LATIN AMERICAN TELECOMMUNICATIONS

AT THE CROSSROADS OF PASSIVE INFRASTRUCTURE SHARING

AUGUST 2024

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Authors

Raul Katz – Ph.D. in Political Science and Management Science, M.S. in Communications Technology and Policy from the Massachusetts Institute of Technology (United States), Maîtrise and Licence in Communication Sciences from the University of Paris (France), Maîtrise in Political Science from the University of Paris-Sorbonne (France). Dr. Katz worked at Booz Allen & Hamilton for 20 years as a lead partner in the Telecommunications Practice in the Americas and member of the firm's Leadership Team. After retiring from Booz Allen, he founded Telecom Advisory Services, LLC, in April 2006. In addition to his role as President of Telecom Advisory Services, Dr. Katz is Director of Business Strategy Research at the Columbia Institute for Tele-Information at Columbia Business School (New York) and Visiting Professor at the Telecommunications Management Graduate Program at the Universidad de San Andrés (Argentina).

Ángel Melguizo – Ph.D. and B.A. in Economics from the Universidad Complutense de Madrid (Spain). Dr. Melguizo is Principal Economist and Consultant at Telecom Advisory Services, based in Madrid, where he specializes in public policy, economic growth and digital regulation. He has nearly 25 years of experience in the private sector (AT&T and BBVA) and the public sector (IDB, OECD and the Economic Office of the President of the Spanish Government). He has participated in several reforms throughout Latin America on telecommunications and digital policy, taxation, competition and social policies.

Fernando Callorda – B.A. and M.A. in Economics from the Universidad de San Andrés (Argentina). Mr. Callorda is a project manager with Telecom Advisory Services, LLC, based in Buenos Aires, Argentina, as well as a researcher affiliated to the National Network of Public Universities of Argentina and professor of Political Economy at UNLaM, where he teaches courses in finance within regulated industries. Before joining Telecom Advisory Services, Mr. Callorda was an analyst in the Argentine National Congress and an auditor at Deloitte.

Ramiro Valencia – Bachelor's in Electrical and Telecommunications Engineering from the Escuela Politécnica Nacional (Ecuador) and M.A. in Development Economics, FLACSO (Ecuador). Mr. Valencia is a consultant with Telecom Advisory Services, based in Quito, Ecuador, specializing in economics of telecommunications regulation. Prior to joining Telecom Advisory Services, Mr. Valencia had a 12-year career in telecommunications regulation and policymaking in Ecuador. In his last assignment, he was Director of Telecommunications Policy at the Ministry of Telecommunications of Ecuador.

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Table of Contents

EXECUTIVE SUMMARY

The development of the Latin American wireless industry over the past 20 years has been remarkable. Coverage of 3G and 4G is now 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 factor that has been instrumental in propelling this progress is the industry's ability and willingness to share infrastructure across operators while preserving competition.

That said, the wireless industry in Latin America still experiences significant challenges. Coverage gaps remain in rural areas, key transportation highways and even in some parts of the biggest cities in the region. While 5G service has been launched in many Latin American countries and spectrum is becoming more widely available, 5G technology remains to be deployed in many areas. Its availability has increased notably in Brazil, Chile and Mexico, however. Wireless broadband adoption is widespread, but affordability is a key factor limiting access for the base of the sociodemographic pyramid. And, while certain structural conditions such as low average revenues per user (ARPUs) still constrain the level of capital spending, the Latin American lag with respect to OECD countries in terms of capital investment remains a concern for future development. In this context, according to the International Telecommunication Union, passive infrastructure sharing is critical as a way to address the wireless industry's forward-looking capital spending challenges, and far less complex to agree on than active sharing, which requires greater collaboration among carriers.[1]

Econometric analysis conducted in this study validates 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% (common in the region) would see the following effects from introducing best practices infrastructure sharing regulation:

- 4G coverage level would rise from 80.00% to 93.03%.
- Unique mobile broadband users would increase from 60.00% to 61.55%.
- The increase in unique mobile broadband users would, in turn, lead to an increase in gross domestic product (GDP) per capita of 0.41%.

In this context, the tower industry's contribution to infrastructure sharing is relevant. In 2024, in the 13 largest countries of Latin America, the number of mobile towers reached 217,022. In parallel with the growth in the number of towers, the tower industry has been gradually evolving toward an increased share of independent and mobile network operator (MNO) owned companies. In Latin American countries, on average, half of the towers are already operated by independent companies. Compared with other regions around the world, Latin America has a highly developed independent tower sector, second only to that

[1] See International Telecommunication Union. Mobile infrastructure sharing. Retrieved in: https://www.itu.int/itunews/manager/display.asp?lang=en&year=2008&issue=02&ipage=sharingInfrastructure-mobile

of South Asia. The gradual divestiture by MNOs of most of their tower infrastructure and the combined development of MNO-owned and independent tower companies in Latin America raises a question about the impact of tower ownership on future industry development: Is the share of independent tower "specialists" associated with improved wireless industry performance (as measured by capital efficiency, network deployment, service adoption and quality)?

The empirical evidence presented in this study provides a positive answer to this question, supported by both correlational and econometric analyses. From a correlational standpoint, Latin American countries with a large share of towers operated by independent companies exhibit higher wireless industry performance metrics than those with a lower share of towers operated by independent towercos. In fact, countries with more than 50% of towers operated by independent companies are associated with:

- Higher 4G coverage (average of 98.5% of the population vs. 90.93%).
- 50% faster wireless broadband speeds (average of 76 Mbps vs. 38 Mbps).
- 43% higher capital investment (average of US$35.8 per capita vs. US$20.34 per capita).
- One-third lower mobile broadband prices as a percentage of per capita income (therefore higher affordability).
- A higher adoption of mobile broadband (average of 70.53% vs. 60.04%).
- More intense competition in the mobile industry (average Herfindahl–Hirschman Index (HHI) of 3,195 vs. HHI = 4,088).

From an econometric standpoint, the causality between independent tower companies and wireless industry development is also examined 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, which measures industry concentration — a lower index depicts more intense competition) of 0.46%.
- Results in improved 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, there are obvious benefits for Latin American countries that support the development of the independent tower industry. These benefits are contingent, however, on several regulatory and public policy initiatives, as 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 information garnered from interviews with regulators and policymakers led to the identification of seven types of initiatives that can contribute to the development and sustainability of an independent tower sector:

(i) **No need for service concession.** The construction of a cell tower does not rely on a public good, as is the case with 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 cases of power transmission or railways. This 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 (iii) below).

(ii) **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 and internet services that are under federal authority. Frequently, in many countries in 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, increasing the cost of deployment.

(iii) **Regulations to prevent over-deployment.** Tower over-deployment, in many cases driven by straight financial speculation, occurs frequently in Latin America, with negative environmental and economic consequences. A simplified financial model developed for this study indicates that, on average, if 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 10-year time horizon.[2] With this in mind, governments should promote policies and regulatory frameworks preventing over-deployment while fostering sharing, especially in rural areas.

(iv) **Establishment of a cap on fees, taxes and rights of construction.** Fees and taxes, also referred to as the "cost of compliance," have an impact on the tower business case. 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 specific fees that either limit deployment of infrastructure or increase revenues. Sometimes these fees become recurrent or subject to annual increase defined on an ad hoc basis. Without making any judgment 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

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

support the connectivity needs of their population.

(v) **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 two and three 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 time and complexity required to approve permits, and provide access to public buildings and rights of way at market prices.

(vi) **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 to limit 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"[3]) and (iii) they would represent a disincentive to invest in infrastructure.

(vii) **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 reinvestment. While the financial profile developed in the context of this study is calculated over a 10-year timeframe, stability and predictability of regulatory frameworks are critical industry requirements.

These policy and regulatory prescriptions have been undertaken by countries that are benchmarks of healthy development of the telecommunications and passive infrastructure sharing industries, including South Korea, the United Kingdom and the United States. As such, these countries:

- 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 and implemented simple procedures for construction permits and references to construction fees that

[3] According to the Better Business Bureau, "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."

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 El Salvador and Guatemala, include the passive infrastructure provider in their regulations, although many lack specific legislation to address passive infrastructure. In addition, countries that do have a specific law on passive infrastructure do not have rules to enforce technical standards regarding the deployment of passive infrastructure.
- In most countries (with the exception of Ecuador, Honduras and Chile) tower companies are not required to apply for any type of registration to obtain a passive operator license from the telecommunications regulator.
- Only Chile has national standards in harmony with local ordinances. In most countries, there are general laws that establish the technical mechanisms of deployment (i.e., distance, height, sharing, co-location) and these coexist with the ordinances and exclusively regulate the field of civil construction of buildings (e.g., building permitting, soil charges, landscape environment). In El Salvador and Guatemala, local ordinances are free from any national restrictions.
- Only Chile, Peru and Panama have implemented straightforward regulatory processes for the deployment and operation of passive infrastructure.
- Only Chile and Costa Rica have clearly established parameters or frameworks that determine fees for the use of space or land use for the deployment of towers.
- In all countries, infrastructure lease prices can be freely negotiated between operators and tower companies.
- Only Brazil, Colombia and Chile have clear plans focused on the development of passive infrastructures for new technologies such as 5G. In addition, Peru and Panama have already defined regulations for the deployment of microcells (low-power stations) in urban sites.

It should be mentioned that between 2022 and 2023, progress in tower sector regulation in Latin America was made in four areas: (i) creation of the passive infrastructure provision figure in Colombia, (ii) harmonization between the national sector regulation and the tower deployment rules in municipalities in Brazil and Costa Rica, (iii) regulatory simplification and streamlining of procedures in Argentina and Peru, and (iv) future planning of regulation related to infrastructure sharing in Brazil and Panama.

Looking toward the future, tower regulatory framework could be improved in two important ways: (i) promotion of regulation related to infrastructure sharing in El Salvador, Guatemala, Honduras, Nicaragua and Panama, and (ii) implementation of minimum distances or other mechanisms to avoid duplicity of infrastructure.

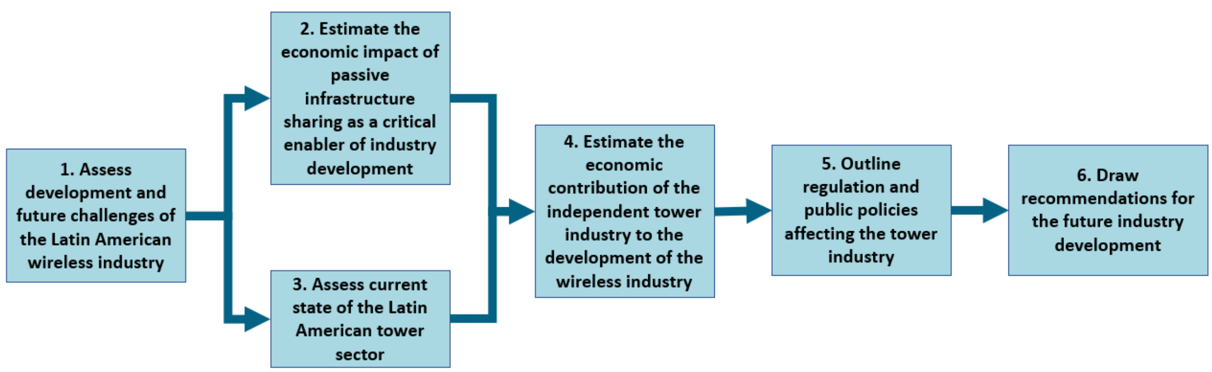
To summarize, as highlighted in this study, the development of a vibrant, sustainable independent tower industry is critical for future development of wireless telecommunications in Latin America. Furthermore, given the expanded potential for tower sites for supporting edge computing, network distribution nodes for both fiber and wireless networks, and future generations 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 is intrinsically linked. Regulators and policymakers should recognize this and support their development.

INTRODUCTION

The development of the Latin American wireless industry over the past 20 years has been remarkable, with notable progress in the areas of technology deployment, adoption and affordability. One factor that has been instrumental in propelling this progress is the industry's ability and willingness to share infrastructure across operators while preserving competition. This study explores these positive trends and the underlying economics that have facilitated them and provides a range of recommendations for continued progress in infrastructure sharing. The recommendations rely on the development of the independent tower sector for accelerating innovation, propelling capital spending in new technologies and tackling the digital divide.

The study is divided into six chapters.

General framework of the study



Chapter 1 presents an analysis of the current development of the Latin American wireless industry, comparing it with that of advanced economies in terms of capital investment, network deployment, affordability of service and quality. While highlighting progress in the sector, the assessment also outlines challenges, such as areas where mobile services still have significant limitations. Chapter 2 examines the contribution of infrastructure sharing to the development of the Latin American wireless industry and presents econometric analyses demonstrating its impact on the development of telecommunications.[4] Elaborating on the concept of infrastructure sharing as an enabling component of the telecommunications value chain, Chapter 3 examines the state of development of the Latin American tower industry, analyzing its deployment and the organization of the industry, in particular its ownership structure. This analysis serves as a backdrop to understanding whether the ownership of tower companies is key in terms of contribution to the performance of the wireless telecommunications sector, which is discussed in Chapter 4. This is supported by evidence of correlations and econometric models, demonstrating the causal relationship between an increase in the number of independent tower companies

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

and several performance indicators of the mobile industry (i.e., increase in 4G coverage, growth in mobile broadband adoption, improvement in quality of service, increase in competition in the mobile market and improvement in the affordability levels of mobile service). The empirical analyses in Chapters 2 through 4 provide the basis for outlining normative and policy prescriptions; in other words, they define what needs to happen in the public policy arena to maximize the development and sustainability of an independent tower industry. Chapter 5 is an assessment of the state of tower regulation in the region and provides a compilation of related best practices in advanced economies. Chapter 6 is a brief overview with recommendations for the future of the tower industry. Finally, the conclusions of the study, recommendations and some lines of future research are proposed in the concluding section.

1. 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 now almost ubiquitous, and 5G exhibits important progress in some countries. 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.

Nevertheless, the wireless industry in Latin America is still experiencing significant challenges. The lack of coverage remains significant in rural areas, 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 Latin American countries and spectrum is becoming more widely available, 5G technology remains merely a future possibility for some countries. Wireless broadband adoption is widespread, but affordability is a key factor limiting service access at the base of the sociodemographic pyramid. And, while certain structural conditions such as low average revenues per user (ARPUs) still constrain the level of capital spending, the Latin American lag with respect to OECD countries in terms of capital investment remains a concern for future development.

This view of progress and future challenges is explained in detail in this chapter, serving as a background to subsequent chapters' examination of the importance of infrastructure sharing and the role it plays in the development of a healthy and thriving tower industry. This is presented as 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 nations.

1.1. Latin America's gap with advanced economies

The Latin American mobile industry has reached a level of adoption that exceeds the global average. In 2023, mobile broadband adoption (measured from unique mobile subscribers rather than total connections) reached 64.19%, compared to the global average of 63.17%. On the other hand, population coverage by 4G technology[5] amounted to 93.68% of the population, slightly below the weighted world average of 96.04% (table 1-1).

[5] 4G is considered to be the technology that provides reliable mobile broadband service. For reference, the coverage of the Latin American population of 3G has reached 97%.

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

	Mobile broadband adoption*							4G coverage**						
	2019	2020	2021	2022	2023	2024 (E)	CAGR (2019-24)	2019	2020	2021	2022	2023	2024 (E)	CAGR (2019-24)
World	51.66%	55.24%	58.47%	60.64%	63.17%	64.69%	4.60%	90.64%	92.60%	94.42%	95.35%	96.04%	96.36%	1.23%
Sub-Saharan Africa	22.83%	24.49%	26.28%	28.33%	30.32%	31.61%	6.73%	47.46%	57.82%	67.52%	74.15%	77.49%	79.69%	10.92%
Latin America and the Caribbean	54.38%	56.98%	59.69%	61.99%	64.19%	65.53%	3.80%	85.02%	86.97%	89.33%	92.00%	93.68%	94.50%	2.14%
North America	78.15%	80.88%	83.02%	85.35%	87.26%	88.11%	2.43%	99.00%	99.00%	99.00%	99.00%	99.00%	99.89%	0.18%
Asia-Pacific	49.05%	53.39%	57.24%	59.63%	62.70%	64.52%	5.64%	96.55%	97.35%	98.07%	98.12%	98.51%	98.52%	0.41%
Western Europe	75.16%	79.19%	82.86%	85.33%	87.12%	88.34%	3.29%	98.23%	98.67%	99.40%	99.51%	99.52%	99.52%	0.26%
Eastern Europe	70.79%	72.59%	74.18%	73.61%	74.27%	74.82%	1.12%	91.95%	94.48%	95.52%	96.37%	96.57%	96.62%	1.00%
Arab States	45.39%	48.42%	51.34%	54.59%	57.40%	59.82%	5.68%	86.66%	93.04%	98.67%	98.97%	99.22%	99.22%	2.74%
BENCHMARKS														
OECD	73.51%	76.90%	80.00%	82.35%	84.18%	85.27%	3.01%	97.00%	97.31%	98.01%	98.45%	98.55%	98.91%	0.39%
United States	78.74%	81.44%	83.48%	85.81%	87.62%	88.42%	2.35%	99.00%	99.00%	99.00%	99.00%	99.00%	100.00%	0.20%
Canada	73.02%	76.01%	79.01%	81.44%	84.22%	85.48%	3.20%	99.00%	99.00%	99.00%	99.00%	99.00%	99.00%	0.00%
United Kingdom	77.58%	82.69%	87.65%	89.19%	89.47%	89.74%	2.95%	99.00%	99.00%	99.58%	99.60%	99.60%	99.60%	0.12%
South Korea	91.73%	92.71%	93.45%	93.97%	94.08%	94.21%	0.53%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	0.00%

* Measured as unique mobile broadband subscribers. (E: estimation)
** Measured as a percentage of the population. (E: estimation)
Sources: GSMA Intelligence; Telecom Advisory Services analysis

As shown in table 1-1, the mobile broadband adoption gap between Latin America and the weighted average of OECD countries (the community of advanced economies) has remained fairly stable (from 19.13 percentage points in 2019 to 19.99 in 2023). On the other hand, the difference in 4G coverage between Latin America and the weighted average of OECD countries decreased from 11.98 percentage points in 2019 to 4.87 in 2023. Unsurprisingly, the adoption gap separating the region from high-income benchmark economies remains wide; structural factors, such as income distribution, account for a large part of this gap.

In parallel with the increase in 4G coverage, the region has made substantial progress in mobile broadband service quality, as measured by average download speed and median service latency (table 1-2). As shown in table 1-2, the average mobile broadband download speed has increased at a rate of 24.02% since 2019, while average latency has decreased at a rate of 6.23%. In sum, despite significant progress in the region, the mobile broadband speed gap with OECD countries has widened in recent years, while the latency gap in the region has closed to some extent.

Table 1-2. Quality of mobile service

	Average mobile broadband download speed (in Mbps)*							Median mobile broadband latency (in ms)						
	2019	2020	2021	2022	2023	2024 (1Q)	CAGR 2019-1Q24	2019	2020	2021	2022	2023	2024 (1Q)	CAGR 2019-1Q24
World	24	41	62	72	105	106	41.41%	38	32	30	30	29	28	-6.86%
Sub-Saharan Africa	16	18	23	29	37	37	21.16%	39	34	30	30	29	29	-6.63%
Latin America and the Caribbean	22	26	29	41	52	54	24.02%	40	34	32	31	32	31	-6.23%
North America	38	48	93	127	177	199	47.35%	39	36	32	32	30	28	-7.42%
Asia-Pacific	24	50	74	82	127	120	46.65%	39	32	30	30	28	28	-7.45%
Western Europe	38	43	68	91	106	109	28.09%	35	32	30	30	29	28	-5.02%
Eastern Europe	26	29	38	48	58	66	24.37%	34	32	30	29	29	28	-4.29%
Arab States	24	35	55	69	94	100	39.35%	35	30	28	28	27	27	-5.68%
BENCHMARKS														
OECD	38	44	74	98	120	130	33.53%	37	33	32	31	31	30	-5.23%
United States	36	45	93	131	185	215	52.69%	40	37	33	32	31	29	-7.51%
Canada	62	69	88	92	108	110	14.25%	30	28	26	25	24	23	-6.25%
United Kingdom	32	36	81	100	104	111	33.81%	39	37	36	36	35	34	-3.06%
South Korea	100	112	194	250	286	318	31.38%	32	34	28	31	28	28	-3.35%

* From 2023 onwards, the evolution of the average values is estimated, based on the evolution of the median of the same indicator.

Sources: Ookla Speedtest; Telecom Advisory Services analysis

Finally, as indicated in table 1-3, the wireless broadband affordability gap between the region and OECD countries, measured as the price of the standard mobile broadband plan as a percentage of monthly GDP per capita, remains five times higher than that of OECD countries. In absolute terms, the situation has improved since 2019 and by 2023 was 3.11% of GDP per capita,[6] despite the economic contraction caused by COVID-19 (table 1-3).

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[6] The Broadband Commission for Sustainable Development stated that by 2025, the affordability target should not exceed 2% of monthly per capita income. See Comisión de la Banda Ancha para el Desarrollo Sostenible (2022). *Objetivos 2025: Conectar a la otra mitad.* Disponible en: https://www.broadbandcommission.org/broadband-targets.

Table 1-3. Affordability of wireless broadband*

	2019	2020	2021	2022	2023	2019-23 CAGR
World	1.66%	1.60%	1.49%	1.32%	1.17%	-8.36%
OECD	0.67%	0.70%	0.74%	0.68%	0.62%	-2.19%
Sub-Saharan Africa	6.07%	5.04%	5.05%	3.94%	3.21%	-14.74%
Latin America and the Caribbean	3.99%	3.65%	3.62%	3.23%	3.11%	-6.07%
North America	0.45%	0.43%	0.69%	0.75%	0.68%	10.97%
Asia-Pacific	0.95%	1.07%	0.85%	0.81%	0.74%	-6.21%
Western Europe	0.54%	0.56%	0.47%	0.38%	0.35%	-9.84%
Eastern Europe	0.92%	0.83%	0.88%	0.72%	0.57%	-11.14%
Arab States	1.27%	1.05%	1.26%	1.23%	0.89%	-8.46%

* Price of a basic basket of mobile broadband as defined each year by the International Telecommunication Union, as a percentage of monthly GDP per capita.
Sources: International Telecommunication Union; Telecom Advisory Services analysis

In summary, Latin American wireless telecommunication has substantially increased population coverage with 4G and improved the quality of services, while maintaining affordability at a stable level, despite the economic contraction.

1.2. Forward-looking challenges

Despite the progress indicated above, the gap between Latin America and the weighted average of OECD countries remains significant. As mentioned, Latin America's mobile adoption gap with OECD countries in 2023 was 19.99 percentage points, while the 4G coverage gap was 4.87 percentage points. While Latin America's average mobile speed has doubled in the last four years (reaching 52 Mbps in 2023), the OECD average has also increased, but at a faster rate (reaching 120 Mbps in 2023). And, while the region has made significant progress in service affordability, the gap with advanced economies remains substantial. The challenges that the mobile industry still faces in the region is reviewed in the following sections.

1.2.1. Uneven mobile broadband coverage and quality of service

Despite the narrowing gap with advanced economies, in terms of coverage and quality of service, the level of development of the Latin American mobile industry by country shows great heterogeneity. For example, the level of mobile broadband coverage varies greatly among countries (table 1-4).

Table 1-4. Latin America: 4G coverage*

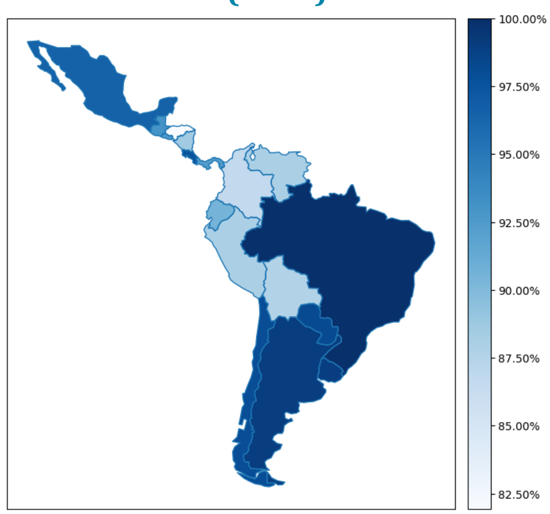
	2019	2020	2021	2022	2023	2024 (E)	CAGR 2019-24
Latin America and the Caribbean	85.02%	86.97%	89.33%	92.00%	93.68%	94.50%	2.14%
Argentina	90.77%	94.58%	97.00%	98.00%	99.00%	99.08%	1.77%
Bolivia	80.96%	82.92%	84.93%	86.00%	87.00%	87.60%	1.59%
Brazil	94.00%	95.00%	97.00%	99.00%	100.00%	100.00%	1.25%
Chile	96.00%	97.00%	98.00%	98.00%	98.00%	98.00%	0.41%
Colombia	71.00%	73.24%	79.00%	85.00%	85.00%	86.70%	4.08%
Costa Rica	89.00%	89.00%	96.00%	96.00%	97.00%	97.50%	1.84%
Ecuador	86.35%	88.00%	88.00%	89.00%	90.00%	90.49%	0.94%
El Salvador	73.63%	89.50%	90.00%	91.00%	92.00%	92.52%	4.67%
Guatemala	86.35%	88.00%	88.00%	88.00%	92.00%	93.08%	1.51%
Honduras	75.00%	75.00%	75.00%	78.16%	80.00%	81.93%	1.78%
Mexico	90.00%	91.00%	93.00%	95.00%	96.00%	96.50%	1.40%
Nicaragua	49.00%	55.00%	63.25%	73.00%	87.40%	88.57%	12.57%
Panama	90.00%	90.00%	90.00%	91.00%	92.00%	92.40%	0.53%
Paraguay	84.08%	87.49%	91.05%	94.74%	98.00%	98.22%	3.16%
Peru	77.00%	83.00%	83.00%	85.98%	88.00%	87.99%	2.70%
Uruguay	88.00%	88.00%	98.00%	98.00%	99.00%	99.00%	2.38%
Venezuela	88.00%	88.00%	88.00%	88.00%	88.00%	88.00%	0.00%

* Measured as percent of the population. (E: estimation)

Sources: GSMA Intelligence; Telecom Advisory Services analysis

Bolivia, Colombia, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Peru and Venezuela are countries where 4G coverage is below the regional average. In addition, in some countries (Argentina, Bolivia, Brazil, Chile, Costa Rica, Ecuador, Guatemala, Honduras, Mexico, Panama and Venezuela), 4G deployment has increased less than the average growth rate. As shown in figure 1-1, lagging 4G coverage is prevalent in Bolivia, Colombia, Ecuador, Venezuela and Central American countries.

Figure 1-1. Latin America 4G coverage levels (% of population) (2024)



Sources: GSMA Intelligence; Telecom Advisory Services analysis

Beyond divergent trajectories in network deployment, the difference in quality of service between countries, as measured by average mobile broadband speed, also remains significant (table 1-5).

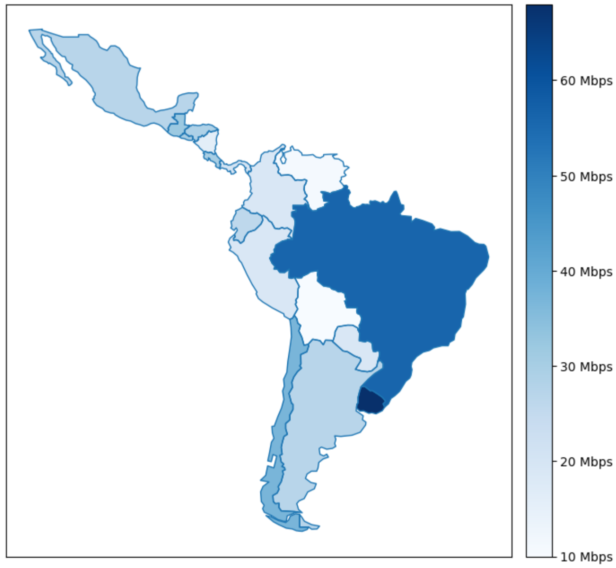
Table 1-5. Latin America vs. benchmark countries: average wireless broadband speeds (in Mbps)*

Countries	Average download speed						Average loading speed					
	2020	2021	2022	2023	2024 (1Q)	CAGR 2020-1Q24	2020	2021	2022	2023	2024 (1Q)	CAGR 2020-1Q24
Latin America and the Caribbean	18	20	26	33	36	23.11%	8	8	10	11	12	11.87%
Argentina	21	22	23	24	27	7.25%	7	7	7	6	7	-0.67%
Bolivia	14	15	10	10	10	-10.97%	9	10	9	9	9	-1.03%
Brazil	19	23	36	52	56	39.38%	7	8	11	13	13	15.58%
Chile	12	16	28	38	37	41.62%	9	10	13	13	14	10.64%
Colombia	12	14	12	13	19	15.63%	7	9	9	10	13	14.30%
Costa Rica	17	18	18	27	30	19.28%	6	7	8	8	9	9.68%
Ecuador	16	18	20	22	26	16.27%	8	9	11	11	13	11.32%
El Salvador	13	22	22	28	30	28.21%	6	9	11	10	10	12.07%
Guatemala	20	18	25	33	32	15.71%	12	13	16	17	17	8.70%
Honduras	20	13	20	29	29	9.47%	8	5	12	13	13	14.92%
Mexico	23	22	26	26	27	4.83%	10	9	11	11	11	2.29%
Nicaragua	12	16	18	18	16	7.83%	7	10	11	12	10	9.78%
Panama	15	16	16	20	20	9.67%	11	11	11	12	13	5.70%
Paraguay	13	16	17	20	19	13.61%	7	7	8	8	7	2.74%
Peru	15	16	17	18	19	7.04%	9	10	12	12	13	9.29%
Uruguay	27	36	36	74	68	32.89%	11	12	11	15	14	6.62%
Venezuela	6	6	6	12	11	22.47%	3	3	4	6	6	16.58%
BENCHMARKS												
OECD	48	61	80	105	120	32.76%	9	9	10	10	11	5.18%
United States	43	54	79	111	129	40.53%	9	8	9	10	10	3.45%
Canada	69	75	87	102	104	13.45%	9	9	12	13	13	9.79%
United Kingdom	30	48	49	51	54	19.70%	8	8	7	7	8	0.82%
South Korea	86	108	123	140	156	20.14%	14	16	16	17	18	6.45%

* Data from December of each year.
Sources: Ookla Speedtest; Telecom Advisory Services analysis

In 2023, the average broadband download speed of 33 Mbps in Latin American countries was three times lower than the average for high-income economies (105 Mbps is the average for OECD countries). In terms of average mobile broadband download speeds, Argentina, Bolivia, Costa Rica, El Salvador, Honduras, Mexico, Nicaragua, Paraguay and Venezuela are below the weighted regional average (figure 1-2).

Figure 1-2. Latin America: average mobile broadband download speed (1Q 2024)



Sources: Ookla Speedtest; Telecom Advisory Services analysis

1.2.2. Slow 5G rollout with some notable exceptions

While the availability of spectrum is advancing at a rapid pace, 5G remains a future possibility in parts of Latin America, with the notable exception of Brazil, where 64.33% of the population was already covered in 2024. In addition to Brazil, there has been some progress in the deployment of 5G with the implementation of services in Chile, Mexico, Peru and Guatemala (table 1-6).

Table 1-6. State of 5G deployment (May 2024)

Countries	Coverage 2024 (% of population)	Spectrum auctioned	Service launched	Cities/areas with 5G service
Argentina	8-10%	250 MHz of spectrum tendered in October 2023 in the 3.5 GHz band	Telecom Personal and Movistar	Movistar: deployed 5G in Retiro, Recoleta, La Plata, Mar del Plata and Pinamar These are in addition to the 68 antennas that Personal has already activated in different parts of Argentina, in addition to the 311 DSS sites that it has in operation
Bolivia	0%	Not yet available Bolivia is in the process of implementing the National Integrated Radio Spectrum System, expected to facilitate 5G technology in 2025	–	Some places with experimental 5G in the 3.5 GHz band (NSA and SA) with ENTEL

Countries	Coverage 2024 (% of population)	Spectrum auctioned	Service launched	Cities/areas with 5G service
Brazil	64.33% (coverage available to more than 140 million Brazilians)	700 MHz, 2.6 GHz, 3.5 GHz and 26 GHz bands	Algar, Claro, Telefónica (Vivo), TIM Regional lots: Sercomtel, Brisanet, Consorcio 5G Sul, Cloud2U, Unifique, VelosoNET	Brasilia and 26 regional capitals 5G deployed in all the country's capitals TIM expanded 5G coverage to 35 Brazilian cities 753 municipalities have licensed 5G infrastructure
Chile	Signal coverage is present in at least 70% of urban locations and 20.83% of population coverage (GSMA), and 5G connections already represent 19.62% of the total (reaching 4 million devices)	Bands in 700 MHz, AWS, 3.5 GHz and 26 GHz Total bandwidth 1400 MHz	Claro, Telefónica, Entel, WOM Entel is positioned as the leader in the segment with 42% of the share, followed by WOM (30%) and Movistar (28%)	Metropolitan region, Tarapacá, Antofagasta, Valparaíso, O'Higgins, Maule, Bío Bío, La Araucanía, Atacama, Conquimbo, Los Lagos and Los Ríos
Colombia	13 capital cities with areas where 5G signal is already received, according to NPERF (34.9%) There are currently more than 1 million enabled customers (1.93%)	Available via the 3.5 GHz spectrum auctioned in December 2023	Claro, WOM, Movistar and Tigo Currently, Tigo has the largest presence in the most territories	Bogota, Cali, Medellin, Barranquilla, Bucaramanga and Cartagena, with expected expansion to other cities
Costa Rica	0%	Not yet available In the process of recovering the 3.5 GHz band from ICE; in the 2024-2027 allocation plans	Liberty reported the official switch-on of its 5G network in the testing phase; in total there will be 34 5G spaces	Tests: San Jose, the campus of the Universidad Latina de Costa Rica and the Ultrapark II Free Zone There are 17 sites awaiting 5G service, including: Paseo Colón, La Sabana, the Nacional and Ricardo Saprissa stadiums, the Viva Park
Ecuador	0%	Used for testing only Not yet available (on 3.5 GHz); in the process of cleaning and valuing the belt	CNT, Claro, Movistar	Quito, Guayaquil, Cuenca
El Salvador	0%	Not yet available Tigo is in plans, but did not define a date and Movistar launched the 5G-ready network in preparation for its LTE-A network to promote a rapid transition to 5G	–	–

Countries	Coverage 2024 (% of population)	Spectrum auctioned	Service launched	Cities/areas with 5G service
Guatemala	Available in all 22 departments of Guatemala According to GSMA, 40% of the population would be covered	Tigo and Claro are developing a 5G NSA network with 700 MHz, 3.5 GHz and AWS In 2023, the 2.5 GHz band was also auctioned for Tigo and the 3.5 GHz band for Claro	Tigo and Claro deploy network focused on improving 4G to 4.5G, rather than a native 5G network	Currently in Guatemala City; to be extended to 22 departments in the future
Honduras	0%	Honduras has channeled and allocated the 3.5 GHz band for a future 5G tender	–	–
Mexico	125 cities with coverage According to GSMA, Mexico has 54% population coverage and 6.6 million users (12.86%)	2.5 GHz and 3.5 GHz bands	Telcel, ATT	Initially, deployed 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, Mexico City and Mérida); by end of 2023, there were 125 cities with 5G service
Nicaragua	0%	Not yet available TELCOR is planning to promote a transition between 4G and 5G; government issued administrative agreement 02-2022, published in La Gaceta, Official State Gazette, on Nov. 24, 2022, informing the reservation of the frequency bands 3.3-3.4, 3.4-3.6 and 3.6-3.7 MHz	–	–
Panama	0%	Not yet available CAF is collaborating with the Panama government to develop a roadmap toward 5G	–	–
Paraguay	0 %	Not yet available National Telecommunications Plan establishes that by 2024, 30% of the population will have access to 5G, in 511 localities, however, it has not yet been implemented	–	–
Peru	According to GSMA, the coverage is 84%, but the areas with service represents 43% of the population of the country	A plan calls for the channeling of important frequency bands for telecommunications services, such as 1.7-2.1 GHz, 1.9 GHz, 2.3 GHz, 2.6 GHz and 3,300-3,800 MHz	Claro, Entel, Telefónica	Lima, Trujillo, Piura, Arequipa, Ancash, Oca, Lambayeque, La Libertad, Tacna, Callao

Countries	Coverage 2024 (% of population)	Spectrum auctioned	Service launched	Cities/areas with 5G service
Uruguay	ANTEL completed the switching on of 5G technology in the 19 departmental capitals and GSMA estimates that the current coverage is 19%	Since 2019, ANTEL has the first commercial 5G network in the region; in the 2.8 GHz and 3.5 GHz bands, 5G tests began In 2023, 100 MHz was auctioned for each operator in the 3.5 GHz band	ANTEL, Claro, Movistar	Barra de Maldonado, Colonia, Montevideo
Venezuela	0%	Not yet available; in testing	Movilnet Venezuela is planning to launch a 5G tender and phase out 2G by 2025	Caracas

Sources: GSMA Intelligence; DPL; Telesemana, Datacenter Dynamics; 5G Americas; BN Americas; Gov.br; Gov.uy; Teleco Brazil; News Line Report; America Economy; ICT Consumption; Digital Confidential; CAF; Telecom Advisory Services analysis

According to GSMA Intelligence estimates, in 2024, Latin America is four years behind OECD countries in the deployment of 5G. Average coverage for the region is expected to reach 51% in 2025, a level similar to that of OECD countries in 2021. This expansion will be led by Chile (projected penetration for 2025: 57%), Brazil (estimated penetration for 2025: 69%), Mexico (penetration projected for 2025: 63%) and Peru (penetration projected for 2025: 87%) (table 1-7).

Table 1-7. Latin America vs. benchmark countries: 5G population coverage (2021-2030)

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Latin America and the Caribbean	8.39%	23.93%	35.53%	43.87%	50.74%	57.78%	64.26%	70.40%	74.98%	77.34%
Argentina	2.00%	4.00%	10.00%	24.29%	38.00%	49.52%	61.73%	72.80%	80.79%	83.87%
Bolivia	0.00%	0.00%	0.00%	7.94%	16.55%	24.27%	32.70%	40.48%	46.15%	48.35%
Brazil	17.00%	29.00%	54.00%	63.01%	69.00%	76.00%	80.71%	85.49%	88.78%	90.00%
Chile	1.93%	8.26%	20.83%	40.07%	56.74%	68.23%	79.54%	89.33%	96.18%	98.76%
Colombia	0.00%	0.00%	0.00%	15.30%	30.33%	40.38%	50.40%	59.13%	65.28%	67.61%
Costa Rica	0.00%	0.00%	0.00%	9.76%	20.08%	28.76%	38.09%	46.60%	52.77%	55.15%
Ecuador	0.00%	0.00%	0.00%	21.99%	40.44%	45.18%	45.79%	45.79%	45.79%	45.79%
El Salvador	0.00%	0.00%	0.00%	0.00%	0.00%	9.89%	23.03%	36.32%	46.56%	50.67%
Guatemala	0.00%	23.00%	40.00%	53.50%	60.00%	65.73%	71.15%	75.71%	78.84%	80.00%
Honduras	0.00%	0.00%	0.00%	0.00%	0.00%	8.46%	19.68%	31.04%	39.79%	43.30%
Mexico	8.00%	45.00%	54.00%	58.67%	63.00%	70.00%	75.89%	82.11%	87.01%	89.00%
Nicaragua	0.00%	0.00%	0.00%	0.00%	0.00%	9.10%	21.19%	33.42%	42.84%	46.62%
Panama	0.00%	0.00%	0.00%	0.00%	0.00%	10.82%	25.18%	39.71%	50.91%	55.40%
Paraguay	0.00%	0.00%	0.00%	16.11%	30.12%	36.57%	41.83%	45.76%	48.21%	49.05%
Peru*	18.00%	80.00%	84.00%	85.58%	87.00%	90.00%	91.14%	92.10%	92.76%	93.00%
Uruguay	0.00%	0.00%	16.05%	19.56%	25.00%	36.56%	50.92%	73.35%	92.03%	99.50%
Venezuela	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
BENCHMARKS										
OECD	52.18 %	62.21 %	70.40 %	77.82 %	83.61 %	84.28%	87.04%	89.24%	91.28%	92.71%
United States	86.00 %	93.64 %	96.52 %	98.00 %	98.00 %	99.20%	100.00%	100.00%	100.00%	100.00%

Canada	66.18 %	83.49 %	90.72 %	97.95 %	98.00 %	92.00%	93.72%	95.34%	96.71%	97.71%
United Kingdom	45.90 %	57.94 %	68.21 %	76.48 %	83.26 %	86.00%	89.42%	92.75%	95.62%	97.61%
South Korea	97.00 %	97.00 %	97.00 %	97.00 %	97.00 %	98.00%	99.84%	100.00%	99.95%	99.33%

* According to GSMA, the coverage in Peru was 84% of the population in 2023, although the cities with service represent 43% of the population of the country.
Sources: GSMA Intelligence; Telecom Advisory Services analysis

1.2.3. Countries lagging behind in mobile technology adoption

In line with the divergence in network deployment, the rate of adoption of mobile, telephony and broadband technology varies widely among countries in the region. Thus, by 2024, Brazil, Ecuador, Honduras, Mexico, Paraguay and Venezuela remained below the Latin American average in mobile telephony, while Bolivia, Colombia, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Peru, Uruguay and Venezuela underperformed the Latin American average in mobile broadband (table 1-8).

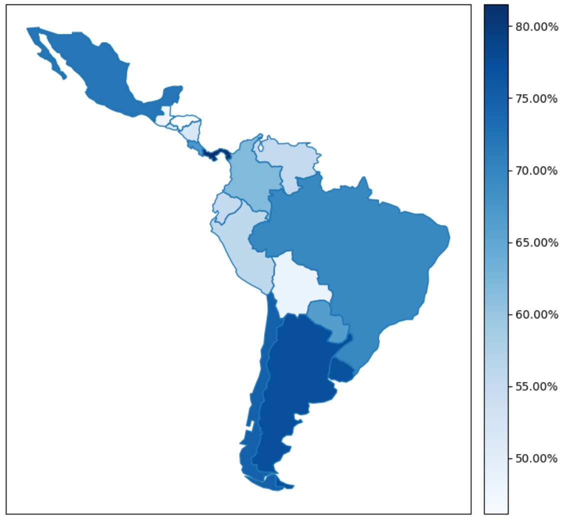
Table 1-8. Latin America's adoption of mobile technology

Countries	Mobile telephony*						Mobile broadband**					
	2019	2020	2021	2022	2023	2024 (E)	2019	2020	2021	2022	2023	2024 (E)
Latin America and the Caribbean	101.06	100.57	107.01	106.96	108.74	110.67	54.38%	56.98%	59.69%	61.99%	64.19%	65.53%
Argentina	126.05	120.65	131.68	132.82	135.13	136.80	64.29%	66.98%	69.97%	72.77%	75.51%	77.15%
Bolivia	101.92	109.47	112.19	110.48	112.66	114.56	40.15%	41.87%	43.79%	45.53%	47.21%	48.32%
Brazil	94.34	95.58	103.06	99.27	98.85	100.37	60.36%	63.02%	65.84%	67.45%	68.66%	69.55%
Chile	138.73	136.58	143.04	145.88	151.31	153.36	67.63%	70.42%	72.01%	72.89%	74.00%	74.84%
Colombia	120.92	122.03	134.82	143.95	150.21	154.28	51.98%	54.16%	56.25%	58.39%	60.55%	61.97%
Costa Rica	168.33	146.35	151.24	151.02	152.21	153.14	55.16%	57.75%	60.44%	63.06%	65.56%	67.21%
Ecuador	89.07	85.71	91.76	93.93	95.92	97.31	45.71%	47.74%	49.83%	51.80%	53.78%	55.16%
El Salvador	147.33	146.84	150.07	152.71	158.98	161.96	39.01%	41.22%	43.02%	46.44%	49.13%	50.90%
Guatemala	118.27	113.55	120.65	109.88	113.02	115.85	35.44%	37.61%	39.54%	43.01%	45.83%	47.78%
Honduras	72.06	71.21	75.09	76.31	79.09	81.34	34.99%	36.98%	38.67%	41.85%	44.41%	46.15%
Mexico	91.99	91.65	94.46	96.11	96.13	97.21	56.28%	59.58%	63.65%	66.46%	70.22%	72.08%
Nicaragua	116.82	121.09	126.85	129.62	132.63	135.24	39.79%	41.90%	43.67%	47.11%	49.87%	51.73%
Panama	114.06	113.04	119.11	121.58	124.05	126.29	61.55%	65.40%	69.62%	74.22%	78.76%	81.51%
Paraguay	99.38	97.38	98.71	101.86	103.41	105.36	55.57%	57.81%	60.30%	62.62%	64.89%	66.40%
Peru	114.77	111.48	120.02	115.87	120.11	121.96	46.91%	49.08%	51.01%	52.89%	54.74%	55.92%
Uruguay	161.06	153.35	165.72	175.74	184.83	187.51	66.76%	69.65%	72.79%	74.51%	75.86%	76.93%
Venezuela	81.53	79.55	80.37	83.10	91.57	94.78	44.24%	46.13%	46.82%	51.89%	53.95%	55.40%

* Connections/population. (E: estimation)
** Unique subscribers of mobile broadband as percent of population. (E: estimation)
Sources: GSMA Intelligence; Telecom Advisory Services analysis

Argentina, Brazil, Chile and Mexico continue to lead in mobile broadband adoption, while Bolivia, Ecuador, Colombia, Peru and Central American countries lag behind (figure 1-3).

Figure 1-3. Latin America's mobile broadband adoption (unique subscribers as % of population) (2024)



Sources: GSMA Intelligence; Telecom Advisory Services analysis

1.2.4. The affordability barrier

Despite significant regional gains since 2013 (driven especially by Brazil), affordability emerges as a key barrier to access of broadband and digital mobile services. The least expensive mobile broadband and mobile telephony plan as a percentage of per capita income in 2023 averages 1.23% and 3.11%, respectively, which is two to three times higher than in high-income countries. Wireless affordability remains an additional barrier to closing adoption gaps (table 1-9).

Table 1-9. Latin America vs. benchmark countries: affordability of mobile telecommunications (price of plan as % of GDP per capita)

	Mobile telephony*		Mobile broadband**	
	2023	CAGR (2018-2023)	2023	CAGR (2018-2023)
Latin America and the Caribbean	1.23	-10.31%	3.11	-10.07%
Argentina	0.48	-32.12%	0.68	-10.29%
Bolivia	3.34	0.00%	1.52	-10.04%
Brazil	0.91	-12.75%	0.81	-29.56%
Chile	0.51	-16.41%	0.47	-11.99%
Colombia	0.97	-7.98%	1.24	-14.66%
Costa Rica	0.52	0.00%	0.91	4.80%
Ecuador	2.29	4.93%	1.90	-2.89%
El Salvador	2.96	-2.09%	2.54	-10.41%
Guatemala	3.12	-15.66%	2.86	-4.39%
Mexico	0.47	-2.00%	0.93	-1.83%
Honduras	6.34	-1.91%	8.05	-1.36%
Nicaragua	6.06	-19.35%	4.47	-13.16%
Panama	0.79	2.45%	1.57	-1.23%

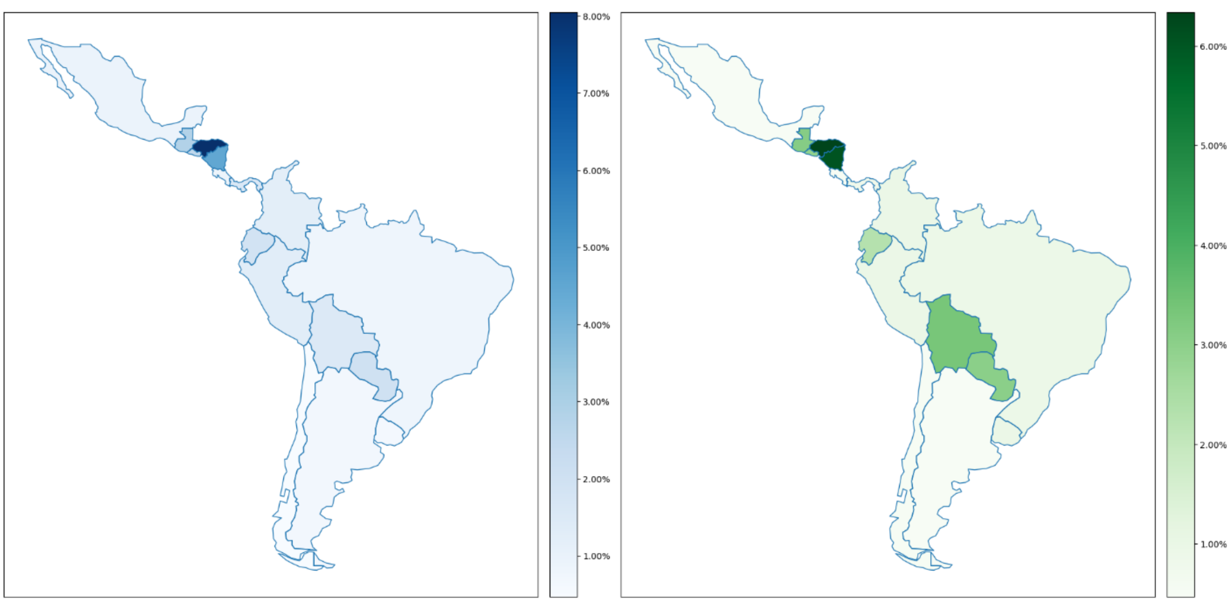
Paraguay	3.03	-0.13%	2.01	-17.18%
Peru	0.97	-13.73%	1.31	-3.56%
Uruguay	0.96	-6.73%	0.62	-15.97%
BENCHMARKS				
OECD	0.57	-2.93%	0.68	-2.54%
United States	0.65	0.95%	0.74	9.79%
Canada	0.33	-10.67%	0.85	1.92%
United Kingdom	0.35	-8.31%	0.35	-8.54%
South Korea	0.62	-11.93%	0.49	-4.45%

* Low consumption basket mobile phone (70 minutes + 20 SMS) connection.
** Data-only mobile broadband connection (2 GB).
Sources: International Telecommunication Union; Telecom Advisory Services analysis

Figure 1-4 provides a comparison of the level of affordability between mobile telephony and mobile broadband showing how mobile broadband remains a major barrier to adoption in the region.

Figure 1-4. Latin America's mobile telephony and mobile broadband affordability (price of mobile plan as % of GNI) (2023)

Mobile broadband affordability **Mobile telephony affordability**



Sources: International Telecommunication Union; Telecom Advisory Services analysis

The affordability barrier to mobile broadband adoption is concentrated at the base of the sociodemographic pyramid. In fact, while average costs are in line with the expected range for developing regions, the high level of inequality in income distribution in the region demonstrates how the cost of broadband access represents an unsustainable burden for the most vulnerable populations. Even focusing on the most affordable mobile services, mobile broadband accounted for 1.8% of average monthly GDP per capita for the entire population in 2020, but up to 10.2% for the bottom 10% of the population (table 1-10).

Table 1-10. Price of broadband service as a percentage of GDP per capita per decile for Latin America and the Caribbean (2020)

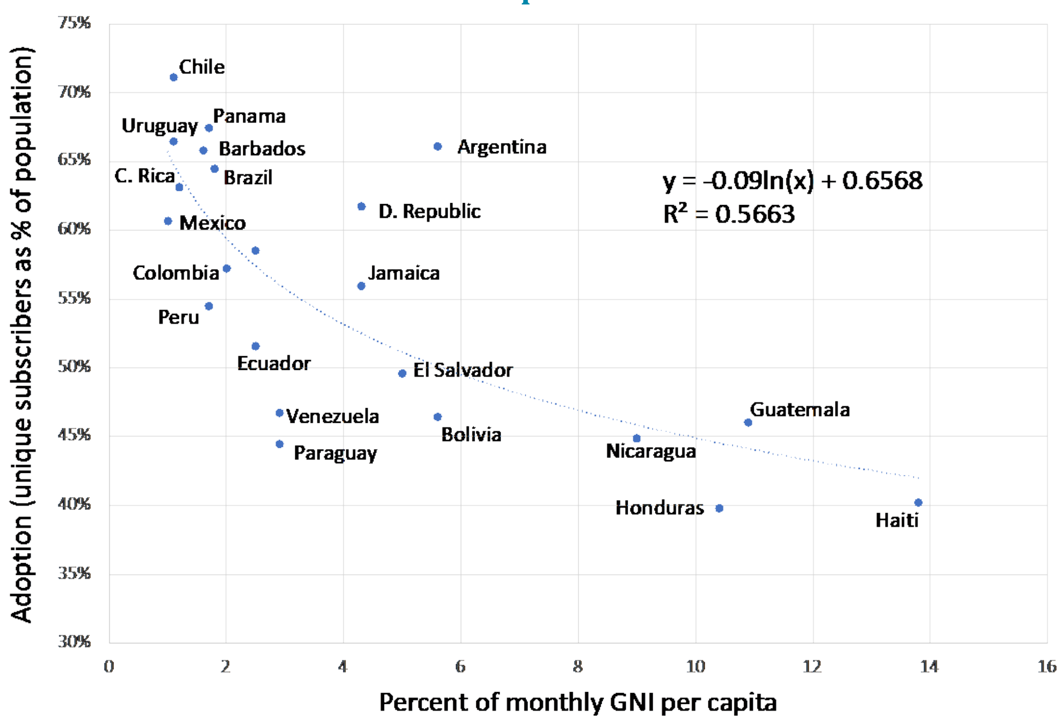
Country	Mean	Decile 1	Decile 2	Decile 3
Fixed broadband	3.6%	20.8%	11.9%	8.8%
Mobile broadband	1.8%	10.2%	5.8%	4.4%

Sources: SEDLAC (CEDLAS and World Bank) based on microdata from household surveys; Katz and Jung (2021); Telecom Advisory Services analysis

Even for the third decile, a social group close to the so-called *vulnerable middle class*, the cost of mobile broadband reaches 4.4% of their monthly income, well above the affordability threshold of 2%. The service affordability barrier extends to devices. The cheapest entry-level smartphone available costs between 4% and 12% of median household incomes across much of the region, and up to 34% for people in Guatemala and Nicaragua or even 84% for those in Haiti (Drees-Gross and Zhang, 2021).

The affordability barrier is why there is not a full correlation between wireless coverage and adoption. Given the level of development of the Latin American mobile industry and the region's revenue distribution, affordability becomes the main driver of future growth in mobile broadband penetration (graphic 1-1).

Graphic 1-1. Latin America and the Caribbean: affordability vs. mobile broadband adoption



Note: Affordability is measured as the cost of service as a percentage of revenue, whereas adoption is measured as the number of unique broadband users for each country.

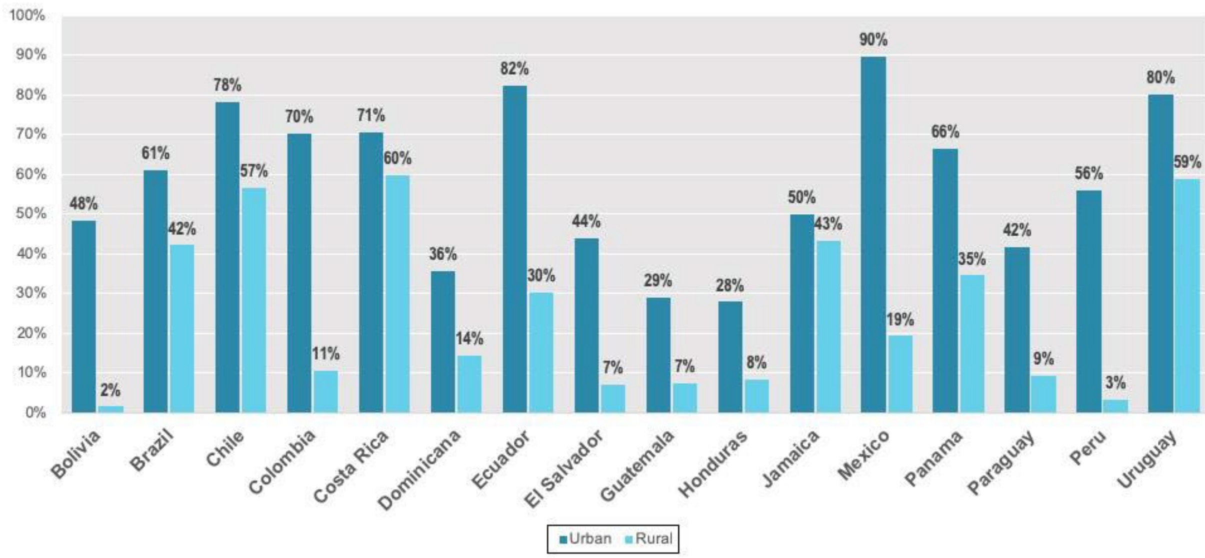
Source: ITU; World Bank; GSMA Intelligence; Telecom Advisory Services analysis

As shown in graphic 1-1, the higher the cost of mobile broadband service as a percentage of monthly GDP per capita, the lower the adoption of the service.

1.2.5. The urban/rural dichotomy

In addition to remaining pockets of limited affordability, rural areas in Latin American countries exhibit lower network coverage than urban concentrations. Both variables, low affordability and limited rural coverage, influence the lower adoption of broadband in rural areas (graphic 1-2).

Graphic 1-2. Latin America's broadband adoption (percentage of households) (2020)



Note: The urban/total and rural/total ratios for previous years (2018 and 2019) were used to estimate ITU national penetration data for 2020.
Sources: ITU, Household Surveys, IDB (2018, 2019, 2020); Telecom Advisory Services analysis

The data in graphic 1-2 underlines the importance of infrastructure sharing. Governments and civil society in the region are aware of the urgent need to bridge the digital divide between urban and rural broadband availability, especially since the pandemic. Indeed, the ongoing dialogue within governments and regulators, not only in the region but around the world, indicates there is a broad consensus that the region cannot afford to face another pandemic with the current level of mobile infrastructure development.

1.2.6. Lagging in capital investment

The Latin America and Caribbean region invests US$35.86 per capita (annual five-year moving average) in telecommunications (mobile and fixed), below the global average and significantly lower than that of advanced economies (table 1-11).

Table 1-11. Annual telecommunications investment per capita (current prices in US$, five-year moving average)

Region	2021	2022	2023	Delta 2021-23
World	$49.15	$48.95	$47.61	-1.54%
Sub-Saharan Africa	$10.58	$10.50	$10.37	-0.21%
Latin America and the Caribbean	$34.79	$34.25	$35.86	1.07%
North America	$269.03	$266.83	$259.77	-9.26%
Asia and the Pacific	$29.20	$28.75	$27.20	-2.00%
Western Europe	$127.46	$131.78	$131.25	3.79%
Eastern Europe	$38.21	$38.94	$39.04	0.83%
Arab States	$38.37	$38.07	$37.16	-1.21%
OECD	$152.10	$153.13	$150.57	-1.52%

Sources: ITU World Telecommunication/ICT Indicators (WTI) Database 2023 and GSMA Intelligence; Telecom Advisory Services analysis

The need to accelerate the deployment of mobile networks is extremely relevant in the current circumstances. As in the other indicators, wireless capital investment per country varies significantly (figure 1-5).

Figure 1-5. Latin America's CAPEX per capita (2024)

Note: Argentina and Venezuela are excluded because of distortion in exchange rates.
Sources: ITU World Telecommunication/ICT Indicators (WTI) Database 2023 and GSMA Intelligence; Telecom Advisory Services analysis

Likewise, many countries in the region show a continuous decrease in wireless capital investment per capita up to 2023, as shown in table 1-12. In 2024, a substantial increase in investment is projected due to the deployment of 5G in several countries.

Table 1-12. CAPEX per capita (2013-2024) (in US$)

Country	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Latin America and the Caribbean	19.02	18.50	18.70	20.53	16.90	17.22	17.86	16.44	18.28	17.38	17.84	19.36
Bolivia	12.05	18.58	20.30	21.49	45.51	45.55	45.49	41.13	42.20	40.19	41.43	47.51
Brazil	14.86	15.17	17.12	16.63	15.42	15.93	16.62	15.92	20.98	17.86	17.27	18.27
Chile	41.93	43.88	41.31	45.90	42.15	40.45	38.43	35.32	44.14	45.42	49.17	53.91
Colombia	18.32	19.20	18.80	17.24	17.07	14.56	17.04	16.66	16.47	15.40	13.60	16.20
Costa Rica	50.15	53.07	58.98	63.53	63.80	50.57	46.25	38.63	35.47	34.33	31.82	35.42
Ecuador	24.72	25.58	22.88	24.29	21.60	20.93	18.59	14.07	13.20	13.19	12.99	16.04
El Salvador	39.11	42.22	42.29	39.54	32.74	32.30	32.71	33.01	31.87	31.22	32.17	32.76
Guatemala	21.53	19.17	22.52	24.49	24.69	25.25	28.60	22.72	19.48	17.54	17.22	16.70
Honduras	11.99	12.33	16.25	17.95	17.58	17.77	18.06	16.47	14.48	14.01	13.68	12.66
Mexico	19.38	16.30	12.87	15.96	8.06	15.79	16.23	15.87	16.21	17.48	20.02	22.67
Nicaragua	20.35	21.13	24.20	31.21	34.68	11.84	11.88	10.60	8.87	9.03	9.80	10.19
Panama	84.05	90.61	88.82	72.00	71.33	62.38	56.35	55.87	54.01	49.07	46.32	46.54
Paraguay	18.89	19.63	18.04	23.71	20.10	25.75	24.89	22.52	18.32	18.45	19.03	23.98
Peru	22.24	27.13	32.87	53.10	34.09	29.03	27.27	19.52	20.32	19.84	21.29	22.34
Uruguay	17.50	23.99	29.21	27.98	25.35	24.83	33.06	21.60	23.99	26.59	28.79	31.13
BENCHMARKS												
OECD	63.74	63.05	59.06	57.24	57.90	60.50	68.97	69.82	75.85	75.68	68.66	68.40
United States	105.50	102.51	101.32	98.71	106.24	116.82	138.13	134.69	144.08	149.74	141.07	140.61
Canada	66.69	71.24	69.85	66.06	66.29	67.88	70.45	68.13	127.38	118.03	75.63	74.01
United Kingdom	41.43	45.72	45.54	45.95	45.68	44.68	45.75	53.10	81.43	71.63	50.66	49.57
South Korea	63.02	59.38	40.76	50.86	48.77	50.12	81.36	69.14	67.42	74.63	69.32	58.56

Countries with year-on-year decline.

Note: Argentina and Venezuela are excluded from the analysis as the series presents inconsistencies due multiple exchange rates.

Sources: GSMA Intelligence; Telecom Advisory Services analysis

Considering the total investment in telecommunications (fixed and mobile), when the historical series is smoothed to limit data volatility, it is clear that capital investment in telecommunications in the region has declined steadily over the period 2018-2022, with a small recuperation in 2023. The CAPEX per capita values in table 1-13 show a constant five-year moving average for each country in the region over the five years, as well as an average compared to the weighted value for OECD countries.

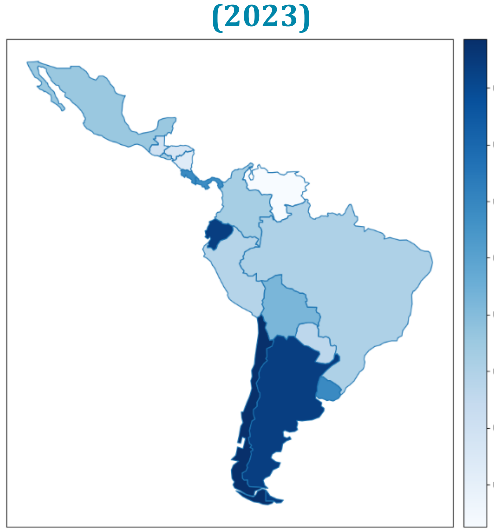
Table 1-13. Annual fixed/mobile telecommunications investment per capita (current prices in US$, five-year moving average)

	2018	2019	2020	2021	2022	2023
Latin America and the Caribbean	$38.38	$37.63	$36.03	$34.79	$34.25	$35.86
Argentina	$72.34	$70.45	$63.12	$58.03	$57.67	$83.64
Bolivia	$36.54	$41.23	$43.26	$44.55	$43.51	$42.23
Brazil	$30.53	$31.19	$30.69	$31.73	$31.57	$30.55
Chile	$88.24	$82.54	$80.58	$83.34	$85.63	$88.65
Colombia	$41.08	$37.01	$35.51	$34.64	$33.47	$32.59
Costa Rica	$95.29	$96.54	$81.77	$70.93	$58.48	$58.48
Ecuador	$72.34	$70.45	$63.12	$58.03	$57.67	$83.64
El Salvador	$37.41	$35.52	$33.70	$32.20	$31.90	$31.87
Guatemala	$33.50	$33.28	$30.49	$26.48	$21.73	$20.18
Honduras	$39.23	$37.85	$31.13	$24.04	$17.17	$17.10
Mexico	$35.16	$34.18	$34.21	$33.57	$34.46	$35.69
Nicaragua	$32.13	$29.61	$26.45	$20.56	$13.77	$13.17
Panama	$77.58	$72.74	$67.31	$65.40	$62.50	$57.82
Paraguay	$30.26	$29.52	$28.75	$27.74	$27.76	$26.43
Peru	$38.56	$39.26	$37.57	$31.70	$29.47	$28.59
Uruguay	$70.35	$65.88	$58.38	$56.63	$57.18	$58.93
Venezuela	$19.85	$14.31	$9.19	$4.94	$2.47	$2.51
BENCHMARK						
OCDE	$148.75	$148.45	$149.41	$152.10	$153.13	$150.57

Sources: ITU World Telecommunication/ICT Indicators (WTI) Database 2023 and GSMA Intelligence; Telecom Advisory Services analysis

The data in table 1-13 allows us to draw three conclusions. First, the Latin America and Caribbean region on a prorated average invests one-fifth of the average of advanced economies of the OECD countries. This is explained in part, but not entirely, by the region's lower average revenue per user (ARPU), which imposes a structural constraint on the sector's capital investment capacity (figure 1-6).

Figure 1-6. Average revenue per user of mobile telecommunications (2023)

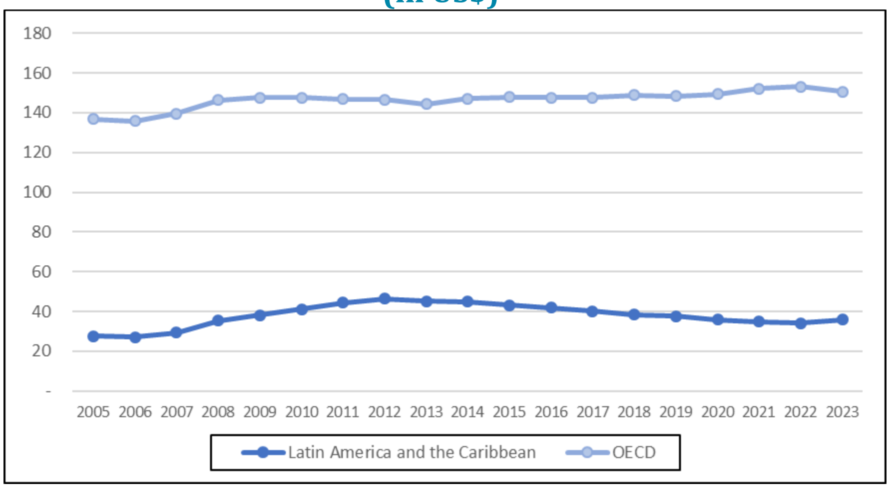


Sources: GSMA Intelligence; Telecom Advisory Services analysis

Indeed, there are certain structural conditions that make it natural for investment levels in the OECD countries to be higher. Typically, countries with a higher per capita income and where, as a consequence, telecommunications revenues per user are considerably higher have a greater capacity to finance and make investments profitable.

Second, beyond the structural difference, the gap in capital investment between Latin America and the OECD countries is widening rather than narrowing: OECD countries are investing more in telecommunications infrastructure, while Latin America is investing less (graphic 1-3).

Graphic 1-3. Telecommunications investment per capita (5-year average) (in US$)



Note: The annual investment has been averaged over five years to reduce the volatility that characterizes annual CAPEX.
Sources: ITU and GSMA Intelligence; Telecom Advisory Services analysis

Third, concurrent with the structural pressure on CAPEX, the region is faced with the imperative to increase network deployment. Considering the need to support the deployment of advanced technologies such as 5G, Latin America's lag behind the OECD countries in terms of capital investment is a worrying factor. According to estimates by the Inter-American Development Bank (Brichetti et al., 2021), the investments needed in the telecommunications sector for the region to meet the United Nations' Sustainable Development Goals by 2030 amount to US$293,675 million.

1.2.7. Uneven progress toward sustainable competition

Economic analysis shows that, in capital-intensive industries such as telecommunications, there is an optimal level of industrial concentration that generates benefits for consumers while ensuring the sustainability of the sector. This postulate is based on three reasons:

- Significant economies of scale for service providers.
- Operational efficiency of large operators.
- Need for greater investment in infrastructure and deployment capacity.

In this sense, *sustainable competition* makes it possible to increase the stimulus to capital investment to the extent that, unlike the model of open and unrestricted competition, operators benefit from an adequate rate of return on investment. The theory 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 diminish.[7]

The level of industry concentration can be measured by the Herfindahl–Hirschman Index (HHI).[8] The region's mobile telecommunications industry has seen a slight rise in the degree of market consolidation in the last 10 years, preserving the difference with high-income economies that have a comparable rise. When measured by the HHI, Chile, El Salvador and Peru exhibit greater competition than the OECD average or that of the United States and the U.K. The main outliers in the region, despite significant progress, continue to be Honduras and Nicaragua, where the concentration remains high, and consequently ARPU is higher than the average (table 1-14).

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

[8] The Herfindahl–Hirschman Index (HHI) is calculated from the sum of the market of each operator squared. The closer you get to the value of 10,000, the more you are in the presence of a monopolistic market; a value below 10,000 indicates some market fragmentation. The U.S. Horizontal Merger Guide considers a market to be highly concentrated when the HHI exceeds 2500 points. These metrics are based on competition models from advanced economies whose application alone does not contemplate one of the most important principles that should guide the supervision of competition models in emerging countries. The model of competition that is defined in the telecommunications sector in emerging countries must pursue the maximization of the objectives of economic development and equity. Thus, effects such as increasing coverage and quality of service, increasing affordability for vulnerable populations and supporting the digitalization of production processes should be considered in the definition of an optimal level of the HHI index, which should be higher than that defined for advanced nations.

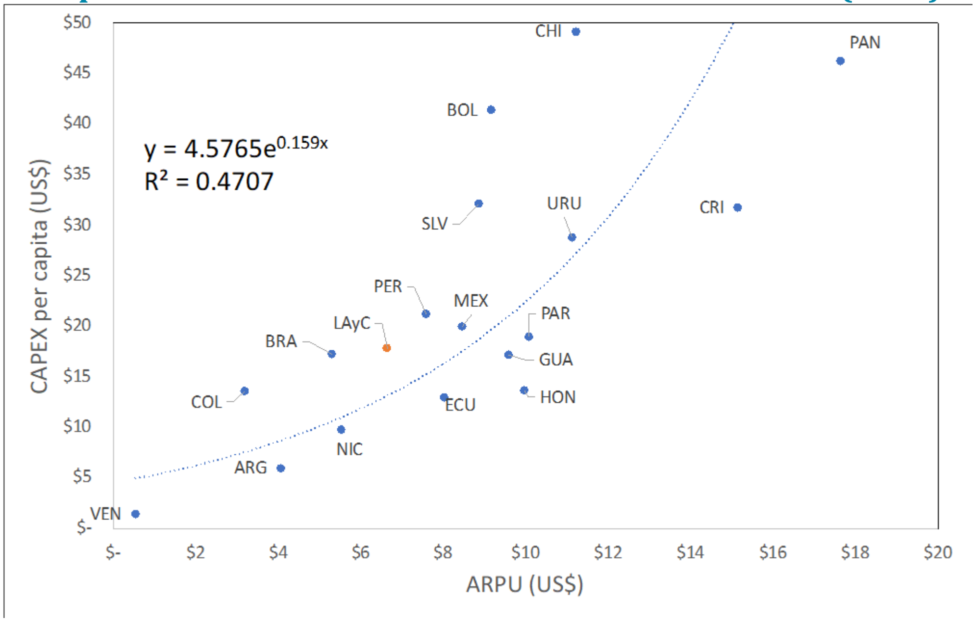
Table 1-14. Competition and profitability of wireless services

	Mobile broadband competition (HHI)		ARPU US$ per subscriber	
	2023	Difference (2013-23)	2023	Difference (2013-23)
Latin America and the Caribbean	3,906.61	161.83	6.65	-0.12
Argentina	3,392.26	166.85	4.06	-3.48
Bolivia	4,174.83	-492.10	9.16	1.08
Brazil	3,312.83	-525.83	5.31	-1.20
Chile	2,601.03	759.05	11.22	-1.05
Colombia	3,501.11	1,399.11	3.19	1.43
Costa Rica	3,672.54	-206.59	15.15	-0.91
Ecuador	3,453.15	1,945.46	8.02	1.74
El Salvador	2,928.52	958.42	8.86	2.72
Guatemala	5,180.12	-982.49	9.59	0.82
Honduras	6,467.70	-1,043.13	9.97	-1.07
Mexico	4,010.74	965.00	8.46	0.45
Nicaragua	5,182.79	25.70	5.54	3.22
Panama	4,191.09	-1,293.66	17.64	-1.38
Paraguay	4,635.06	-1,059.75	10.08	-3.33
Peru	2,575.41	1,909.86	7.59	-0.43
Uruguay	4,223.34	-353.59	11.14	-3.32
Venezuela	4,451.98	70.45	0.54	7.16
BENCHMARKS				
OECD	3,137.69	129.82	23.03	3.00
United States	3,067.45	-397.56	46.49	3.80
Canada	2,245.98	759.40	39.71	3.72
United Kingdom	2,155.78	455.09	16.61	5.23
South Korea	3,365.66	920.65	23.78	7.29

Sources: GSMA Intelligence; Telecom Advisory Services analysis

The sample of the Latin American countries shown in table 1-14 saw their ARPUs fall to $6.65 per subscriber in 2023, which was seven times less than the figures for the U.S. or Canada. There are big differences among countries, with Panama, Costa Rica and Chile at the high end (over US$10 per subscriber) and Colombia and Argentina lower, with less than US$5 per subscriber. Lower ARPUs is one reason for low investment (as indicated by operators' CAPEX) in the mobile industry in Latin America (graphic 1-4).

Graphic 1-4. Mobile broadband ARPU vs. mobile CAPEX (2023)



Sources: GSMA Intelligence; Telecom Advisory Services analysis

As indicated in table 1-12, not only is investment in the U.S. eight times higher than the average of the 11 Latin American economies (US$141.07 per subscriber compared to US$17.84 in 2023), but it has increased significantly since 2013, in line with a more intense use and exploitation of connectivity in the U.S. (while investment remained at very low levels in Latin America).

1.3. Conclusions

To conclude, despite the remarkable regional advances, it is worth highlighting the high degree of heterogeneity in Latin America in terms of the development of its mobile industry. Positive trends include:

- Near total 3G deployment.
- High 4G coverage in most countries, closing the gap with advanced economies.
- Some progress in the deployment of 5G in Brazil, Mexico and Chile and the launch of services in Peru and Guatemala, among others.
- High adoption of services driven by affordability in higher-income countries in the region.
- An increasingly competitive sector.

As for the challenges:

- Coverage gaps in Colombia, Costa Rica, Ecuador, Guatemala, Honduras, Nicaragua and Peru.
- Embryonic development of 5G in some countries.
- Lack of connectivity in Central America, which affects 5 out of 10 citizens.

- Limited coverage and adoption of mobile broadband in rural areas.
- Low penetration of services due to poor affordability, mainly in Central American countries.
- Decrease in capital investment limited by low ARPUs.

A decisive factor in the positive evolution of the mobile telecommunications sector has been the deployment of passive infrastructure as a way of controlling capital investment and operating expenses. In the next chapter, the causal relationships and correlations between passive infrastructures and the different performance indicators of the mobile industry are analyzed econometrically.

2. PASSIVE INFRASTRUCTURE SHARING: A CRITICAL ENABLER OF THE LATIN AMERICAN WIRELESS INDUSTRY

Passive infrastructure sharing comprises multiple models. In the wireless segment, at its most basic level, it entails the sharing of the geographic location of base stations, where network components at the site belong to each operator. This model essentially offers savings on the cost of leasing or purchasing a site, although it can be difficult sometimes to find a location that suits all operators. A higher level of wireless passive sharing involves towers, where each operator deploys its own radio equipment and has control over it but leases space in a tower. In this case, while the infrastructure sharing agreement is signed between two or more operators, there might also be a third-party independent company acting as a neutral host. In this model, costs can be significantly reduced when operators share physical assets and transport networks; sharing can be managed by the site owner, which acts as a landowner for the operators that 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 can include the use of ducts provided by an infrastructure operator (e.g., electric utility, water company, subways, etc.) or a pole from an electric utility that charges a fixed fee for pole attachment.

The rationale for infrastructure sharing is quite straightforward and the justification has already been validated by empirical research. For example, Claussen et al. (2012) examined how outsourcing of a core service affects carrier performance in the context of the mobile telephony industry, covering 50 mobile network operators in 28 countries from 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 (earnings before income taxes and depreciation) to revenues increases by about eight percentage points. In a 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 (2013) confirm evidence on the impact of infrastructure sharing on savings in operating expenditures, investment, competitive position and risk and returns (among many others). GSMA (2018) added to these same strategic and commercial benefits a positive contribution to environmental sustainability.

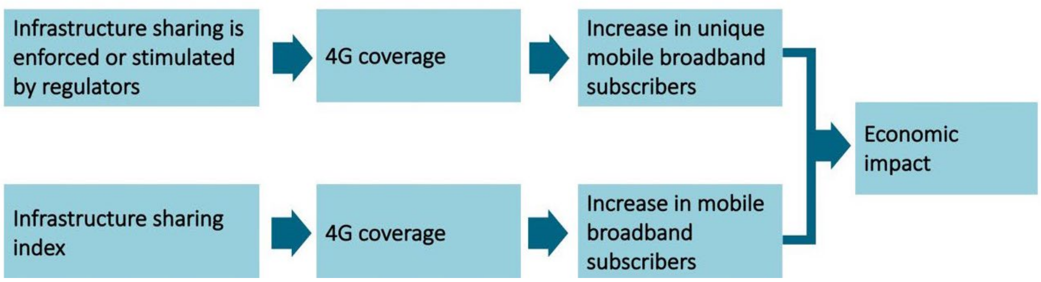
More recently, Houngbonon et al. (2021) demonstrated how infrastructure sharing can accelerate digital connectivity at lower cost (especially in the least developed markets where returns to investment can be limited) and reduce investment costs and operating expenses for investors and operators, as well as increase their balance sheet sustainability, while also benefiting consumers by enhancing competition, lowering prices and raising service quality. Similarly, Cabello et al. (2021) projected that infrastructure sharing would increase by up to 16 percentage points by 2030, driven both by the growing market share of infrastructure companies (which are naturally more prone to sharing than mobile network operators), expected to reach over 67% for total sites, and by a higher level of network sharing as public spaces become more easily available and agreements are made with other sectors, such as utilities. Wang and Sun (2022), focusing on China's mobile telecommunications industry, showed that 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, on economic development. We first introduce the theoretical framework and describe the data upon which the analysis is based. Following this, we present the results of the empirical modeling and, on these bases, discuss the implications.

2.1. Theoretical framework

As mentioned, the objective of this analysis is to demonstrate the relationship between improved infrastructure sharing regulation and economic performance (figure 2-1).

Figure 2-1. Focus of the analysis

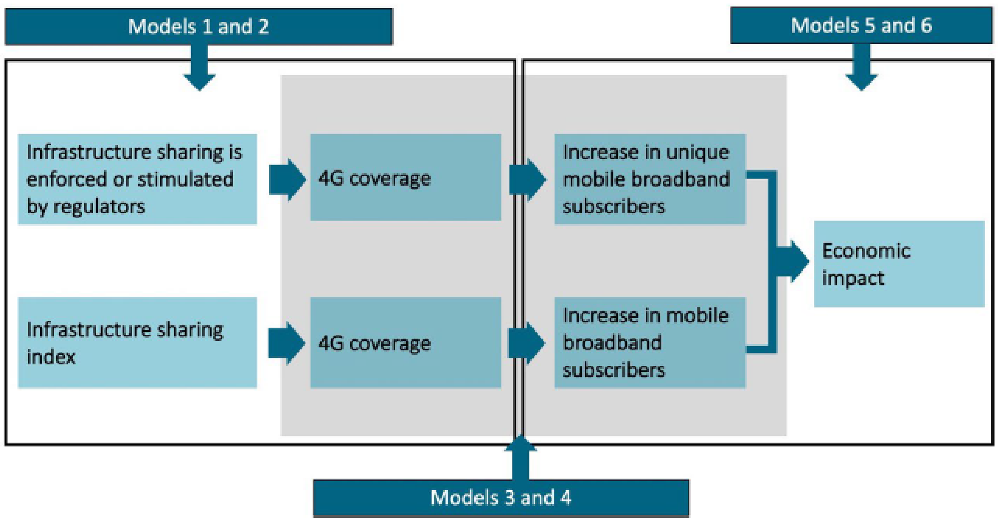


Source: Telecom Advisory Services

To show this relationship, we 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.[9] 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 is analyzed (models 1 and 2 in figure 2-2). Then, in a second stage, the relationship between an increase in 4G coverage and an increase in unique mobile broadband users is quantified (models 3 and 4 in figure 2-2). Finally, the relationship between an increase in the number of unique mobile broadband users and an enhancement in economic indicators is estimated (models 5 and 6 in figure 2-2).

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

Figure 2-2. Stages of analysis



Source: Telecom Advisory Services

The models rely on information published by the International Telecommunication Union (ITU) in the "ICT Regulatory Tracker."[10] 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 (i.e., towers, radio bases, poles, conduits, etc.) mandatory and/or is sharing proactively encouraged?
2. Is location or site sharing mandatory and/or is it proactively encouraged?
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 as it involves sharing more passive components (i.e., towers, base stations, poles, ducts, etc.), maintaining facilities and increasing the productivity of resource use.

The second question 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.

[10] https://app.gen5.digital/tracker/about

The third question refers to local loop unbundling, which is 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 users' premises.

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

- Only using the second question as 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 1 million inhabitants. This decision was made to avoid bias in the results due to the presence of small countries. 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 covers the period from 2010 to 2020.[11] Thus, the models rely on a total of 209 observations over 19 countries and 11 years.

The first econometric model assesses 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):

$$\text{Coverage 4G} = \beta_0 + \beta_1 . \text{Treatment}_{it} + \beta_2 . \text{Year}_t + \beta_3 \text{A}rea_i + \beta_4 . X_{it} + \mu_{it} \; (1)$$

Where:

- 4G coverage: percentage of population with 4G coverage[12]
- Treatment: variable that distinguishes each country based on:
  - 1, when there is forced or proactively stimulated co-location/sharing of sites[13]
  - 0, otherwise
- Year: fixed effect for each year between 2010 and 2020
- Area: fixed effect for each country in the regression
- *X*: matrix of other independent variables that are used as controls, in particular GDP per capita

[11] Despite the existence of data since 2007, only data from 2010 to 2020 are considered, as inconsistencies were found in the database in the first years.
[12] Source: GSMA.
[13] Source: ITU Regulatory Tracker.

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:

$$\text{Coverage 4G} = \beta_0 + \beta_1.\ \text{Index}_{it} + \beta_2.\text{Year}_t + \beta_3\text{A}rea_i + \beta_4.X_{it} + \ \mu_{it}\ (2)$$

Where:

- 4G coverage: percentage of population with 4G coverage[14]
- Index: index that takes the value of 100 if all three answers are affirmative; 66.66 if two are affirmative; 33.33 if only one is affirmative; and 1 if all three responses are negative[15]
- Year: fixed effect for each year between 2010 and 2020
- Area: fixed effect for each country in the regression
- *X*: 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:

$$\text{Unique MBB users}_{it} = \beta_0 + \beta_1.\ \text{Coverage 4G}_{it} + \beta_2.\text{Year}_t + \beta_3\text{A}rea_i + \beta_4.X_{it} + \ \mu_{it}\ (3)$$

Where:

- Unique mobile broadband users: percentage of the population that is a mobile broadband user[16]
- 4G coverage: percentage of population with 4G coverage[17]
- Year: fixed effect for each year between 2010 and 2020
- Area: fixed effect for each country in the regression
- *X*: matrix of other independent variables that are used as controls, in particular, the model 1 treatment variable and the model 2 index

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

2.2. Econometric model results

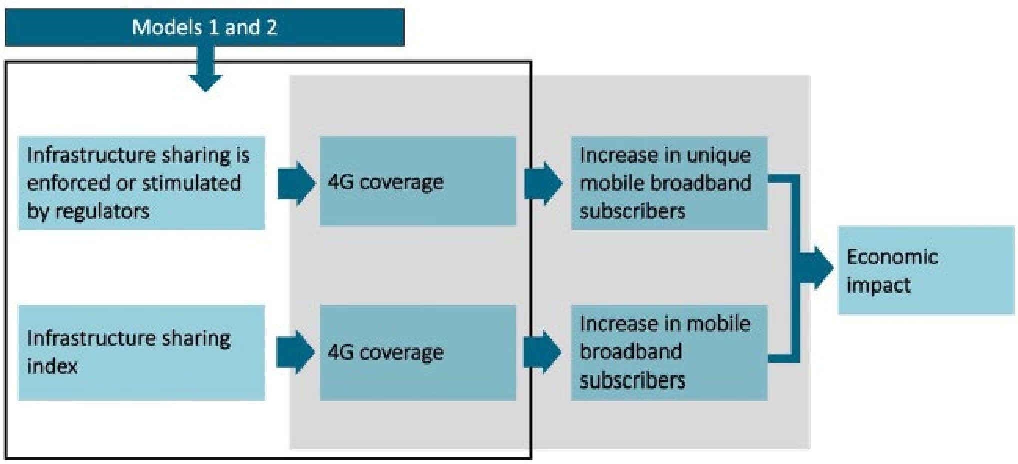
This section presents the results of the econometric models presented above in a sequential fashion.

[14] Source: GSMA
[15] Source: ITU Regulatory Tracker
[16] Source: GSMA
[17] Source: GSMA

2.2.1. 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 (figure 2-3).

Figure 2-3. First analysis module



Source: Telecom Advisory Services

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 increases 4G coverage level by 1.54 percentage points. This result implies that with each additional measure in favor of sharing (out of the three considered), the index increases by 33 points, which in turn generates an increase in 4G coverage of 5.08 percentage points (table 2-1).

Table 2-1. Econometric models with 4G coverage as a dependent variable

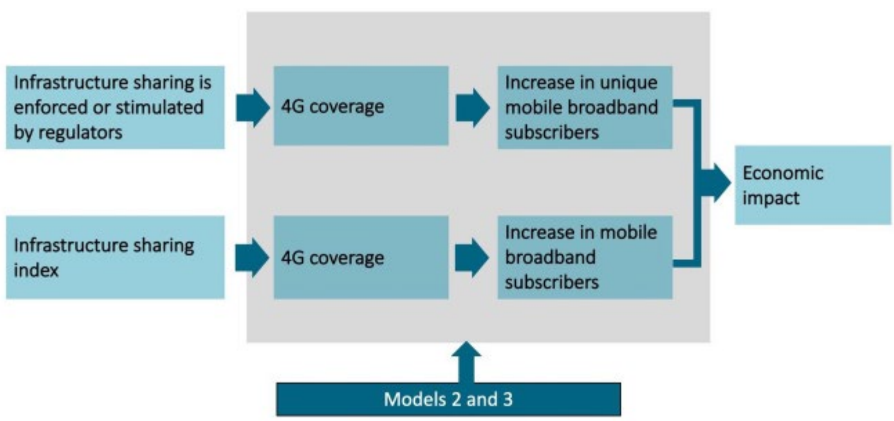
4G coverage	Results	
	Model 1	Model 2
Ln (GDP per capita)	-0.0094265	-0.0093197
	(0.0813132)	(0.0821491)
Treatment	0.1302603 ***	–
	(0.0452936)	–
Index	–	0.0015407 **
	–	(0.0006526)
Fixed effects	Country and year	Country and year
Year	2010-2020	2010-2020
R^2	0.8471	0.8338

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

2.2.2. 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) (figure 2-4).

Figure 2-4. Second analysis module



Source: Telecom Advisory Services

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, the number of unique users will increase from 60% (assuming that this is the initial level) to 61.19%. From this result it is important to note that the treatment only has an effect through the increase in 4G coverage (table 2-2) but has no additional direct effect on the percentage of unique users. Then, in a variant of model 3 (model 4 in table 2-2), where instead of controlling for treatment we control for the sharing regulation index, similar results are found (table 2-2).

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

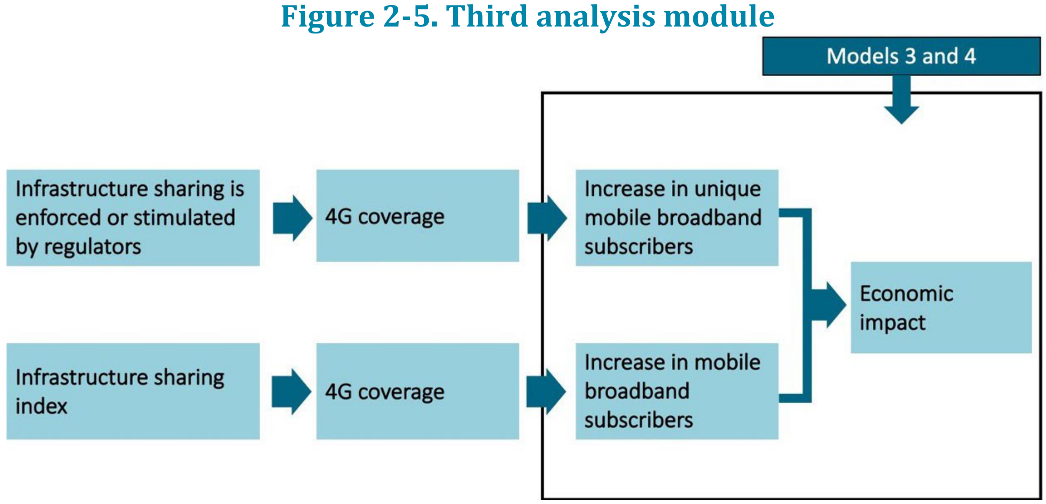
Unique subscribers of mobile broadband (% population)	Results	
	Model 3	Model 4
Coverage 4G	0.1186981 ***	0.110544 ***
	(0.0240667)	(0.0238254)
Ln (GDP per capita)	0.0343244	0.040168
	(0.0261098)	(0.0261137)
Treatment	-0.0095116	–
	(0.0148774)	–
Index	–	0.0002492
	–	(0.0002107)
Fixed effects	Country and year	Country and year
Years	2010-2020	2010-2020
R^2	0.7483	0.7690

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

2.2.3. Economic impact of mobile broadband penetration

This section presents 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 (figure 2-5).

Figure 2-5. Third analysis module



Source: Telecom Advisory Services

For this econometric model 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 (table 2-3).

Table 2-3. Econometric model of the impact of an increase in mobile broadband subscribers on GDP per capita

GDP per capita (PPP)	Results
Mobile broadband subscriber penetration	0.160***
Gross fixed capital formation	0.137***
Education	0.048***
Mobile broadband subscriber penetration	
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 revenue	
GDP per capita	0.517***
Mobile broadband pricing	0.129***
Mobile broadband competition	-1.547***
Growth of mobile broadband adoption	
Mobile broadband revenue	-0.008***
Observations	5,227
Country fixed effect	Yes
Year fixed effect	Yes
Years	2010-2020
R^2	0.993

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

2.3. 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 co-location:

- 4G coverage level would increase from 80.00% to 93.03% (applying the coefficient of econometric model 1 of table 2-1).
- 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 of table 2-2).
- 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 2-3 to the previous result).

Similarly, having one more affirmative answer out of the three that make up the sharing regulation index described in the ITU ICT Regulatory Tracker (section 2.1) generates the following effects:

- 4G coverage level would increase from 80.00% to 85.08% (applying coefficient of econometric model 2 of table 2-1).

- 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 4 of table 2-2).
- The increase in unique users would generate an increase in GDP per capita of 0.15% (applying the coefficient of the model in table 2-3 to the previous result).

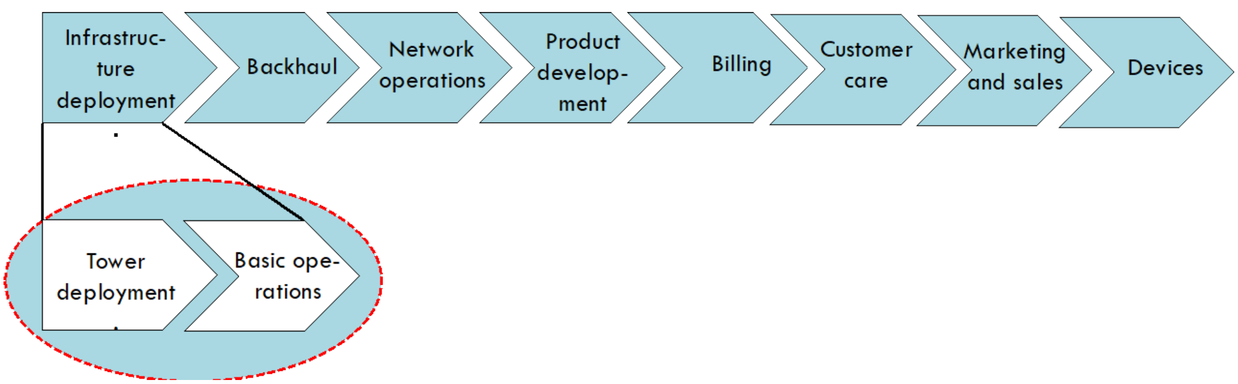
In conclusion, these first econometric models have provided empirical evidence of the positive impact of infrastructure sharing on the development of the wireless industry, service adoption and economic development. We now turn, in Chapter 3, to a specific segment of infrastructure sharing: wireless towers.

3. THE CURRENT STATE OF THE LATIN AMERICAN TOWER INDUSTRY

Over the past 15 years, the mobile telecommunications industry has witnessed the emergence of what in economic terms are called "value chain specialists": communications tower companies. The study of the value chain throughout the life cycle of any industry indicates that, in the initial phase of development, companies need to manufacture their own inputs and, therefore, they must generate specialized equipment. This leads to the integration of the value chain, in which companies control all the stages and functions necessary for the development of the final product. However, over time, as upstream input suppliers become more knowledgeable about the technology and its reliability increases, the incentive to maintain vertical integration along the chain decreases. This leads to a fragmentation of the value chain, with the consequent emergence of specialists that benefit from efficiencies associated with economies of scale and knowledge.[18]

Such has been the case in the tower sector in mobile telecommunications, where the emergence of tower operators can be observed (figure 3-1).

Figure 3-1. Emergence of the tower industry



This trend is evident in Latin America, as elsewhere. In 2024, in the 13 largest countries in the region, the deployment of communication towers reached more than 217,022 units[19] (table 3-1).

[18] This process was described by Stigler (1951).
[19] No distinction was made between tower types. Ground towers are usually freestanding structures and are more prevalent in less populated areas. Roof towers are (usually) installed in pre-existing buildings and are normally located on the roof, on the sidewalk or in high windows. (EY-Parthenon and European Mobile Infrastructure Association, EWIA (2019)).

Table 3-1. Latin America tower deployment

	2016	2017	2018	2019	2020	2021	2022	2023	2024 1T	CAGR (16-24)
Argentina	–	–	–	17,279	17,399	17,577	17,683	17,632	17,632	–
Brazil	58,358	56,957	59,778	64,790	68,542	67,903	68,616	72,760	73,507	2.93%
Chile	8,640	8,926	8,968	9,164	9,029	9,441	9,946	10,163	10,571	2.55%
Colombia	15,359	15,448	16,442	17,552	17,473	17,943	18,554	21,592	21,555	4.33%
Costa Rica	3,055	3,302	3,926	3,999	3,780	4,255	4,077	4,121	4,124	3.82%
Ecuador	–	–	–	–	–	5,930	5,945	5,787	5,776	–
El Salvador	1,264	1,267	1,683	1,728	1,760	2,850	3,062	3,548	3,570	13.86%
Guatemala	3,638	3,676	3,742	4,002	4,002	6,571	6,561	8,536	8,515	11.22%
Honduras	–	–	–	–	–	–	4,528	4,528	4,528	–
Mexico	26,069	29,797	31,548	33,874	34,835	37,060	39,042	42,637	42,954	5.00%
Nicaragua	1,025	1,155	1,231	1,364	1,364	1,785	1,789	2,289	2,304	10.65%
Panama	1,577	1,639	1,656	1,726	1,726	2,211	2,209	2,480	2,803	7.45%
Peru	9,167	10,604	11,121	12,452	14,656	14,765	18,660	19,233	19,183	9.67%
Total	**131,152**	**132,771**	**139,796**	**167,931**	**174,566**	**188,291**	**200,672**	**215,306**	**217,022**	**6.50%**

Sources: TowerXchange; Telecom Advisory Services analysis

Notwithstanding the missing values in table 3-1, it is evident the Latin American mobile industry's installed base of towers grew in the time period shown: from 131,152 in 2016 to 217,022 in 2024 (a compound annual growth rate of 6.50%). The middle-income nations of Central America exhibit the greatest dynamism in terms of growth rate since the mid-2010s: El Salvador, 13.86%; Guatemala, 11.22%; Nicaragua, 10.65%; and Peru, 9.67%. In the rest of the Latin American economies, the deployment of towers has grown at a compound rate ranging from 2.55% to 5.00%.

A comparison of the density of the installed base of towers provides an indication of the different deployment patterns among countries. For example, Costa Rica has 772 towers per million mobile subscribers and Panama 621. At the other end of the distribution, Ecuador has 312 and Mexico 325. This could indicate possible over-deployment in some countries, a topic that will be addressed in subsequent chapters (table 3-2).

Table 3-2. Latin America tower density (1Q 2024)

Country	Number of towers	Number of towers per million inhabitants	Number of towers per million mobile subscribers	Number of towers per km^2 of surface
Argentina	17,632	373	273	0.63
Brazil	73,507	340	338	0.86
Chile	10,571	521	339	1.40
Colombia	21,555	409	265	1.89
Costa Rica	4,124	772	504	8.06
Ecuador	5,776	312	321	2.25
El Salvador	3,570	540	333	16.97
Guatemala	8,515	437	377	7.82
Honduras	4,528	425	522	4.03
Mexico	42,954	325	334	2.19
Nicaragua	2,304	342	253	1.77
Panama	2,803	621	492	3.71
Peru	19,183	550	451	1.49
Total/mean	**217,022**	**377**	**335**	**1.26**

Higher than average

Sources: TowerXchange; Telecom Advisory Services analysis

An analysis of the evolution in tower density allows us to locate the moment in each country when a significant increase in deployment took place (table 3-3).

Table 3-3. Latin America towers per million population (2016-1Q24)

Country	2016	2017	2018	2019	2020	2021	2022	2023	1Q 2024
Argentina	–	–	–	384	383	383	382	377	373
Brazil	284	275	287	308	324	319	321	338	340
Chile	476	485	478	480	464	479	499	505	521
Colombia	328	326	341	355	347	351	360	414	409
Costa Rica	622	665	–	788	737	821	779	780	772
Ecuador	–	–	–	–	–	334	330	317	312
El Salvador	199	198	262	268	271	437	467	539	540
Guatemala	219	217	217	227	223	358	351	447	437
Honduras	–	–	–	–	–	–	440	432	425
Mexico	237	240	252	268	273	287	300	325	325
Nicaragua	162	181	191	209	210	273	271	343	342
Panama	391	400	398	409	403	510	503	557	621
Peru	291	333	346	376	438	436	546	557	550
Mean	**284**	**284**	**291**	**321**	**330**	**342**	**355**	**377**	**377**

Rapid increase in deployment

Sources: TowerXchange; Telecom Advisory Services analysis

In parallel with the growth of the installed base and confirming the trend toward the emergence of "specialists" within the value chain, the tower sector has gradually evolved toward a higher proportion of independent tower companies and companies owned by mobile operators. In fact, following a trend that has taken place in more mature markets such as Europe and the United States, the divestment of towers by operators in Latin America is evident. This is the reason why the stable proportion of independent tower companies exists in parallel with the spin-off of a major regional telecommunications operator, which created a tower company of its own (table 3-4).

Table 3-4. Tower ownership by operators

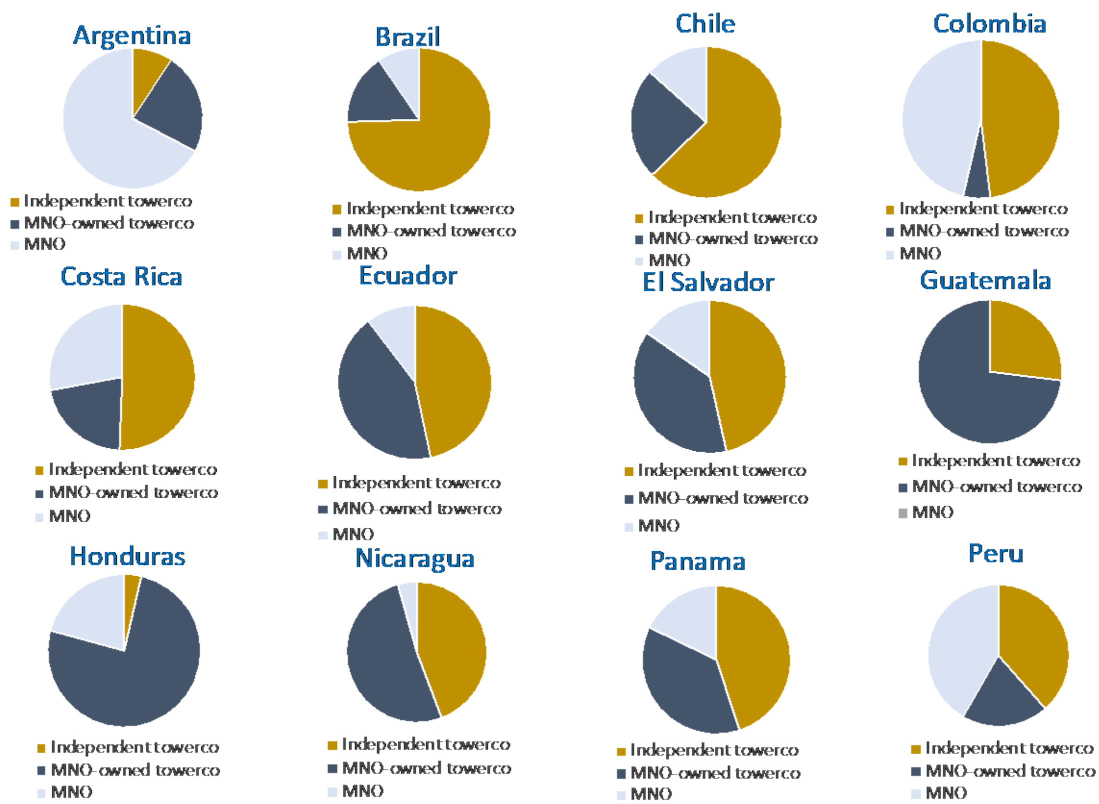
Country	Tower type	2016	2017	2018	2019	2020	2021	2022	2023	1Q2024
Argentina	MNOs	–	–	–	16,000	16,000	11,565	11,565	11,870	11,870
	MNO-owned towerco	–	–	–	335	335	4,435	4,435	4,130	4,130
	Independent towerco	–	–	–	944	1,064	1,577	1,683	1,632	1,632
Brazil	MNOs	19,607	17,000	17,000	19,000	19,000	6,700	7,000	7,000	7,000
	MNO-owned towerco	1,655	1,655	1,655	1,869	3,885	12,539	11,233	11,360	11,713
	Independent towerco	37,096	38,302	41,123	43,921	45,657	48,664	50,383	54,400	54,794
Chile	MNOs	6,371	6,371	6,371	6,455	4,475	1,640	1,620	1,020	1,420
	MNO-owned towerco	328	327	327	368	540	2,545	2,545	2,520	2,520
	Independent towerco	1,941	2,228	2,270	2,341	4,014	5,256	5,781	6,623	6,631
Colombia	MNOs	10,300	10,300	9,500	9,520	8,800	8,940	9,726	10,000	10,000
	MNO-owned towerco	–	–	–	–	–	–	0	1,185	1,185
	Independent towerco	5,059	5,148	6,942	8,032	8,673	9,003	8,828	10,407	10,370
Costa Rica	MNOs	1,450	1,450	1,516	1,585	1,615	1,150	1,150	1,150	1,150
	MNO-owned towerco	216	248	272	298	302	871	871	892	887
	Independent towerco	1,389	1,604	1,839	2,116	1,863	2,234	2,056	2,079	2,087
Ecuador	MNOs	–	–	–	–	–	1 000	1 000	600	600
	MNO-owned towerco	–	–	–	–	–	2,368	2,368	2,500	2,480
	Independent towerco	–	–	–	–	–	2,562	2,577	2,687	2,696
El Salvador	MNOs	1 000	800	737	735	735	415	415	500	500
	MNO-owned towerco	–	–	–	–	–	1,153	1,153	1,245	1,250
	Independent towerco	264	467	946	993	1,025	1,282	1,494	1,503	1,520
Guatemala	MNOs	2,700	2,700	2,700	2,810	2,810	2,110	2,110	0	0
	MNO-owned towerco	–	–	–	–	–	3,264	3,264	3,100	3,080
	Independent towerco	938	976	1,042	1,192	1,192	1,197	1,187	1,136	1,135
Honduras	MNOs	–	–	–	–	–	–	940	940	940
	MNO-owned towerco	–	–	–	–	–	–	3,425	3,425	3,425
	Independent towerco	–	–	–	–	–	–	163	163	163
Mexico	MNOs	2,000	2,000	2,000	2,300	2,500	2,500	2,500	3,000	3,000
	MNO-owned towerco	14,708	14,863	15,559	16,308	17,297	18,568	19,742	22,476	22,787
	Independent towerco	12,361	12,934	13,989	15,266	15,038	15,992	16,800	17,161	17,167
Nicaragua	MNOs	350	350	350	375	375	70	70	100	100
	MNO-owned towerco	–	–	–	–	–	774	774	1,200	1,185
	Independent towerco	675	805	881	989	989	941	945	989	1,019
Panama	MNOs	790	790	790	820	820	680	680	500	500
	MNO-owned towerco	–	–	–	–	–	547	547	1,044	1,044
	Independent towerco	787	849	866	906	906	984	982	936	1,259
Peru	MNOs	6,800	7,860	7,790	7,810	8,000	4,000	7,500	8,000	8,000
	MNO-owned towerco	900	849	849	1,608	1,925	3,687	3,687	3,910	3,800
	Independent towerco	1,467	1,895	2,482	3,034	4,731	7,078	7,473	7,323	7,383

Total	MNOs	51,368	49,621	48,754	67,410	65,130	40,770	46,276	44,680	45,080
	MNO-owned towerco	17,807	17,942	18,662	20,786	24,284	50,751	54,044	63,587	64,086
	Independent towerco	61,977	65,208	72,380	79,735	85,152	96,770	100,352	107,039	107,856

Sources: TowerXchange; Telecom Advisory Services analysis

The structure of the tower industry in the region indicates that half of the installed base is operated by independent companies. However, the percentage of towers owned by independent companies ranges from high (Brazil, Chile, Costa Rica, Colombia and Ecuador) to low (Honduras, Guatemala, Argentina and Bolivia), while some countries have a more balanced proportion (Mexico, Peru, El Salvador and Nicaragua) (graphic 3-1).

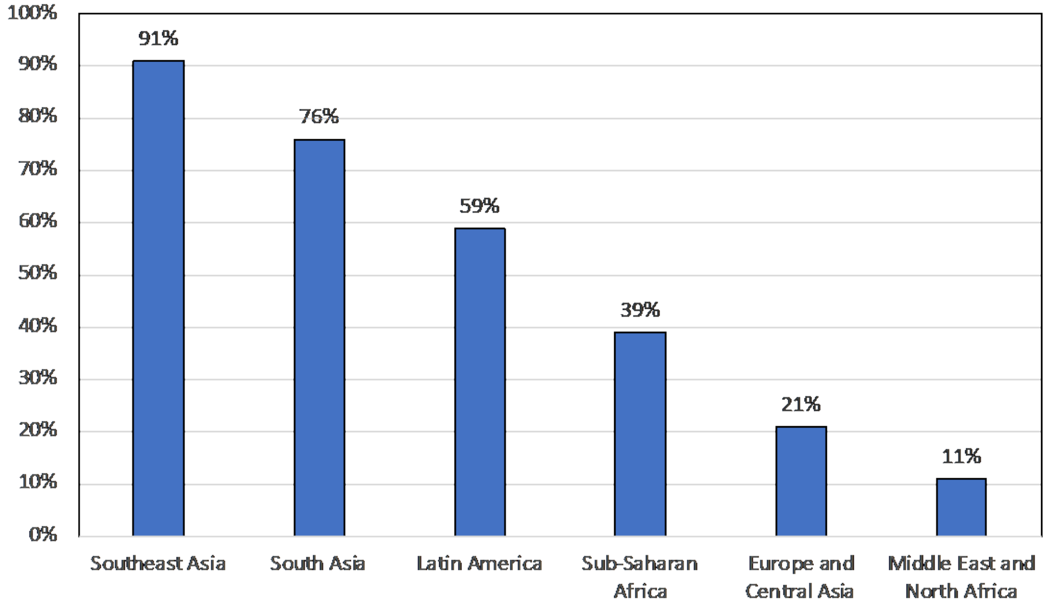
Graphic 3-1. Tower market structure (1Q 2024)



Source: TowerXchange; Telecom Advisory Services analysis

When compared to other regions of the world, the Latin American tower industry is well developed, with indicators trailing only southeast and south Asia (graphic 3-2).

Graphic 3-2. Share of towers managed by tower companies



Source: Houngbonon et al. (2021)

The gradual divestment of telecom operators from most of their tower infrastructure and the combined development of operator-owned tower companies and independent companies in Latin America raise the question of the economic impact of tower ownership on the development of the industry: Is the proportion of towers operated by independent companies related to the performance of the mobile industry, as measured by capital efficiency, network deployment, service adoption and quality? This is the subject of the next chapter.

4. THE INDEPENDENT LATIN AMERICAN TOWER INDUSTRY: AN ASSET FOR THE DEVELOPMENT OF THE WIRELESS TELECOMMUNICATIONS SECTOR

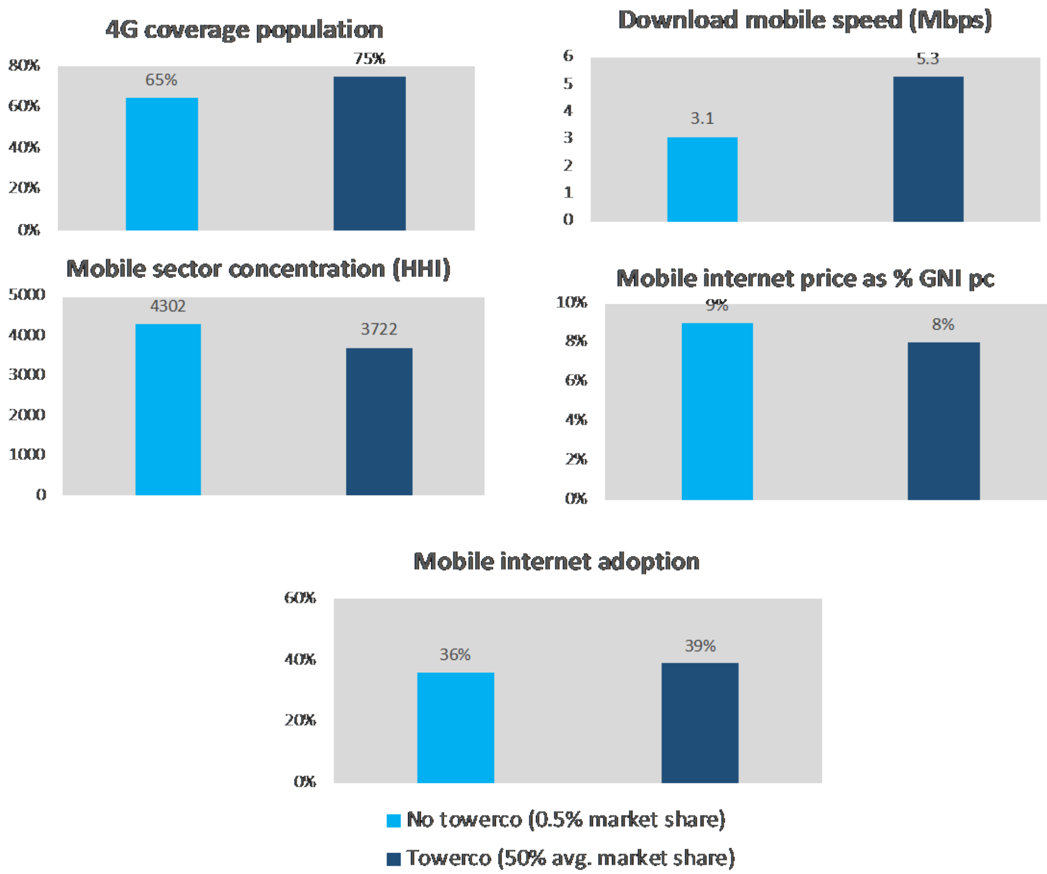
Chapter 3 provided evidence of the changes taking place around the world in the structure of the tower industry, in particular the emergence of the independent tower sector. Does this change in the ownership structure of towers have an effect on the performance of the mobile industry? In economic terms, does the emergence of a "specialized" sector focused exclusively on the provision of passive infrastructure represent an impact on the value chain of the mobile industry?

To answer these questions, one can consider the correlation analysis that divides a sample of countries into those experiencing significant growth in the tower business sector and those that are not, and measure various parameters that assess the development of the mobile industry. If the industry and connectivity is more developed in countries with a considerable presence of tower companies, it can be concluded that there is some association. However, it cannot be assumed that this correlation indicates causation (i.e., that the emergence of the tower company sector will lead to further development of the mobile sector). For this, it is necessary to build an econometric model that controls for exogenous factors and allows to substantiate the existence of a causality. To provide a rigorous quantitative analysis, this chapter presents two analyses: a correlational analysis in section 4.1 and an econometric analysis in section 4.2.

4.1. Impact of the tower industry on industry deployment: correlation analysis

The only empirical research on this topic to date was published by economists at the World Bank's International Finance Corporation (IFC). Houngbonon et al. (2021) analyzed 56 mobile markets by calculating the correlation between the business success of tower companies and the development of mobile telecommunications. The study defines tower companies as "companies specialising in the management of mobile network infrastructures, e.g., towers and small cell sites," although it does not differentiate between companies owned by mobile network operators, independent companies and associated companies, and between independent entities and mobile operators (joint ventures between mobile network operators). Despite this lack of differentiation between the ownership of tower companies, the study indicates that there is a positive correlation between the success of the tower companies' business and the development of the mobile telecommunications industry. For example, the analysis provides evidence that in markets where the penetration of the tower companies' business model is higher (i.e., indicates a market share of more than 50% compared to countries with a market share of less than 5%), the coverage of the population with 4G technology is 10 percentage points higher, average download speeds are 2.2 Mbps higher, the price of mobile internet as a percentage of monthly revenue is 1 percentage point lower and markets are 13% less concentrated, i.e., more competitive (graphic 4-1).

Graphic 4-1. Towercos and mobile connectivity



Source: Houngbonon et al. (2021)

This analysis is replicated for Latin America by differentiating tower companies from those owned by mobile operators and independent ones, including the metric of towers per capita, and expanding the performance indicators of the mobile telecommunications industry that include the industry's capital investment. On the basis of these two metrics, Latin American countries can be divided into three groups (table 4-1, panel A). To gain statistical and economic representativeness, the main group and the laggards were regrouped and two categories were established: (i) leaders, in which the share of towers owned by independent companies is more than 50% and independent towers per capita exceed 225 and (ii) the rest of the countries, where the share of independent firms is less than 50% and the density of towers per capita is less than 225 (table 4-1).

Table 4-1. Country groupings by independent towercos development

Panel A.

	Leaders		Main		Laggards	
	Conditions	Countries	Conditions	Countries	Conditions	Countries
Share of independent towercos	**>50%**	• Brazil (75%) • Chile (63%) • Costa Rica (51%)	**44-50%**	• Colombia (48%) • Ecuador (47%) • Nicaragua (44%) • Panama (45%)	**<44%**	• Argentina (9%) • El Salvador (43%) • Guatemala (13%) • Honduras (3.60%) • Mexico (40%) • Peru (38%)
Towers per capita owned by independent towercos	**>225**	• Brazil (253) • Chile (327) • Costa Rica (391) • El Salvador (230) • Panama (279)	**144-225**	• Colombia (197) • Ecuador (146) • Nicaragua (151) • Peru (212)	**<144**	• Argentina (35) • Guatemala (58) • Honduras (15) • Mexico (130)

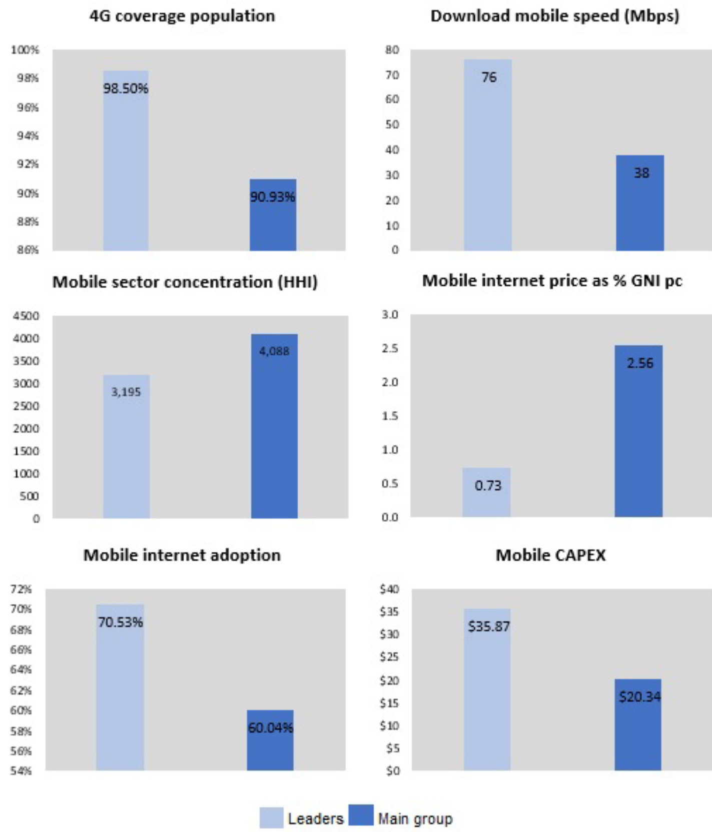
Panel B

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

Source: Telecom Advisory Services analysis

A visual analysis of the economic impact of the tower industry indicates that countries with a higher proportion of independent tower companies and a greater deployment of towers have higher performance metrics than those with a lower proportion and lower tower deployment (graphic 4-2).

Graphic 4-2. Latin America towercos and wireless industry development



Source: Telecom Advisory Services analysis

The development of independent tower companies is associated with better mobile industry performance metrics (higher than those calculated in the study by Houngbonon et al., 2021):

- Better coverage and access: Leading countries are almost seven percentage points higher than the rest of the countries in terms of infrastructure deployment (98.5% vs. 90.93%).
- Higher speed: Mobile broadband is 50% faster in leading countries than elsewhere (76 Mbps vs. 38 Mbps).
- More intense mobile competition: Competition is more intense in the leading countries than in the rest (21.84% less concentration).
- Improved affordability: Mobile broadband services account for almost one-third of costs in per capita terms in leading countries, relative to the rest of the countries (0.73% vs. 2.56%).
- Increased adoption of mobile broadband service: Leading countries show higher broadband adoption than the rest (70.53% vs. 60.04%).
- More investment: Capital investment is 43% higher in leading countries than in

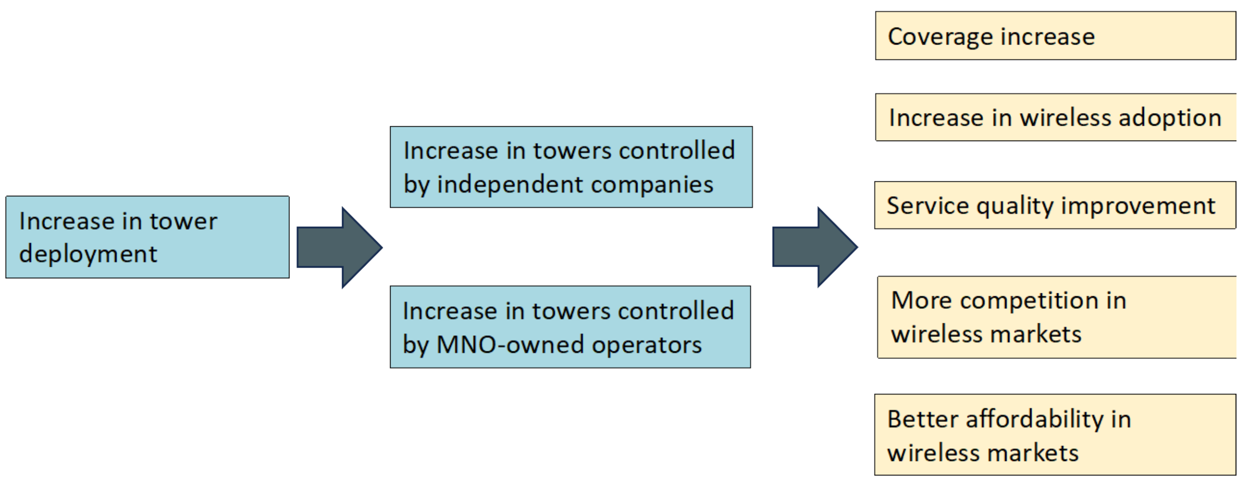
other countries (US$35.8 per capita vs. US$20.34 per capita).

These results are in line with those of the global analysis by Houngbonon et al. (2021), and in some ways they are more compelling. It is important to consider that the evidence presented in this chapter is based on correlations where a cause/effect relationship cannot be established; this requires a causal assessment such as that presented in the econometric models in the next section.

4.2. Econometric analysis of the impact of the independent tower industry in Latin America

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 (figure 4-1).

Figure 4-1. Focus of the analysis



Sources: Telecom Advisory Services

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. Following this, we present the results of the empirical modeling and, on these bases, discuss the implications.

4.2.1. Theoretical framework

To quantify the relationship between tower deployment and mobile sector performance, we first build an econometric model (referred to as "No Fixed Effects" in table 4-3, section 4.2.2.) 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-owned towers) and GDP per capita. Because we are examining 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) (equation 1).

$$\ln(\text{dependent variable}) = \beta_0 + \beta_1 . \ln(\text{towers deployment})_{it} + \beta_2 . (\text{GDP } per\ capita)_{it} + \mu_{it} \quad (1)$$

The following indicators are included in the econometric model:

- Dependent variables:
  - 4G coverage[20]
  - Mobile broadband adoption[21]
  - Quality of mobile service measured by mobile broadband download speed[22]
  - Level of competition in the mobile market as measured by HHI[23]
  - Level of affordability of a basic mobile basket[24]
- Number of towers:
  - Total towers
  - Towers owned by telecom operators
  - Independent towercos
- GDP per capita[25]

An additional model ("Fixed Effects" in table 4-3) is proposed for robustness, which includes a country fixed effect control that seeks to capture the effects of each country that is not considered through the inclusion of GDP per capita (equation 2).

$$\ln(\text{dependent variable}) = \beta_0 + \beta_1 . \ln(\text{tower deployment})_{it} + \beta_2 . (\text{GDP } per\ capita)_{it} + \beta_3 . (\text{country})_t + \mu_{it} \quad (2)$$

This analysis is based on information provided by Tower Xchange for 12 countries in the

[20] Source: GSMA
[21] Source: GSMA
[22] Source: Ookla/Speedtest
[23] Source: GSMA
[24] Source: International Telecommunication Union
[25] Source: International Monetary Fund

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 (table 4-2).

Table 4-2. 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 supplied by TowerXchange

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.

4.2.2. Impact of deploying independent towers on 4G coverage

According to the models presented in table 4-3, an increase in the number of independent towers (last two columns) of 10% is associated with an increase in 4G coverage levels of 0.96% (model no fixed effects) or 5.54% (model with fixed effects). Additionally, it is found that 4G coverage increases by 0.95% for a 10% (no fixed effects column) increase in total towers (11.40% in the model with fixed effect). This result for MNO towers is 0.74% and 4.33% respectively. In order to be conservative with the results found, we opted for the model without fixed effects for the conclusions.

Table 4-3. Econometric models with dependent variable coverage

Ln (coverage)	Total towers		MNO towers		Independent towers	
	No fixed effects	Fixed effects	No fixed effects	Fixed effects	No fixed effects	Fixed effects
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 capita)	0.1590487 **	0.164351	0.163087 ***	0.5308929	0.171005 **	0.2182255
	(0.0672837)	(0.3374592)	(0.057997)	(0.4358097)	(0.0698268)	(0.3627445)
Fixed effects	No	Country	No	Country	No	Country
Years	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022
R^2	0.2796	0.6467	0.2611	0.3946	0.275	0.591

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

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 (table 4-4).

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

	Mean difference	
	No fixed effects	Fixed effects
Difference	0.021849800 ***	0.121169700 ***
95% interval	0.012459017	0.082146716
	0.031240583	0.160192684

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

4.2.3. 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 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% (fixed and no fixed effects columns in table 4-5). Again, in order to be conservative, we opted for the model without fixed effects for the conclusions.

Table 4-5. Econometric models with the dependent variable mobile broadband adoption

Ln (adoption)	Total towers		MNO towers		Independent towers	
	No fixed effects	Fixed effects	No fixed effects	Fixed effects	No fixed effects	Fixed effects
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 capita)	0.22561 ***	-0.0836802	0.2547614 ***	0.0502101	0.2477615 ***	-0.0463682
	(0.0453197)	(0.1002834)	(0.0345798)	(0.1422545)	(0.0385214)	(0.1233549)
Fixed effects	No	Country	No	Country	No	Country
Years	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022
R^2	0.6905	0.9233	0.7311	0.8415	0.714	0.8838

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

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 (table 4-6).

Table 4-6. Test of difference of means between independent tower model and MNO tower model (with dependent variable adoption)

	Mean difference	
	No fixed effects	Fixed effects
Difference	0.018113800 ***	-0.002513500
95% interval	0.012954892	-0.015383914
	0.023272708	0.010356914

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

4.2.4. Impact of deploying independent towers 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 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% (columns with no fixed effects and fixed effects in table 4-7). In order to be conservative with the estimated coefficients, the model without fixed effects was chosen to draw the conclusions.

Table 4-7. Econometric models with the dependent variable of quality of service

Ln (speed)	Total towers		MNO towers		Independent towers	
	No fixed effects	Fixed effects	No fixed effects	Fixed effects	No fixed effects	Fixed effects
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 per capita)	-0.1616302	-0.3890475	-0.1412978	0.2179391	-0.1099319	-0.1976697
	(0.1432014)	(0.5027467)	(0.1013945)	(0.6799496)	(0.1413069)	(0.6084333)
Fixed effects	No	Country	No	Country	No	Country
Years	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022
R^2	0.1848	0.6608	0.1683	0.3625	0.1393	0.5023

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

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 (table 4-8).

Table 4-8. Test of difference of means between independent tower model and MNO tower model (with dependent variable quality)

	Mean difference	
	No fixed effects	Fixed effects
Difference	0.034640900 ***	0.004520600
95% interval	0.016937334	-0.057516063
	0.052344466	0.066557263

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

4.2.5. 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 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 (table 4-9). Again, in order to be conservative with the results found, the model without fixed effects was chosen to draw the conclusions.

Table 4-9. Econometric models with the dependent variable mobile market concentration

Ln (mobile HHI)	Total towers		MNO towers		Independent towers	
	No fixed effects	Fixed effects	No fixed effects	Fixed effects	No fixed effects	Fixed effects
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 per capita)	-0.021163	-0.0101682	-0.0536181	-0.0409802	-0.0204345	-0.0078265
	(0.0450328)	(0.0476399)	(0.048378)	(0.0520942)	(0.0437433)	(0.046446)
Fixed effects	No	Country	No	Country	No	Country
Years	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022	2016-2022
R^2	0.0419	0.9866	0.1107	0.9835	0.0506	0.9872

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

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 (table 4-10).

Table 4-10. Test of difference of means between independent tower model and MNO tower model (with dependent variable mobile market concentration)

	Mean difference	
	No fixed effects	Fixed effects
Difference	-0.032151700 ***	-0.032858900 ***
95% interval	-0.036719361	-0.037607124
	-0.027584039	-0.028110676

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

4.2.6. Impact of deploying independent towers 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 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 (table 4-11). In order to be conservative with the results found, the model without fixed effects was chosen to draw the conclusions.

Table 4-11. Econometric models with the dependent variable mobile affordability

Ln (affordability as share of GDP)	Total towers		MNO towers		Independent towers	
	No fixed effects	Fixed effects	No fixed effects	Fixed effects	No fixed effects	Fixed effects
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 per capita)	-0.982563 ***	-0.2421697	-1.149615 ***	-0.2821037	-1.055496 ***	-0.2077791
	(0.2537373)	(0.4117507)	(0.254749)	(0.4591996)	(0.2229642)	(0.4023775)
Fixed effects	No	Country	No	Country	No	Country
Years	2016-2021	2016-2021	2016-2021	2016-2021	2016-2021	2016-2021
R^2	0.6907	0.9637	0.7667	0.9548	0.7542	0.9654

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

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 (table 4-12).

Table 4-12. Test of difference of means between the independent tower model and the MNO tower model (with dependent variable mobile affordability)

	Mean difference	
	No fixed effects	Fixed effects
Difference	-0.217285900 ***	-0.302001600 ***
95% interval	-0.250729989	-0.352976195
	-0.183841811	-0.251027005

Note: ***, **, * significant at 1%, 5% and 10%, respectively.
Source: Telecom Advisory Services analysis

4.3. Conclusions

The evidence presented in this chapter is 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 those with lower:

- Better coverage: Country leaders depict seven percentage points higher coverage than the rest of countries.
- Faster speed: Wireless broadband is 50% faster among country leaders than the rest (76 Mbps vs. 38 Mbps).

- More investment: Capital spending is 43% higher in country leaders (US$35.87 per capita vs. US$20.34 per capita).
- Better affordability: Wireless broadband services represent one-third of costs per capita in country leaders relative to the rest of countries (0.73% vs. 2.56%).
- Higher adoption of mobile broadband service: Country leaders exhibit higher broadband adoption than in the rest (70.53% vs. 60.04%).
- More intense competition: Wireless competition is more intense in country leaders (21.84% 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, or is associated with:

- An increase in 4G coverage levels of at least 0.96%.
- An increase in wireless broadband adoption levels of 0.51%.
- An increase in service quality levels (measured as mobile broadband download speed) of 2.05%.
- 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 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 is 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. 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. Chapter 5 focuses on some of these variables and assesses the region's current situation relative to their fulfillment.

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

Chapter 4 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 we follow is to outline a list of regulatory and policy requirements that are critical to fostering the development of the sector. Once formalized, the list is validated through an examination of international best practices. Finally, we will examine the state of such specifications in Latin America.

5.1. Regulations to ensure the sustainability of the tower industry

A review of the research literature and interviews with regulators and policymakers allow us to identify 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, as follows.

5.1.1. Concessions and past 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 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 (Kerf, 1998).

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 in 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 of non-ionizing radiation and fixing their own limitations on minimum distances and tower heights, use of public spaces or how environmental impact should be measured. There are countless laws that regulate elements that are, or should be, quite standard and common (table 5-1).

Table 5-1. Problems encountered in regulation of 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 misunderstanding of regulations • 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/Analysys Mason (2017)[26]

These problems 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, and some impose extremely high contributions from tower companies. Interestingly, in other infrastructure areas (e.g., ports), national authorities are increasingly gaining jurisdictional leverage over local governments. This is a case of "vertical policy coherence," where a national imperative, such as addressing the digital divide or deploying 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.

[26] Summarized by the authors from the CAF report "Mobile Broadband Expansion" (2017), produced by Analysys Mason.

5.1.2. Regulations to avoid excessive deployment of towers

Tower over-deployment, in many cases driven by financial speculation, is common in Latin America. As mentioned in the assessment of tower density discussed in chapter 4, some countries in the region have in relative terms an extremely large number of towers per population and wireless subscribers. The consequences of this are not only environmental but also economic. A simplified economic-financial model developed for this study indicates that if a single tower is not supporting the radios of more than one operator (preferably three or more), its profitability is questionable (a detailed account of this is included in Appendix A.2).

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

- Tenant ratio: estimate revenues from one, two, three or 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, on the 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, the percentage corresponds to conventional corporate levies and excludes additional municipal fees and permits, all of which can add to the fiscal burden (see detail in section 5.1.3). On this basis, the model projects free and accumulated cash flows and net present value (NPV) to provide metrics of profitability. The net present value for the three environments under consideration are given in table 5-2.

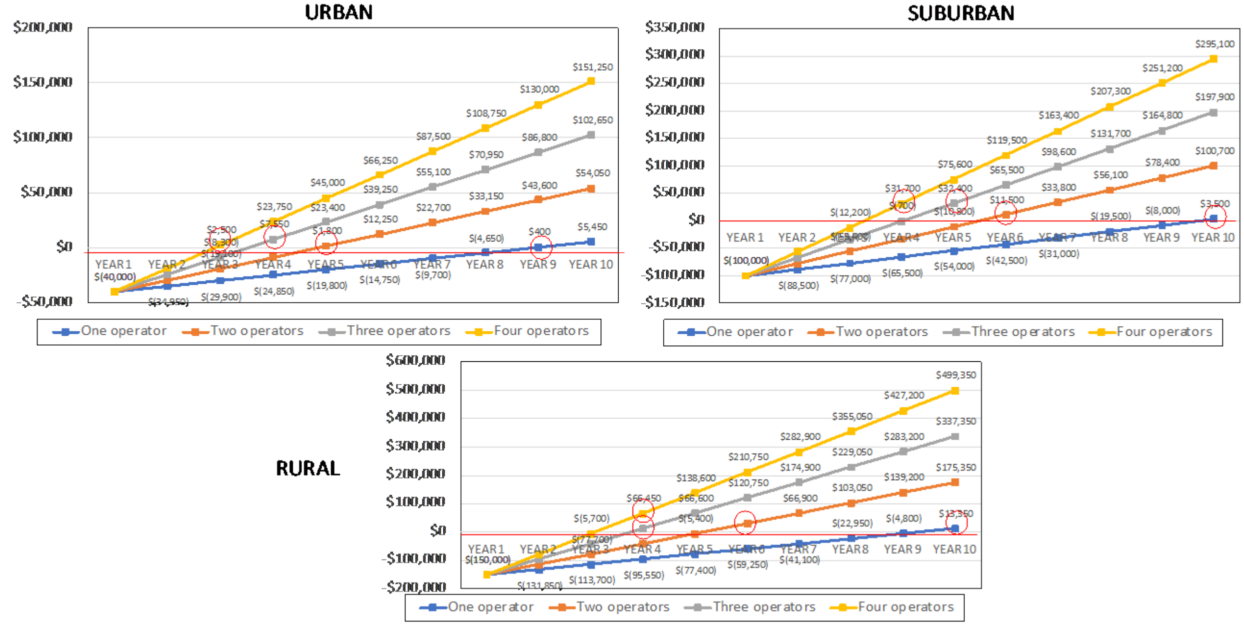
Table 5-2. Latin America: net present value (10 years, without terminal value)

Number of operators	Urban (US$)	Suburban (US$)	Rural (US$)
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

Sources: industry interviews; Telecom Advisory Services analysis

As indicated in table 5-2, the single-tower business is highly dependent on the number of operators served by the infrastructure. In all three scenarios, the NPV if only one operator is served is always negative. In addition to estimating NPV, the model estimates cumulative cash flows to determine when different investment scenarios turn positive (figure 5-1).

Figure 5-1. Latin America: cumulative cash flows



Sources: industry interviews; Telecom Advisory Services analysis

As indicated in figure 5-1, when considering cumulative cash flows, under one-tenant condition, the financials turn cash positive only in year 10 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 one to two tenant ratios.
- Heavy initial CAPEX should be accompanied by relatively stable and predictable rules to ensure profitability and reinvestment. While the financials are calculated over a 10-year timeframe, stability and predictability of regulatory frameworks are critical industry requirements.
- Regional disparities in urban, suburban and rural settings should drive the need to develop regulatory frameworks and policies that account for different economics 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 (e.g., tax reductions, import duty exemptions, etc.).

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

- Encourage the co-location of telecommunications equipment on existing infrastructure.
- Encouraging sharing of infrastructure.
- Determine 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.

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

Fees and taxes, also referred to as "cost of compliance," have a significant impact on the business case presented. 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). Because 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.

Broadly speaking, most of the macroeconomic research literature has identified tax regimes as playing a key role in determining capital flows, when controlling for economic development, employment rates and currency fluctuations (Slemrod, 1990; Devereux and Freeman, 1995; Billington, 1999). Consequently, when a company has to make an investment decision, taxation plays a determining role. Taxes affect a company's incentives to make investments and the supply of funds available to finance them. A number of empirical studies indicate that, all other things being equal, marginal and average tax rates have a negative effect on investment decisions. Research has shown that a reduction in the tax determines, over time, an increase in the level of gross fixed capital formation (Talpos and Vancu, 2009). These effects are expected to be more significant in emerging market economies, where investment needs are greater.

Katz and Callorda (2019) provided empirical evidence on the impact of the tax framework on capital investment in telecommunications networks in the United States. The authors assessed the impact of taxation on the level of investment in the telecommunications and cable industry in a model that included data for all U.S. states. According to econometric models developed by the authors, a decrease of one percentage point in the weighted average rate of state and local taxes affecting initial equipment purchases (from 4.58% to 3.58%) would increase investment by 1.97% from current levels (Katz and Callorda, 2019).

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 limiting deployment of infrastructure or augmenting 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 (table 5-3).

Table 5-3. Municipal taxes by country (all values in US$, except where noted) (2024)

Country	Fees per site
Argentina	• Country average: $185/month, although it varies by municipality ○ Buenos Aires metropolitan area: $385/month

Brazil	• Two types of annual municipal tax (urban tax and environmental tax) and a single tax (for both concepts)
	  ○ The urban tax ranges from 6,000 reais (Gravatai, Guarulhos-São Paulo, Itaquaquecetuba and Recife) to zero reais
	  ○ The environmental fee ranges from 2,000 reais (state of Rio Grande do Norte) to zero reais
	  ○ The combined single fee is 6,000 reais for the Prefeitura de Natal
	  ○ The largest combined fare is 6,000 reais

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

Colombia	• Variety and extreme rates in municipalities:
	  ○ In Bogota, the deployment permit includes a one-time fee for installation at private sites ($50-$175) and an annual fee of $8,100 for an installation at public sites
	  ○ In Cali, deployment at private sites only requires a one-time processing fee of $15, while payment for permits for deployment at public sites is assessed on a case-by-case basis
	  ○ In Palmyra, all sites require an average annual fee of $4,000, although the amount depends on the height and type of site
	  ○ In Barranquilla, installation is only allowed in public places, although the exact amount of the fee is determined annually based on height and other factors
	  ○ In small municipalities, deployment at private sites is usually waived, although fees at public sites can be as high as $1,600 (the operator bears the burden of taxes in most cases)

Costa Rica	• Municipalities collect three fees:
	  ○ Building permit: 1% of construction costs (estimated with the College of Engineers and Architects)
	  ○ Municipal tax: business tax on all commercial enterprises operating in the canton, ranging from 0.1% to 0.4% of gross receipts
	  ○ Property tax: 0.25% of the value of the property assessed by the Tax Agency

Ecuador	• Nationwide: one-time payment of $4,250 • Exceptions (such as the municipality of Quito): $1,700 per year

El Salvador	• Municipalities charge monthly fees and taxes on physical goods:
	  ○ Monthly fees are imposed for land use, maintenance and operation (an average of $250, but in one case as high as $10,000)
	  ○ Monthly taxes based on the value of the physical asset ($30 to $150)

Guatemala	• The average one-time municipal tax is $10,000 • In addition, the Single Property Tax represents an average annual payment of $440
Nicaragua	• Property tax calculated as 1% of 80% of the value of the physical asset (average annual tax: $390) • Municipal tax: 1% of the income generated in the municipality (monthly)
Panama	• Permit ranges from 1% to 5% of construction costs (one-time): $600-$2000

Source: prepared by Telecom Advisory Services, based on interviews

Without making any judgment about the need of municipalities to collect revenues to support the delivery of public services, it's clear 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 and 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.

5.1.4. Policies to promote infrastructure sharing for 5G deployment

The deployment of 5G networks will require a significant increase in the level of densification and deployment of antennas to provide useful coverage in spaces with high data traffic (e.g., shopping malls, train stations, busy streets and avenues, highways, stadiums, industrial estates, etc.). Cell densification requires the installation of a significant number of antennas, which are not necessarily installed on specific towers, but on the sides of buildings, on poles or on street infrastructure.

Analysts have estimated that, in a conservative scenario, by 2025 the densest points of the three most populated cities in each country will be covered, and by 2030 this coverage will reach the 15 main urban areas of each country. Following the recommendations of the Small Cell Forum (2017; 2018) and COMMSCOPE (2018) and with implementation of 225 small cells per km^2 in densely populated areas, and 10 per macrocell, this would be a very high growth of radio base stations: between three and four times more than currently by 2030. The number of base stations does not necessarily imply a proportional increase in the number of sites, as there may be several base stations per site, combined with sharing between mobile operators. Small cells, however, would not be useful if deployed at current sites. Therefore, regardless of the optimization of current sites and even site sharing, it could be argued that a significant percentage of microcells will require new sites. Projecting the current ratio of base stations per site in each country and then adding the new ones to be deployed for 4G and 5G, and assume a sharing level of 25%, it is estimated that by 2030, two to three times the current number of sites will be required. Thus, Argentina could need 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) (Cabello et al., 2021).

Considering these deployments, zoning regulation will become critical. Small cells are installed in light poles or on utility posts, at a height of approximately 15 meters, not higher than 10% of neighboring structures and they do not require civil engineering or new structures. That being said, they should require the following 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 limited to small cells of up to 15 meters.
- Minimum distance among small cells should also be applied on private property.
- Siting on public buildings and public rights of way should be offered at market prices.

- Permits for small deployment to include the authorization for laying down backhaul fiber.
- Small cell regulation that does not discriminate against macrocells or cellular towers.
- Permits for micro and small cells delivered in no more than 30 days.

5.1.5. 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 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 telecommunications service providers and tower companies for the lease of tower space are entered into between private parties on the basis of agreed prices.
- The determination of the price does not reflect an excessive, or excessive price of an, essential good.
- The regulation of access prices to towers represents a disincentive to invest in infrastructure. The regulation of access conditions and prices affects the return that an infrastructure owner would expect to receive as a result of their investment efforts. In economic terms, the nature of ex post access regulation has an impact on ex ante incentives to invest (Cave et al., 2001).

5.1.6. Long-term guarantees and legal certainty 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 included in Appendix A.2, 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 that smooths the ups and downs and fosters long-term domestic and international investment.

5.2. International best practices

Regulations and policies aimed at fostering the development of a sustainable independent tower sector were validated through a study of international best practices. Information was collected from South Korea, the United Kingdom, Canada and the United States.

5.2.1. 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 Business Act[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 Business Act, the construction of ICT infrastructure is also regulated by the Information and Communications Construction Business Act,[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 that manages a construction enterprise 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, are 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 attached structures, and surface. In such cases, the telecommunications joint venture operator should first consult with the owners or occupants of the land. 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 should be established.

5.2.2. Infrastructure sharing in the United Kingdom

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

Mobile services in the United Kingdom are regulated by the Communications Act of 2003.[30] While local administrations oversee the issuing of 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.

5.2.3. Infrastructure sharing in Canada

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

As in the U.K., there are initiatives to promote the development of high-speed networks through the Telecom 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 or modifying or replacing a structure, if necessary, with the objective of extending coverage in a harmonized manner. In addition, Customer Procedure Circular CPC-2-0-17[37] (Conditions of License for Mandatory Roaming and Antenna Tower and Site Sharing and to Prohibit Exclusive Site Arrangements) determines

[30] https://bit.ly/3eiF735
[31] https://bit.ly/3wQFdVQ
[32] https://bit.ly/3CQEwQj
[33] https://bit.ly/3RrWaO8
[34] https://bit.ly/3RPlv59
[35] https://bit.ly/2xJh8AW
[36] https://bit.ly/3Qej2zU
[37] https://bit.ly/3efp9Xk

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 other things, that the Canadian Radio-television and Telecommunications Commission (CRTC) 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.

5.2.4. Infrastructure sharing in the United States

The Telecommunications Act of 1996[40] 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.

The rule to accelerate the deployment of wireless broadband by removing barriers to infrastructure investment[41] 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[42] 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 co-location in existing structures and 90 days for new construction) and provides between 90 and 150 days for approval of 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 2012[43] 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.

[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] https://bit.ly/3RbTa9d
[40] https://www.congress.gov/bill/104th-congress/senate-bill/652#:~:text=Directs%20the%20FCC%20to%3A%20(1,stations%20by%20a%20cable%20system.
[41] https://bit.ly/2vjaErO
[42] https://bit.ly/3RgyCMw
[43] https://bit.ly/3eetUQV

Finally, 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 was recommended.

*   *   *   *   *

A review of Latin American best practices yields the following:

- Nine out of 12 Latin American countries evaluated have specific laws to regulate the deployment of passive infrastructures.
- Three-fifths of countries do not require independent tower companies to register with regulatory authorities to begin operations.
- In addition, two-thirds of the countries in a sample of 12 have enacted laws that are in line with local ordinances and have straightforward procedures for building permits and references to construction fees known to infrastructure operators.
- Two-thirds of the countries do not have pricing rules for shared infrastructure.
- Three-fifths of the countries submit information promoting the deployment of networks for new technologies such as 5G and microcells.
- Four out of 12 countries have plans or manuals of good practices that complement the regulatory frameworks that promote the orderly construction of shared telecommunications infrastructures.

The review of international experience in the benchmark countries (South Korea, United Kingdom, Canada and the United States) has validated six areas that contribute to the development and sustainability of a free-standing tower sector (table 5-4).

Table 5-4. International best practices

Best practices	Observations
No concessions required and fast permit approvals	• In one out of the four benchmark countries, it's not necessary to register with the regulator to start trading. • Two out of the four benchmark countries have laws that are in line with local ordinances and have straightforward procedures for building permits and references to construction fees known to infrastructure operators. • National regulations cover the technical aspects of tower installation that municipalities comply with in the U.K. and South Korea.
Regulation to prevent overexploitation	• All benchmark countries have plans or manuals of good practices that complement the regulatory frameworks that promote the orderly construction of telecommunications structures. • Regulations to encourage sharing and co-location while controlling infrastructure sprawl are in place in the U.S., U.K. and South Korea. • Standard Building Permit Regime and National Guidelines for the Collection of Infrastructure Charges exist in the U.K.
Limit on fees and taxes	• Codes of good practice or central government incentives that guide municipal processes are in place in the U.S., U.K. and South Korea.
Policies to promote the development of infrastructure for sharing in view of the deployment of 5G	• One-third of benchmark countries present information promoting the deployment of networks for new technologies such as 5G and small cells.
Price regulation	• Three out of four benchmark countries do not have pricing rules to determine the infrastructure leasing relationship between infrastructure operators and service operators.
Long-term warranties on the regulations and permits	• Three out of four benchmark countries have specific laws to regulate the deployment of passive infrastructure.

Source: Telecom Advisory Services analysis

5.3. The state of regulation and public policies affecting the tower industry in Latin America

An evaluation of the regulation and public policies affecting the tower industry in Latin America was carried out on the basis of two inputs: (i) desk research on regulatory and public policy frameworks and (ii) interviews with regulators to validate the information investigated and obtain more information on the current situation.[44]

The analysis focuses on four aspects: (i) the regulations governing 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 situation and prospects of the regulatory framework of the tower industry. These four aspects relate to the strengths and weaknesses that enable or inhibit the deployment of infrastructures and, therefore, the advanced development of mobile services. This assessment also sought to identify potential regulatory initiatives at

[44] A list of the authorities interviewed is given in Appendix A.1.

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 findings compiled for 11 Latin American countries: Argentina, Brazil, Chile, Colombia, Costa Rica, Ecuador, Peru, Panama, El Salvador, Guatemala and Nicaragua.[45] Each country's framework is evaluated in the light of the best practices identified in table 5-4, and these lead to recommendations for improvement.

5.3.1. Argentina

In its Decree 1060, Argentina defined a specific technical classification for the passive infrastructure provider (referred to as an independent passive infrastructure operator).[46] To provide services, such an entity requires a simple request for notification of commencement of activities, for which a certificate is issued. This means there is no requirement to obtain a license or be registered.

The resolution (RESOL-2019-2537-APN-ENACOM#JGM)[47] that regulates independent infrastructure operators complements Decree 1060 in three fundamental aspects: (i) it precisely defines the characteristics of an independent passive infrastructure operator,[48] (ii) it determines the obligation to notify the start of operations and report infrastructure information to ENACOM (telecommunications regulatory body) and (iii) it establishes the nature of the relationship between passive infrastructure operators and telecommunications service licensees.

Regarding the issuance of guidelines for the deployment of passive infrastructures, Argentina presents a mechanism for partial harmonization between national and local regulations, because Resolution 105/2020[49] establishes the general guidelines for the distribution and deployment of infrastructures that must be followed by local authorities. However, in aspects related to camouflage, minimum distance or land use fees, it is up to each municipality to issue its own particular ordinance. It is worth mentioning that the Argentine Federation of 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 the Argentine regulatory framework are:

- The administrative procedure for carrying out procedures includes an online one-stop shop (Platform for Remote Procedures — TAD) for the notification of the

[45] Detailed information is contained in Appendix A.2.
[46] https://bit.ly/3P8rFMM
[47] https://bit.ly/3uGCuNw
[48] Independent infrastructure operators are authorized to operate aerial, terrestrial or underground infrastructures supporting networks for the provision of telecommunications services. These infrastructures include towers, masts, poles, conduits, channels, cameras, cables, easements, rights-of-way, fiber-optic cables and antennas.
[49] https://bit.ly/3uLc9ht

deployment of the passive infrastructure.

- Infrastructure sharing is the only concept that allows sharing and leasing between independent operators and ICT service operators.
- There is only one standard that covers the operation of aerial, physical or underground infrastructures.

Some needs for improvement in the Argentine regulatory framework relate to:

- Partial standardization of national regulations and their harmonization with local governments. Efforts are currently underway through the FMA to implement codes of good practice in all municipalities.
- Continuity of service to end users. One of the causes of termination of sharing agreements is non-payment, so continuity of service is not guaranteed.

5.3.2. Brazil

Brazil has enacted a law and corresponding regulations to regulate the deployment and sharing of infrastructures: Law 13.116[50] (2015) and Resolution 683-2017.[51] Both instruments specify that the passive infrastructure provider is the natural or legal person that provides support or supporting infrastructure. Launching operations do not require any formal process; however, for the installation of facilities, the granting of a license is required through a simplified process (Article 7, Law 13.116).

The regulation aims to optimize the deployment of sites to avoid duplication (Article 3, Resolution 683). In addition, the passive infrastructure provider can gain access to aerial and ground infrastructure supporting networks for service delivery, 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, municipalities and the Federal District are prohibited from imposing conditions that may affect the selection of technology, the topology of the networks and the quality of the services provided. Therefore, while each municipality has the competence to issue its own ordinance, the rules should be in accordance with the federal law.

In addition, the same national legislation establishes general guidelines for sharing, co-location, camouflage, minimum distance and land use fees (Article 12, Law 13.116). The so-called "Antenna Law" aims to achieve national harmonization in terms of deployment. However, there are still municipalities that issue their own ordinances that the central administration intends to standardize. In addition, it is worth noting that the Shared

[50] https://bit.ly/3BnFHWA
[51] https://bit.ly/3OIjjdt

Infrastructure Operating Manual[52] was issued in 2019 for general guidance.

It is important to note that the Chamber of Deputies voted in October 2022 in favor of "positive administrative silence" for the installation of antennas and the granting of temporary licenses when the competent authorities do not respond to the requests within the stipulated period of 60 days.[53]

The strengths of the Brazilian regulatory framework are:

- Standardization, simplification and agility of licensing procedures and criteria, as well as minimizing urban or environmental impact.
- It incentivizes network deployment and capacity expansion. Article 15 of Decree 10480 exempts small cells (active equipment) from the granting of licenses or authorizations. In addition, articles 134, paragraph 4, and 135 of Law 13097 eliminate the fee for this type of equipment.
- The process of deploying passive infrastructure is agile and low cost.

Areas where improvements could be made involve three aspects:

- Although positive administrative silence is set at 60 days, it can represent an extended period in the facility approval process that could delay or accrue deployment approval.
- Some municipalities and states continue to issue licenses and ordinances of their own.
- Absence of regulation of minimum distances, which was eliminated in Law 11934 of 2009 (article 10), is a problem.

5.3.3. Chile

In Chile, a specific law was enacted for the deployment of passive infrastructures, called the "Tower Law" (Law 20.559).[54] In addition, Decree 99[55] defines a passive infrastructure provider as a concessionaire of infrastructure or intermediate services. Passive infrastructure providers are required to obtain a concession from the regulatory authority, SUBTEL. All operators that obtain this permit have the right to apply for the deployment of tower structures in the respective municipalities.

The Tower Law establishes three important rules: (i) definition of the minimum distances between base stations, (ii) general and area-specific requirements (urban and rural) for site authorization and (iii) guidelines for the deployment of towers to be followed by municipal works departments.

[52] https://bit.ly/2xRMO7T
[53] https://www.gsma.com/latinamerica/es/despliegue-infraestructura-brasil/
[54] https://bit.ly/3voKQd3
[55] https://bit.ly/3AuCN1y

With regard to the issuance of guidelines for the construction of infrastructure, Chile presents a harmonized framework between national and local regulations, as Law 20.599 establishes the procedures and guidelines for their installation. However, building permits related to aspects such as camouflage, height or land use rates are issued by each municipality. In addition, it is worth mentioning that the General Law of Urbanism and Construction[56] establishes a guide to address these requirements.

Finally, the Chilean Congress approved internet access as a public service. In the law denominated "Access to internet as a public service of telecommunications," the obtaining of authorizations for the deployment of infrastructure was ratified. Although the law establishes optimization and efficiency in deployment, it is determined that only operators will be able to access authorization for the construction of new sites. This could limit the previously established capacity of the infrastructure provider due to not being a direct provider of services.

The strengths of the Chilean regulatory framework are:

- It contains detailed rules on the procedures to be followed in approving the deployment of passive infrastructure.
- It addresses issues related to security risks. It even establishes a sanctioning framework related to electromagnetic radiation.
- Exempt Resolution 471 of 2007[57] establishes general guidelines for the installation of low-power stations (small cells).
- The new internet access as a public service law establishes the determination of required sharing conditions in order to improve expansion and competition and eliminate entry barriers.

Its main weaknesses are:

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

5.3.4. Colombia

The development of information technology infrastructures is generally established in Law 1753 (Article 193).[58] Recently, resolution 7120 of 2023[59] was issued, which creates the

[56] https://bit.ly/3PHfdU9
[57] https://bit.ly/3ApOaYp
[58] https://www.funcionpublica.gov.co/eva/gestornormativo/norma.php?i=61933
[59] https://bit.ly/3UJAgdK

figure of Infrastructure Provider and establishes tariff caps for sharing of different structures (for towers it is $133,009 pesos per month). This resolution includes an amendment to Resolution 5890 of 2020 (Infrastructure Sharing). 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.[60]

With regard to the issuance of guidelines for the implementation of infrastructure, Colombia presents a partial harmonization between national and local regulations, given that even its constitution grants autonomy to municipalities for the management and administration of land use. However, there is a great deal of effort in the deployment of infrastructure through the Good Practice Policy.[61] Thus, at the request of each mayor's office, the CRC (Comisión de Regulación de Comunicaciones) advises on the construction of ordinances with concepts that promote deployment[62] and seeks to eliminate barriers to the development of structures through an incentive procedure for the eligibility of projects that have to do with the obligations to be done in their localities.

Although important advances are reported, the modification of Resolution 5050 of 2016, through resolution 7285 of January 23, 2024,[63] establishes an additional volume of regulatory management for operators with a dominant position. These operators would have to publish and detail basic offers for sharing excess infrastructure on their own sites or where they have control or rights. This aspect could force infrastructure operators to share infrastructure where a possible dominant operator that does not own the physical site is renting it.

The main strengths of Colombia's regulations are as follows:

- The passive infrastructure provider is not required to obtain a specific permit.
- Development of infrastructures is promoted through plans and a code of good practices to be applied in municipalities.

The weak point of the regulatory framework relies on the timing for approval of permits for tower deployment, which can last up to 30 days. This delay adds to the lack of a framework that specifies the technical details to be defined by each municipality.

5.3.5. Costa Rica

Law 10216 "Infrastructure Deployment Law,"[64] which encourages and promotes the construction of telecommunications infrastructure, was enacted in June 2022. However, the bill establishes only the relationship between the passive infrastructure provider (PIP) and service operators. In addition, the activities of PIPs are described in relation to the

[60] https://bit.ly/3cSkhqc
[61] https://bit.ly/3BmM6RW
[62] https://bit.ly/3S8kZjw
[63] CRC, https://www.crcom.gov.co/sites/default/files/normatividad/00007285.pdf
[64] https://www.crhoy.com/wp-content/uploads/2022/07/ley-10216.pdf

application in each municipality for a permit for construction of infrastructure. However, Law 10216 establishes that the deployment permits by municipalities must be accorded within a period of four months.

Regarding the issuance of guidelines for the deployment of infrastructure, Costa Rica recently updated its Construction Regulations,[65] which determines that land use certification is not required for the installation of antennas to support existing telecommunications networks. This is significant progress in the harmonization of national and local regulations, and it complements efforts by the Metropolitan Federation of Municipalities, which developed general guidelines for the location of infrastructure within certain localities through the General Regulation of Municipal Telecommunications Licenses.[66]

On the other hand, Resolution RJD-222-2017[67] regulates the shared use of infrastructure for the support of public telecommunications networks and covers external networks, pipes, conduits, poles, towers, stations and other facilities necessary for the installation and operation of public telecommunications networks, as well as the provision of services available to the public and co-location of teams.

It is noteworthy that an additional regulation to Law 10216 was issued to encourage and promote the construction of telecommunications infrastructure. While this is an improvement in terms of promotion of a single central national regime to deploy infrastructure, the rules for minimum distances between towers are eliminated.

The strengths of Costa Rican tower regulatory framework are:

- The push for immediate authorization to operate as an infrastructure provider.
- It establishes single general guidelines for the operation of aerial, physical and underground infrastructures.
- It determines that failure to comply with the financial conditions is not considered a ground for termination of service contracts to guarantee continuity of service.
- It applies positive administrative silence to expedite permit requests submitted to municipalities.

The weaknesses of this regulatory framework are the following:

- Although the Infrastructure Deployment Law was recently approved, it is still in a transition period that does not allow for the standardization of processes for the construction of facilities in each municipality.
- There is no regulation regarding minimum distances between towers, which results in the proliferation of structures over short distances.

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[65] https://www.invu.go.cr/documents/20181/32857/Reglamento+de+Construcciones Articles 385 and 388.
[66] https://bit.ly/3uKSdvo
[67] https://bit.ly/3cboN2L

- Approval of the license for the construction of each infrastructure can take up to 30 days, which delays deployment.

5.3.6. Ecuador

A technical regulatory framework for the provision of passive infrastructure in Ecuador was enacted in Resolution ARCOTEL- 2017-0806.[68] It defines the parties that provide access to the infrastructure as passive infrastructure providers (PIP). PIPs need to apply for registration with ARCOTEL, the national regulator, while municipalities have local rules regarding distances, camouflage (based on the infrastructure camouflage policy issued by the Ministerial Agreement 013-2019)[69] and land occupation rates (as formalized in ordinances defined in Agreement 041-2015[70]).

With regard to the enactment of guidelines for the deployment of infrastructure, Ecuador exhibits partial harmonization between national and local regulations, given that specific policies exist for issues such as tower mimicry. Other general guidelines contemplate limits for the rates of use of public infrastructure or tariff ranges for leasing towers ($1327-$2040), monopoles ($1165-$1703) or masts ($667-$753) (Ministerial Agreement 006-2018[71]).

The main strengths of the tower regulatory framework in Ecuador are:

- Recommendations exist that guide the formulation of municipal ordinances with respect to specific tower deployment rules.
- There are mandatory permits for the deployment of infrastructure, which ensures the formal acceptance of the tower deployment by the local population.

Its weaknesses include:

- While they are only mentioned in the policy in a general way, there are no general rules for mimicry, minimum distances or co-location.
- A lack of procedural, administrative and fiscal impositions for the deployment of infrastructures in each municipality.
- The existence of tariff bands for infrastructure leasing that have to be updated periodically.

5.3.7. El Salvador

The only legal tool to regulate the deployment of telecommunications infrastructure in El

[68] https://bit.ly/3AmJd37
[69] https://bit.ly/3NWJv3S
[70] https://bit.ly/3TzTBvl
[71] https://bit.ly/3Aoq7cG

Salvador is the Telecommunications Law (Decree 142)[72] and its amendment.[73] Both instruments establish physical co-location, promoting sharing and leasing of physical structures of telecommunication operators. However, they do not stipulate a specific figure for players that do not have a concession to offer telecommunications services. In this context, the operator that owns towers is not required to obtain licenses or permits from the national authority. That said, a municipality may establish operator licenses or building permits.

With regard to the issuance of guidelines for the deployment of networks, El Salvador national and local standards are not harmonized. Technical and administrative processes are left to municipal authorities, which may have several different and non-standardized provisions for authorizing tower deployment.

There are efforts to promote standardized deployment in the 14 municipalities that make up the metropolitan area of the Department of San Salvador, through the Council of the Metropolitan Area of San Salvador. Based on this planning, a standard regulation was created that can be replicated in the different municipalities for the installation of antennas in the area (i.e., the regulatory ordinance for the installation of antennas or telecommunications towers[74] in the Municipality of Mexicanos[75]).

The main weaknesses of the Salvadorean regulatory framework are:

- A lack of harmonization among municipalities: each municipality controls and supervises the construction of towers.
- While the Telecommunications Law formulates a framework for competition, it does not specify the regulation for the construction of tower infrastructure.

5.3.8. Guatemala

There are no specific regulations to promote the deployment of telecommunications infrastructure in Guatemala. The only existing regulatory tool is the Telecommunications Law (Decree 94-96 of the Congress of the Republic of Guatemala[76] and its amendments), which establishes the mandatory placement of equipment for main telecommunications services providers. It does not provide a specific denomination for providers that lease physical infrastructure. Passive infrastructure operators are not required to obtain licenses or permits from the national authority; however, each municipality may establish permits for the construction of infrastructure (e.g., the Municipality of Palín[77]).

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[72] https://bit.ly/3Jd0Ogl
[73] https://bit.ly/3bglTK8
[74] In Spanish, Norma Técnica para la Provisión de Infraestructura Física a ser usada por prestadores de servicios del régimen general de telecomunicaciones en sus redes públicas de telecomunicaciones"
[75] https://bit.ly/3zk340H
[76] file:///Users/raulkatz/Downloads/Decreto%2094-96%20Ley%20General%20de%20Telecomunicaciones%20(2).pdf
[77] https://bit.ly/3JhX4Kd

National and local regulations for deploying network infrastructure in Guatemala are not harmonized. Technical or administrative procedures are left to municipal authorities. Therefore, the main weaknesses of the regulatory framework include:

- Lack of information to standardize or have references to codes of good practice for the installation of tower infrastructure.
- No adequate delimitation of protected areas, so permits for the construction of towers in areas of interest to operators may be refused.
- Discretionary processes for the granting of permits or authorizations for camouflage.

5.3.9. Honduras

The regulation attached to the Honduran Framework Law of the Telecommunications Sector (Agreement 141-2002 of the Secretary of State in the Office of the Interior and Justice[78]) defines in its article 13 the role of private telecommunications infrastructure. The construction or installation of telecommunications infrastructure will require written authorization from CONATEL, the telecommunications regulator, as stipulated in article 47A of the law. Access to mandatory shared infrastructure, as established in article 186, is only conceived as an instrument to increase competition.

It is important to note that telecommunications service operators in Honduras are obliged to carry out open architecture designs that allow the application of the principle of an integrated service network (article 192). In that sense, they must allow physical or virtual co-location of their network equipment.

In 2022, the Honduran government issued the Regulations for Access and Shared Use of Networks[79] with the aim of promoting the deployment of infrastructure that encourages construction, joint operation or sharing agreements. These regulations highlight aspects such as: (i) environmental responsibility for the supplier, (ii) neutrality and competition, (iii) transparency in access and non-discrimination, (iv) application process and access to infrastructure, (v) application of obligations to operators with market power and (vi) encouraging municipal governments to use public infrastructure for the implementation of networks and respect the principles that encourage deployment.

The main strengths of Honduran regulations are as follows:

- The regulatory structure encourages infrastructure sharing and agreement between parties.
- They promote the use of public infrastructure for network deployment.

The main weakness is that they do not mention anything about the rights of municipalities to issue construction, land use or tariff regulations. That is to say, there is no harmonization between national and local standards.

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[78] https://shorturl.at/rtBDG
[79] https://shorturl.at/ginpI

5.3.10. Nicaragua

To promote the deployment of tower infrastructure, Nicaragua enacted the Law on Construction of Structures (Law 843 – 2013)[80] and its regulations (Executive Decree 15-2014[81]). The type of certificate that the physical infrastructure provider (PIP) must obtain is a registration, for which it must pay a one-time fee of US$3000 for access to the single window for approval and for the registration as a tower operator (see Administrative Agreement 03-98[82]). The law and regulations for the construction of tower structures define very detailed procedures in aspects such as management, approval, control and sanction for the deployment of infrastructure.

Regarding the issuance of guidelines for the deployment of networks, national and local regulations in Nicaragua are partially harmonized as the national regulatory rules serve as the basis for the development of specific ordinances that municipalities develop for the use of physical space.

The strengths of the Nicaraguan tower regulatory framework are:

- Establishment of authorization procedures through a digital one-stop shop.
- Unification and simplification of procedures.
- Detailed regulations for infrastructure deployment permits.

The main weaknesses are:

- Sanctioning procedure with high fines compared to other Latin American countries.
- Fees for spectrum use and charges that may pose obstacles to deploying the network or applying for permits to build towers.

5.3.11. Peru

Peru's Law 29022[83] and its amendments, as well as the Supreme Decree 024-2014-MTC,[84] define the role of passive infrastructure provider (PIP). A PIP can launch activities without requiring a license to operate. However, passive infrastructure providers require registration and building permits issued by each district for the towers that will be deployed. Negative administrative silence rules allow the fast deployment of towers.

With regard to the issuance of guidelines, national and local tower rules in Peru are harmonized. Deployment approval processes are concentrated within the Directorate of Regulation and Policies of the Ministry of Transport and Communications (MTC). In

[80] https://bit.ly/3BrwrR9
[81] https://bit.ly/3OLgSqK
[82] https://bit.ly/3zFr0Nq
[83] https://bit.ly/3zkscUP
[84] https://bit.ly/3IkJl4U

addition, the general technical, management and control guidelines are established through the Regulations for the Strengthening of the Expansion of Infrastructure (Supreme Decree 003-2015[85]).

In February 2024, the Supreme Decree No. 005-2024-MTC[86] was issued to regulate the sharing of active infrastructure with Radio Spectrum, which is intended to quickly expand the offer of public mobile telecommunications services in uncovered and low-density areas. In terms of service deployment, this encourages the efficient use of infrastructure in places without coverage and promotes competition in places where there is a high population density. Along these lines, Law No. 31809, Law for the Promotion of a Connected Peru,[87] encourages the streamlining of procedures related to tower infrastructure construction permits through the creation of the digital single window as the only channel for processing permits for the deployment of telecommunications infrastructure.

The main strengths of the Peruvian tower regulatory framework are:

- The procedures for registration are very simple and ruled through positive administrative silence.
- There is a general standard with guidelines for national application of permits.
- Infrastructure certification procedures are concentrated within a single MTC entity (the Directorate of Policy and Regulation).
- Municipalities are exclusively responsible for the control of civil construction, while the MTC provides the guarantee for the registration of the infrastructure.

Weaknesses are related to the process of automatic registration for the deployment of infrastructure, which has resulted in problems as applications for tower deployment are occasionally not properly socialized with the population.

5.3.12. Panama

Panama's Resolution AN 2848-Telco[88] and its annex[89] regulates the installation, operation and sharing of towers and/or structures that support telecommunications antennas and expansion of infrastructure. The concept of passive infrastructure provider is defined as the "installer" and the lessor of tower space for infrastructure sharing. While the passive infrastructure provider does not require an operating permit, its infrastructure must be registered with the National Public Services Authority (ASEP). Installers are required to obtain construction permits for the structure, issued by municipal authorities, and they are required to complete land use requirements, submit plans and designs, and obtain authorizations from the Civil Aeronautics Authority and approvals issued by ASEP and the Fire Department Safety Office.

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[85] https://bit.ly/3OLl6hQ
[86] https://www.gob.pe/institucion/mtc/normas-legales/5187213-005-2024-mtc
[87] https://leyes.congreso.gob.pe/Documentos/2021_2026/ADLP/Texto_Consolidado/31809-TXM.pdf
[88] https://bit.ly/3PG7W7c
[89] https://bit.ly/3JuyCpr

Panamanian national and local regulations are well harmonized. Regulation 2848-Telco (Articles 7, 8 and 9), which regulates tower deployment, also issues comprehensive guidelines for the operation of radiant equipment, infrastructure sharing and electromagnetic radiation. The requirements for obtaining permits from the telecommunications authority are clearly stated, and coordination with municipalities on structural construction permits is also defined in the process.

The regulatory framework governing tower deployment and operations exhibit strengths in terms of simplification, standardization, uniformity and coordination among local and national authorities. In addition, sharing is ruled by a framework outlining coordination between wireless service providers and tower installers. Along the same lines, efforts are being made to generate infrastructure sharing regulations for 5G deployment. That being said, the installation of radio equipment in Panama has proliferated on advertising boards, driving duplicity and preventing the application of the law regarding minimum distance rules.

The strengths of Panama's regulatory framework are:

- It presents good harmonization between national and local standards because the regulations provide guidelines on the operation of radiant equipment, infrastructure sharing and electromagnetic radiation.
- There is precision and agility in the licensing processes, and there is good coordination with the municipalities for the issuance of construction standards.

Areas where improvements could be made involve two aspects:

- Updating standards to promote the deployment of 5G infrastructure.
- Regulatory review on minimum distances and use of public space to prevent over-deployment on advertising billboards.

5.4. Summary of current regulation and public policies in Latin America

Among the specific parameters that were investigated regarding the laws and regulations of tower deployment in Latin American countries, the following characteristics were noted:

- 83% of countries include the concept of passive infrastructure provider in their regulations, even if they do not have a specific law on the subject.
- 75% of countries have specific rules (laws, regulations or technical standards) on the deployment of passive infrastructure.
- 25% of countries stipulate that some form of registration or concession application is required to obtain a passive operator license from the telecommunications regulator.
- Only 17% of countries can be considered to have national standards that are highly aligned with local ordinances. On the one hand, there are general laws that establish

the technical mechanisms of deployment (i.e., distance, height, sharing, co-location) and, on the other hand, municipal ordinances regulate civil construction of the building (i.e., building permits, soil charges, landscape environment).

- 33% of countries have procedures for the operation of the passive infrastructure operator or the deployment of its infrastructure that are based on few formal rules.
- 67% of countries have not established parameters or reference tables that determine rates for the consideration of space use or land use for the implementation of infrastructure.
- In all countries, infrastructure lease prices are preferably established between the parties; however, 33% of countries partially determine some type of bands or ranges within which trading should be governed.
- 25% of countries have plans focused on developing infrastructure for new technologies such as 5G. In addition, 33% establish some specific mention or regulation on the deployment of microcells (low-power stations) or street facilities.
- 25% of countries have future plans already defined or in place for regulating the passive infrastructure provider. The same percentage of countries have models of good practices that complement general laws for the deployment of infrastructure or attempt to guide the orderly development of infrastructure in the absence of laws.
- Between 2022 and 2023, progress occurred in four ways: (i) creation of the passive infrastructure provision concept (Colombia), (ii) contributions to the harmonization of laws of the sector and the deployment regulations in municipalities (Brazil, Costa Rica), (iii) regulatory simplification and streamlining of procedures (Argentina, Peru) and (iv) future planning on regulation related to sharing (Brazil, Panama).
- Important recommendations were made in two areas: (i) promotion and review of regulations related to sharing (El Salvador, Guatemala, Nicaragua, Panama, Honduras) and (ii) the avoidance of proliferation and analysis of minimum distances for the deployment of infrastructure (Costa Rica, Panama).

Table 5-5 summarizes these characteristics by country.

Table 5-5. Regulatory characteristics for the deployment of passive infrastructures

Dimension / Country	CRI	ECU	COL	PER	PAN	CHI	SLV	ARG	BRA	NIC	GTM	HON
Passive infrastructure regulation	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes
Specific regulation for tower industry	Yes	Yes	Partially	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes
No need for concession of tower operators	Yes	No	Yes	Partially	Yes	No	Yes	Partially	Yes	Yes	Yes	No
Nationally harmonized deployment	Partially	Partially	Partially	Partially	Partially	Yes	No	Partially	Yes	Partially	No	Partially
Need for fast permit approvals	Yes	Partially	Partially	Yes	Yes	No	No	Yes	Partially	No	No	Partially
Establishment of caps on fees and taxes	Yes	Partially	No	Partially	No	Yes	No	No	Partially	Partially	No	No
No need for contract price regulation	Partially	Partially	Partially	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Partially
Policies to promote deployment of 5G	Partially	No	Yes	Partially	Partially	Yes	No	Partially	Yes	No	Partially	No
Future infrastructure sharing plans	No	No	Yes	Yes	Partially	Yes	Partially	No	Partially	No	No	No
Sharing best practice manuals	Partially	Partially	Yes	No	No	Yes	Partially	Yes	Yes	Partially	No	No
OVERALL REGULATORY LEVEL	Partially	Partially	Partially	Partially	Partially	Yes	No	Partially	Yes	Partially	No	No

Yes · No · Partially

Source: Telecom Advisory Services

6. A LOOK AHEAD AT THE LATIN AMERICAN TOWER INDUSTRY

Beyond the ongoing support of deployment of wireless infrastructure, the future business of tower companies in Latin America will involve a migration from a pure passive infrastructure "specialist" to a vertically integrated value-added supplier, provided institutions and regulation allow and incentivize them to go through this profound transformation. Now that the expansion of wireless telecommunications in Latin America is very advanced, a significant share of market development opportunities is dependent on building collaboration opportunities with independent tower companies. There is an opportunity for towercos to become more agile, more data-driven and more focused on new revenue flows (Schicht et al., 2020). Towercos should move away from being "grass and steel" financial partners (Casahuga et al., 2022) toward more business diversification as they expand in new areas of the digital ecosystem. Regulatory framework can incentivize this digital and corporate transformation and help enrich the digital ecosystem with an impact not only on the telecommunications industry but also on the country's economy and its citizens. Business opportunities are evident both in the traditional tower company space — going smarter — and in the addition of new telecommunication services and new types of digital businesses.

6.1. Smarter traditional tower companies

First, funded on the economics and financials built in this report, towercos can go deeper into optimizing some of their services by sharing them with the different tenants, such as telecommunication operators. When allowed and fostered by regulation, the resultant cost savings can be directed at improving and modernizing infrastructure, making it more eco-friendly beyond the sustainable approaches of power-as-a-service or investing in digital transformation inside and outside the companies. This diversification can contribute to telecommunication wireless services with opportunities for improving quality, affordability and sustainability.

Second, there are significant potential gains from digitizing the core, implementing real-time smart data systems in installed infrastructure and moving away from passive-only infrastructure provision. This allows the gathering of real-time, precise state evaluation of infrastructures (e.g., degree of corrosion, energy consumption, tenants' ratio, financials per site) and their environments, from climate conditions to identifying competitors (Cane, 2022; Schicht et al., 2020). The starting point is challenging, as a 2020 survey by TowerXchange and Analysys Mason showed: 28% of towercos are still using basic processing tools rather than state-of-the-art data management platforms as their unique service platforms and less than half had embarked on a data strategy of any form.

6.2. New opportunities in IoT and smart cities

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

6.2.1. New telecommunications services, 5G and beyond

Towercos can take an active role in network densification for 5G instead of simply adapting to its deployment. As reviewed in chapter 2, 5G connectivity requires macro towers as well as small cells, with massive site numbers and backhaul provisioning. This 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 rollout that will characterize most of 5G infrastructure expansion. Investing in small-cell backhaul could be riskier in terms of call handling, although initial results in the U.S. and Europe appear promising (Wilson, 2016). Operators that do not already have dense fiber infrastructure need to build stronger and frequent relationships with towercos to facilitate deployment of appropriate backhaul infrastructure as 5G rollouts begin.

Towercos should also develop business lines as partners to industries involved in 5G private networks, which should start deployment earlier than the massive retail 5G service. Autonomous networks can address various needs of different industries or even local governments supported by 4G and 5G capabilities and integrate them into national networks from manufacturing (e.g., automobile), energy and mining, and ports and transportation. This will enable more reliable and high-performance industry 4.0 solutions for different sectors.

6.2.2. New digital services

New open standards and cloud-based developments are making it easier to disaggregate network hardware and software components. These open 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).

While the revenue opportunity for towercos from the Internet of Things and smart-city segments could be lower than for the small-cells segment, the CAPEX involved is also low. However, the upside of these services is likely higher than one might expect, given the variety of new services that can be supported, from imaging and logistics to asset-heavy sectors (energy) complementing drones, data intelligence and smart cities (e.g., weather, traffic, energy as a service). More generally, towercos' business scope could be enlarged by entering into edge computing businesses, enabled by the regional and local footprints of installed infrastructure and services already offered today (Cane, 2022; Wilson 2016).

6.2.3. Forward-looking regulation to favor a diversified value-added tower sector

Some relevant conditions need to be fulfilled in this towerco transformation for increased capabilities and better technology, processes and labor organization.

The envisioned diversification faces regulatory and strategic challenges. First, any new business opportunities both in the telecommunication sector and in other digital services should be pursued in a way that protects towercos' relationships with their current main clients, the carriers. Second, as their core business does not require licenses or all the associated regulatory burden, policymakers and regulators should support this diversification 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 continent and in many urban areas 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 for retail 5G services, private networks are starting to be developed across the region; once started, 5G takeoff will be fast. Therefore, planning it in advance will have significant benefits.

Regulators should foster light-touch regulation, even experimenting before regulating in controlled environments 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 ecosystem. In the absence of significant regulatory reforms to deal with new business models and technologies in 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 simple authorization regimes, replacing burdensome and slow processes, minimum and reasonable reporting obligations, 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 from towercos; for example, in investing in equipment, implementing new digital processes and training the workforce. Easing regulatory impositions that are not core and offering training resources are potential approaches that could facilitate the process of digital transformation of towercos.

CONCLUSIONS

A vibrant independent tower industry is a pillar for a Latin America 4.0, enabling it to be more productive, more inclusive and more sustainable, socially and environmentally.

This report has shown that the tower industry sector is going through profound changes in Latin America, revealing many opportunities for strategic partnerships. Due to the towerco sector's dynamism and also to the divestments from some traditional telecommunication operators, on average, half of the installed base is carried out by independent companies. There is a close interdependence between wireless service providers and passive infrastructure providers, not only as tenants of the latter, but as potential partners as additional services emerge from digital transformation. A particular area of mutual win-wins is infrastructure sharing, as tower companies secure a relatively stable monetization of their significant investments and operators can accumulate savings to reinvest in better-quality services or future ones, through research and development, for example.

Beyond this positive trend, this report quantitatively shows that the increasing importance of independent towercos is an asset for the digital economy and, in particular, for the wireless industry in Latin America. Using the methodology developed by the World Bank's IFC, we showed that from 2016 to 2023, countries in Latin American with a more dynamic independent towerco sector exhibited better wireless connectivity in terms of coverage, use, affordability and quality (download speed). At the same time, the wireless industry in these countries benefited from more competition and more investment, demonstrating once again the potential win-wins. More precisely, 4G coverage in these countries is higher compared to the rest of countries (98.5% of the population compared to 90.93%); wireless broadband is 50% faster in these countries compared to the rest (76 Mbps vs. 38 Mbps); capital expenditure is 43% higher in country leaders (US$35.8 per capita vs. US$20.34 per capita); and wireless broadband services account for one-third of the costs in terms of per capita income in the country leaders relative to the rest of the countries. Furthermore, country leaders exhibit higher broadband adoption than in the rest of the region (70.53% vs. 60.04%) and wireless competition is more intense in countries with a higher proportion of independent tower deployment (HHI wireless broadband = 3,195 vs. 4,088).

These correlational results are confirmed in our original econometric modeling, as independent towercos show a significantly higher impact on wireless broadband use, coverage, speed and affordability, favoring a more competitive telecommunications industry. A 10% increase in the number of independent towers leads to:

- An increase in 4G coverage levels of at least 0.96%.
- An increase in wireless broadband adoption levels of 0.51%.
- An increase in service quality levels (measured as mobile broadband download speed) of 2.05%.
- An increase in mobile market competition levels (measured as a decrease in the Herfindahl–Hirschman index that measures industry concentration — a lower index represents more intense competition) of 0.46%.

- An improvement in the level of mobile affordability (measured as a decrease in the price of the service relative to monthly GDP per capita) of 3.18%.

If there ever was a good time to make public policies right, it's now. This involves implementing a smart and flexible regulation of the independent tower sector — 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 telecommunications sector. A review of the research literature and interviews with regulators and policymakers led to the identification of seven types of initiatives that can contribute to the development and sustainability of an independent tower sector: (i) the absence of service concessions, (ii) the need for fast permit approvals, (iii) regulations to prevent over-deployment, (iv) the establishment of caps on fees, taxes and construction rights, (v) policies to promote infrastructure sharing for 5G deployment, (vi) the absence of price regulation of tower companies' contracts with service providers and (vii) long-term guarantees in regulations and permits.

The good news is that these policy and regulatory prescriptions have already been undertaken by some countries, which should be considered benchmarks for the development of the telecommunications and passive infrastructure sharing industries. South Korea, the United Kingdom and the United States have a lot to offer in terms of design and implementation, bolstered by specific laws that regulate the deployment of passive infrastructure:

- They do not require independent tower companies to register with the regulatory authorities to begin operations.
- They have enacted laws that are in harmony with local ordinances, simple procedures for construction permits and references to construction fees known to infrastructure operators.
- They do not have pricing regulations for shared infrastructure.
- They present information that promotes the deployment of networks for new technologies such as 5G and small cells.
- They 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 going through a deep transformation to render its core business more agile, digital and environmentally sustainable, and at the same time diversify both in telecommunications services and other businesses in support of digital developments. Regulators must accompany this process and encourage the emergence of an additional, forward-looking view.

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APPENDICES

A.1. List of interviews with regulators

Country	Interviews	Policymaking unit
Costa Rica	• Glenn Fallas, Director General de Calidad • Ivannia Morales, Asesora del Consejo • Juan Gabriel García, Dirección General de Mercados	Superintendencia de Telecomunicaciones
Peru	• 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, Subdirector de Telecomunicaciones	Superintendencia General de Electricidad y Telecomunicaciones
Panama	• Hildeman Rangel, Director Nacional de Telecomunicaciones	Autoridad Nacional de Servicios Públicos

A.2. Financial profitability model of the tower sector (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%

A.3. Econometric models

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

Table A.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:                                      Obs per group:
     Within  = 0.9030                                         min =         11
     Between = 0.1069                                         avg =       11.0
     Overall = 0.8338                                         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 A.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:                                      Obs per group:
     Within  = 0.9286                                         min =         11
     Between = 0.5841                                         avg =       11.0
     Overall = 0.7483                                         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 A.3.3. 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 A.3.4. 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 A.3.5. 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:
Within = 0.3530
Between = 1.0000
Overall = 0.5023

Obs per group:
min = 2
avg = 6.3
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 A.3.6. 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:
Within = 0.2034
Between = 0.0372
Overall = 0.0419

Obs per group:
min = 2
avg = 6.3
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 A.3.7. 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)
------------------------------------------------------------------------------
```

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