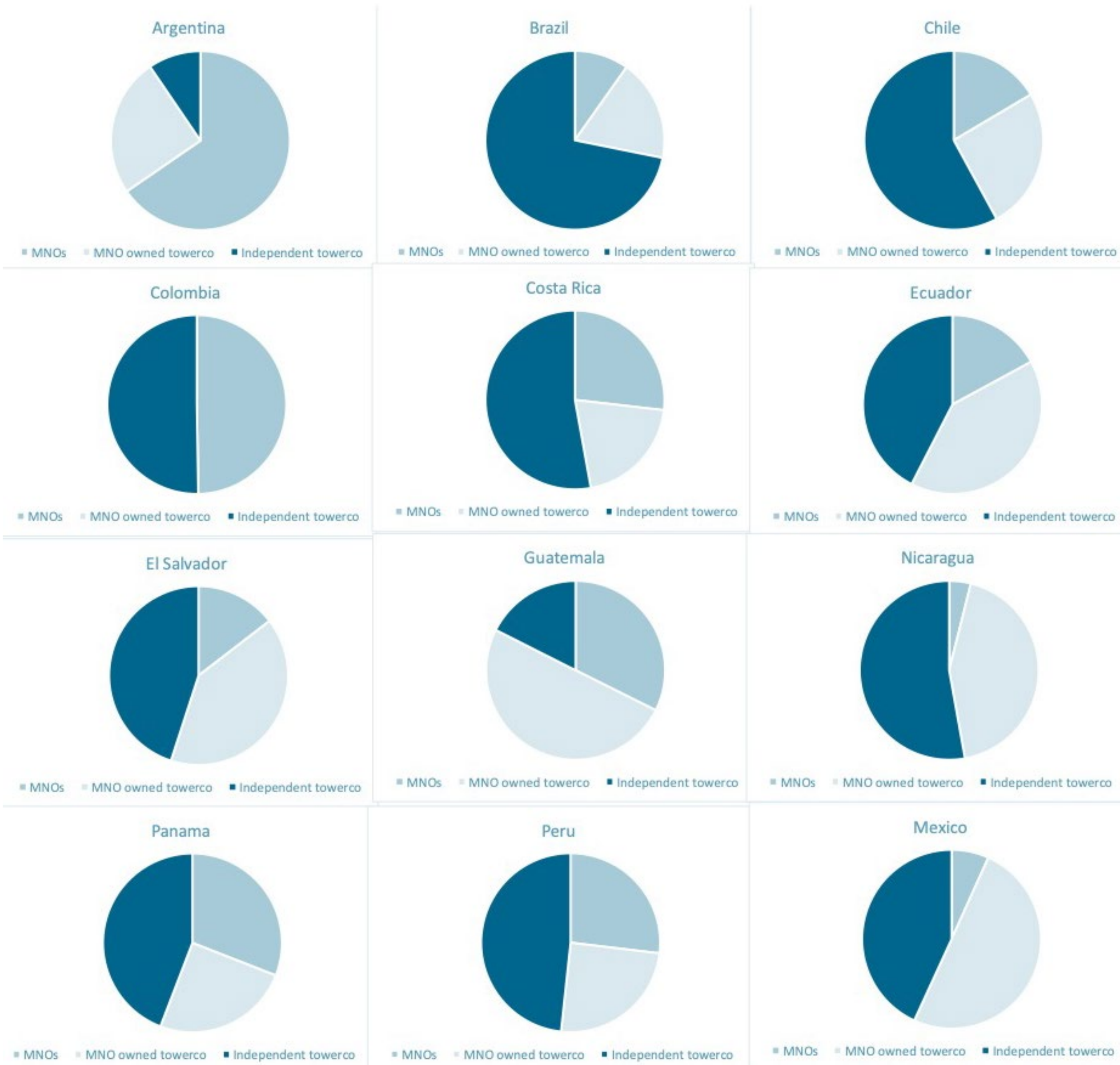
Country	Tower type	2016	2017	2018	2019	2020	2021	2022q2
Argentina	MNOs	- - -	- - -	- - -	16,000	16,000	11,565	11,565
	MNO owned towerco	- - -	- - -	- - -	335	335	4,435	4,435
	Independent towerco	- - -	- - -	- - -	944	1,064	1,577	1,683
Brazil	MNOs	19,607	17,000	17,000	19,000	19,000	6,700	6,700
	MNO owned towerco	1,655	1,655	1,655	1,869	3,885	12,539	12,539
	Independent towerco	37,096	38,302	41,123	43,921	45,657	48,664	49,086
Chile	MNOs	6,371	6,371	6,371	6,455	4,475	1,640	1,640
	MNO owned towerco	328	327	327	368	540	2,545	2,545
	Independent towerco	1,941	2,228	2,270	2,341	4,014	5,256	5,765
Colombia	MNOs	10,300	10,300	9,500	9,520	8,800	8,940	8,940
	MNO owned towerco	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	Independent towerco	5,059	5,148	6,942	8,032	8,673	9,003	9,032
Costa Rica	MNOs	1,450	1,450	1,516	1,585	1,615	1,150	1,150
	MNO owned towerco	216	248	272	298	302	871	871
	Independent towerco	1,389	1,604	1,839	2,116	1,863	2,234	2,265
Ecuador	MNOs	- - -	- - -	- - -	- - -	- - -	1,000	1,000
	MNO owned towerco	- - -	- - -	- - -	- - -	- - -	2,368	2,368
	Independent towerco	- - -	- - -	- - -	- - -	- - -	2,562	2,484

Country	Tower type	2016	2017	2018	2019	2020	2021	2022q2
El Salvador	MNOs	1,000	800	737	735	735	415	415
	MNO owned towerco	- - -	- - -	- - -	- - -	- - -	1,153	1,153
	Independent towerco	264	467	946	993	1,025	1,282	1,283
Guatemala	MNOs	2,700	2,700	2,700	2,810	2,810	2,110	2,110
	MNO owned towerco	- - -	- - -	- - -	- - -	- - -	3,264	3,264
	Independent towerco	938	976	1,042	1,192	1,192	1,197	1,144
Mexico	MNOs	2,000	2,000	2,000	2,300	2,500	2,500	2,500
	MNO owned towerco	14,708	14,863	15,559	16,308	17,297	18,568	19,742
	Independent towerco	12,361	12,934	13,989	15,266	15,038	15,992	16,796
Nicaragua	MNOs	350	350	350	375	375	70	70
	MNO owned towerco	- - -	- - -	- - -	- - -	- - -	774	774
	Independent towerco	675	805	881	989	989	941	945
Panama	MNOs	790	790	790	820	820	680	680
	MNO owned towerco	- - -	- - -	- - -	- - -	- - -	547	547
	Independent towerco	787	849	866	906	906	984	971
Peru	MNOs	6,800	7,860	7,790	7,810	8,000	4,000	4,000
	MNO owned towerco	900	849	849	1,608	1,925	3,687	3,687
	Independent towerco	1,467	1,895	2,482	3,034	4,731	7,078	7,181
Total	MNOs	51,368	49,621	48,754	67,410	65,130	40,770	40,770
	MNO owned towerco	17,807	17,942	18,662	20,786	24,284	50,751	51,925
	Independent towerco	61,977	65,208	72,380	79,735	85,152	96,770	98,635

Source: TowerXchange; Telecom Advisory Services analysis

A view of tower industry structure by Latin American country indicates a regional average where half of the installed base is run by independent companies. However, the percentage of towers managed by independent companies ranges from high (Guatemala, and Brazil) to low (Colombia, and Argentina), and some countries presenting a more balanced share (Ecuador, El Salvador, and Nicaragua) (see graphic 4-1).

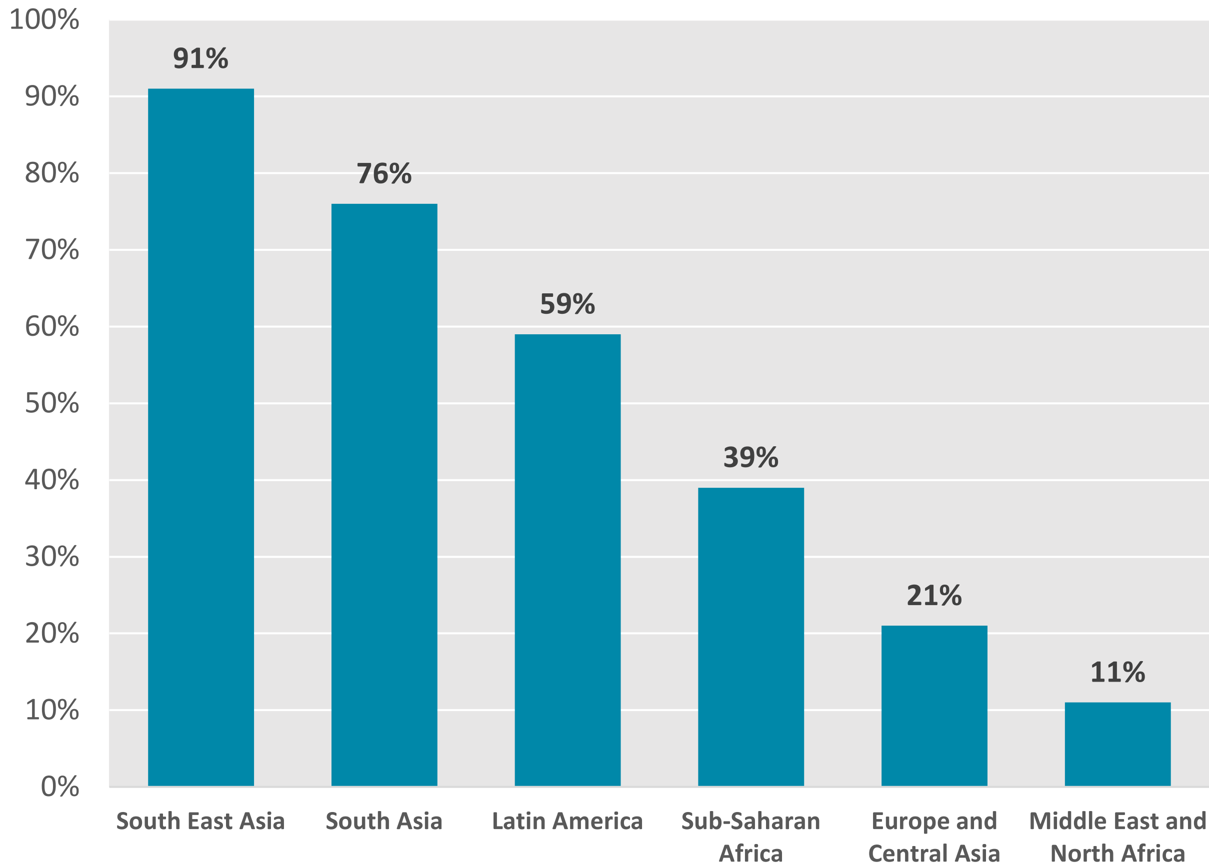
Graphic 4-1. Latin America: Tower market structure (2021)



Source: TowerXchange; Telecom Advisory Services analysis

When compared against other regions, Latin America is a fairly developed tower company market, behind South and South Emerging Asia (see graphic 4-2).

Graphic 4-2. Share of towers managed by Tower Companies



Source: Houngbonon, G; Rossotto, C., and Strusani, D. (2021). Enabling a competitive mobile sector in emerging markets through the development of tower companies. EM Compass Note 104 (June); Washington, DC: International Finance Corporation, World Bank.

The gradual divestiture of MNOs of most of their tower infrastructure and the combined development of MNO-owned towercos and independent companies in Latin America raise the question of the impact of tower ownership on industry development. In other words, is the share of independent tower “specialists” related to industry performance, as measured by capital efficiency, network deployment, service adoption and quality? This will be the subject of the next chapter.

5. THE INDEPENDENT LATIN AMERICAN TOWER INDUSTRY: AN ASSET FOR DEVELOPMENT OF THE WIRELESS COMMUNICATIONS SECTOR

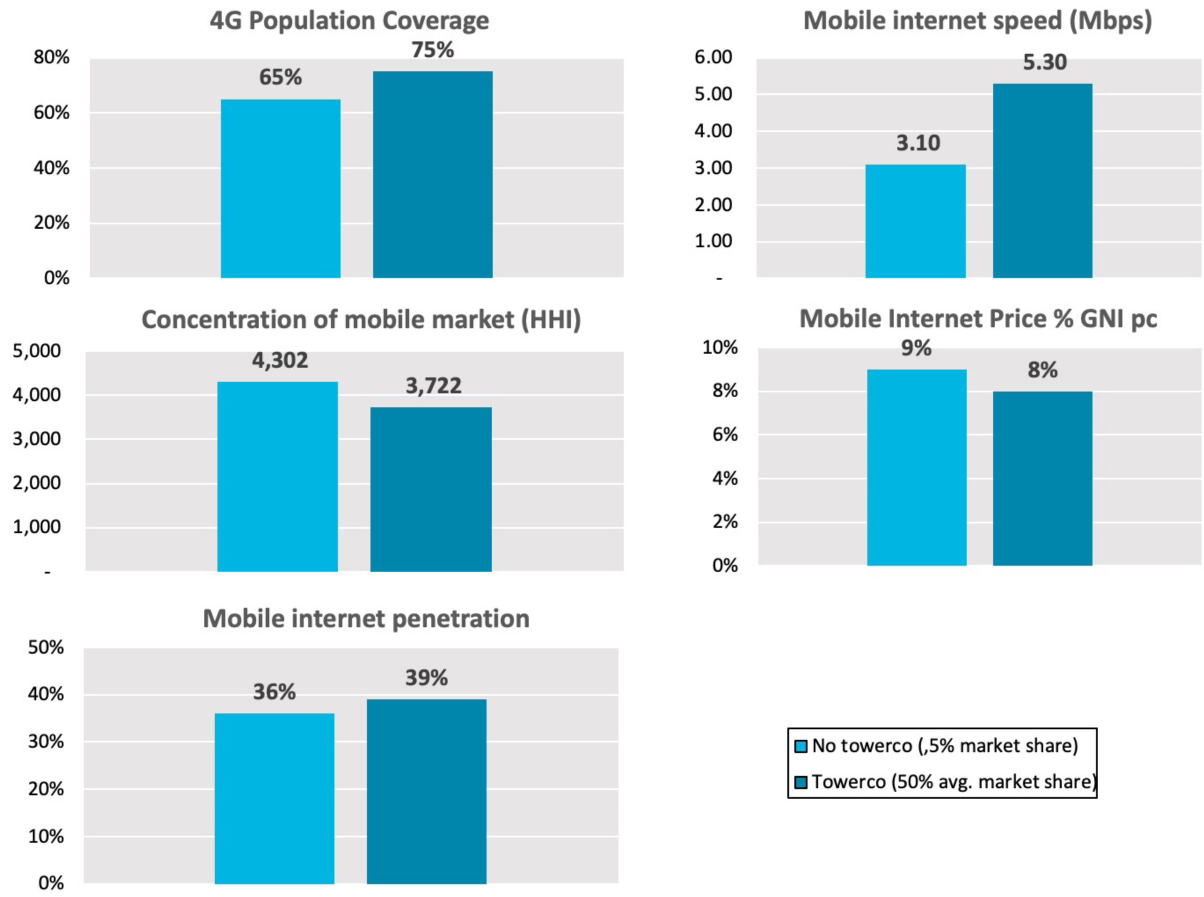
Chapter 4 has provided evidence of the shifts occurring worldwide regarding the tower industry structure, in particular the emergence of the independent tower sector. Are the shifts in tower ownership having an impact on industry performance? In economic terms, does the emergence of a “specialist” sector focused exclusively on passive infrastructure have an impact of the wireless industry value chain?

There are two approaches to generating answers to these questions. A correlation-based approach divides a sample of countries between those that witness a sizable growth of the tower company sector and those that not and measures a series of metrics that assess the development of the wireless industry. If industry/connectivity is more developed in countries with sizable presence of tower companies, then it can be concluded that there is some association. However, correlation cannot be assumed to be causation (in other words, that tower company sector emergence **leads** to higher development of the wireless sector. For this purpose, an econometric modelling is required. This chapter provides the two sets of analyses: a correlational one in section 5.1 and an econometric one in section 5.2.

5.1. Does the emergence of the tower company sector have an impact on industry deployment? A correlational analysis

The only empirical research on this subject existing until now was published by economists of the World Bank’s IFC. Houngbonon et al (2021) analyzed 56 towerco markets calculating the correlation between the market success of the towerco business and the development of mobile connectivity markets. The study defines towercos as “specialized companies focused on the management of mobile network infrastructure such as towers and small cell sites” although it does not differentiate between joint ventures between mobile network operators, independent companies, and joint ventures of independent entities and MNOs. Despite this lack of differentiation among ownership of tower companies, the study indicates that there is a positive correlation between the market success of the towerco business and the development of mobile connectivity markets. For example, the analysis provides evidence that in those markets where the penetration of the towerco business model is deeper (namely a market share over 50% vs. countries with a market share lower than 5%), 4G population coverage is 10 percentage points higher; median download speed is 2.2 Mbps higher; the price of mobile Internet, in percentage of monthly income, is 1 percentage point lower; and markets are 13 percent less concentrated (see graphic 5-1).

Graphic 5-1. Towercos and mobile connectivity



Source: Houngbonon, G; Rossotto, C., and Strusani, D. (2021). Enabling a competitive mobile sector in emerging markets through the development of tower companies. EM Compass Note 104 (June); Washington, DC: International Finance Corporation, World Bank.

We have replicated this analysis for Latin America, enhancing the definition of towercos (differentiating between MNO-owned, and independents) including the metric of towers per capita, and expanding the indicators to cover investment. Based on these two metrics, Latin American countries can be grouped in three groups (see Table 5-1, panel A). To gain statistical and economic representation, we re-grouped the main group and the laggards and set two categories: Leaders (where share of towers owned by independent players is higher than 52%, and independent towers per capita exceeds 225) and the rest of countries (where independent company share is below 52% and towers per capita is under 225) (see table 5-1).

Table 5-1. Country groupings by independent towercos development

Panel A

	Lead		Main		Laggards	
	Conditions	Countries	Conditions	Countries	Conditions	Countries
Share of independent towercos	**>52%**	• Brazil (72%) • Chile (56%) • Costa Rica (53%) • Nicaragua (53%)	**44-52%**	• Colombia (50%) • El Salvador (45%) • Panama (44%) • Peru (48%) •	**<44%**	• Argentina (9%) • Ecuador (43%) • Guatemala (18%) • Mexico (43%)
Towers per capita owned by independent towercos	**>225**	• Brazil (229) • Chile (267) • Costa Rica (431) • Panama (227)	**144-225**	• Colombia (176) • Ecuador (144) • El Salvador (197) • Nicaragua (144) • Peru (209)	**<144**	• Argentina (34) • Guatemala (65) • Mexico (124)

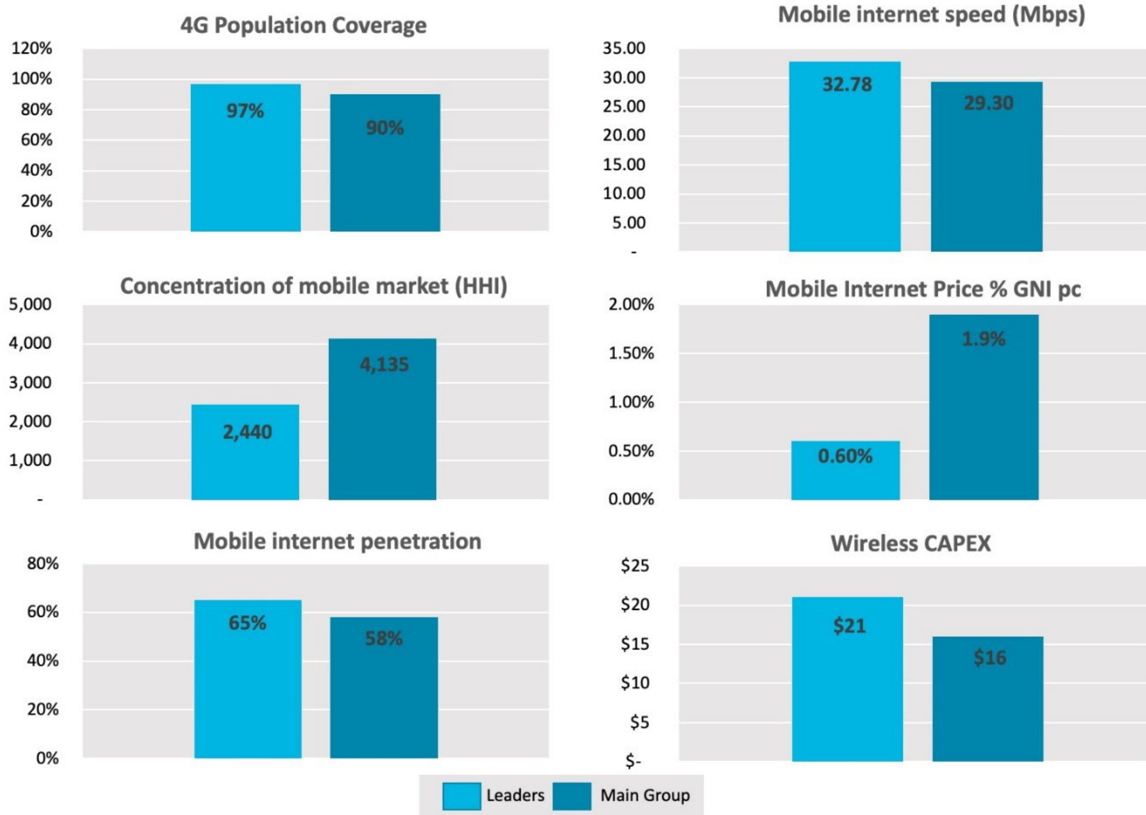
Panel B

Lead countries	Main group
Brazil Chile Costa Rica Panama	Argentina Colombia Ecuador El Salvador Guatemala Mexico Nicaragua Peru

Source: Telecom Advisory Services analysis

A visual analysis of the economic impact of the tower industry indicates that countries with a larger share of independent towercos and higher tower deployment exhibit higher performance metrics than the rest (see graphic 5-2).

Graphic 5-2. Latin America: Towercos and wireless industry development



Source: Telecom Advisory Services analysis

An association of independent tower companies share of total plant with improved industry performance metrics (higher than those calculated in the IFC study):

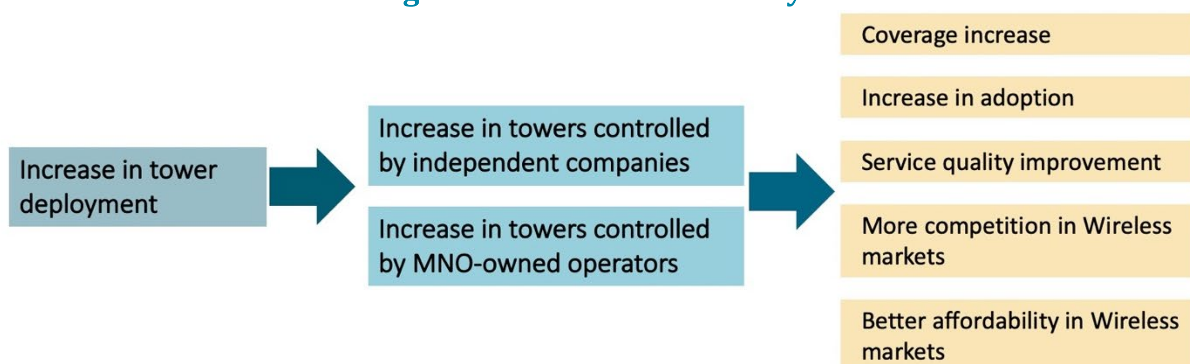
- Better coverage and access: Country leaders depict seven percentage points higher than the rest of countries (97& vs 90%)
- Faster speed: wireless broadband is 12% faster among country leaders than the rest (33 Mbps vs. 29 Mbps)
- More investment: capital spending is 31% higher in country leaders (USD 21 per capita vs. USD 16 per capita)
- Better affordability: wireless broadband services represent 1/3 of costs in terms of per capita in country leaders relative to the rest of countries (0.6% vs. 1.9%)
- Higher adoption of mobile broadband service: country leaders exhibit higher broadband adoption than in the rest (65% vs. 58%)
- More intense competition: wireless competition is more intense in country leaders (41% less concentration)

These results are in line – probably more powerful – thathose from the aforementiong global analysis by Houngbonon et al (2021). However, these associations are based on correlations; this requires a causal assessment which is presented in the econometric modelling of the next section.

5.2. An econometric analysis of the impact of the independent Latin American tower industry

The objective of this analysis is to go beyond the previous correlational analysis and demonstrate the causal relationship between an increase in the number of towers on several mobile industry indicators. In particular, we test, estimating different econometric models, the impact of an increase in the number of total towers, independent towers and MNO-owned towers on industry performance. Among the dependent variables to be considered, we include the increase in 4G coverage, the increase in mobile broadband adoption, quality enhancement of mobile service as measured through mobile broadband download speed, the increase in competition in the mobile market and the improvement in the affordability levels of mobile service (see Figure 5-1).

Figure 5-1. Focus of the analysis



Source: Telecom Advisory Services, LCC

The focus of this chapter is to add to the understanding of causal relationships, demonstrating that the increase in towers controlled by independent companies has a differentiated (i.e., positive and bigger) impact on the development of the wireless industry and, in turn, to economic development. We first introduce the theoretical framework and describe the data upon which the analysis will be based on. Following this, we present the results of the empirical modelling and, on these bases, discuss the implications.

Theoretical framework

In order to quantify the relationship between tower deployment and mobile sector performance, we first build an econometric model (referred to as "a" in the results section) where the different dependent variables (4G coverage, mobile broadband adoption, quality of mobile service measured through mobile broadband download speed, level of competition in the mobile market and the level of affordability of mobile service) are explained by the number of towers (total towers, independent towers and MNO towers) and GDP per capita. Since the question to be answered is the relationship between the increase in the number of towers and the increase in the mobile indicators, the natural logarithm is taken on both sides of the equation to obtain results that indicate the relationship between a 1% increase in the independent variable (number of towers) and a percentage increase in the dependent variables (mobile market indicators) (see Equation 1).

$$\ln(Dependent\ variables) = \beta_0 + \beta_1 . \ln(Tower\ deployment)_{it} + \beta_2 . (GDP\ Per\ Capita)_{it} + \mu_{it} \quad (1)$$

The following indicators are included in the econometric model:

- Dependent Variables:
  - 4G Coverage (Source: GSMA)
  - Mobile broadband adoption (Source: GSMA)
  - Mobile quality of service measured by mobile broadband download speed (Source: Ookla/Speedtest)
  - Level of competition in the mobile market measured by HHI (Source: GSMA)
  - Affordability level of a basic mobile basket (Source: International Telecommunication Union)
- Number of towers:
  - Total Towers
  - MNO Towers
  - Independent Towers
- GDP per capita (Source: IMF)

In addition, an additional model (called "b" in the results section) is proposed for robustness, which includes a country fixed effect control that seeks to capture the effects of each country that are not considered through the inclusion of GDP per capita (see Equation 2).

$$\ln(Dependent\ variables) = \beta_0 + \beta_1 . \ln(Tower\ deployment)_{it} + \beta_2 . (GDP\ Per\ Capita)_{it} + \beta_3 . (Country)_t + \mu_{it} \quad (2)$$

This analysis is based on information provided by Tower Xchange for 12 countries in the region: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Mexico, Nicaragua, Panama, and Peru. The available data covers the period from 2016 to 2022, except that there is no information available for Argentina between 2016 and 2018; and there is no information available for Ecuador between 2016 and 2020 Thus, there are 76 observations across 12 countries and 7 years (see table 5-2).

Table 5-2. Countries and years with available information on the number of towers

Country	Towercos	2016	2017	2018	2019	2020	2021	2022
Argentina	Independent				+	+	+	+
	MNO				+	+	+	+
Brazil	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+
Chile	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+
Colombia	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+
Costa Rica	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+
Ecuador	Independent						+	+
	MNO						+	+
El Salvador	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+
Guatemala	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+
Mexico	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+
Nicaragua	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+
Panama	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+
Peru	Independent	+	+	+	+	+	+	+
	MNO	+	+	+	+	+	+	+

Source: Telecom Advisory Services analysis, based on information provided by Tower Xchange

The econometric model allows testing the hypotheses presented in the theoretical framework. Also, through a mean difference test, we analyze whether the results found for the independent tower models are statistically different or not in relation to the MNO-owned tower models.

Impact of independent tower deployment on 4G coverage

According to the models presented in table 6-4, an increase in the number of independent towers of 10% is associated with an increase in 4G coverage levels of 0.96% (model without fixed effects) or 5.54% (model with fixed effects). Additionally, it is also found that 4G coverage increases by 0.95% for a 10% increase in total towers (11.40% in the model with fixed effect). This result for MNO towers is 0.74% and 4.33%. In order to be conservative with the results found, we opted for the model without fixed effects for the conclusions.

Table 5-3. Econometric models with dependent variable coverage

Ln (Coverage)	Total Towers		MNO Towers		Independent Towers	
	(a)	(b)	(a)	(b)	(a)	(b)
Ln (Towers)	0.094525 ***	1.140173 ***	0.0740873 ***	0.4328737 ***	0.0959371 ***	0.5540434 ***
	(0.0323773)	(0.1489519)	(0.0267938)	(0.1495521)	(0.0316031)	(0.0853065)
Ln (GDP per cap)	0.1590487 **	0.164351	0.163087 ***	0.5308929	0.171005 **	0.2182255
	(0.0672837)	(0.3374592)	(0.057997)	(0.4358097)	(0.0698268)	(0.3627445)
E.F.	No	Country	No	Country	No	Country
Years	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022
Countries						
Remarks						
R^2	0.2796	0.6467	0.2611	0.3946	0.275	0.591

NOTE: ***, **, * significant at 1%; 5% and 10% respectively

The ratio is statistically significantly higher for the independent towers in relation to the MNO towers at 0.22% for each 10% increase in towers (model without country fixed effects). For the model with fixed effects, this difference rises to 1.21% for each 10% increase in towers (see Table 5-4).

Table 5-4. Test of difference of means between independent tower model and MNO tower model (with dependent variable coverage).

	Difference in averages	
	(a)	(b)
Difference	0.021849800 ***	0.121169700 ***
95% interval	0.012459017 0.031240583	0.082146716 0.160192684

NOTE: ***, **, * significant at 1%; 5% and 10% respectively

Impact of independent tower deployment on mobile broadband adoption

An increase in the number of independent towers of 10% is associated with an increase in wireless broadband adoption levels of 0.51% (model with no fixed effects) or 1.94% (model with fixed effects). In addition, it is also found that adoption increases by 0.68% for a 10% increase in total towers (4.42% in model with fixed effects). This result for MNO towers is 0.33% and 1.96% (See Table 5-5). Again, in order to be conservative, we opted for the model without fixed effects for the conclusions.

Table 5-5. Econometric models with dependent variable adoption

Ln (Adoption)	Total Towers		MNO Towers		Independent Towers	
	(a)	(b)	(a)	(b)	(a)	(b)
Ln (Towers)	0.0681056 ***	0.4417392 ***	0.0333624 **	0.1962655 ***	0.0514762 ***	0.193752 ***
	(0.021641)	(0.0442643)	(0.0156521)	(0.0488159)	(0.0165255)	(0.0290093)
Ln (GDP per cap)	0.22561 ***	-0.0836802	0.2547614 ***	0.0502101	0.2477615 ***	-0.0463682
	(0.0453197)	(0.1002834)	(0.0345798)	(0.1422545)	(0.0385214)	(0.1233549)
E.F.	No	Country	No	Country	No	Country
Years	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022
Countries						
Remarks						
R^2	0.6905	0.9233	0.7311	0.8415	0.714	0.8838

NOTE: ***, **, * significant at 1%; 5% and 10% respectively.

The ratio is statistically significantly higher for the independent towers relative to the MNO towers at 0.18% for every 10% increase in towers (model without fixed effect). For the model with fixed effect, there is no significant difference between the two results (see Table 5-6).

Table 5-6. Test of difference of means between independent tower model and MNO tower model (with dependent variable adoption).

	Difference in averages	
	(a)	(b)
Difference	0.018113800 ***	-0.002513500
95%	0.012954892	-0.015383914
interval	0.023272708	0.010356914

NOTE: ***, **, * significant at 1%; 5% and 10% respectively.

Impact of independent tower deployment on mobile broadband quality of service

An increase in the number of independent towers of 10% is associated with an increase in service quality levels (measured as mobile broadband download speed) of 2.05% (model with no fixed effect) or 8.25% (model with fixed effects). In addition, it is also found that the quality-of-service increases by 2.39% for a 10% increase in total towers (19.57% in the model with fixed effects). This result for MNO towers is 1.71% and 8.21% (See Table 5-7). In order to be conservative with the coefficients found, we opted for the model without fixed effects for the conclusions.

Table 5-7. Econometric models with dependent variable quality

Ln (Speed)	Total Towers		MNO Towers		Independent Towers	
	(a)	(b)	(a)	(b)	(a)	(b)
Ln (Towers)	0.2394347 ***	1.956797 ***	0.1706196 ***	0.8205748 ***	0.2052605 ***	0.8250954 ***
	(0.068728)	(0.2219085)	(0.0467019)	(0.233331)	(0.0626096)	(0.143085)
Ln (GDP p cap)	-0.1616302	-0.3890475	-0.1412978	0.2179391	-0.1099319	-0.1976697
	(0.1432014)	(0.5027467)	(0.1013945)	(0.6799496)	(0.1413069)	(0.6084333)
E.F.	No	Country	No	Country	No	Country
Years	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022
Countries						
Remarks						
R^2	0.1848	0.6608	0.1683	0.3625	0.1393	0.5023

NOTE: ***, **, * significant at 1%; 5% and 10% respectively.

The ratio is statistically significantly higher for the independent towers relative to the MNO towers at 0.35% for every 10% increase in towers (model without fixed effects). For the model with fixed effect, there is no significant difference between the two results (see Table 5-8).

Table 5-8. Test of difference of means between independent tower model and MNO tower model (with dependent variable quality).

	Difference in averages	
	(a)	(b)
Difference	0.034640900 ***	0.004520600
95%	0.016937334	-0.057516063
interval	0.052344466	0.066557263

NOTE: ***, **, * significant at 1%; 5% and 10% respectively.

Impact of independent tower deployment on mobile competition

An increase in the number of independent towers of 10% is associated with an increase in mobile market competition levels (measured as a decrease in HHI) of 0.46% (model with no fixed effects) or 0.47% (model with fixed effects). Additionally, it is also found that mobile market competition increases by 0.76% for a 10% increase in total towers (0.81% in the model with fixed effects). This result for MNO towers is not significant (See Table 5-9). Again, to be conservative with the results found, we opted for the model without fixed effects for the conclusions.

Table 5-9. Econometric models with dependent variable mobile market concentration

Ln (moving HHI)	Total Towers		MNO Towers		Independent Towers	
	(a)	(b)	(a)	(b)	(a)	(b)
Ln (Towers)	-0.0758692 ***	-0.0813904 ***	-0.0142229	-0.0145584	-0.0463746 ***	-0.0474173 ***
	(0.0200453)	(0.0210279)	(0.0170784)	(0.0178766)	(0.0106987)	(0.0109227)
Ln (GDP p cap)	-0.021163	-0.0101682	-0.0536181	-0.0409802	-0.0204345	-0.0078265
	(0.0450328)	(0.0476399)	(0.048378)	(0.0520942)	(0.0437433)	(0.046446)
E.F.	No	Country	No	Country	No	Country
Years	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022
Countries						
Remarks						
R^2	0.0419	0.9866	0.1107	0.9835	0.0506	0.9872

NOTE: ***, **, * significant at 1%; 5% and 10% respectively

The ratio is statistically significantly higher for the independent towers relative to the MNO towers at 0.32% for every 10% increase in towers (model without fixed effects). For the model with fixed effect, this difference rises marginally to 0.33% for every 10% increase in towers (see Table 5-10).

Table 5-10. Test of difference of means between independent tower model and MNO tower model (with dependent variable mobile market concentration).

	Difference in averages	
	(a)	(b)
Difference	-0.032151700 ***	-0.032858900 ***
95% interval	-0.036719361	-0.037607124
	-0.027584039	-0.028110676

NOTE: ***, **, * significant at 1%; 5% and 10% respectively

Impact of independent tower deployment on mobile broadband affordability

An increase in the number of independent towers of 10% is associated with an improvement in the level of mobile affordability (measured as a decrease in service price relative to the monthly GDP per capita) of 3.18% (model with no fixed effects) or 3.86% (model with fixed effects).

In addition, it is also found that the affordability of the mobile market improves by 3.27% for a 10% increase in total towers (7.09% in the model with fixed effects). This result for MNO towers is not significant (See Table 5-11). In order to be conservative with the results found, we opted for the model without fixed effects for the conclusions.

Table 5-11. Econometric models with dependent variable mobile affordability

Ln (Affordability measured as % of GDP)	Total Towers		MNO Towers		Independent Towers	
	(a)	(b)	(a)	(b)	(a)	(b)
Ln (Towers)	-0.3267791 ***	-0.7094847 ***	-0.1002962	-0.0838212	-0.3175821 ***	-0.3858228 ***
	(0.1215102)	(0.2007087)	(0.1096487)	(0.1813382)	(0.0790925)	(0.0978736)
Ln (GDP pcap)	-0.982563 ***	-0.2421697	-1.149615 ***	-0.2821037	-1.055496 ***	-0.2077791
	(0.2537373)	(0.4117507)	(0.254749)	(0.4591996)	(0.2229642)	(0.4023775)
E.F.	No	Country	No	Country	No	Country
Years	2016-2021	2016-2021	2016-2021	2016-2021	2016-2021	2016-2021
Countries						
Remarks						
R^2	0.6907	0.9637	0.7667	0.9548	0.7542	0.9654

NOTE: *, **, * significant at 1%; 5% and 10% respectively**

The ratio is statistically significantly higher for the independent towers in relation to the MNO towers at 2.17% for each 10% increase in towers (model without fixed effects). For the model with fixed effect, this difference rises to 3.02% for each 10% increase in towers (see Table 5-12).

Table 5-12. Test of difference of means between the independent tower model and the MNO tower model (with dependent variable mobile affordability).

	Difference in averages	
	(a)	(b)
Difference	-0.217285900 ***	-0.302001600 ***
95% interval	-0.250729989	-0.352976195
	-0.183841811	-0.251027005

NOTE: ***, **, * significant at 1%; 5% and 10% respectively

5.3. Conclusion and implications

The evidence presented in this chapter has been consistent across both the correlational and econometric analyses.

From a correlational standpoint, Latin American countries with a larger share of independent tower companies and higher tower deployment exhibit higher performance metrics than the rest:

- Better coverage: Country leaders depict seven percentage points higher coverage than the rest of countries
- Faster speed: wireless broadband is 12% faster among country leaders than the rest (33 Mbps vs. 29 Mbps)

- More investment: capital spending is 31% higher in country leaders (USD 21 per capita vs. USD 16 per capita)
- Better affordability: wireless broadband services represent 1/3 of costs in terms of per capita in country leaders relative to the rest of countries (0.6% vs. 1.9%)
- Higher adoption of mobile broadband service: country leaders exhibit higher broadband adoption than in the rest (65% vs. 58%)
- More intense competition: wireless competition is more intense in country leaders (41% less concentration)

From an econometric standpoint, the causality between independent tower companies and wireless industry development has been proven:

- An increase in the number of independent towers of 10% leads to, at least, an increase in 4G coverage levels of 0.96%
- An increase in the number of independent towers of 10% is associated with an increase in wireless broadband adoption levels of 0.51%
- An increase in the number of independent towers of 10% is associated with an increase in service quality levels (measured as mobile broadband download speed) of 2.05%
- An increase in the number of independent towers of 10% is associated with an increase in mobile market competition levels (measured as a decrease in the Herfindahl Hirschman Index that measures industry concentration-a lower index depicts more intense competition) of 0.46%
- An increase in the number of independent towers of 10% is associated with an improvement in the level of mobile affordability (measured as a decrease in service price relative to the monthly GDP per capita) of 3.18%

Given this evidence, it would be important for Latin American countries to maximize the development of the independent tower industry. This effect is, however, contingent upon several regulatory and public policy initiatives. In other words, the regulatory and policy variables play an important role in the development of the independent tower company sector beyond the willingness of the private sector to invest. The next chapter will focus on some of these variables and assess where the region is relative to their fulfillment.

6. REGULATION AND PUBLIC POLICIES AFFECTING THE TOWER INDUSTRY: A KEY REQUIREMENT

Chapter 5 has quantitatively demonstrated the causal relationship between the growth of an independent tower sector and the development of the wireless industry across all relevant indicators, ranging from competition and investment maximization to service coverage affordability and quality. In light of this evidence, it is relevant to examine whether the current regulatory frameworks and public policies favor the development of the sector. The methodology followed in this case is to outline a list of regulatory and policy requirements that are critical to foster the development of the sector. Once formalized, the list was validated through the examination of international best practices. Finally, we will examine the state of such specifications in Latin America.

6.1. Regulations and policies ensuring the tower industry sustainability

A review of the research literature and interviews of regulators and policymakers have led to the identification of six types of initiatives that can contribute to the development and sustainability of an independent tower sector:

- No need for concession and the need for fast permit approvals
- Regulations to prevent over-deployment
- Establishment of caps on fees and taxes, and rights of construction
- Policies to promote development of infrastructure sharing for present and future technologies, in particular 5G
- Absence of price regulations of tower company contracts with service providers
- Long-term guarantees in regulations and permits

Each type is explained in detail in turn.

No need for concession and the need for fast permit approvals

A concession is a grant of rights, land or property by a government, or local authority to a private company that has the exclusive right to operate, maintain and invest in the facility under conditions of significant market power. Common concession agreements take place in water supply, transportation highways, and mining.

The construction of a cell tower does not rely on a public good, as is the case of spectrum. Therefore, it shouldn't be ruled by a concessionary framework. Furthermore, the tower industry is not a natural monopoly requiring a concessionary regime, like in the case of power transmission, and railways.[18]

[18] See Kerf, M. (1998). *Concessions for infrastructure: A guide to their design and award*. World Bank Technical Paper no. 399.

At present, many Latin American municipalities have constitutional autonomy to grant installation permits for antennas and rights of way for fiber rollout. Accordingly, they can interfere with the provision of telecommunications/internet services that are under federal authority. Frequently, in many countries of the region, local regulations have been imposed over federal authority, becoming very restrictive, not transparent, bureaucratic, and even irrational for obtaining municipal permits. Local governments or municipalities exercise power by applying their own interpretations about non-ionizing radiation and fix their own limitations on minimum distances and tower heights, use of public spaces or how environmental impact should be measured. This has meant that there are countless laws that regulate elements that are quite standard and common (see Table 6-1).

Table 6-1: Main regulations on local infrastructure deployment

Administrative	Environmental	Health	Technological
• Request for unnecessary or excessive information • Request for information by multiple institutions • Lack of regulatory uniformity • Lack of regulations or ignorance • Lack of knowledge regarding the Good Practice code • Absence or extension of deadlines • Establishment of public consultation • Lack of regulation regarding rights of way • Lack of continuity for local decisions • Disproportionate or disparate rates • Lack of legal certainty in appeal processes	• Minimum distance between antennas • Minimum Area Requirement • Land use restriction • Designation of special places • Excessive camouflage requirements • Authorization by aeronautical authorities • Prohibition in places of cultural and heritage conservation • Prohibition on the use of land that is under rural or natural preservation	• Lack of exposure limit regulations for non-ionizing radiation • Lack of dissemination of current regulations and international recommendations • Approval of different exposure limits and control procedures • Use of different exposure limits depending on the area • Request for studies by multiple institutions • High periodicity in the delivery of radiation reports	• Prohibition of shared use • Obligation of operators to prepare their infrastructure for shared use • Lack of differentiation between macro and small cells • Establishment of different rates per technology

Source: CAF/Analysis Mason (2017)[19]

These barriers increase the opportunity cost for deploying passive infrastructure, increasing the cost of deployment. Municipal jurisdictions can become a "choke" point in terms of processing authorizations or imposing extremely high contributions from tower companies. Interestingly enough, in other infrastructure areas (for example, ports), the national authorities are increasingly gaining jurisdictional leverage over local governments. The

[19] Summarized by the authors based on the "Mobile Broadband Expansion" CAF report (2017) by Analysis Mason.

concept at play in this case is that "vertical policy coherence". Under this term, a national imperative, such as addressing the digital divide or deploy 5G for industry development reasons, overrides a local government consideration. A number of approaches are being implemented to address dual jurisdiction in the field of infrastructure development.

Regulations to prevent over-deployment

Tower over-deployment, in many cases driven by straight financial speculation, is a frequent feature in Latin America. As pointed out in the assessment of tower density presented in chapter 4, some countries in the region depict an extremely large number of towers per population and wireless subscribers. The consequences of this situation are not only environmental but also economic. A simplified economic-financial model developed for this study indicates that unless a single tower is not supporting the radios of more than one operator (preferably three), its profitability is questionable (detailed structure of the model is included in appendix A).

The model estimates the economics and financials of a single tower in three settings (urban, suburban, rural) focusing on three market conditions:

- Tenant ratio: estimate revenues from one, two, three, four operators
- Time horizon: from 1 to 10 years
- Regional disparities: urban, suburban, and rural

Assumptions are made, based on industry experience in the region about capital required to build a tower, operating expenditures, depreciation rates, taxes, and cost of capital. It is important to note that, while a 25% tax rate was included in the financial analysis, it corresponds to conventional corporate levies, hereby excluding additional municipal fees and permits that can add to the fiscal burden (see detail below). On this basis, the model projects free and accumulated cashflows and Net Present Value to provide metrics of profitability. The Net Present Value for the three environments under consideration are presented in table 6-2.

Table 6-2. Latin America: Net Present Value (10 years - without terminal value)

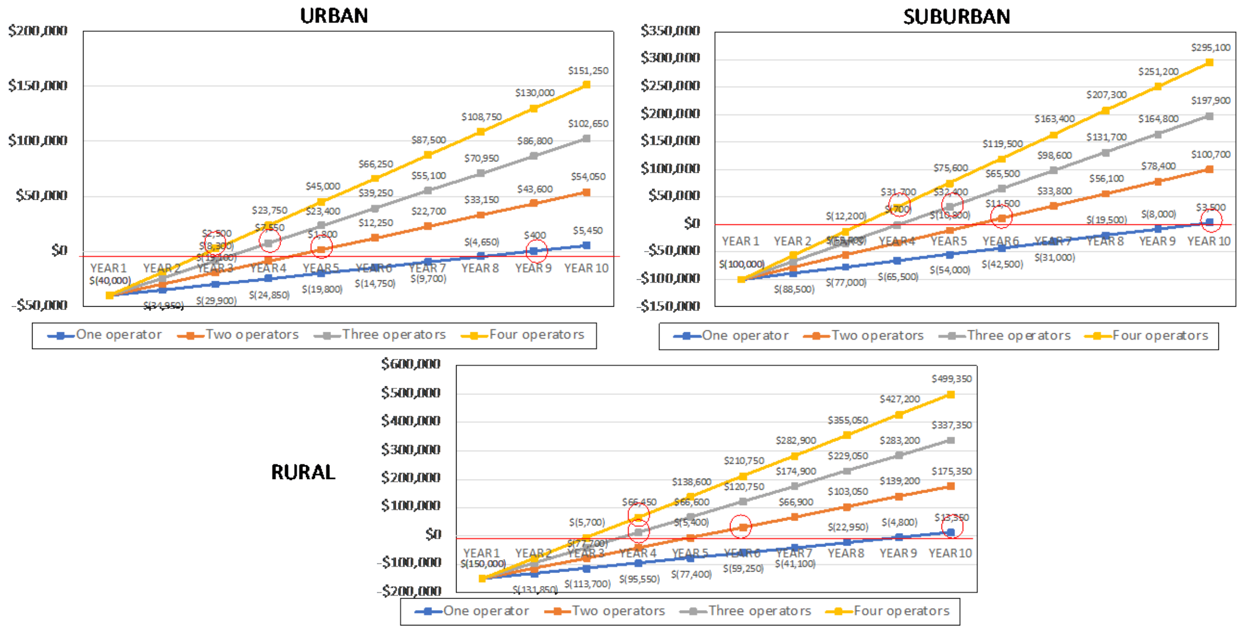
Number of Operators	Urban	Suburban	Rural
One	($5,996.88)	($22,023.29)	($27,410.06)
Two	$27,752.38	$45,475.23	$85,087.48
Three	$61,501.64	$112,973.75	$197,585.02
Four	$95,250.91	$180,472.28	$310,082.55

Source: Industry interviews; Telecom Advisory Services analysis

As indicated in table 6-1, the business case of a single tower is highly contingent upon the number of operators served by the infrastructure. In all three settings, the NPV if only one tenant were to be served is always negative. This situation drives a related perverse effect: under these financials, tower providers not subject to quality of construction certification would underinvest in capital to improve their return. With this derived effect, the wireless industry and, ultimately, the consumer welfare would be negatively affected. This is why it is so relevant to develop a whole cycle of permitting, deployment and construction under consistent processes and reasonable timeframes.

In addition to NPV estimation, the model estimates cumulative cashflows to determine when the different investment scenarios turn cash positive (see graphic 6-1).

Graphic 6-1. Latin America: Cumulative Cashflows



Source: Industry interviews; Telecom Advisory Services analysis

As indicated in the Graphic 6-1, when considering cumulative cashflows, under one-tenant condition, the financials turn cash positive only in year ten both in the suburban and rural scenarios.

The policy and regulatory implications of the financial analysis are clear:

- Unless **distance between towers and sharing mechanisms** are not formalized from a regulatory standpoint, the long-term viability of independent tower infrastructure is questionable in suburban and rural settings. The financial metrics exhibit a significant change from 1 to 2 tenant ratios.
- Heavy initial CAPEX should be accompanied by **relatively stable and predictable rules** to ensure profitability and re-investment. While the financials are calculated over a ten-year timeframe, stability and predictability of regulatory frameworks are critical industry requirement.
- Regional disparities in urban, suburban and rural settings should drive the need to develop regulatory frameworks and policies that account for different economics in order to ensure a consistent deployment effort. For example, it would be advisable to establish **incentives to facilitate deployment in rural and remote geographies** to have a positive impact on reduction of the digital divide (tax reductions, import duty exemptions, among others)

On this basis, governments should promote policies and regulatory frameworks preventing over-deployment:

- Regulation encouraging the co-location of telecommunications equipment on existing infrastructure
- Regulation and/or guidelines encouraging sharing of infrastructure
- Regulation with determination of minimum distances for the construction of towers to prevent proliferation of structures

Beyond the strictly over-deployment prevention mechanisms, governments should encourage the fulfillment of quality requirements, such as construction guarantees that certify the quality of tower construction. In an indirect fashion, this ruling would prevent some of speculation incurred around tower deployment.

Establishment of caps on fees, taxes, and rights of construction

Fees and taxes, also referred to as "cost of compliance", have a significant impact on the business case presented above. Fiscal obligations applied to the telecom operators are those that usually affect the resources available for capital expenditure (investment in network deployments, or even on research and development). Since taxes tend to raise the required pre-tax rate of return of capital invested, the aggregate capital stock in a given economy depends on the effective tax rate. These contributions can be general taxes, or contrarily, industry specific.

In general terms, most macroeconomic research literature has found that taxation regimes play an important role in driving capital flows, when controlling for economic development, unemployment, and currency fluctuations[20]. Accordingly, when a firm must make an investment decision, taxation plays a significant role. Taxes affect both the incentives of a company to make investments and reduce the supply of funds available to finance them. Several empirical studies indicate that, all things being equal, marginal, and average tax rates have a negative effect on investment decisions. Research has shown that a reduction of corporate income taxation determines, over time, an increase in the level of gross fixed capital formation.[21] These effects can be expected to be more important in emerging market economies, where investment needs are greater. Katz and Callorda (2019) provided empirical evidence on the impact of taxation on network investment in the United States.

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[20] Slemrod, J. (1990). Tax effects on Foreign Direct Investment in the United States: evidence from a cross-country comparison, in A. Razin and J. Slemrod eds. *Taxation in the Global Economy*, Chicago: University of Chicago Press, 79-117; Devereux, M. & Freeman, H. (1995). The impact of tax on foreign direct investment: empirical evidence and the implications for tax integration schemes, *International Tax and Public Finance,* 2: 85-106; Billington, N. (1999). The location of foreign direct investment: an empirical analysis, *Applied Economics,* 31: 65-76.

[21] Talpos, I. and Vancu, I. (2009). Corporate Income Taxation Effects on Investment Decisions in the European Union, *Annales Universitatis Apulensis Series Oeconomica*, 11 (1): 513-518.

They assessed the impact of taxation on the level of telecommunications and cable industry investment in a model that included data from all US states, plus adding several specific state case studies (Florida, Georgia, Illinois, Kentucky, Oklahoma, Tennessee, and Texas). According to the econometric models developed by the authors, a decrease of 1 percentage point in the average weighted state and local sales tax rate affecting initial equipment purchases (from 4.58% to 3.58%) would increase investment by 1.97% over the current levels.[22]

In this context, tower deployment is affected by the fiscal burden imposed by municipalities in the form of specific fees with the purpose of either limit deployment of infrastructure or augment revenues. Sometimes these fees become recurrent and even subject to annual increase defined on an ad-hoc basis, although the rate and type of levy varies significantly across countries and even municipalities (see table 6-3).

Table 6-3. Latin America. Municipal Fees by country (2022)

Country	Fees per site
Argentina	• Country average: USD185/month, although it varies by municipality ○ Buenos Aires metropolitan area: USD 385/month

Brazil	• Two types of annual municipal fee (urban fee and Environment fee) and a single fee (for both items)
	  ○ The urban fee ranges between R$ 6,000 (Gravatai, Guarulhos-Sao Paulo, Itaquaquecetuba, and Recife) and none
	  ○ The environmental fee ranges between R$ 2,000 (Estado de Rio Grande do Norte) and none
	  ○ The combined single fee is R$ 6,000 for the Prefeitura de Natal
	  ○ The largest combined fee is R$ 6,000

Chile	• Municipal permits fixed by law (5% of construction costs)

Colombia	• Extreme variety and rates across municipalities
	  ○ In Bogota, the deployment permit includes a one-time fee for installation in private sites (USD 50 – USD 175) and an annual fee of USD 8,100 for an installation in public sites
	  ○ In Cali, deployment in private sites only requires a one-time processing fee of USD 15, while permits payments for deployment in public sites are assessed on a case-by-case basis
	  ○ In Palmira, all sites require an annual average fee of USD 4,000, although the amount depends on height and site type.
	  ○ In Barranquilla, installation is only allowed in public places, although the exact fee amount is determined annually based on height, and other factors
	  ○ In small municipalities, deployment in private sites is typically not charged, although charges in public sites can reach up to USD 1,600 (although the operator carries the burden of taxation in most cases)

Costa Rica	• Municipalities collect three levies: ○ Construction permit: 1% of the construction costs (estimated with the Association of Engineers and Architects)

[22] Katz, R. & Callorda, F. (2019). *Assessment of the economic impact of taxation on communications investment in the United States*. A report to the Broadband Tax Institute. Telecom Advisory Services.

Country	Fees per site
	○ Municipal tax: commercial tax to all commercial enterprises operating in the Canton, ranging between 0.1% and 0.4% of gross revenues ○ Property tax: 0.25% of the property value assessed by the fiscal agency
Ecuador	• Nationally: one-time payment of USD 4,250 • Exceptions (such as Quito municipality): USD 1,700 annually
El Salvador	• Municipalities collect monthly fees and monthly taxes on physical assets ○ Monthly fees are imposed on land use, maintenance, and operating (average USD 250, although it reached USD 10,000 in one case) ○ Monthly taxes based on the value of physical asset (ranging between USD 30 and USD 150)
Guatemala	• Average municipal one-time tax ranges between USD 9,740 and USD 13,000, although some municipalities upfront payment reaches USD 32,500 plus recurring annual payments of USD 600 • Additionally, property tax (Impuesto Único sobre Propiedad Inmueble) entails an average annual payment of USD 440
Nicaragua	• Property tax calculated as 1% of 80% of the value of physical asset (average annual tax: USD 390) • Municipal tax: 1% of revenues generated in the municipality (monthly)
Panama	• Permit ranges between 1% and 5% of construction costs (one time): USD 600 – USD 2,000

Source: Compiled by Telecom Advisory Services from interviews

Without making any judgement about the need of municipalities to collect revenues to support the delivery of public services, it is also the case that by increasing the pre-tax cost of tower deployment, local authorities limit the capacity for the wireless industry to support the connectivity needs of their population. Since network deployment is causally linked to wireless broadband adoption, an extremely high taxation and construction rights burden, hampers the tower deployment business case, limits deployment and economic growth. In addition, the extreme variety of fees and rates by municipality imposes an additional burden on the tower company in terms of determining project feasibility on a case-by-case basis which adds to the cost of doing business.

Policies to promote infrastructure sharing for the deployment of 5G

The deployment of 5G will require significant expansion of the level of densification and antenna arrangements so as to have useful coverage in some high data traffic spaces (shopping centers, train stations, busy streets and avenues, highways, stadiums, industrial parks, etc.). Cell densification will require the installation of significant quantities of small cells, which are not necessarily installed on specific roofs or towers but rather on the sides of buildings, on poles or on street infrastructure. The capacity of these cells will generally be limited to a couple of frequencies.

It is estimated that, under a conservative scenario, by 2025 the densest points of the three largest cities in terms of population in each country will be covered, and by 2030 this coverage will reach fifteen of the principal urban areas. Following the recommendations of the Small Cell Forum (2017 and 2018)[23] and COMMSCOPE[24], and considering an implementation of 225 small cells per km^2 in these densely populated areas, and 10 for each macrocell, this could imply very high growth of radio base stations, by between 3 and 4 times as many by 2030. The number of radio base stations does not necessarily imply a proportional increase in the number of sites, as there may be several radio base stations per site along with sharing between mobile operators**.** On the other hand, small cells would not be useful if they are located at current sites, whereas regardless of the optimization of current sites and even sharing facilities between them, it could effectively be argued that a significant percentage of those small cells will require new sites. If the existing proportion of radio base stations per site in each country is projected, the new ones to be deployed for 4G and 5G are added, and a 25% sharing level is assumed, it can be estimated that by 2030 between 2 and 3 times the current number of sites will be required. Accordingly, Argentina might require 55,000 new sites (3.1x), Brazil 240,000 (3.7x), Chile 24,000 (2.6x) Colombia 56,000 (3.2x), Mexico 141,000 (4.0x), and Peru 59,000 (3.9x).[25]

Considering these deployments, zoning regulation will become critical. Small cells are installed in light poles or utility posts, with height of approximately 15 meters, not higher than 10% of neighboring structures, and do not require civil engineering or new structures. That being said, they require some regulation to prevent over-deployment:

- Minimum distance of 50 meters among 15-meter poles and 100 meters for heights higher than 15 meters;
- Right-of-way regulation should be limited to small cells of up to 15 meters;
- Minimum distance among small cells should be also applied in the case of private property;
- Siting in public buildings and right-of-way should be offered at market prices;
- Permits for small deployment have to include the authorization for laying down backhaul fiber;
- Small cell regulation should not discriminate against macrocells or cellular towers;
- Permits for micro and small cells should be delivered in no more than thirty days, but permits are not required in case the radios are attached to an existing urban structure (buildings).

Absence of price regulation of tower company contracts with service providers

Price regulation is the practice of governments dictating how much certain commodities or products may be sold for both in the retail marketplace and at other stages in the production

[23] Small Cell Forum (2017) "Vision for Densification into the 5G Era," Document 110.10.01, December 2017 and Small Cell Forum and 5G Americas report (2018):"Small Cell sitting Challenges and Recommendations," Document 195.10.01 August 2018 where between 10 and 30 small cells for each macrocell is estimated.

[24] COMMSCOPE (2018). "Powering the future of small cells and beyond" where between 100 and 350 small cells per km2 for densely populated areas is estimated.

[25] Cabello, S., D. Rooney and M. Fernandez (2021), *New Approaches to Telecom Infrastructure Management in Latin America*. SMC+ Consulting.

process. In economic terms, price regulation is normally justified when markets fail to produce competitive prices. Price regulation has been applied in the telecommunication sector to meet efficiency (under scarcity conditions) and equity objectives (fair access to an essential service). Similarly, interconnection prices have been regulated at times to ensure anti-competitive behavior of incumbent carriers at times of market liberalization.

None of these conditions apply to price regulation between a provider of infrastructure and a service provider. Prices to be charged between an independent tower company and wireless operators should not be regulated for multiple reasons:

- Contracts between service providers and tower companies for leasing of tower space are enacted between private parties on the basis of agreed upon prices;
- Price determination does not reflect excessive or unconscionable pricing of an essential good
- Regulating prices of tower access represents a disincentive to invest in infrastructure. Regulation of access terms and prices affects the return an infrastructure owner can expect to receive as a result of its investment efforts. In economic terms, the nature of ex post access regulation has an impact on ex ante incentives to invest.[26]

Long-term guarantees in regulations and permits

The tower industry sector is capital-intensive, with significant amounts of resources invested upfront. As shown in the economic-financial modeling, a full monetization of capex tends to occur after several years, if not a full decade. These financials, compounded by the relatively high volatility of Latin America – both in terms of economic growth and financial variables – notably exchange rates -, strongly recommend a predictable and stable regulatory and institutional framework does smooths the ups and downs and fosters long-term domestic and international investment.

6.2. International best practices

The regulations and policies focused on fostering the development of a sustainable independent tower sector were validated through a study of international best practices. Information was compiled for South Korea, the United Kingdom, Canada, and the United States.

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[26] See Cave, M., Majumdar, S. and Rood, H. *Regulation and infrastructure competition*. Retrieved in: https://www.acm.nl/sites/default/files/old_publication/publicaties/7859_relationship_accesspricing_infrastructure_260301.pdf

Infrastructure sharing in South Korea

South Korea is a country with an orderly regulatory system and forward-looking telecommunications policies. In this regard, the Telecommunications Companies Law[27] establishes as "common telecommunications services", among others, the leasing of telecommunications line equipment and facilities. It also states that "telecommunications line equipment and facilities" are constituted by a set of means and all the facilities attached thereto. Equipment and facilities are defined as ducts, common utility lines, poles, cables, stations, or other equipment, needed by telecommunications operators acquired by entering into a contract.

Beyond the Telecommunications Common Law, the construction of ICT infrastructure is also regulated by the Law on Information and Communications Construction Enterprises[28] , where information and communications construction projects mean works for the installation, maintenance and repair of information and communications facilities, and other related works. In this law, an "information and communications construction enterprise operator" is defined as an entity who manages a construction enterprise that is responsible for certifying the quality of the construction of a structure as established by local authorities.

Infrastructure sharing takes place when a telecommunications common carrier receives a request for "joint use" of radio facilities from other carriers. In such cases, the prices for joint use by the common telecommunications business operators to be determined and publicly announced by the Minister of Science, ICT and Future Planning (MCTPF) will be calculated and adjusted in a fair and reasonable manner. Although price regulation is not determined in the sharing or leasing agreements, the procedures and methods for paying such prices, and the scope and guidelines for the conditions, procedures, methods and calculation of prices for joint use will be determined and publicly announced by the MCTPF.

If necessary for the installation of lines, antennas and related facilities for telecommunications services, a telecommunications joint venture operator may use a third party's land, or buildings and structures attached thereto, and surface. In such cases, the telecommunications joint venture operator shall first consult with the owners or occupants of the land in question. Where the consultation does not lead to an agreement or is not carried out, a telecommunications common carrier operator may use the land of a third party in accordance with the Law on Acquisition of Land for Public Works[29] and compensation for it shall be established.

[27] Source: https://bit.ly/3dZfdkJ
[28] Source: https://bit.ly/3PJxJKV
[29] Source: https://bit.ly/3wQz3Fm

Infrastructure sharing in the United Kingdom

Mobile services in the United Kingdom are regulated by the Communications Law of 2003[30]. While local administrations oversee the issuing permits for civil structures for telecommunications equipment, local authorities cannot prohibit the installation of new infrastructure or impose minimum distances between new installations. However, operators or tower companies must submit to local authorities detailed project description and location information that may be subject to comments in a public consultation process.

Although the deployment of new technology infrastructure (small cells) is encouraged through the exemption of permits for structures whose height does not exceed 6 meters, the calculation of fees for active equipment differs according to the type of technology, being higher in the case of small cells.

In addition, a code of good practices[31] specifies the requirements for the authorization of a civil installation that complements the regulations on access to infrastructure[32] and the EU regulations concerning the incentive for the deployment of high-speed networks[33] where the figure of physical infrastructure is specified.

Finally, tower deployment taxes and fees are regulated through a unified referential rate (*business rates*) that represents a tax for the location of infrastructure, which is set by Parliament and cannot be modified by municipalities.

Infrastructure sharing in Canada

Canada is one of the countries where plans and standards related to telecommunications infrastructure installation processes have been enacted. In addition, the telecommunications authority has established a guide to assist land use authorities in the development of protocols for the location of antenna systems[34] . Moreover, the use of public infrastructure for network deployment is also permitted.

As in the UK, there are initiatives to promote the development of high-speed networks through the Telecommunications Regulatory Policy CRTC 2016-496[35] . The Customer Procedure Circular CPC-2-0-03[36] (Radiocommunications and Broadcasting Antenna Systems) establishes the conditions for tower deployment and sharing. It encourages stakeholders to consider sharing an existing antenna system, modifying or replacing a structure, if necessary, with the objective of extending coverage in a harmonized manner. In

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[30] Source: https://bit.ly/3eiF735
[31] Source: https://bit.ly/3wQFdVQ
[32] Source: https://bit.ly/3CQEwQj
[33] Source: https://bit.ly/3RrWaO8
[34] Source: https://bit.ly/3RPlv59
[35] Source: https://bit.ly/2xJh8AW
[36] Source: https://bit.ly/3Qej2zU

addition, Customer Procedure Circular CPC-2-0-17[37] (License conditions for mandatory roaming and antenna tower and site sharing and to prohibit exclusive site arrangements) determines the procedure for requesting and responding to requests for mandatory shared access between operators.[38]

Finally, in the 2020 final report of the Broadcasting and Telecommunications Legislative Review Panel[39] , it is recommended among others that the CRTC (Canadian Radio-television and Telecommunications Commission) should have operational oversight of the antenna siting process, including managing interaction with municipalities and land use authorities (Recommendation 36). It also requires the CRTC to consult with the relevant municipality or other public authority before exercising its discretion to grant permits to construct telecommunications facilities. In addition, the CRTC is empowered to review and revise the terms and conditions of access to provincially regulated utility support structures to ensure non-discriminatory arrangements (Recommendation 37), although this authority is not exercised in practice.

Infrastructure sharing in the United States

The Telecommunications Law of 1996 establishes the parameters upon which infrastructure sharing is regulated. In addition, it determines the regulatory power that each State has for the installation of mobile infrastructure; furthermore, it establishes that States must adhere to the deadlines for the resolution of a permit application as determined by the central authority.

Along the same lines, the rule to accelerate the deployment of wireless broadband by removing barriers to infrastructure investment[40] , promotes the deployment of small cells (declaring them exempt from evaluations or permits) and establishes a process with deadlines for the review of new construction applications and co-location requests. Along those lines, the FCC issued guidance DA 19-277[41] establishing specific rules regarding the amount of time it might take to review and approve the wireless infrastructure siting permit. It establishes two new review periods for small wireless facilities (60 days for collocation in existing structures and 90 days for new construction) and provides between 90 and 150 days for small wireless facilities.

Separately, the rule implementing the obligation of state and local governments to approve certain wireless facility modification requests under Section 6409(a) of the Spectrum Act of

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[37] Source: https://bit.ly/3efp9Xk

[38] While Bell and Telus have essentially split the country and share active infrastructure in their respective regions, they have historically defended against sharing of their sites with other operators (Rogers, Freedom) as a competitive advantage.

[39] Source: https://bit.ly/3RbTa9d

[40] Source: https://bit.ly/2vjaErO

[41] Source: https://bit.ly/3RgyCMw

2012[42] clarifies several key elements that determine whether a modification request qualifies as an eligible facility request that a state or local government must approve within 60 days for the purpose of promoting infrastructure replacement toward 5G.

Finally, it has also been recommended the creation of a database with information on available public infrastructure at the federal level, including location and tariffs, to promote location in areas of interest to operators.

* * * * *

A review of these international best practices yields the following conclusions for Latin America:

- A third of the Latin American countries evaluated have specific laws to regulate the deployment of passive infrastructure.
- Two thirds of countries do not require independent tower companies to register with the regulatory authorities to begin operations
- Similarly, two thirds of the countries in the sample have enacted laws that are in harmony with local ordinances, light procedures for construction permits, and references to construction fees that are known to infrastructure operators.
- A same percentage do not have pricing regulations for shared infrastructure.
- A similar number of countries present information that promotes the deployment of networks for new technologies such as 5G and small cells.
- All countries have plans or manuals of good practices that make it possible to supplement or complement the regulatory frameworks that promote the orderly construction of shared telecommunication infrastructure.

The review of international experience in benchmark countries has validated the six areas that are considered to contribute to the development and sustainability of an independent tower sector (see table 6-4).

Table 6-4. International Best Practices by country

Best Practice	Countries
No need for concession and fast permit approvals	• A third of country benchmarks do not require registration with the regulator to begin operations • A third of the benchmark countries in the sample have laws that are in harmony with local ordinances, light procedures for construction permits, and references to construction fees that are known to infrastructure operators • National regulations cover technical aspects of tower installation that are complied with by municipalities (United Kingdom, South Korea)

[42] Source: https://bit.ly/3eetUQV

Regulation to prevent over-deployment	• All countries have plans or manuals of good practices that make it possible to supplement or complement the regulatory frameworks that promote the orderly construction of telecommunication structures • Regulations to encourage sharing and co-location while controlling the proliferation of infrastructure (United States, United Kingdom, South Korea, Philippines) • Standardized construction permit regime and national guidelines for infrastructure fee collection (United Kingdom, United Kingdom)
Cap on fees and taxes	• Codes of good practices or incentives of the central administration that guide the processes of the municipalities (United States, United Kingdom, South Korea)
Policies to promote development of infrastructure to be share in view of deployment of 5G	• A third of benchmark countries present information that promotes the deployment of networks for new technologies such as 5G and small cells
Price regulation	• A third benchmark countries do not have pricing regulations to fix the infrastructure leasing relationship between infrastructure operators and service operators
Long-term guarantees in regulations and permits	• A third of benchmark of benchmark countries have specific laws to regulate the deployment of passive infrastructure

Source: Telecom Advisory Services analysis

6.3. The state of regulation and public policies impacting the Latin American tower industry

The assessment of regulation and public policies impacting the Latin American tower industry was conducted based on two inputs: (i) desk research of regulatory and public policy frameworks, and (ii) interviews with regulators to validate the information researched and obtain further input on the current situation.[43]

The analysis focuses mainly on four aspects: (i) the normative regulating permits for passive infrastructure providers, (ii) the process of national and local (*municipal or district*) harmonization of administrative procedures for the siting of towers, (iii) the tariff regime for the use of public space, and (iv) the status and outlook of regulatory framework of the tower industry. These four aspects are related to the strengths and weaknesses that enable or inhibit the deployment of infrastructure and, therefore, the advanced development of mobile services. This assessment also sought to identify possible regulatory initiatives at the national or municipal level that could have a negative impact on the economies of scale of the physical infrastructure deployment business model.

The following is a summary of the main conclusions that have been compiled for eleven Latin American countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, Panama, El Salvador, Guatemala, and Nicaragua.[44] Each country's framework is assessed in light of

[43] A list of authorities interviewed is included in the Appendix.
[44] Detailed information is included in the Appendix.

the best practices identified above. They lead to the formulation of recommendations for improvement.

Argentina

Argentina defined in its Decree 1060 a specific technical classification for the passive infrastructure provider (referred to as an independent passive infrastructure operator.[45] In order to provide services, such entity requires a simple request for notification of the start of activities, for which a certificate is issued. This means that it is not required to obtain a license or to be registered.

Resolution RESOL-2019-2537-APN-ENACOM#JGM[46] which regulates Independent Infrastructure Operators complements Decree 1060 along three key aspects: (i) Precisely defines the characteristics of an independent passive infrastructure operator[47], (ii) determines the obligation to notify the start of operations and report infrastructure information to ENACOM (the telecommunications regulatory agency), and (iii) establishes the nature of relationship between passive infrastructure operators and the telecommunications services licensees.

Regarding the issuance of guidelines for the deployment of passive infrastructure, Argentina presents a partial harmonization mechanism between national and local regulations, since Resolution 105/2020[48] establishes general guidelines for infrastructure sharing and deployment to be followed by local authorities. However, in aspects related to mimicry, minimum distance, or land use fees, it is up to each municipality to issue its particular ordinance. It is important to mention that the Federation of Argentine Municipalities (FMA) has developed a model of good practices to guide local administrations in the management of structures for the development of telecommunications.

In light of best practices, the strengths of Argentina's regulatory framework are:

- The administrative procedure for the completion of procedures includes an online single window for the notification of passive infrastructure deployment.
- Infrastructure sharing is the only figure that allows both sharing and leasing between independent operators and ICT service operators.
- There is only one standard that covers the operation of overhead, physical or underground infrastructure.

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[45] Source: https://bit.ly/3P8rFMM
[46] Source: https://bit.ly/3uGCuNw
[47] The Independent Infrastructure Operators are authorized to operate aerial, terrestrial or subway infrastructure that supports networks for the provision of telecommunications services; such infrastructure includes towers, masts, poles, ducts, channels, ducts, cameras, cables, easements, rights of way, fiber optic cables, and antennas.
[48] Source: https://bit.ly/3uLc9ht

Some improvement needs are related to:

- Partial standardization of national regulations and their harmonization with local governments; efforts are currently being made through the FMA to implement codes of good practices applicable in some of the municipalities.
- One of the causes for termination of sharing agreements is non-payment; therefore, continuity of service to end users is not ensured.

Brazil

Brazil has enacted a law and corresponding rules for regulating the deployment and sharing of infrastructure (Law 13.116[49] and Res. No. 683-2017[50]). Both instruments specify the passive infrastructure provider as the natural or legal person that provides support or support infrastructure. The launch of operations does not require any formal process; however, for the installation of the structures, the award of a license through a simplified process is required (Art. 7 Law 13.116).

The regulation aims to optimize deployment of sites, trying to avoid duplication (Art. 3 Res. 683). In addition, the passive infrastructure provider can gan access to aerial and terrestrial infrastructure to support networks for the provision of services, such as poles, towers, masts, cabinets, surface structures and suspended structures.

Regarding the issuance of guidelines for the deployment of infrastructure, Brazil has a partial harmonization scheme between national and local regulations. While Article 4, paragraph II, of Law 13.116 determines that the regulation of telecommunications infrastructure is the exclusive competence of the federal government, it is forbidden for Municipalities and Federal District to impose conditions that may affect the selection of technology, the topology of the networks and the quality of the services provided. That being said, each municipality has the competence to issue its own ordinance.

In addition, the same national regulations establish general guidelines for sharing, co-location, mimicry, minimum distance, and land use fees (Art. 12 Law 13.116). The so-called "Antenna Law" aims to achieve national harmonization on the matter of deployment. However, there are still municipalities that have issued their own ordinances that the central administration seeks to standardize. In addition, it is important to mention that an Infrastructure Sharing Operating Manual[51] was issued for overall guidance.

The strengths of the Brazilian regulatory framework are:

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[49] Source: https://bit.ly/3BnFHWA
[50] Source: https://bit.ly/3OIjjdt
[51] Source: https://bit.ly/2xRMO7T

- Standardization, simplification and speed of the procedures and criteria for the granting of licenses; as well as the minimization of urban or environmental impact.
- Incentivizes network deployment and capacity expansion. Article 15 of Decree 10,480 exempts the issuance of licenses or authorizations for small cells (active equipment). In addition, article 134, numeral 4 and 135 of Law 13,097 eliminates the fee for this type of equipment.
- The process to deploy passive infrastructure is agile and low-cost.

As points to be improved, they are related to:

- Although the positive administrative silence is established at 60 days, it may represent a prolonged period for the installation approval process which could delay or accumulate the deployment approval.
- Some municipalities and States still have a series of licenses and ordinances of their own.
- Absence of regulation of minimum distances, which was eliminated in Law 11.934 (Art. 10) of 2009.

Chile

A specific law for the deployment of passive infrastructure, called "Ley de Torres" (Law 20.559[52]) has been enacted in Chile. Furthermore, the Decree 99[53] defines the passive infrastructure provider as an infrastructure concessionaire or intermediate services concessionaire. Passive infrastructure providers are required to obtain a concession from the regulatory authority, Subtel. All operators that obtain this permit are entitled to apply for the deployment of tower structures in the respective municipalities.

The "Ley de Torres" establishes three important regulations: (i) definition of minimum distances between base stations, (ii) general and specific requirements by zones (*urban and rural*) for site authorization, and (iii) guidelines for the deployment of towers to be followed by the Municipalities' Directorates of Works.

Regarding the issuance of guidelines for the implementation of infrastructure, Chile presents a harmonized framework between national and local regulations since Law 20.599 establishes the procedures and guidelines for their installation. However, construction permits related to aspects such as mimicry, height, or land use fees, are issued by each municipality. In addition, it is important to mention that the General Law of Urbanism and Construction[54] establishes a guide to address such requirements.

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[52] Source: https://bit.ly/3voKQd3
[53] Source: https://bit.ly/3AuCN1y
[54] Source: https://bit.ly/3PHfdU9

The strengths of Chilean regulatory framework are:

- Detailed rules regarding the procedures to be followed for the approval of the deployment of passive infrastructure.
- It addresses issues related to safety risks. It even determines a sanctioning framework related to electromagnetic radiation.
- Exempt Resolution No. 471 of 2007[55] establishes the general guidelines for the installation of low power stations (small cells).

Its main weaknesses are:

- The infrastructure site approval process contains a detailed, but lengthy process for approval of an application for deployment, including after its submission, at least 30 days for its receipt.
- The infrastructure approval process consists of two requests: one submitted to SUBTEL (the telecommunications regulatory agency), which issues a certificate; and another to the municipality, which takes at least 15 working days.

Colombia

There is no specific law for the deployment of infrastructure in general. The development of structures is established in a general manner in Law 1753 (Art. 193). Neither is the physical infrastructure provider mentioned as a regulated actor. However, its activities are related to the application for a permit for the construction of infrastructure in each municipality and the requirements are linked to Article 2.2.2.2.5.12 of Decree 1078 of 2015[56] .

Regarding the issuance of guidelines for the implementation of infrastructure, Colombia presents a partial harmonization between national and local regulations, given that even the Constitution provides autonomy to municipalities for the management and administration of land use. However, there is a great effort in the deployment of infrastructure through the policy of good practices[57] . Thus, at the request of each mayor's office, the CRC is advising on the construction of ordinances with concepts that promote the deployment[58] , and seek to remove barriers to the development of structures through a process of incentives for the eligibility of projects that have to do with obligations to do in their localities.

Its main strengths are related to:

- It does not require specific permission for the passive infrastructure provider.

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[55] Source: https://bit.ly/3ApOaYp
[56] Source: https://bit.ly/3cSkhqc
[57] Source: https://bit.ly/3BmM6RW
[58] Example: https://bit.ly/3S8kZjw

- Promote the development of infrastructure through plans and a code of good practices to be applied by the municipalities.

Regulatory weaknesses could be focused on:

- The approval of the license for the construction of each infrastructure can take up to 30 days, which could delay deployment in the absence of a regulation specifying the technical details to be evaluated by each municipality.

Costa Rica

Recently, Law 10.216[59] was issued, which encourages and promotes the construction of telecommunications infrastructure. However, the infrastructure sharing resolution establishes as the only figure for the relationship between passive infrastructure provider (PIP) and service operators. Also, the activities of the PIPs are related to the application for a permit for the construction of infrastructure in each municipality. Although Law 10,216 establishes that within 6 months the deployment in the municipalities must be standardized.

Regarding the issuance of guidelines for infrastructure deployment, Costa Rica does not currently have harmonization between national and local regulations. Although, there are efforts of the Metropolitan Federation of Municipalities where they developed general guidelines for the location of infrastructure for certain localities through the General Regulation for Municipal Licenses in Telecommunications[60] .

On the other hand, Resolution RJD-222-2017[61] regulates on the shared use of infrastructure for the support of public telecommunications networks covering external networks, pipelines, ducts, poles, towers, stations and other facilities required for the installation and operation of public telecommunications networks, as well as for the provision of services available to the public, and the co-location of equipment.

The strengths identified in these regulations are related to:

- Immediate authorization to operate as an infrastructure provider.
- A single standard contains general guidelines for the operation of overhead, physical and underground infrastructure.
- Non-compliance with economic conditions is not considered as a cause for termination of sharing contracts due to service continuity issues.

The weaknesses contained in this regulation focus on:

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[59] Source: https://bit.ly/3zIhUzA
[60] Source: https://bit.ly/3uKSdvo
[61] Source: https://bit.ly/3cboN2L

- Although the Infrastructure Deployment Law was recently passed, it is still in a transition period that does not allow for the standardization of processes for the construction of structures in each municipality.
- There is no regulation of minimum distances that encourages the proliferation of structures in short distances.
- Approval of the license for the construction of each infrastructure may take up to 30 days, which would delay deployment.

Ecuador

There is a technical standard for the provision of passive infrastructure (Resolution ARCOTEL-2017-806[62]). The figure for actors that provide access to infrastructure is passive infrastructure provider (PIP). Likewise, the activities of PIPs are related to the application for a registration before ARCOTEL; while, each municipality provides local legislation regarding distances, mimicry (based on the infrastructure mimicry policy (Ministerial Agreement 013-2019[63]) and land occupation rates in ordinances that have their particularity around Agreement 041-2015[64] .

Regarding the issuance of guidelines for infrastructure deployment, Ecuador presents a partial harmonization between national and local regulations, given that specific policies have been issued for issues such as mimicry; and, other general guidelines on limits for public infrastructure use fees or tariff ranges for the consideration for tower leasing ($ 1,327 - $ 2,040), monopoles ($ 1,165 - $ 1,703) or masts ($ 667 - $ 753) (Ministerial Agreement 006-2018[65]). In addition, there is an analysis of deployment barriers that have generated recommendations to work within the framework of the competencies of the central State and municipal decentralized governments.

The main strengths of the standard are linked to:

- Recommendations of studies that guide the generation of municipal ordinances with respect to a general standard.
- Mandatory socialization process for infrastructure deployment to ensure acceptance of the towers by the population.

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[62] Source: https://bit.ly/3AmJd37
[63] Source: https://bit.ly/3NWJv3S
[64] Source: https://bit.ly/3TzTBvl
[65] Source: https://bit.ly/3Aoq7cG

Its weaknesses are associated with:

- There is no general regulation for mimicry, minimum distances or co-location, they are only mentioned in the policy in a general way.
- Procedural, administrative and tax framework for the installation of different infrastructure in each municipality.
- Rates regulated as rate bands for infrastructure leasing that would have to be updated periodically.

El Salvador

The only legal tool to leverage the deployment of telecommunications infrastructure is the Telecommunications Law (Decree 142[66] and its reform[67]) which establishes physical colocalization or co-location as a definition that promotes the sharing and leasing of physical structures of telephone operators; however, it does not stipulate a specific figure for other types of actors that do not have a concession to provide telecommunications services. In that sense, the operator that owns structures is not required to obtain licenses or permits before the national authority; however, each municipality may establish licenses for the operator or construction permits (Example: Municipality of Soyapango[68] establishes the extension of the permit application in 10 working days).

Regarding the issuance of guidelines for network deployment, El Salvador does not have harmonization between national and local standards. Both the technical and administrative processes are left to the municipal authorities, so there may be several different and non-standardized provisions for the request for the location of structures.

There are efforts to promote standardized deployment in 14 municipalities that make up the metropolitan area of the Department of San Salvador through the Metropolitan Area Council of San Salvador. Based on this planning, a standard regulation was created so that it can be replicated by the different municipalities for the installation of antennas in the area (Example: Regulatory ordinance for the installation of antennas or telecommunications towers in the Municipality of Mejicanos[69]).

The main weaknesses of the regulations are related to:

- Specific regulation for each municipality to control and supervise the construction of towers.
- Although the Law proposes a competition framework, it does not specify the regulatory frameworks for the implementation of infrastructure.

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[66] Source: https://bit.ly/3Jd0Ogl
[67] Source: https://bit.ly/3bglTK8
[68] Source: https://bit.ly/3bmVM46
[69] Source: https://bit.ly/3zk340H

Guatemala

There are no specific regulations to leverage the deployment of telecommunications infrastructure. The only tool is the Telecommunications Law (Decree 94-96 of the Congress of the Republic of Guatemala[70] and its reforms) that establishes the colocation of equipment in an enforceable manner for major providers; however, it does not stipulate a specific figure for providers that lease physical infrastructure. That is, the passive infrastructure operator is not required to obtain licenses or permits from the national authority; however, each municipality may establish permits for the construction of infrastructure (Example: Municipality of Palín[71]).

Guatemala does not have harmonization between its national and local regulations for network deployment. The technical or administrative procedures are at the disposal of the municipal authorities.

The main weaknesses of the regulation are focused on:

- Lack of information to standardize or have references to codes of good practice for infrastructure installation.
- There is no adequate delimitation of protected areas; therefore, permits may be denied for the construction of towers in areas of interest to operators.
- Discretionary processes for the issuance of permits or authorization for mimicry.

Nicaragua

To promote the deployment of infrastructure, Nicaragua has the Structures Construction Law (Law No. 843 - 2013[72]) and its regulations (Executive Decree 15-2014[73]). The type of certificate to be obtained by the physical infrastructure provider (PIF) is a registration, for which it has to cancel for access to the Single Window a value of $3,000 (one-time) and for the registration of "Torrero" according to Administrative Agreement 03-98[74] .

Regarding the issuance of guidelines for network deployment, Nicaragua presents a partial harmonization between national and local regulations, since the regulatory tools serve as a basis for the construction of specific ordinances that municipalities develop for the implementation of infrastructure and fees for the use of physical space.

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[70] Source: https://bit.ly/3Q0RJcA
[71] Source: https://bit.ly/3JhX4Kd
[72] Source: https://bit.ly/3BrwrR9
[73] Source: https://bit.ly/3OLgSqK
[74] Source: https://bit.ly/3zFr0Nq

Although the Law and regulations for the construction of structures define a very detailed procedure, which contains aspects of management, approval, control and sanction for the implementation of infrastructure, it could be inferred that there are high values that are obligated by the administration for concepts of registration, use of platforms or sanctioning regime.

The strengths of the regulation are related to:

- Establishment of permitting procedures through a digital one-stop shop.
- Unification and simplification of procedures.
- Detailed regulations for permits to deploy infrastructure

The main weaknesses are related to:

- Sanctioning procedure with high fines compared to the countries analyzed.
- In addition to spectrum usage fees, there are charges that may represent barriers to network deployment or permit applications for network construction.

Peru

There is Law 29022[75] for infrastructure expansion and Supreme Decree 024-2014-MTC[76] which provides for the figure of the passive infrastructure provider (PIP). Likewise, a PIP can start its activities immediately because it does not need a license to operate. However, it requires to perform a registration and obtain construction permits for the structure that are issued by each district. Administrative silence is even applied to accelerate deployment.

Regarding the issuance of guidelines, Peru presents a harmonization between national and local standards. The processes for the approval of deployment are concentrated in the Directorate of Regulation and Policies of the Ministry of Transport and Communications (MTC). In order to complement, the general technical guidelines, management and control are established through the Regulation for the Strengthening of Infrastructure Expansion (Supreme Decree 003-2015[77]).

The main strengths are developed around:

- The formalities for registration are very simple and the time is proceeded even by positive administrative silence.
- There is a general standard with guidelines for national application.

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[75] Source: https://bit.ly/3zkscUP and its amendments established in Law 30228 (Source: https://bit.ly/3PYE3P6)
[76] Source: https://bit.ly/3IkJl4U
[77] Source: https://bit.ly/3OLl6hQ

- Infrastructure certification procedures are concentrated in a single entity MTC (Dirección de Políticas y Regulación).
- The municipalities are exclusively in charge of the control of civil construction, while the MTC provides the endorsement for the registration of the infrastructure.

Weaknesses are linked to:

- The automatic registration process for the deployment of infrastructure has generated inconveniences due to the implementation of infrastructure at times and places that sometimes are not properly socialized with the population.

Panama

AN Resolution No. 2848-Telco[78] and its Annex[79] govern the installation, operation and shared use of towers and/or structures that support telecommunication antennas, infrastructure expansion. The figure of the passive infrastructure provider is determined as "installer" and the figure for leasing between these actors and the service concessionaires is determined by infrastructure sharing. The installer does not require operating permits; however, it is necessary to register its infrastructure with the National Public Services Authority (ASEP).

Installers are required to obtain construction permits for the structure, which are issued by the Municipal Authorities. They are required to complete land use requirements, submit plans and designs, authorizations from the Civil Aeronautics Authority, approval issued by the ASEP and the Fire Department Safety Office.

Panama has good harmonization between national and local regulations. Regulation 2848-Telco (articles 7, 8 and 9) governing deployment also issues comprehensive guidelines on the operation of radiating equipment, infrastructure sharing and electromagnetic radiation. The prerequisites for obtaining permits from the telecommunications authority are clearly stipulated and coordination with municipalities on structure construction permits are also defined in the process.

The implemented regulations present strengths in terms of simplification, standardization, uniformity and sector coordination. In addition, sharing is determined as a single figure for the support of antennas between service operators and tower installers.

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[78] Source: https://bit.ly/3PG7W7c
[79] Source: https://bit.ly/3JuyCpr

6.4. Summary of current Latin American situation

Finally, among the specific parameters that were investigated in the laws and regulations of the different countries, it can be noted that:

- Seventy-three percent (73%) include the passive infrastructure provider in their regulations, even though they do not have a specific law on the subject.
- 73% have specific rules (laws, regulations, or technical standards) on passive infrastructure deployment.
- In 18%, some type of registration or concession application is required to obtain a passive operator's license from the telecommunications regulator.
- Only 9% can be considered to have national standards that are highly harmonized with local ordinances. That is to say, on the one hand, there are general laws that establish the technical mechanisms of deployment (distance, height, sharing, co-location); and, on the other hand, ordinances that exclusively govern the civil construction field of building (building permit, land charges, landscape environment).
- 27% have a light procedure for the operation of the passive infrastructure operator or deployment of its infrastructure.
- 18% have clearly established parameters or reference tables that determine fees for consideration for the use of space or land use for the implementation of infrastructure.
- In all countries, it is preferred that infrastructure lease prices be established between the parties; however, 27% partially determine some type of bands or ranges over which the negotiation should be governed.
- 27% have plans focused on the development of infrastructure for new technologies such as 5G. In addition, 36% establish some specific mention or regulation on the deployment of microcells (low power stations) or urban furniture.
- Twenty-seven percent have future plans already defined or underway for the passive infrastructure provider. In addition, an equal percentage of countries have best practice models that complement general laws for infrastructure deployment or attempt to guide the orderly development of infrastructure in the absence of laws.

A summary of these characteristics is presented in Table 4-1.

Table 4-1: Regulatory Characteristics for Passive Infrastructure Deployment

Dimension \ Country	CRI	ECU	COL	PER	PAN	CHI	SLV	ARG	BRA	NIC	GTM
Regulation mentions the infrastructure provider	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No
Specific regulation for the tower industry	Yes	Yes	No	Yes	Yes	Yes	No	Yes	Yes	Yes	No
No License required or obtain certificate	Yes	No	Yes	Partially	Yes	No	Yes	Partially	Yes	Yes	Yes
Nationally harmonized deployment	No	Partially	Partially	Partially	Partially	Yes	No	Partially	Partially	Partially	No
Lightweight procedure to deploy infrastructure	Yes	Partially	Partially	Yes	Yes	No	No	Partially	Partially	No	No
Fees for the implementation established by the central administration	Yes	Partially	No	Partially	No	Yes	No	No	Partially	Partially	No
Lease rates are not determined by the central administration	Partially	Partially	Partially	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5G infrastructure deployment policy	No	No	Yes	Partially	Partially	Yes	No	No	Yes	No	No
Plans for future regulation	Partially	No	Yes	Yes	No	Yes	Partially	No	No	No	No
Good practice models	Partially	Partially	Yes	No	No	No	Partially	Yes	Yes	Partially	No

Yes No Partially

Desk research only

Source: Telecom Advisory Services

7. A FORWARD-LOOKING VIEW ON THE TOWER INDUSTRY

Beyond the ongoing support of deployment of wireless infrastructure, the future business of tower companies entails migrating from a pure passive infrastructure "specialist" to a vertically integrated value-added supplier, provided institutions and regulation allow and incentivize them to go through a profound transformation. Now that carrier's expansion in Latin America is established, a significant share of market opportunities from their tower divestures lies in the independent tower companies' balance sheet. Along these lines, there is an opportunity for towercos, to become more agile, more data-driven and more focused on new revenue flows (Schicht et al., 2020)[80]. In other words, towercos will move away from the current view of them as "grass and steel" financial partners (Casahuga et al., 2022)[81], and move decidedly towards more diversification, expanding in the digital ecosystem. Regulation and institutions in Latin America should accompany this process, even incentivizing this digital and corporate transformation of towercos to enrich the digital ecosystem. Business opportunities are evident both in the traditional tower company space – going smarter -, and in the addition of new telecommunication services and new lines of digital businesses.

7.1. Smarter traditional towerco business

First, funded on the economics and financials built in this report, towercos opportunities imply going deeper into optimizing some services by sharing them with the different tenants, in particular telecommunication operators sharing the same infrastructures. Should this be allowed and fostered by regulation, cost savings could be directed towards improving and modernizing infrastructure, making it more eco-friendly or investing into digital transformation inside and outside the companies. This diversification will have an additional contribution on telecommunication wireless services as additional resources can be focused on improving quality, affordability and sustainability.

Second, there are significant gains from digitizing the core, implementing real-time smart data systems in installed infrastructure, and moving away from just passive infrastructure provision. This would allow gathering real-time precise state evaluation of the infrastructures (degree of corrosion, energy consumption, tenants' ratio, financials per site), and its environment, from climate conditions to identifying competitors (Cane, 2022; Schicht et al., 2020)[82]. The starting point is challenging, as a 2020 survey run by TowerXchange and Analysis Mason shows 28 percent of towercos are still using Microsoft Excel as their unique data management tool, and less than half had embarked into a data strategy of any form.

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[80] Schicht, R., S. Banerjee, J. Arias, and A. Voytenko (2020), *The New Digital Landscape for Tower Companies.* Boston Consulting Group.
[81] Casahuga G., P. Ugarte and F. Merry del Val (2022), *Attention Towercos: It's time to listen to your customer*. Arthur D. Little.
[82] Cane, R. (2022), *TowerXchange Meetup Americas 2022*, July.

7.2. New opportunities in the IoT and smart cities market spaces

Beyond improving the core business, tower companies will expand into other diversification spaces, such as enhanced support of 5G, and IoT, combined with a more sustainable "green" profile.

New telecommunication services, 5G and beyond

Towercos could take an active role in network densification for 5G, and not just adapt to its deployment. As reviewed above, 5G connectivity requires macro towers as well as small cells, with massive site numbers and backhaul provisioning. This process will have a notable impact on passive infrastructures.

In this context, Towercos should secure fast and flexible permits from local authorities for the small-cell roll-out that will characterize most of 5G infrastructure expansion. Investing in small-cell backhaul could be riskier, but initial results in the US and Europe appear promising (Wilson, 2016)[83]. Operators that do not already have dense fiber infrastructure need to build stronger and frequent relationships with towercos as 5G roll-outs begin.

Towercos could also develop business lines directly as business partner to industries in 5G private networks in support of business cases, which will start deployment earlier than the massive retail 5G service. These autonomous networks can address various needs of industry verticals or even local governments supported by 4G and 5G capabilities and integrated to national networks, from manufacturing (e.g., automobile), energy and mining, ports and transportation, areas with a significant support in Latin America from development banks. This will enable more reliable and high-performance industry 4.0 solutions for different sectors (Wilson, 2016).

New digital services

New open standards, and cloud-based developments are making it easier to disaggregate network hardware and software components. This opens the way to increase the 'active' components of towercos infrastructure business lines, such as antennas and radio transmission equipment. In this model of multiple digital services, towercos play the role of neutral host model (Carvalho et al, 2021).[84]

While the revenue opportunity for towercos on the Internet of Things and smart-city segments could be lower than for the small-cells segment, the capex involved is also low. On the other hand, the upside of these services could be higher than expected, given the variety of new services that could be supported, from imaging and logistics to asset-heavy sectors

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[83] Wilson, S. (2016), *Revenue Opportunities for Towercos and MNOs now and in the 5G era. Small cell densification and IoT*. Analysis Mason.

[84] Carvalho, J., G.CR Budden and P.M. Vaz (2021), *The Rise of the Netcos*. Deloitte.

(energy) complementing drones, data intelligence and smart cities (weather, traffic, energy as a service). More generally, towercos' perimeter could be enlarged entering into edge computing businesses, thanks to the right regional and local footprint of installed infrastructure and services offered today (Cane, 2022; Wilson 2016).

A forward-looking regulation to favor a diversified value-added tower sector

Some relevant conditions need to be fulfilled in this transformation. The required capabilities, technology, processes, and labor organization inside towercos cannot be taken for granted.

In addition, the envisioned diversification faces regulatory and strategic challenges. First, the new business opportunities both in the telecommunication sector and in other digital services should be pursued protecting their relationships with their current main clients, the carriers. Second, as their core business does not require licenses or all the associated regulatory burden, policy makers and regulators should accompany this process by allowing and proactively supporting towerco transformation, while properly regulating deployments based on quality and sustainability standards.

First and foremost, regulators in Latin America should allow and foster infrastructure and services sharing as a key element for further investment in capital and innovative services. The observed over-deployment in some countries of the region, and in many urban areas all along Latin America is a waste of resources and has a negative impact on the environment. Second, regulators should accelerate the issuance of permits from local municipalities for small-cell rollouts, especially for 5G services. Despite the slow start that most expect for retail 5G services except for Brazil and Chile, and probably Argentina, private networks are starting to be developed across the region; and once started, 5G take off will be fast. Therefore, planning it in advance will have significant benefits.

Also, regulators could foster light-touch regulation, even experimenting before regulating in controlled environment using regulatory sandboxes, for example regarding the entry of new players to these innovative services around smart cities. Digital technologies and data availability can enable new real-time ways to regulate the digital eco-system. In the absence of significant regulatory reforms to deal with new business models and technologies as the increasingly converging audiovisual sector, sandboxes are seen as a way for regulators to promote competition by fostering and unleashing disruptive innovation. Additionally, regulatory sandboxes allow authorities and industry players to gather information on new markets and services (as the ones towercos could enter), where the behavior of agents, such as firms and consumers, might still be unknown and unpredictable (Enríquez and Melguizo, 2021). This framework could serve to test light authorization regimes, replacing burdensome and slow processes; minimum and reasonable reporting obligations (as experimented during the Covid-19 lockdowns), or tax incentives to foster infrastructure expansions in rural and remote areas.

Finally, business transformation is not easy, but public authorities and development banks could support the digital transformation inside towercos. Digitizing and training will take time and resources for investing in equipment, implementing new digital processes, and training the workforce, easing not core regulatory burdens and offering training resources.

8. CONCLUSION: STUDY RESULTS AND IMPLICATIONS

A vibrant independent tower industry is a pillar for a Latin America 4.0, more productive, more inclusive, more sustainable (socially and environmentally).

This report has showed that the tower industry sector is going through profound changes in Latin America, opening opportunities for strategic partnerships. In particular, due to its dynamism and also to the divestments from some traditional telecommunication operators, on average half of the installed base is run by independent companies. Still, there is a close interdependence between wireless industry players and passive infrastructure providers, not only as tenants of the latter, but as potential partners as additional services arise from digital transformation. A particular area for mutual win-wins comes from infrastructure sharing, as tower companies secure a relatively stable monetization of its substantial investments, and operators can cumulate savings to re-invest in better quality services of future ones (via R&D).

Beyond this positive trend, this report has quantitively shown that the increasing position of independent towercos is an asset for the digital economy, and in particular for the wireless industry. Following the methodology developed by World Bank's IFC, we showed that from 2016 to 2022 countries in Latin American with a more dynamic independent towerco sector exhibit better wireless connectivity in terms of coverage, use, affordability and quality (speed). At the same time, the wireless industry shows more competition and more investment, demonstrating once again the potential win-wins. More precisely, higher 4G coverage than the rest of countries (97% of the population vs. 90%), wireless broadband is 12% faster than the rest (33 Mbps vs. 29 Mbps), capital spending is 31% higher in country leaders (USD 21 per capita vs. USD 16 per capita), wireless broadband services represent 1/3 of costs in terms of per capita income in country leaders relative to the rest of countries, country leaders exhibit higher broadband adoption than in the rest of the region (65% vs. 58%), and wireless competition is more intense in countries with higher share of independent tower deployment (wireless broadband of HHI= 2,440 vs. 4,135)

These correlational results have been confirmed in our original econometric modelling, as independent towers show a significantly higher impact on wireless broadband use, coverage, speed and affordability, favoring a more competitive telecommunication industry. A 10 percent increase of the number of independent towers leads to, at least, an increase in 4G coverage levels of 0.96%, is causally linked to an increase in wireless broadband adoption levels of 0.51%, is associated with an increase in service quality levels (measured as mobile broadband download speed) of 2.05%, leads to an increase in mobile market competition levels (measured as a decrease in the Herfindahl Hirschman Index that measures industry concentration-a lower index depicts more intense competition) of 0.46%, and results in an improvement in the level of mobile affordability (measured as a decrease in service price relative to the monthly GDP per capita) of 3.18%

Now is the time to set public policies right. This involves implementing a smart and flexible regulation of the independent towerco sector – both covering its quality and security standards, but also its environmental impact and sustainability - securing the predictability and stability that a capital-intensive sector requires for its financial viability and long-term sustainability and favoring infrastructure sharing all along the telecommunication sector. A review of the research literature and interviews of regulators and policymakers have led to the identification of seven types of initiatives that can contribute to the development and sustainability of an independent tower sector: no need for service concession; need for fast permit approvals; regulations to prevent over-deployment; establishment of caps on fees and taxes, and rights of construction; policies to promote infrastructure sharing for deployment of 5G; absence of price regulation of tower company contracts with service providers; long-term guarantees in regulations and permits.

The good news is that these policy and regulatory prescriptions have been undertaken by some countries that should be considered as benchmarks when it comes to development of the telecommunications and passive infrastructure sharing industries, learning from their design and implementation: South Korea, United Kingdom, and the United States. In a nutshell, these countries have specific laws to regulate the deployment of passive infrastructure, do not require independent tower companies to register with the regulatory authorities to begin operations, have enacted laws that are in harmony with local ordinances, light procedures for construction permits, and references to construction fees that are known to infrastructure operators, do not have pricing regulations for shared infrastructure. present information that promotes the deployment of networks for new technologies such as 5G and small cells and have plans or manuals of good practices that make it possible to supplement or complement the regulatory frameworks that promote the orderly construction of shared telecommunication infrastructure.

The tower industry in Latin America and globally is also going through a deep transformation to render its core business more agile, digital and environmentally sustainable, and at the same time diversify both in telecommunication services and other ones favors by digital developments. Regulators should also accompany this process and favor the emergence of an additional digital sector with a forward-looking view.

To conclude, there are some areas where further research would be welcome in support of industry development. First, it would be advisable to widen the geographic coverage, taking advantage of readily available data sources comparable to the one used in this report. This would strengthen the statistical power of the results, and at the same time enrich the range of good regulatory practices. Second, and complementary, it would be useful to go much more granular in the Latin American footprint analyzing deployments at local levels. Market and analysist consensus is that many of the regulatory, financial, and environmental challenges are concentrated in some parts of the countries and the cities. Third, there is growing evidence globally of the opportunities from a digital transformation of the tower industry. Adding some estimates of the potential for the sector, and how the regulatory framework would help to support the development of a Latin America 4.0, more productive, more inclusive and more sustainable.

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APPENDICES

A. List of regulator interviews

Country	Interviews	Policy making unit
Costa Rica	• Glenn Fallas, *Director General Dirección General de Calidad* • Ivannia Morales, *Asesora del Consejo* • Juan Gabriel García, *Dirección General de Mercados*	Superintendencia de Telecomunicaciones
Perú	• Naylamp López, *Asesor Viceministerio* • Ronald Farromeque, *Dirección de Políticas y Regulaciones*	Ministerio de Transportes y Comunicaciones
Colombia	• Alejandra Arenas Pinto, *Coordinadora de Política Regulatoria*	Comisión de Regulación de Comunicaciones
Chile	• Virginia Reginato, *División Política Regulatorio y Estudios*	Subsecretaría de Telecomunicaciones de Chile
Ecuador	• Paul Meza, *Subsecretario de Telecomunicaciones y Asuntos Postales* • Mónica Zurita, *Directora de Telecomunicaciones y Asuntos Postales*	Ministerio de Telecomunicaciones
El Salvador	• Rafael Arbizu, *Sub Gerente de Telecomunicaciones*	Superintendencia General de Electricidad y Telecomunicaciones
Panamá	• Hildeman Rangel, *Director Nacional de Telecomunicaciones*	Autoridad Nacional de Servicios Públicos

B. Financial profitability model of tower industry (based on a single tower model)

			Año 1	Año 2	Año 3	Año 4	Año 5	Año 6	Año 7	Año 8	Año 9	Año 10
INGRESOS												
	Variables											
	Ingreso mensual por operador											
	Urbano	$ 600										
	Suburbano	$ 1,200										
	Rural	$ 2,000										
	Escenario urbano											
	Un operador			$ 7,200	$ 7,200	$ 7,200	$ 7,200	$ 7,200	$ 7,200	$ 7,200	$ 7,200	$ 7,200
	Dos operadores			$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400
	Tres operadores			$ 21,600	$ 21,600	$ 21,600	$ 21,600	$ 21,600	$ 21,600	$ 21,600	$ 21,600	$ 21,600
	Cuatro operadores			$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800
	Escenario suburbano											
	Un operador			$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400	$ 14,400
	Dos operadores			$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800	$ 28,800
	Tres operadores			$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200
	Cuatro operadores			$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 57,600	$ 57,600
	Escenario rural											
	Un operador			$ 24,000	$ 24,000	$ 24,000	$ 24,000	$ 24,000	$ 24,000	$ 24,000	$ 24,000	$ 24,000
	Dos operadores			$ 48,000	$ 48,000	$ 48,000	$ 48,000	$ 48,000	$ 48,000	$ 48,000	$ 48,000	$ 48,000
	Tres operadores			$ 72,000	$ 72,000	$ 72,000	$ 72,000	$ 72,000	$ 72,000	$ 72,000	$ 72,000	$ 72,000
	Cuatro operadores			$ 96,000	$ 96,000	$ 96,000	$ 96,000	$ 96,000	$ 96,000	$ 96,000	$ 96,000	$ 96,000
OPEX												
	Variables											
	O&M por torre											
	Urbano	$ 150										
	Suburbano	$ 200										
	Rural	$ 400										
	Escenario urbano			$ 1,800	$ 1,800	$ 1,800	$ 1,800	$ 1,800	$ 1,800	$ 1,800	$ 1,800	$ 1,800
	Escenario suburbano			$ 2,400	$ 2,400	$ 2,400	$ 2,400	$ 2,400	$ 2,400	$ 2,400	$ 2,400	$ 2,400
	Escenario rural			$ 4,800	$ 4,800	$ 4,800	$ 4,800	$ 4,800	$ 4,800	$ 4,800	$ 4,800	$ 4,800
CAPEX		Dress tower addition	35%									
		Microwave backhaul										
	Variables											
	Urbano	$ 40,000	$ 40,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Suburbano	$ 100,000	$ 100,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
	Rural	$ 150,000	$ 150,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
EBITDA												
	Urbano											
	Un operador			$ 5,400	$ 5,400	$ 5,400	$ 5,400	$ 5,400	$ 5,400	$ 5,400	$ 5,400	$ 5,400
	Dos operadores			$ 12,600	$ 12,600	$ 12,600	$ 12,600	$ 12,600	$ 12,600	$ 12,600	$ 12,600	$ 12,600
	Tres operadores			$ 19,800	$ 19,800	$ 19,800	$ 19,800	$ 19,800	$ 19,800	$ 19,800	$ 19,800	$ 19,800
	Cuatro operadores			$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000	$ 27,000
	Suburbano											
	Un operador			$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,000	$ 12,000
	Dos operadores			$ 26,400	$ 26,400	$ 26,400	$ 26,400	$ 26,400	$ 26,400	$ 26,400	$ 26,400	$ 26,400
	Tres operadores			$ 40,800	$ 40,800	$ 40,800	$ 40,800	$ 40,800	$ 40,800	$ 40,800	$ 40,800	$ 40,800
	Cuatro operadores			$ 55,200	$ 55,200	$ 55,200	$ 55,200	$ 55,200	$ 55,200	$ 55,200	$ 55,200	$ 55,200
	Rural											
	Un operador			$ 19,200	$ 19,200	$ 19,200	$ 19,200	$ 19,200	$ 19,200	$ 19,200	$ 19,200	$ 19,200
	Dos operadores			$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200	$ 43,200
	Tres operadores			$ 67,200	$ 67,200	$ 67,200	$ 67,200	$ 67,200	$ 67,200	$ 67,200	$ 67,200	$ 67,200
	Cuatro operadores			$ 91,200	$ 91,200	$ 91,200	$ 91,200	$ 91,200	$ 91,200	$ 91,200	$ 91,200	$ 91,200
DEPRECIACION												
	Urbano			$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000	$ 4,000
	Suburbano			$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000	$ 10,000
	Rural			$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000	$ 15,000

EBIT												
	Urbano											
	Un operador			$ 1,400	$ 1,400	$ 1,400	$ 1,400	$ 1,400	$ 1,400	$ 1,400	$ 1,400	$ 1,400
	Dos operadores			$ 8,600	$ 8,600	$ 8,600	$ 8,600	$ 8,600	$ 8,600	$ 8,600	$ 8,600	$ 8,600
	Tres operadores			$ 15,800	$ 15,800	$ 15,800	$ 15,800	$ 15,800	$ 15,800	$ 15,800	$ 15,800	$ 15,800
	Cuatro operadores			$ 23,000	$ 23,000	$ 23,000	$ 23,000	$ 23,000	$ 23,000	$ 23,000	$ 23,000	$ 23,000
	Suburbano											
	Un operador			$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000	$ 2,000
	Dos operadores			$ 16,400	$ 16,400	$ 16,400	$ 16,400	$ 16,400	$ 16,400	$ 16,400	$ 16,400	$ 16,400
	Tres operadores			$ 30,800	$ 30,800	$ 30,800	$ 30,800	$ 30,800	$ 30,800	$ 30,800	$ 30,800	$ 30,800
	Cuatro operadores			$ 45,200	$ 45,200	$ 45,200	$ 45,200	$ 45,200	$ 45,200	$ 45,200	$ 45,200	$ 45,200
	Rural											
	Un operador			$ 4,200	$ 4,200	$ 4,200	$ 4,200	$ 4,200	$ 4,200	$ 4,200	$ 4,200	$ 4,200
	Dos operadores			$ 28,200	$ 28,200	$ 28,200	$ 28,200	$ 28,200	$ 28,200	$ 28,200	$ 28,200	$ 28,200
	Tres operadores			$ 52,200	$ 52,200	$ 52,200	$ 52,200	$ 52,200	$ 52,200	$ 52,200	$ 52,200	$ 52,200
	Cuatro operadores			$ 76,200	$ 76,200	$ 76,200	$ 76,200	$ 76,200	$ 76,200	$ 76,200	$ 76,200	$ 76,200
IMPUESTOS		25%										
	Urbano											
	Un operador			$ 350	$ 350	$ 350	$ 350	$ 350	$ 350	$ 350	$ 350	$ 350
	Dos operadores			$ 2,150	$ 2,150	$ 2,150	$ 2,150	$ 2,150	$ 2,150	$ 2,150	$ 2,150	$ 2,150
	Tres operadores			$ 3,950	$ 3,950	$ 3,950	$ 3,950	$ 3,950	$ 3,950	$ 3,950	$ 3,950	$ 3,950
	Cuatro operadores			$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750	$ 5,750
	Suburbano											
	Un operador			$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500	$ 500
	Dos operadores			$ 4,100	$ 4,100	$ 4,100	$ 4,100	$ 4,100	$ 4,100	$ 4,100	$ 4,100	$ 4,100
	Tres operadores			$ 7,700	$ 7,700	$ 7,700	$ 7,700	$ 7,700	$ 7,700	$ 7,700	$ 7,700	$ 7,700
	Cuatro operadores			$ 11,300	$ 11,300	$ 11,300	$ 11,300	$ 11,300	$ 11,300	$ 11,300	$ 11,300	$ 11,300
	Rural											
	Un operador			$ 1,050	$ 1,050	$ 1,050	$ 1,050	$ 1,050	$ 1,050	$ 1,050	$ 1,050	$ 1,050
	Dos operadores			$ 7,050	$ 7,050	$ 7,050	$ 7,050	$ 7,050	$ 7,050	$ 7,050	$ 7,050	$ 7,050
	Tres operadores			$ 13,050	$ 13,050	$ 13,050	$ 13,050	$ 13,050	$ 13,050	$ 13,050	$ 13,050	$ 13,050
	Cuatro operadores			$ 19,050	$ 19,050	$ 19,050	$ 19,050	$ 19,050	$ 19,050	$ 19,050	$ 19,050	$ 19,050
FLUJOS DE CAJA LIBRE												
	Urbano											
	Un operador		$ (40,000)	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050	$ 5,050
	Dos operadores		$ (40,000)	$ 10,450	$ 10,450	$ 10,450	$ 10,450	$ 10,450	$ 10,450	$ 10,450	$ 10,450	$ 10,450
	Tres operadores		$ (40,000)	$ 15,850	$ 15,850	$ 15,850	$ 15,850	$ 15,850	$ 15,850	$ 15,850	$ 15,850	$ 15,850
	Cuatro operadores		$ (40,000)	$ 21,250	$ 21,250	$ 21,250	$ 21,250	$ 21,250	$ 21,250	$ 21,250	$ 21,250	$ 21,250
	Suburbano											
	Un operador		$ (100,000)	$ 11,500	$ 11,500	$ 11,500	$ 11,500	$ 11,500	$ 11,500	$ 11,500	$ 11,500	$ 11,500
	Dos operadores		$ (100,000)	$ 22,300	$ 22,300	$ 22,300	$ 22,300	$ 22,300	$ 22,300	$ 22,300	$ 22,300	$ 22,300
	Tres operadores		$ (100,000)	$ 33,100	$ 33,100	$ 33,100	$ 33,100	$ 33,100	$ 33,100	$ 33,100	$ 33,100	$ 33,100
	Cuatro operadores		$ (100,000)	$ 43,900	$ 43,900	$ 43,900	$ 43,900	$ 43,900	$ 43,900	$ 43,900	$ 43,900	$ 43,900
	Rural											
	Un operador		$ (150,000)	$ 18,150	$ 18,150	$ 18,150	$ 18,150	$ 18,150	$ 18,150	$ 18,150	$ 18,150	$ 18,150
	Dos operadores		$ (150,000)	$ 36,150	$ 36,150	$ 36,150	$ 36,150	$ 36,150	$ 36,150	$ 36,150	$ 36,150	$ 36,150
	Tres operadores		$ (150,000)	$ 54,150	$ 54,150	$ 54,150	$ 54,150	$ 54,150	$ 54,150	$ 54,150	$ 54,150	$ 54,150
	Cuatro operadores		$ (150,000)	$ 72,150	$ 72,150	$ 72,150	$ 72,150	$ 72,150	$ 72,150	$ 72,150	$ 72,150	$ 72,150
FLUJOS DE CAJA LIBRE ACUMULADOS												
	Urbano											
	Un operador		$ (40,000)	$ (34,950)	$ (29,900)	$ (24,850)	$ (19,800)	$ (14,750)	$ (9,700)	$ (4,650)	$ 400	$ 5,450
	Dos operadores		$ (40,000)	$ (29,550)	$ (19,100)	$ (8,650)	$ 1,800	$ 12,250	$ 22,700	$ 33,150	$ 43,600	$ 54,050
	Tres operadores		$ (40,000)	$ (24,150)	$ (8,300)	$ 7,550	$ 23,400	$ 39,250	$ 55,100	$ 70,950	$ 86,800	$ 102,650
	Cuatro operadores		$ (40,000)	$ (18,750)	$ 2,500	$ 23,750	$ 45,000	$ 66,250	$ 87,500	$ 108,750	$ 130,000	$ 151,250
	Suburbano											
	Un operador		$ (100,000)	$ (88,500)	$ (77,000)	$ (65,500)	$ (54,000)	$ (42,500)	$ (31,000)	$ (19,500)	$ (8,000)	$ 3,500
	Dos operadores		$ (100,000)	$ (77,700)	$ (55,400)	$ (33,100)	$ (10,800)	$ 11,500	$ 33,800	$ 56,100	$ 78,400	$ 100,700
	Tres operadores		$ (100,000)	$ (66,900)	$ (33,800)	$ (700)	$ 32,400	$ 65,500	$ 98,600	$ 131,700	$ 164,800	$ 197,900
	Cuatro operadores		$ (100,000)	$ (56,100)	$ (12,200)	$ 31,700	$ 75,600	$ 119,500	$ 163,400	$ 207,300	$ 251,200	$ 295,100
	Rural											
	Un operador		$ (150,000)	$ (131,850)	$ (113,700)	$ (95,550)	$ (77,400)	$ (59,250)	$ (41,100)	$ (22,950)	$ (4,800)	$ 13,350
	Dos operadores		$ (150,000)	$ (113,850)	$ (77,700)	$ (41,550)	$ (5,400)	$ 30,750	$ 66,900	$ 103,050	$ 139,200	$ 175,350
	Tres operadores		$ (150,000)	$ (95,850)	$ (41,700)	$ 12,450	$ 66,600	$ 120,750	$ 174,900	$ 229,050	$ 283,200	$ 337,350
	Cuatro operadores		$ (150,000)	$ (77,850)	$ (5,700)	$ 66,450	$ 138,600	$ 210,750	$ 282,900	$ 355,050	$ 427,200	$ 499,350
WACC		6.5%										
g		1%										
NPV sin Terminal Value												
Urbano												
Un operador		($5,996.88)										
Dos operadores		$27,752.38										
Tres operadores		$61,501.64										
Cuatro operadores		$95,250.91										
Suburbano												
Un operador		($22,023.29)										
Dos operadores		$45,475.23										
Tres operadores		$112,973.75										
Cuatro operadores		$180,472.28										
Rural												
Un operador		($27,410.06)										
Dos operadores		$85,087.48										
Tres operadores		$197,585.02										
Cuatro operadores		$310,082.55										

NPV con Terminal Value	
Urbano	
Un operador	$ 39,931.70
Dos operadores	$ 122,792.71
Tres operadores	$ 205,653.72
Cuatro operadores	$ 288,514.73
Suburbano	
Un operador	$ 82,566.54
Dos operadores	$ 248,288.56
Tres operadores	$ 414,010.58
Cuatro operadores	$ 579,732.59
Rural	
Un operador	$ 137,659.98
Dos operadores	$ 413,863.34
Tres operadores	$ 690,066.70
Cuatro operadores	$ 966,270.06
TIR sin Terminal Value	
Urbano	
Un operador	2.63%
Dos operadores	21.65%
Tres operadores	37.35%
Cuatro operadores	51.89%
Suburbano	
Un operador	0.69%
Dos operadores	16.78%
Tres operadores	29.97%
Cuatro operadores	42.03%
Rural	
Un operador	1.74%
Dos operadores	19.10%
Tres operadores	33.40%
Cuatro operadores	46.56%
TIR con Terminal Value	
Urbano	
Un operador	17.68%
Dos operadores	33.13%
Tres operadores	45.88%
Cuatro operadores	58.03%
Suburbano	
Un operador	16.06%
Dos operadores	29.21%
Tres operadores	39.86%
Cuatro operadores	49.74%
Rural	
Un operador	16.93%
Dos operadores	31.08%
Tres operadores	42.65%
Cuatro operadores	53.52%

C. Econometric models

Each statistical model is presented with the corresponding table it refers to:

Table 3-1. Econometric models with 4G coverage as dependent variable

```
Fixed-effects (within) regression               Number of obs     =        209
Group variable: country_id                      Number of groups  =         19

R-squared:                                      Obs per group:
     Within  = 0.9044                                         min =         11
     Between = 0.2224                                         avg =       11.0
     Overall = 0.8471                                         max =         11

                                                F(12,178)         =     140.31
corr(u_i, Xb) = -0.0045                         Prob > F          =     0.0000
```

coverage_4g	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
ln_gdpc	-.0094265	.0813132	-0.12	0.908	-.1698885	.1510355
co_location	.1302603	.0452936	2.88	0.005	.0408788	.2196419
y1	-.842822	.0416424	-20.24	0.000	-.9249984	-.7606457
y2	-.8539221	.0384681	-22.20	0.000	-.9298342	-.7780099
y3	-.8243798	.0386324	-21.34	0.000	-.9006163	-.7481434
y4	-.7468049	.0391471	-19.08	0.000	-.8240571	-.6695527
y5	-.6403178	.039379	-16.26	0.000	-.7180276	-.562608
y6	-.4868832	.0386279	-12.60	0.000	-.5631107	-.4106557
y7	-.3776531	.0385155	-9.81	0.000	-.4536589	-.3016473
y8	-.1809828	.0395191	-4.58	0.000	-.2589691	-.1029966
y9	-.0888816	.0397413	-2.24	0.027	-.1673064	-.0104568
y10	-.0377281	.0393528	-0.96	0.339	-.1153861	.0399299
y11	0	(omitted)				
_cons	.8625181	.7174958	1.20	0.231	-.5533743	2.278411
sigma_u	.09631951					
sigma_e	.11765685					
rho	.40126357	(fraction of variance due to u_i)				

Fixed-effects (within) regression — Number of obs = 209
Group variable: country_id — Number of groups = 19

R-squared:
Within = 0.9030
Between = 0.1069
Overall = 0.8338

Obs per group:
min = 11
avg = 11.0
max = 11

F(12,178) = 138.06
corr(u_i, Xb) = -0.0282 — Prob > F = 0.0000

coverage_4g	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
ln_gdpc	-.0093197	.0821491	-0.11	0.910	-.1714312	.1527917
sharing_index	.0015407	.0006526	2.36	0.019	.0002529	.0028285
y1	-.8368669	.0438915	-19.07	0.000	-.9234816	-.7502523
y2	-.8488751	.0392616	-21.62	0.000	-.9263532	-.771397
y3	-.8193381	.0393711	-20.81	0.000	-.8970323	-.7416438
y4	-.7443899	.0396599	-18.77	0.000	-.822654	-.6661258
y5	-.6406073	.0397372	-16.12	0.000	-.719024	-.5621907
y6	-.481566	.038932	-12.37	0.000	-.5583936	-.4047384
y7	-.372335	.0388244	-9.59	0.000	-.4489503	-.2957196
y8	-.1756714	.0398012	-4.41	0.000	-.2542142	-.0971285
y9	-.0862742	.040015	-2.16	0.032	-.165239	-.0073095
y10	-.0351188	.0396267	-0.89	0.377	-.1133174	.0430799
y11	0	(omitted)				
_cons	.8626344	.7268516	1.19	0.237	-.5717207	2.296989
sigma_u	.10488547					
sigma_e	.11851803					
rho	.43920424	(fraction of variance due to u_i)				

Table 3-2. Econometric models with dependent variable 4G coverage

Fixed-effects (within) regression — Number of obs = 209
Group variable: country_id — Number of groups = 19

R-squared:
Within = 0.9286
Between = 0.5841
Overall = 0.7483

Obs per group:
min = 11
avg = 11.0
max = 11

F(13,177) = 177.01
corr(u_i, Xb) = 0.1320 — Prob > F = 0.0000

bam_unique~n	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
coverage_4g	.1186981	.0240667	4.93	0.000	.0712035	.1661927
ln_gdpc	.0343244	.0261098	1.31	0.190	-.0172022	.0858511
co_location	-.0095116	.0148774	-0.64	0.523	-.0388714	.0198483
y1	-.2761506	.0242945	-11.37	0.000	-.3240947	-.2282065
y2	-.2328478	.0239773	-9.71	0.000	-.2801661	-.1855296
y3	-.1888311	.0233987	-8.07	0.000	-.2350075	-.1426547
y4	-.1505602	.0219324	-6.86	0.000	-.1938429	-.1072775
y5	-.1178881	.0199337	-5.91	0.000	-.1572265	-.0785497
y6	-.0946525	.0170628	-5.55	0.000	-.1283251	-.0609798
y7	-.0711621	.0153476	-4.64	0.000	-.1014499	-.0408742
y8	-.0582771	.0134159	-4.34	0.000	-.0847528	-.0318013
y9	-.0354317	.0129386	-2.74	0.007	-.0609655	-.0098979
y10	-.0183651	.0126684	-1.45	0.149	-.0433655	.0066354
y11	0	(omitted)				
_cons	.1456624	.2313139	0.63	0.530	-.3108257	.6021504
sigma_u	.07508853					
sigma_e	.03777842					
rho	.79800299	(fraction of variance due to u_i)				

```
Fixed-effects (within) regression               Number of obs     =        209
Group variable: country_id                      Number of groups  =         19

R-squared:                                      Obs per group:
     Within  = 0.9290                                         min =         11
     Between = 0.5563                                         avg =       11.0
     Overall = 0.7690                                         max =         11

                                                F(13,177)         =     178.07
corr(u_i, Xb) = 0.1313                          Prob > F          =     0.0000
```

bam_unique_~n	Coefficient	Std. err.	t	P>|t|	[95% conf.	interval]
coverage_4g	.110544	.0238254	4.64	0.000	.0635257	.1575624
ln_gdpc	.040168	.0261137	1.54	0.126	-.0113663	.0917022
sharing_index	.0002492	.0002107	1.18	0.238	-.0001665	.000665
y1	-.2735385	.0243352	-11.24	0.000	-.3215631	-.225514
y2	-.2358953	.0237654	-9.93	0.000	-.2827953	-.1889953
y3	-.1919286	.0231882	-8.28	0.000	-.2376896	-.1461677
y4	-.1537179	.0217594	-7.06	0.000	-.1966591	-.1107766
y5	-.1206992	.0198116	-6.09	0.000	-.1597965	-.0816019
y6	-.0981915	.0168757	-5.82	0.000	-.131495	-.064888
y7	-.0737533	.0151986	-4.85	0.000	-.1037471	-.0437594
y8	-.059636	.0133259	-4.48	0.000	-.0859342	-.0333378
y9	-.0365372	.0128846	-2.84	0.005	-.0619643	-.01111
y10	-.0189449	.0126239	-1.50	0.135	-.0438576	.0059679
y11	0	(omitted)				
_cons	.0792352	.2319567	0.34	0.733	-.3785215	.5369919
sigma_u	.07123765					
sigma_e	.03767334					
rho	.78145022	(fraction of variance due to u_i)				

Table 5-3. Econometric models with dependent variable coverage

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.3836                                         min =          2
     Between = 0.7032                                         avg =        6.3
     Overall = 0.2796                                         max =          7

                                                Wald chi2(2)      =      21.95
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000
```

ln_coverage	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_towers	.094525	.0323773	2.92	0.004	.0310666	.1579834
ln_gdppc	.1590487	.0672837	2.36	0.018	.0271752	.2909223
_cons	-2.524748	.5631797	-4.48	0.000	-3.62856	-1.420936
sigma_u	.05382594					
sigma_e	.20456612					
rho	.06475054	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.5020                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.6467                                         max =          7

                                                Wald chi2(13)     =     113.47
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
 ln_coverage | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
   ln_towers |   1.140173   .1489519     7.65   0.000     .8482321    1.432113
    ln_gdppc |    .164351   .3374592     0.49   0.626    -.4970569     .825759
          c1 |  -.2643311   .1825304    -1.45   0.148    -.6220841    .0934218
          c2 |  -1.727735   .2658499    -6.50   0.000    -2.248792   -1.206679
          c3 |   .3995791   .3111322     1.28   0.199    -.2102288    1.009387
          c4 |  -.4394234   .1225402    -3.59   0.000    -.6795977   -.1992491
          c5 |   1.350024   .3161399     4.27   0.000     .7304014    1.969647
          c6 |    1.00034   .1968269     5.08   0.000     .6145665    1.386114
          c7 |   1.941428   .3203322     6.06   0.000     1.313588    2.569267
          c8 |   1.198877   .2171573     5.52   0.000     .7732561    1.624497
          c9 |  -1.096793   .2051277    -5.35   0.000    -1.498836     -.69475
         c10 |   2.430816   .4776317     5.09   0.000     1.494675    3.366957
         c11 |    2.03008   .4387345     4.63   0.000     1.170176    2.889984
         c12 |          0  (omitted)
       _cons |  -12.45583   3.035181    -4.10   0.000    -18.40467    -6.50698
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .20456612
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.1391                                         min =          2
     Between = 0.7262                                         avg =        6.3
     Overall = 0.2611                                         max =          7

                                                Wald chi2(2)      =      25.79
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
 ln_coverage | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
      ln_MNO |   .0740873   .0267938     2.77   0.006     .0215724    .1266022
    ln_gdppc |    .163087    .057997     2.81   0.005      .049415     .276759
       _cons |  -2.334633   .4740018    -4.93   0.000    -3.263659   -1.405606
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .26777946
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.1466                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.3946                                         max =          7

                                                Wald chi2(13)     =      40.40
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0001
```

ln_coverage	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_MNO	.4328737	.1495521	2.89	0.004	.1397569	.7259904
ln_gdppc	.5308929	.4358097	1.22	0.223	-.3232783	1.385064
c1	-.2849438	.2493485	-1.14	0.253	-.7736579	.2037702
c2	-.3247231	.2145486	-1.51	0.130	-.7452305	.0957844
c3	-.0660372	.3987119	-0.17	0.868	-.8474981	.7154238
c4	-.105068	.1471897	-0.71	0.475	-.3935545	.1834185
c5	.4234515	.3936757	1.08	0.282	-.3481387	1.195042
c6	.5956815	.2568833	2.32	0.020	.0921996	1.099164
c7	.8824387	.3980068	2.22	0.027	.1023598	1.662518
c8	.5969691	.2627683	2.27	0.023	.0819526	1.111986
c9	-.4377558	.2365577	-1.85	0.064	-.9014004	.0258888
c10	1.61319	.6561942	2.46	0.014	.3270728	2.899307
c11	.5203104	.5209665	1.00	0.318	-.5007651	1.541386
c12	0	(omitted)				
_cons	-8.857401	3.941307	-2.25	0.025	-16.58222	-1.132581
sigma_u	0					
sigma_e	.26777946					
rho	0	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.3921                                         min =          2
     Between = 0.5626                                         avg =        6.3
     Overall = 0.2750                                         max =          7

                                                Wald chi2(2)      =      21.18
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000
```

ln_coverage	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_independ~t	.0959371	.0316031	3.04	0.002	.0339962	.157878
ln_gdppc	.171005	.0698268	2.45	0.014	.034147	.3078631
_cons	-2.55048	.6002417	-4.25	0.000	-3.726932	-1.374028
sigma_u	.07136091					
sigma_e	.22008979					
rho	.09512794	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.4235                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.5910                                         max =          7

                                                Wald chi2(13)     =      89.59
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000
```

ln_coverage	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_independ~t	.5540434	.0853065	6.49	0.000	.3868458	.721241
ln_gdppc	.2182255	.3627445	0.60	0.547	-.4927406	.9291916
c1	.6521413	.2224876	2.93	0.003	.2160737	1.088209
c2	-1.286576	.2489213	-5.17	0.000	-1.774453	-.7986993
c3	.0616695	.3240549	0.19	0.849	-.5734664	.6968053
c4	-.5003351	.138524	-3.61	0.000	-.7718372	-.228833
c5	.2807816	.263581	1.07	0.287	-.2358277	.797391
c6	.3256494	.1809831	1.80	0.072	-.029071	.6803698
c7	.5916306	.2295323	2.58	0.010	.1417554	1.041506
c8	.6843578	.2028524	3.37	0.001	.2867744	1.081941
c9	-.7877973	.2013625	-3.91	0.000	-1.18246	-.3931341
c10	.7257649	.4373659	1.66	0.097	-.1314565	1.582986
c11	.5331549	.3454765	1.54	0.123	-.1439666	1.210276
c12	0	(omitted)				
_cons	-6.69162	3.139564	-2.13	0.033	-12.84505	-.5381875
sigma_u	0					
sigma_e	.22008979					
rho	0	(fraction of variance due to u_i)				

Table 5-5. Econometric models with dependent variable adoption

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.2230                                         min =          2
     Between = 0.8234                                         avg =        6.3
     Overall = 0.6905                                         max =          7

                                                Wald chi2(2)      =      52.30
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000
```

ln_mbb	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_towers	.0681056	.021641	3.15	0.002	.02569	.1105212
ln_gdppc	.22561	.0453197	4.98	0.000	.136785	.314435
_cons	-3.236498	.3807104	-8.50	0.000	-3.982677	-2.49032
sigma_u	.05434207					
sigma_e	.06079131					
rho	.44415984	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.6191                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.9233                                         max =          7

                                                Wald chi2(13)     =     746.79
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
      ln_mbb | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
   ln_towers |   .4417392   .0442643     9.98   0.000     .3549827    .5284957
    ln_gdppc |  -.0836802   .1002834    -0.83   0.404    -.2802321    .1128717
          c1 |   .1309393   .0542429     2.41   0.016     .0246252    .2372535
          c2 |   -.542595   .0790031    -6.87   0.000    -.6974383   -.3877517
          c3 |   .4988045   .0924598     5.39   0.000     .3175867    .6800223
          c4 |  -.1182512   .0364155    -3.25   0.001    -.1896243   -.0468781
          c5 |   .7233081   .0939479     7.70   0.000     .5391736    .9074426
          c6 |   .3286707   .0584914     5.62   0.000     .2140297    .4433118
          c7 |    .685972   .0951937     7.21   0.000     .4993957    .8725483
          c8 |   .2210832   .0645331     3.43   0.001     .0946007    .3475656
          c9 |  -.3338133   .0609582    -5.48   0.000    -.4532892   -.2143375
         c10 |   .5788539   .1419388     4.08   0.000     .3006591    .8570488
         c11 |   1.120534   .1303796     8.59   0.000     .8649952    1.376074
         c12 |          0  (omitted)
       _cons |  -4.096459   .9019706    -4.54   0.000    -5.864289   -2.328629
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .06079131
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------

Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.0553                                         min =          2
     Between = 0.8973                                         avg =        6.3
     Overall = 0.7311                                         max =          7

                                                Wald chi2(2)      =      83.90
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
      ln_mbb | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
      ln_MNO |   .0333624   .0156521     2.13   0.033     .0026849    .0640399
    ln_gdppc |   .2547614   .0345798     7.37   0.000     .1869863    .3225365
       _cons |   -3.16628   .2834842   -11.17   0.000    -3.721899   -2.610661
-------------+----------------------------------------------------------------
     sigma_u |  .04797378
     sigma_e |  .08740701
         rho |  .23150337   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.2125                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.8415                                         max =          7

                                                Wald chi2(13)     =     329.22
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000
```

ln_mbb	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_MNO	.1962655	.0488159	4.02	0.000	.100588	.2919429
ln_gdppc	.0502101	.1422545	0.35	0.724	-.2286035	.3290237
c1	.1076987	.0813909	1.32	0.186	-.0518245	.2672219
c2	-.0215337	.0700317	-0.31	0.758	-.1587933	.1157259
c3	.336875	.1301452	2.59	0.010	.0817951	.591955
c4	.0077068	.0480448	0.16	0.873	-.0864593	.1018729
c5	.4127954	.1285013	3.21	0.001	.1609374	.6646534
c6	.1975054	.0838503	2.36	0.019	.0331617	.3618491
c7	.3338047	.129915	2.57	0.010	.0791759	.5884335
c8	.0112539	.0857713	0.13	0.896	-.1568547	.1793626
c9	-.0983328	.0772158	-1.27	0.203	-.2496729	.0530074
c10	.3358584	.2141911	1.57	0.117	-.0839484	.7556652
c11	.6059006	.1700508	3.56	0.000	.2726071	.9391942
c12	0	(omitted)				
_cons	-2.889233	1.286498	-2.25	0.025	-5.410724	-.3677428
sigma_u	0					
sigma_e	.08740701					
rho	0	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.2053                                         min =          2
     Between = 0.8213                                         avg =        6.3
     Overall = 0.7140                                         max =          7

                                                Wald chi2(2)      =      66.58
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000
```

ln_mbb	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_independ~t	.0514762	.0165255	3.11	0.002	.0190869	.0838656
ln_gdppc	.2477615	.0385214	6.43	0.000	.172261	.323262
_cons	-3.234724	.3326795	-9.72	0.000	-3.886763	-2.582684
sigma_u	.05523623					
sigma_e	.07484374					
rho	.35261442	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.4226                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.8838                                         max =          7

                                                Wald chi2(13)     =     471.59
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000
```

ln_mbb	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_independ~t	.193752	.0290093	6.68	0.000	.1368947	.2506092
ln_gdppc	-.0463682	.1233549	-0.38	0.707	-.2881393	.195403
c1	.4593809	.0756591	6.07	0.000	.3110917	.60767
c2	-.3225153	.0846482	-3.81	0.000	-.4884227	-.1566079
c3	.3525098	.1101981	3.20	0.001	.1365255	.5684941
c4	-.1248899	.0471065	-2.65	0.008	-.2172169	-.0325628
c5	.2867123	.0896334	3.20	0.001	.1110341	.4623905
c6	.0628143	.0615451	1.02	0.307	-.0578119	.1834405
c7	.1407518	.0780548	1.80	0.071	-.0122328	.2937363
c8	.0050812	.068982	0.07	0.941	-.130121	.1402834
c9	-.1895402	.0684753	-2.77	0.006	-.3237494	-.055331
c10	-.0904506	.1487307	-0.61	0.543	-.3819573	.2010562
c11	.4998911	.1174827	4.26	0.000	.2696292	.7301531
c12	0	(omitted)				
_cons	-1.838034	1.06764	-1.72	0.085	-3.930571	.2545021
sigma_u	0					
sigma_e	.07484374					
rho	0	(fraction of variance due to u_i)				

Table 5-7. Econometric models with dependent variable quality

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.5340                                         min =          2
     Between = 0.4525                                         avg =        6.3
     Overall = 0.1848                                         max =          7

                                                Wald chi2(2)      =      12.16
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0023
```

ln_speed	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_towers	.2394347	.068728	3.48	0.000	.1047304	.374139
ln_gdppc	-.1616302	.1432014	-1.13	0.259	-.4422997	.1190393
_cons	9.161554	1.19893	7.64	0.000	6.811694	11.51141
sigma_u	.15574272					
sigma_e	.30476257					
rho	.20707376	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.5590                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.6608                                         max =          7

                                                Wald chi2(13)     =     120.76
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000
```

ln_speed	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_towers	1.956797	.2219085	8.82	0.000	1.521864	2.391729
ln_gdppc	-.3890475	.5027467	-0.77	0.439	-1.374413	.596318
c1	-.2342012	.2719337	-0.86	0.389	-.7671815	.2987791
c2	-2.985198	.3960632	-7.54	0.000	-3.761468	-2.208928
c3	.7632407	.4635247	1.65	0.100	-.1452511	1.671733
c4	-.8553154	.1825603	-4.69	0.000	-1.213127	-.4975037
c5	2.217645	.4709852	4.71	0.000	1.294531	3.14076
c6	1.627241	.2932327	5.55	0.000	1.052515	2.201966
c7	3.112044	.4772309	6.52	0.000	2.176688	4.047399
c8	1.832336	.3235209	5.66	0.000	1.198247	2.466426
c9	-1.549751	.3055992	-5.07	0.000	-2.148714	-.9507875
c10	3.785326	.7115757	5.32	0.000	2.390663	5.179988
c11	3.757531	.6536266	5.75	0.000	2.476447	5.038616
c12	0	(omitted)				
_cons	-5.078181	4.521812	-1.12	0.261	-13.94077	3.784408
sigma_u	0					
sigma_e	.30476257					
rho	0	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.1485                                         min =          2
     Between = 0.5107                                         avg =        6.3
     Overall = 0.1683                                         max =          7

                                                Wald chi2(2)      =      13.35
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0013
```

ln_speed	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_MNO	.1706196	.0467019	3.65	0.000	.0790855	.2621538
ln_gdppc	-.1412978	.1013945	-1.39	0.163	-.3400274	.0574318
_cons	9.690288	.8287279	11.69	0.000	8.066011	11.31457
sigma_u	.07125381					
sigma_e	.4177891					
rho	.02826506	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.1713                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.3625                                         max =          7

                                                Wald chi2(13)     =      35.25
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0008

------------------------------------------------------------------------------
    ln_speed | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
      ln_MNO |   .8205748    .233331     3.52   0.000     .3632545    1.277895
    ln_gdppc |   .2179391   .6799496     0.32   0.749    -1.114738    1.550616
          c1 |  -.3110652   .3890331    -0.80   0.424    -1.073556    .4514257
          c2 |  -.6385295   .3347383    -1.91   0.056    -1.294605    .0175456
          c3 |   .0143561   .6220697     0.02   0.982    -1.204878     1.23359
          c4 |  -.2912269   .2296452    -1.27   0.205    -.7413231    .1588693
          c5 |   .7592611   .6142123     1.24   0.216    -.4445728    1.963095
          c6 |   1.002411   .4007889     2.50   0.012     .2168796    1.787943
          c7 |   1.452641   .6209695     2.34   0.019     .2355633    2.669719
          c8 |   .8628818   .4099708     2.10   0.035     .0593539     1.66641
          c9 |  -.4726822    .369077    -1.28   0.200     -1.19606    .2506954
         c10 |   2.582748   1.023793     2.52   0.012     .5761499    4.589345
         c11 |   1.357613   .8128111     1.67   0.095    -.2354673    2.950694
         c12 |          0  (omitted)
       _cons |   .5891765   6.149221     0.10   0.924    -11.46307    12.64143
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |   .4177891
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.3512                                         min =          2
     Between = 0.1845                                         avg =        6.3
     Overall = 0.1393                                         max =          7

                                                Wald chi2(2)      =      10.77
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0046

------------------------------------------------------------------------------
    ln_speed | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
ln_independ~t |   .2052605   .0626096     3.28   0.001     .0825479    .3279732
    ln_gdppc |  -.1099319   .1413069    -0.78   0.437    -.3868883    .1670245
       _cons |   9.207065   1.217605     7.56   0.000     6.820603    11.59353
-------------+----------------------------------------------------------------
     sigma_u |  .19138381
     sigma_e |   .3691578
         rho |  .21183721   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.3530                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.5023                                         max =          7

                                                Wald chi2(13)     =      62.56
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000
```

ln_speed	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_independ~t	.8250954	.143085	5.77	0.000	.5446539	1.105537
ln_gdppc	-.1976697	.6084333	-0.32	0.745	-1.390177	.9948376
c1	1.178445	.3731796	3.16	0.002	.4470268	1.909864
c2	-1.932265	.417517	-4.63	0.000	-2.750583	-1.113946
c3	.0907814	.543539	0.17	0.867	-.9745354	1.156098
c4	-.8578011	.2323471	-3.69	0.000	-1.313193	-.4024091
c5	.2481763	.4421059	0.56	0.575	-.6183353	1.114688
c6	.4424823	.303564	1.46	0.145	-.1524921	1.037457
c7	.6615079	.3849958	1.72	0.086	-.0930701	1.416086
c8	.8490538	.3402454	2.50	0.013	.182185	1.515923
c9	-.8716738	.3377463	-2.58	0.010	-1.533644	-.2097031
c10	.8066393	.7335962	1.10	0.272	-.6311829	2.244462
c11	.943649	.5794696	1.63	0.103	-.1920904	2.079389
c12	0	(omitted)				
_cons	4.966069	5.266008	0.94	0.346	-5.355116	15.28725
sigma_u	0					
sigma_e	.3691578					
rho	0	(fraction of variance due to u_i)				

Table 5-9. Econometric models with dependent variable mobile market concentration

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.2034                                         min =          2
     Between = 0.0372                                         avg =        6.3
     Overall = 0.0419                                         max =          7

                                                Wald chi2(2)      =      15.97
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0003
```

ln_HHI_Mob~e	Coefficient	Std. err.	z	P>|z|	[95% conf.	interval]
ln_towers	-.0758692	.0200453	-3.78	0.000	-.1151571	-.0365812
ln_gdppc	-.0211636	.0450328	-0.47	0.638	-.1094263	.0670991
_cons	9.039113	.4098593	22.05	0.000	8.235804	9.842422
sigma_u	.26438769					
sigma_e	.02887906					
rho	.98820949	(fraction of variance due to u_i)				

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.2042                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.9866                                         max =          7

                                                Wald chi2(13)     =    4558.31
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_HHI_Mob~e | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
   ln_towers |  -.0813904   .0210279    -3.87   0.000    -.1226043   -.0401765
    ln_gdppc |  -.0101682   .0476399    -0.21   0.831    -.1035407    .0832042
          c1 |   .3681165   .0257682    14.29   0.000     .3176117    .4186213
          c2 |   .0530353   .0375306     1.41   0.158    -.0205234     .126594
          c3 |   .0458462   .0439232     1.04   0.297    -.0402418    .1319341
          c4 |   .4522044   .0172993    26.14   0.000     .4182984    .4861103
          c5 |    .175601   .0446302     3.93   0.000     .0881274    .2630746
          c6 |   .7152491   .0277865    25.74   0.000     .6607885    .7697096
          c7 |  -.0051789    .045222    -0.11   0.909    -.0938125    .0834546
          c8 |   .2351588   .0306566     7.67   0.000      .175073    .2952446
          c9 |   .6727058   .0289583    23.23   0.000     .6159485    .7294631
         c10 |    .342795   .0674283     5.08   0.000     .2106379    .4749521
         c11 |   .0027357   .0619371     0.04   0.965    -.1186589    .1241303
         c12 |          0  (omitted)
       _cons |   8.736054   .4284833    20.39   0.000     7.896242    9.575866
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .02887906
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.0220                                         min =          2
     Between = 0.0993                                         avg =        6.3
     Overall = 0.1107                                         max =          7

                                                Wald chi2(2)      =       2.19
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.3338

------------------------------------------------------------------------------
ln_HHI_Mob~e | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
      ln_MNO |  -.0142229   .0170784    -0.83   0.405     -.047696    .0192501
    ln_gdppc |  -.0536181    .048378    -1.11   0.268    -.1484372     .041201
       _cons |   8.768812   .4413556    19.87   0.000     7.903771    9.633853
-------------+----------------------------------------------------------------
     sigma_u |  .26437729
     sigma_e |  .03200884
         rho |   .9855532   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.0224                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.9835                                         max =          7

                                                Wald chi2(13)     =    3698.95
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_HHI_Mob~e | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
      ln_MNO |  -.0145584   .0178766    -0.81   0.415    -.0495959    .0204791
    ln_gdppc |  -.0409802   .0520942    -0.79   0.431     -.143083    .0611225
          c1 |   .3608581   .0298057    12.11   0.000       .30244    .4192762
          c2 |  -.0599997   .0256459    -2.34   0.019    -.1102648   -.0097347
          c3 |   .0896509   .0476598     1.88   0.060    -.0037605    .1830623
          c4 |   .4262868   .0175942    24.23   0.000     .3918027    .4607708
          c5 |   .2694822   .0470578     5.73   0.000     .1772507    .3617138
          c6 |   .7587925   .0307064    24.71   0.000     .6986091    .8189759
          c7 |   .1036759   .0475755     2.18   0.029     .0104297    .1969221
          c8 |   .2914988   .0314098     9.28   0.000     .2299366    .3530609
          c9 |   .6143006   .0282768    21.72   0.000     .5588791     .669722
         c10 |   .4433822   .0784377     5.65   0.000     .2896471    .5971173
         c11 |   .1507394   .0622734     2.42   0.015     .0286858     .272793
         c12 |          0  (omitted)
       _cons |   8.372215   .4711215    17.77   0.000     7.448834    9.295596
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .03200884
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.2413                                         min =          2
     Between = 0.0441                                         avg =        6.3
     Overall = 0.0506                                         max =          7

                                                Wald chi2(2)      =      20.49
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_HHI_Mobile | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
--------------+----------------------------------------------------------------
ln_independ~t |  -.0463746   .0106987    -4.33   0.000    -.0673436   -.0254056
     ln_gdppc |  -.0204345   .0437433    -0.47   0.640    -.1061699    .0653008
        _cons |   8.723327   .3891131    22.42   0.000     7.960679    9.485975
--------------+----------------------------------------------------------------
      sigma_u |  .26403475
      sigma_e |  .02818043
          rho |  .98873701   (fraction of variance due to u_i)
-------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         76
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.2423                                         min =          2
     Between = 1.0000                                         avg =        6.3
     Overall = 0.9872                                         max =          7

                                                Wald chi2(13)     =    4790.24
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_HHI_Mobile | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
--------------+---------------------------------------------------------------
ln_independ~t |  -.0474173   .0109227    -4.34   0.000    -.0688254   -.0260092
     ln_gdppc |  -.0078265    .046446    -0.17   0.866     -.098859    .0832061
           c1 |   .2926719   .0284874    10.27   0.000     .2368375    .3485062
           c2 |   .0400469    .031872     1.26   0.209    -.0224212    .1025149
           c3 |   .0641796   .0414922     1.55   0.122    -.0171435    .1455028
           c4 |   .4629362   .0177367    26.10   0.000     .4281729    .4976995
           c5 |   .2435207   .0337491     7.22   0.000     .1773737    .3096677
           c6 |   .7617328   .0231732    32.87   0.000     .7163142    .8071514
           c7 |   .0827949   .0293895     2.82   0.005     .0251926    .1403971
           c8 |   .2656163   .0259733    10.23   0.000     .2147095    .3165231
           c9 |   .6598918   .0257826    25.59   0.000     .6093589    .7104247
          c10 |   .4612293   .0560006     8.24   0.000     .3514702    .5709885
          c11 |   .0942786    .044235     2.13   0.033     .0075795    .1809776
          c12 |          0  (omitted)
        _cons |   8.334061   .4019916    20.73   0.000     7.546171     9.12195
--------------+---------------------------------------------------------------
      sigma_u |          0
      sigma_e |  .02818043
          rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Table 5-11. Econometric models with dependent variable mobile affordability

```
Random-effects GLS regression                   Number of obs     =         64
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.1025                                         min =          1
     Between = 0.6769                                         avg =        5.3
     Overall = 0.6907                                         max =          6

                                                Wald chi2(2)      =      30.20
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_afforda~y | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
   ln_towers |  -.3267791   .1215102    -2.69   0.007    -.5649346   -.0886235
    ln_gdppc |   -.982563   .2537373    -3.87   0.000    -1.479879    -.485247
       _cons |   12.34322   2.219913     5.56   0.000     7.992275    16.69417
-------------+----------------------------------------------------------------
     sigma_u |  .51947285
     sigma_e |  .22940465
         rho |  .83680621   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         64
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.2060                                         min =          1
     Between = 1.0000                                         avg =        5.3
     Overall = 0.9637                                         max =          6

                                                Wald chi2(13)     =    1326.31
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_afforda~y | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
   ln_towers |  -.7094847   .2007087    -3.53   0.000    -1.102866    -.316103
    ln_gdppc |  -.2421697   .4117507    -0.59   0.556    -1.049186    .5648468
          c1 |    .811066   .2317467     3.50   0.000     .3568507    1.265281
          c2 |   .9465271   .3697981     2.56   0.010      .221736    1.671318
          c3 |  -.5796544   .3635186    -1.59   0.111    -1.292138    .1328291
          c4 |   .0006443   .1508593     0.00   0.997    -.2950344     .296323
          c5 |  -2.065063   .3761593    -5.49   0.000    -2.802322   -1.327804
          c6 |  -.1649006   .2881705    -0.57   0.567    -.7297044    .3999033
          c7 |  -.8714388   .4579546    -1.90   0.057    -1.769013    .0261357
          c8 |   .4135964   .3031698     1.36   0.172    -.1806055    1.007798
          c9 |  -.3798572   .2774607    -1.37   0.171    -.9236701    .1639557
         c10 |    .378856   .6623169     0.57   0.567    -.9192611    1.676973
         c11 |  -1.981105   .5278607    -3.75   0.000    -3.015693   -.9465166
         c12 |          0  (omitted)
       _cons |   9.474589   4.033927     2.35   0.019     1.568238    17.38094
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .22940465
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         64
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.0098                                         min =          1
     Between = 0.7670                                         avg =        5.3
     Overall = 0.7667                                         max =          6

                                                Wald chi2(2)      =      26.17
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_afforda~y | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
      ln_MNO |  -.1002962   .1096487    -0.91   0.360    -.3152036    .1146113
    ln_gdppc |  -1.149615    .254749    -4.51   0.000    -1.648914   -.6503164
       _cons |   11.75044   2.168507     5.42   0.000     7.500249    16.00064
-------------+----------------------------------------------------------------
     sigma_u |  .52319872
     sigma_e |  .25592674
         rho |  .80692317   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         64
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.0118                                         min =          1
     Between = 1.0000                                         avg =        5.3
     Overall = 0.9548                                         max =          6

                                                Wald chi2(13)     =    1055.84
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_afforda~y | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
      ln_MNO |  -.0838212   .1813382    -0.46   0.644    -.4392376    .2715952
    ln_gdppc |  -.2821037   .4591996    -0.61   0.539    -1.182118    .6179109
          c1 |   .6110912   .2702822     2.26   0.024     .0813477    1.140835
          c2 |  -.1465389   .2420382    -0.61   0.545     -.620925    .3278472
          c3 |   -.379906   .4055395    -0.94   0.349    -1.174749    .4149367
          c4 |  -.2297005   .1515953    -1.52   0.130    -.5268218    .0674208
          c5 |  -1.328872   .4275104    -3.11   0.002    -2.166777   -.4909667
          c6 |   .2486984   .3288763     0.76   0.450    -.3958872    .8932841
          c7 |   .3054791   .4922605     0.62   0.535    -.6593338    1.270292
          c8 |   1.056286   .3094856     3.41   0.001     .4497054    1.662867
          c9 |  -1.014175      .2561    -3.96   0.000    -1.516121   -.5122277
         c10 |   1.650857    .780932     2.11   0.035     .1202581    3.181455
         c11 |  -.7778254   .5753572    -1.35   0.176    -1.905505     .349854
         c12 |          0  (omitted)
       _cons |   3.924573   4.340405     0.90   0.366    -4.582465    12.43161
-------------+----------------------------------------------------------------
     sigma_u |          0
     sigma_e |  .25592674
         rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         64
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.1806                                         min =          1
     Between = 0.7759                                         avg =        5.3
     Overall = 0.7542                                         max =          6

                                                Wald chi2(2)      =      46.55
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_affordab~y | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
--------------+----------------------------------------------------------------
ln_independ~t |  -.3175821   .0790925    -4.02   0.000    -.4726005   -.1625637
     ln_gdppc |  -1.055496   .2229642    -4.73   0.000    -1.492497   -.6184939
        _cons |   12.58681   1.972808     6.38   0.000     8.720176    16.45344
--------------+----------------------------------------------------------------
      sigma_u |  .46712765
      sigma_e |  .22401348
          rho |  .81302587   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

```
Random-effects GLS regression                   Number of obs     =         64
Group variable: Country_id                      Number of groups  =         12

R-squared:                                      Obs per group:
     Within  = 0.2429                                         min =          1
     Between = 1.0000                                         avg =        5.3
     Overall = 0.9654                                         max =          6

                                                Wald chi2(13)     =    1393.36
corr(u_i, X) = 0 (assumed)                      Prob > chi2       =     0.0000

------------------------------------------------------------------------------
ln_affordab~y | Coefficient  Std. err.      z    P>|z|     [95% conf. interval]
--------------+----------------------------------------------------------------
ln_independ~t |  -.3858228   .0978736    -3.94   0.000    -.5776515    -.193994
     ln_gdppc |  -.2077791   .4023775    -0.52   0.606    -.9964246    .5808664
           c1 |   .1690928   .2370218     0.71   0.476    -.2954613    .6336469
           c2 |   .7865988    .303158     2.59   0.009     .1924201    1.380778
           c3 |  -.4318857   .3497307    -1.23   0.217    -1.117345    .2535738
           c4 |   .0936373   .1563143     0.60   0.549    -.2127331    .4000077
           c5 |  -1.434853   .2846571    -5.04   0.000    -1.992771   -.8769356
           c6 |   .2778568   .2466836     1.13   0.260    -.2056342    .7613478
           c7 |  -.0090968   .2718964    -0.03   0.973    -.5420039    .5238104
           c8 |   .7850812   .2353012     3.34   0.001     .3238994    1.246263
           c9 |  -.5009015   .2402064    -2.09   0.037    -.9716974   -.0301057
          c10 |   1.518952   .5007094     3.03   0.002     .5375797    2.500325
          c11 |  -1.113151   .3667344    -3.04   0.002    -1.831937   -.3943647
          c12 |          0  (omitted)
        _cons |    5.59762    3.58836     1.56   0.119    -1.435435    12.63068
--------------+----------------------------------------------------------------
      sigma_u |          0
      sigma_e |  .22401348
          rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```