

Multilevel Governance and Infrastructure Sharing for Digital Sustainability in Latin America

Gobernanza multinivel y compartición de infraestructura para la sostenibilidad digital en América Latina

Gabriel-Sánchez-Suárez¹  

¹ UCON de Educación Superior. Ibagué, Colombia.

How to cite?

Sánchez-Suárez G. Multilevel Governance and Infrastructure Sharing for Digital Sustainability in Latin America. Ingeniería y Competitividad, 2026, 28(2) e-20815491

<https://doi.org/10.25100/iyv.v28i2.15491>

Received: 23/01/26

Reviewed: 27/05/26

Accepted: 08/07/26

Online: /15/07/26

Correspondence 

gabriel_suarez@cun.edu.co

Abstract

Objective: To analyze the causal interaction between regulatory fragmentation and infrastructure sharing as determinants of the effectiveness, speed, and sustainability of 4G/5G network deployment in Latin America.

Methodology: A sequential explanatory mixed-methods design (QUAN $\square$ QUAL) was employed through a comparative analysis of four national cases: Colombia, Brazil, Mexico, and Chile. Quantitative indicators of coverage, investment, and regulatory harmonization for the 2020–2024 period were integrated with qualitative data from documentary analysis.

Results: The quality of governmental coordination was the most important predictor of performance. Brazil and Chile, with formal coercive harmonization mechanisms, showed significantly higher 5G coverage and site density indicators. A regulatory paradox was confirmed: the legal authorization of active sharing (MORAN/MOCN) is insufficient without economic incentives or neutral actors capable of overcoming strategic distrust, as evidenced by the Mexican case. Furthermore, the emerging integration of environmental and social sustainability criteria acts as a positive moderator of legitimacy and operational efficiency.

Conclusions: An Adaptive Governance Model is proposed, based on coercive multilevel coordination, proactive incentives for infrastructure sharing, and sustainability as a core regulatory criterion, providing a roadmap to accelerate inclusive and resilient connectivity across the region.

Keywords: multilevel governance; infrastructure sharing; telecommunications regulation; digital sustainability; Latin America; 5G.

Resumen

Introducción: El despliegue sostenible de redes 4G/5G en América Latina enfrenta desafíos estructurales de gobernanza, especialmente la fragmentación regulatoria multinivel y la limitada adopción de modelos de compartición de infraestructura.

Objetivo: Analizar la interacción causal entre la fragmentación regulatoria y la compartición de infraestructura como determinantes de la eficacia, velocidad y sostenibilidad del despliegue de redes 4G/5G en América Latina.

Metodología: Se empleó un diseño de métodos mixtos explicativos secuenciales (QUAN $\square$ QUAL) mediante el análisis comparativo de cuatro casos nacionales: Colombia, Brasil, México y Chile. Se integraron indicadores cuantitativos de cobertura, inversión y armonización regulatoria para el periodo 2020-2024 con datos cualitativos provenientes del análisis documental.

Resultados: La calidad de la coordinación gubernamental fue el predictor más importante del desempeño. Brasil y Chile, con mecanismos formales de armonización coercitiva, mostraron indicadores de cobertura 5G y densidad de sitios significativamente superiores. Se confirmó una paradoja regulatoria: la habilitación legal de la compartición activa (MORAN/MOCN) resulta insuficiente sin incentivos económicos o actores neutrales que superen la desconfianza estratégica, como evidencia el caso mexicano. Además, la integración incipiente de criterios de sostenibilidad ambiental y social actúa como moderador positivo de la legitimidad y la eficiencia operativa.

Conclusiones: Se propone un Modelo de Gobernanza Adaptativa basado en coordinación multinivel coercitiva, incentivos proactivos para la compartición y sostenibilidad como criterio regulatorio central, como hoja de ruta para acelerar una conectividad inclusiva y resiliente en la región.

Palabras clave: gobernanza multinivel; compartición de infraestructura; regulación de telecomunicaciones; sostenibilidad digital; América Latina; 5G



Spanish version



Why was this study conducted?

To fill the critical research gap on how multilevel governance and infrastructure sharing models interact to determine the effectiveness, speed, and sustainability of 4G/5G deployment in Latin America. The study aimed to identify regulatory bottlenecks and propose an evidence-based Adaptive Governance Model capable of overcoming fragmentation, incentivising sharing, and integrating sustainability as a central pillar of public policy.

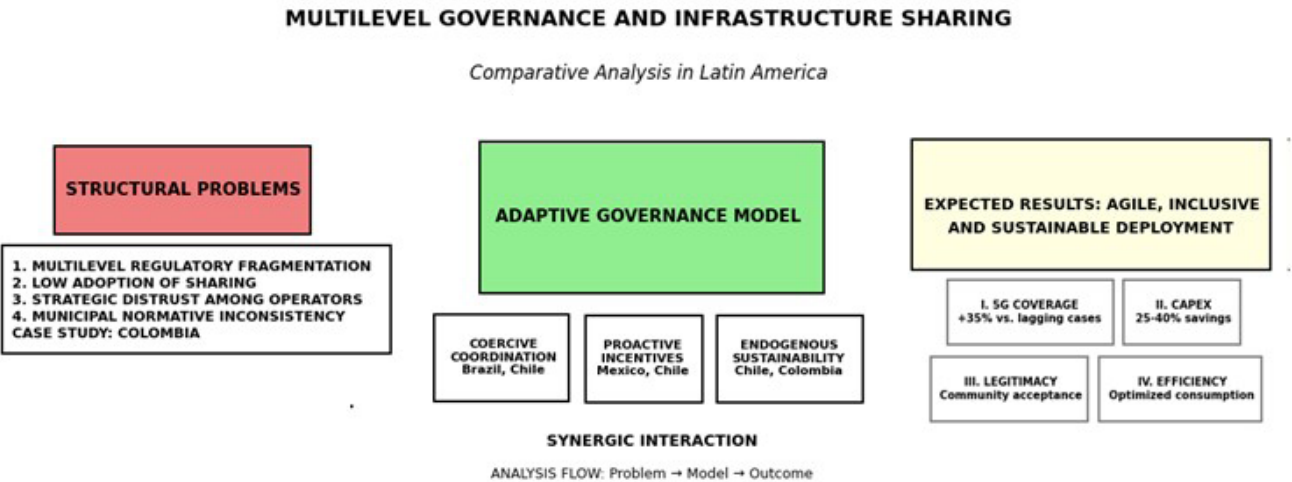
What were the most relevant findings?

The quality of intergovernmental coordination—particularly coercive regulatory harmonisation—is the strongest factor associated with deployment performance, with Brazil and Chile significantly outperforming fragmented Colombia. A regulatory paradox exists: legal enablement of active sharing (MORAN/MOCN) is insufficient without proactive incentives or neutral operators to overcome strategic distrust. (3) Early integration of environmental and social sustainability criteria correlates with greater social legitimacy and operational efficiency.

What do these findings contribute to?

They contribute a novel Adaptive Governance Model that integrates coercive multilevel coordination, incentive-driven sharing, and sustainability criteria. This framework provides a diagnostic and policy-design tool for emerging economies facing similar institutional fragmentation and digital divides. The findings also offer concrete recommendations for modernising telecommunications regulation in Latin America’s transition to 5G/6G, particularly on reducing CAPEX, extending rural coverage, and aligning digital development with climate and social commitments.

Graphical Abstract



Introduction

Wireless telecommunications infrastructure is a critical asset for economic development, social inclusion, and competitiveness in the 21st century. Technologies such as 5G and the Internet of Things (IoT) promise to transform productive sectors, improve public services, and catalyze innovation. Despite this vision, the efficient, equitable, and sustainable deployment of these networks depends not only on technological advances but also on robust governance frameworks and adaptive regulatory systems capable of managing the technical, economic, and social complexity inherent to these projects [\(2\)](#).

In Latin America, this challenge is aggravated by unique structural conditions, understood as institutional path dependency, rugged topography that raises the cost of physical deployment, and political centralism that delegates connectivity responsibilities to municipalities without sufficient technical or financial transfers [\(1\)](#). In this scenario, despite advances in mobile coverage, deep digital divides persist between urban and rural areas, as well as marked heterogeneity in state capacity to plan and execute connectivity policies. The literature has diagnosed recurrent problems, such as regulatory fragmentation [\(3\)](#), as recently documented in analyses of Colombia's digital transformation policies [\(22\)](#), which is not limited to a multiplicity of norms but rather to a vertical incoherence where national 5G goals collide with local land-use regulations designed for analog technologies, generating an administrative deadlock due to concurrent competences. To this are added bureaucratic permitting processes and limited integration of environmental and social sustainability criteria [\(3\)](#). In response, international organizations and the industry promote infrastructure sharing —active (Multi-Operator Radio Access Network, MORAN, and Multi-Operator Core Network, MOCN) and passive (towers, sites)— as a key mechanism to optimize resources, reduce capital expenditures (CAPEX), and accelerate expansion in low-profitability areas [\(1,4\)](#).

There is a critical research gap: the lack of comprehensive analyses on how multilevel governance (national-regional-local coordination) and sharing models interact [\(4\)](#). Previous studies have separately examined national regulatory frameworks [\(3\)](#) or the technical advantages of sharing [\(4\)](#), but they lack comparative perspectives that explain the “regulatory paradox” —a concept grounded here in the implementation gap described by authors such as Hooghe and Marks [\(12\)](#) and Bauer [\(15\)](#), which occurs when high-level (national) legal frameworks are formally enabling, but their effectiveness is neutralized by micro-regulatory disincentives and bureaucratic transaction costs at the local level. This omission limits the ability of policy-makers to systematically address bottlenecks, especially in development contexts where intergovernmental coordination mediates the effectiveness of sharing [\(5\)](#).

To close this gap, the study focuses on four countries in the region that represent maximum variation in the key dimensions of the phenomenon: Colombia (persistent regulatory fragmentation), Brazil (coercive harmonization and developed tower market), Mexico (top-down sharing mechanism with a neutral operator), and Chile (high technical efficiency and early integration of sustainability). The choice of these cases, justified in the Materials and Methods section, allows analytical generalization to build an explanatory model [\(11\)](#). Unlike previous studies that address sharing only from engineering [\(4\)](#) or national frameworks [\(3\)](#) in isolation, here the multilevel governance

dimension is integrated, whose mediating effect has been identified as critical in development contexts (5,12).

This article fills this gap by answering the question: What is the effect of the interaction between multilevel governance mechanisms and infrastructure sharing models on the effectiveness, speed, and sustainability of wireless network deployment in Latin America? To this end, a sequential explanatory mixed-methods design (QUAN → QUAL) (9) is adopted in a comparative multiple case study (Colombia, Brazil, Mexico, Chile) (11), triangulating quantitative indicators with qualitative policy analysis.

The main objective is to analyze the interaction between governance and sharing to identify patterns, enabling factors, and barriers. The specific objectives include: 1) To evaluate multilevel coordination and regulatory harmonization; 2) To measure the adoption and impact of sharing models; 3) To examine the integration of sustainability; and 4) To propose an adaptive governance model as a regional roadmap. The contributions are threefold: it integrates previously isolated dimensions (policy, engineering, sustainability); it offers empirical comparative evidence; and it provides inputs for modernizing regulations in the transition to next-generation networks.

Materials and methods

Research Design

This study is based on a mixed-methods design with unequal status (QUAN → QUAL) (9), with a comparative-interpretive scope. The first (quantitative) phase aims to characterize and compare performance patterns in infrastructure deployment and regulatory frameworks across a sample of countries in the region. The second (qualitative) phase seeks to delve into the dynamic policies and institutional mechanisms that explain the patterns observed in the initial phase. Under this scheme, the approach is primarily qualitative-comparative (11); quantitative data are used for contextualization, trend identification, and initial contrast, without any claim to statistical causal inference from them.

Case Selection and Criteria

The population for this study consists of Latin American countries that have formalized regulatory frameworks and active 4G and 5G network deployment processes. For sample selection, purposive maximum variation sampling (17) is applied, aiming to include a broad spectrum of institutional configurations and outcomes. Strict exclusion criteria were established, discarding countries with incipient regulatory frameworks, high instability in sectoral governance, or lack of transparency in official data reporting (e.g., Venezuela, Nicaragua). The selection criteria include, among others, the degree of multilevel regulatory harmonization—from centralized or harmonized models to fragmented systems—the variation in predominant infrastructure sharing models, both active (MORAN/MOCN) and passive, and the availability and accessibility of reliable quantitative and documentary data. Based on the above, four national cases are selected: Colombia, Brazil, Mexico, and Chile. This selection enables analytical generalization (11), aimed at constructing and refining

an explanatory model —adaptive governance— rather than statistical generalization. This sample is justified by representing the critical variability of the region: Brazil (harmonized model and 5G pioneer), Chile (high technical efficiency and competitiveness), Mexico (federal system with complex coordination challenges), and Colombia (scenario of persistent regulatory fragmentation and recent deployment processes).

Data Sources and Collection

Data collection is carried out from secondary and primary sources, structured to feed both phases of the study. The quantitative phase, based on secondary sources, employs a balanced country-year panel dataset for the period 2020-2024, generating 20 observations (4 countries × 5 years). Key indicators, obtained from databases and specialized reports, include 4G and 5G network coverage [\(1,6\)](#), mobile network investment per capita, cell site density, and a regulatory harmonization score constructed from the ITU ICT Regulatory Tracker (International Telecommunication Union, 2023). This tracker evaluates four pillars with equal weighting (25% each): (i) regulatory authority (independence and mandate), (ii) competition framework (market policies), (iii) access and interconnection framework, and (iv) market participation framework (licensing and spectrum). The original ITU score (0-100 scale) was rescaled to a 1-10 metric using min-max normalization to facilitate comparison with other indicators. In turn, the qualitative phase combines sources through documentary analysis covering national regulatory frameworks (laws, decrees, resolutions), public policy reports, sectoral studies, and relevant academic literature for each case. Likewise, coverage and investment data are complemented by recent academic analyses on 5G deployment in the region [\(18,19\)](#) and on the relationship between investment and coverage expansion [\(20\)](#).

Analysis Procedures

Data analysis follows the sequential logic of the design, integrating findings through triangulation.

Quantitative Analysis (Descriptive and Contextual): Descriptive statistics are used to characterize the performance of each country. To explore associations between key variables (e.g., regulatory harmonization and 5G coverage), Spearman's rank correlation coefficients (ρ) are calculated. As a consistency test, the results were contrasted with Pearson's coefficient, obtaining similar association patterns ($r = 0.82$; $p = 0.79$). Given the mixed-methods design and the small number of national units ($n=4$), these coefficients are interpreted exclusively as descriptive trends and contextual patterns that feed into the qualitative phase, without any claim to statistical causal inference.

Qualitative Analysis: This is carried out through thematic content analysis with hybrid coding (deductive-inductive), using Atlas.ti v.23 software, whose initial system of deductive categories is based on the theoretical dimensions of Vertical Governance, Economic Incentives, and Environmental Sustainability. Inductive categories (such as 'Municipal Discretion' and 'Administrative Litigiousness') emerged through the constant comparison method applied to the documentary corpus. To increase the reliability of the process, a test-retest technique was applied with double coding of 20% of the analyzed material at two different times separated by a four-week interval. Consistency between both codings was assessed using Cohen's Kappa coefficient, obtaining a value > 0.80 on the unit of analysis 'thematic segment'. This approach allows the identification of emerging categories, discursive patterns, and explanatory mechanisms linked to governance, sharing, and sustainability.

Integration and Triangulation: The qualitative phase was used to explain, nuance, and deepen the patterns identified in the quantitative phase, which was formalized through a results triangulation matrix, where statistical patterns were systematically contrasted with documentary evidence. Specifically, the associations or trends identified in the quantitative phase were deepened in the qualitative phase through the identification of institutional mechanisms and specific regulatory bottlenecks in each national case. Methodological triangulation between quantitative data and documentary analysis constitutes the basis for identifying valid mechanisms and robust associations that support the discussion and the proposed model.

Methodological Rigor and Transparency

To ensure the robustness of the analysis, strategies typical of secondary source research and case study are implemented. Methodological triangulation is achieved by contrasting the patterns observed in the quantitative data with the characteristics identified in the regulatory documentary analysis, supported by continuous and critical review in light of the specialized literature. To control interpretive bias, three safeguards were implemented: 1) investigator triangulation through cross-review of findings; 2) the use of a reflexivity journal to document coding decisions; and 3) theoretical saturation of emerging categories, ensuring that conclusions do not depend on isolated evidence but on recurrent and contrastable patterns across the four countries in the sample.

Scope and Inferential Limitations

This design allows generating acceptable causal explanations that are empirically grounded on the interaction between multilevel governance, sharing models, and deployment outcomes. Even so, it does not constitute a strict counterfactual design; therefore, claims about “mechanisms” or “mediations” are derived from the consistency and robustness of triangulated evidence, and are presented as explanatory contributions to theory and policy, which need to be validated in future studies with causal identification designs. The main limitation of the quantitative analysis lies in the small number of cases, so its results are understood as a contextual complement to the broader econometric evidence existing in the literature [\(2\)](#) and to the robust qualitative-comparative analysis developed here.

Results

Comparative Quantitative Analysis: Performance and Regulation Patterns (2020-2024)

The quantitative phase, which served as contextual input and for trend identification, revealed significant disparities in performance indicators across the four countries. A central descriptive finding was the strong positive association between the Regulatory Harmonization Index (ITU, 2023) and urban 5G coverage levels [\(6\)](#), with a Pearson correlation coefficient of $r = 0.82$ and a Spearman coefficient of $\rho = 0.79$ (calculated on 20 country-year observations). This initial pattern suggested a relationship that merited in-depth qualitative exploration. Table 1 summarizes the average values of key indicators for the analyzed period.

Table 1. Comparative infrastructure and regulation performance indicators (average 2020-2024)

Indicator	Colombia	Brasil	México	Chile	Main Source
4G Coverage (%)	91.2	94.8	88.5	97.1	(1)
5G Coverage (%urban pop.)	15.3	28.7	22.4	35.6	(6)
Mobile network investment per capita (USD)	16.5	22.1	18.3	20.8	GSMA
Site density (per 10,000 inhabitants)	3.8	5.2	4.1	4.9	ANATEL, IFT, SUBTEL, CRC
Regulatory Harmonization Index (ITU, 1-10)	5.1	7.8	6.9	7.2	ITU (2023)
Active sharing adoption (MORAN/MOCN)	Incipient (<10%)	Medium (30-40%)	High (>60%)	Medium (30-40%)	Sector Reports

Sources: (1,6,7)

The Regulatory Harmonization Index is constructed from the ITU ICT Regulatory Tracker (International Telecommunication Union, 2023), normalized and rescaled to a 1-10 metric. Sensitivity tests ($\pm 20\%$ in pillar weights) suggest consistency of the overall ranking patterns across countries. Furthermore, the values reported in Table 1 correspond to annual averages for the period 2020-2024; interannual variability is not shown for simplicity, but disaggregated data can be consulted in the original sources [\(1,6,7\)](#) and in the annexes of the cited national regulators.

The data allowed the identification of three main trends:

5G deployment gap: Chile and Brazil show the greatest progress in initial 5G coverage (35.6% and 28.7% of urban population, respectively), consistent with their higher levels of per capita investment and infrastructure density. Colombia shows the most modest progress (15.3%), lagging behind the group.

Disassociation between framework and adoption: An initial paradox is observed where the existence of a formally enabling regulatory framework (as in Colombia) does not translate into high adoption of active sharing models. Mexico, in contrast, presents the highest adoption rate (>60%) despite an intermediate harmonization index.

Heterogeneity in models: Brazil stands out for its higher investment and density, reflecting a competitive market and economies of scale. Mexico compensates for relatively lower 4G coverage with a distinctive sharing model. Chile combines high coverage performance with the highest harmonization index.

These quantitative patterns raise key questions about the related institutional mechanisms, addressed in the qualitative phase.

Qualitative Findings: Mechanisms and Emerging Dimensions from Documentary Analysis

The qualitative analysis, based on the review of regulatory frameworks and specialized literature, provides the contextual depth to explain the observed variations, identifying three central analytical dimensions derived from the contrast between the case studies that emerged from a hybrid coding process in which 'Governance' was deductive, while 'Local Adaptive Capacity' and 'Integrated Sustainability' emerged inductively by observing the recurrent patterns of success in Chile and Brazil that were not anticipated in the initial theoretical framework.

1. Multilevel governance: contrasting coordination architectures

Documentary analysis reveals a dichotomy in intergovernmental coordination models. On the one hand, countries such as Brazil and Chile have implemented coercive harmonization schemes, characterized by national laws that limit the ability of local governments to make autonomous decisions and establish their own definitive rules and deadlines. This approach has been documented in comparative infrastructure policy studies and correlates with greater predictability for investors (2,12). Colombia, for its part, exemplifies a fragmented coordination model, where municipal autonomy, despite the existence of a national framework, generates a regulatory mosaic, as documented in the literature (3).

2. Unpacking the regulatory paradox in infrastructure sharing

Sector reports and academic analyses document a regulatory paradox whereby the existence of enabling legal frameworks (MORAN/MOCN) does not guarantee their effective adoption (4). The contrast between cases is illustrative. In Mexico, adoption was driven by a top-down mechanism and the presence of a neutral wholesale operator, a strategy documented in sharing policy analyses (8). In contrast, in Colombia, what the literature describes as "strategic distrust" among operators prevails, where a gap between the legal framework and practice is observed, associated in sector analyses with the absence of proactive regulatory incentives (2,3). These findings align with previous analyses on the effects of mandatory sharing on telecommunications investment in the region (21).

3. Sustainability: an emerging pillar on the regulatory agenda

The analysis identifies sustainability as the least institutionalized dimension. On the environmental side, explicit energy efficiency guidelines are observed only in the regulation of one country that is a leader in the area, while in others they are isolated initiatives, as documented in studies on the environmental challenges of 5G networks [\(5,13\)](#). On the social dimension, an insufficient shift towards “shared value” models is identified, where telecommunications infrastructure incorporates community benefits. This approach is observed emergently in some cases, but not yet as a regional standard [\(5,16\)](#).

The above describes the documentary patterns observed in the regulatory frameworks and sectoral literature, whose interpretive analysis and contrast with theory are presented in the Discussion section.

Integrated Synthesis: Country Profiles and Explanatory Patterns

The triangulation of both phases allowed consolidating distinctive national profiles (Table 2) that explain how governance configurations interact with sharing models, moderated by the degree of sustainability integration. These profiles were derived through a simplified Qualitative Comparative Analysis (QCA), grouping countries according to the presence or absence of three conditions: legal harmonization, sharing incentives, and multilevel coordination mechanisms. Likewise, the 5G Performance levels in Table 2 were defined using the following thresholds: High (>40% urban coverage), Medium (15-40%), and Low (<15%), based on the regional deployment average reported by GSMA for 2024.

Table 2. Country profiles: governance, sharing, and performance configuration

Country Profile	Distinctive Governance Feature	Sharing Model	5G	Sustainability Integration
Governance and Sustainability Leader (Chile)	Centralized and rapid harmonization	Medium adoption (market incentives)	High (35.6)	High (explicit guidelines)
Market and Investment Leader (Brazil)	Strong harmonized framework (Antenna Law)	Medium adoption (towerco market)	High (28.7)	Medium (market-driven)
Shared Network Model (Mexico)	Top-down sharing mechanism	High adoption (mandatory/wholesale)	Medium (22.4)	Medium (local innovations)
Regulatory	Fragmented and inconsistent coordination	Incipient adoption (strategic distrust)	Low (15.3)	Low (incipient stages)

Sources: [\(1,6\)](#)

The synthesis confirms that coherent governance configurations (Brazil, Chile) generate associative forces with sharing, facilitating better overall performance. On the other hand, fragmentation (Colombia) decouples these elements, resulting in lagging indicators. Sustainability acts as a positive moderator, enhancing social legitimacy and efficiency in cases where it is integrated. These profiles provide the empirical basis for the adaptive governance model discussed below.

Discussion

Multilevel governance as a structural mediator: beyond national regulation

This study corroborates that the existence of a national regulatory framework is a necessary but not sufficient condition for efficient deployment [\(2\)](#). Countries with coercive harmonization mechanisms (Brazil, Chile) exhibit comparatively higher 5G coverage and site densities, whose leadership in early 5G deployment has been documented in recent academic literature [\(18\)](#), while those with regulatory fragmentation (Colombia) face legal uncertainty and administrative

bottlenecks (22). This evidence validates the recommendations of international organizations (OCDE) and advances by identifying specific causal mechanisms in the Latin American context. In contrast to previous studies focused on isolated national regulations (3), this analysis reveals that multilevel governance acts as a critical aligning factor that aligns—or misaligns— incentives across government levels. The legal limitation of municipal discretion and the creation of technical coordination bodies, as in Brazil with its Antenna Law, reduce transaction costs and uncertainty for investors, thereby extending the theoretical framework of multilevel governance (12) to the specific issue of telecommunications in emerging economies.

From legal enablement to effective adoption

The research exposes a fundamental regulatory paradox whereby formally enabling legal frameworks do not guarantee the adoption of infrastructure sharing models. The gap between norm and practice, exemplified by the Colombian case, is explained by political economy factors and market culture. “Strategic distrust” among operators, in the absence of concrete incentives, perpetuates solitary deployment models even in low-profitability areas. This qualifies the linear assumptions present in part of the technical literature (1), which often emphasizes operational advantages without considering behavioral and institutional barriers. Mexico and Brazil demonstrate that overcoming this paradox requires proactive and asymmetric regulatory interventions: the creation of a neutral wholesale operator (Red Compartida) or the promotion of a vigorous tower company market, accompanied by incentives such as priority spectrum access. Thus, sharing transcends its technical optimization dimension (4) to become a public policy tool oriented toward equity, closing rural gaps through CAPEX reduction.

Sustainability as a pillar of legitimacy and efficiency

Sustainability, still basic in its regulatory integration, emerges with transformative potential for social legitimacy and long-term operational efficiency. Chile’s leadership in energy efficiency standards and the “shared value” practices observed in Mexico and Brazil (e.g., community sensors, public WiFi) represent a paradigm shift. These practices go beyond treating sustainability as an externality, aligning with principles of energy justice (5) and extending debates on digital divides (1). In the cases of Mexico (shared value programs in rural areas) and Chile (energy efficiency guidelines), lower community conflict is observed in projects that incorporated these criteria early on, suggesting a positive association between sustainability and social legitimacy, consistent with the literature (5,16). However, the absence of homogeneous quantitative data across the four countries prevents establishing a statistical correlation. The current lack of mandatory standards in the region represents a missed opportunity, particularly critical given the higher energy consumption of 5G networks (13). Making sustainability a central pillar of regulation is therefore imperative for the resilience and legitimacy of the digital ecosystem.

Toward an adaptive governance model

The triangulation of findings allows synthesizing and proposing an Adaptive Governance Model for wireless infrastructure deployment in the context of emerging countries. This model posits

that ideal performance —characterized by agile deployment, inclusive coverage, and operational sustainability— is the result of synergy among three interconnected pillars. First, it requires coherent and coercive multilevel governance, capable of eliminating fragmentation and aligning incentives across different levels of government. Second, it depends on the creation of sharing ecosystems driven by proactive incentives and the participation of neutral actors, essential mechanisms to overcome strategic distrust among operators. Finally, it demands the integration of environmental and social sustainability criteria into the regulatory and project cycle, as a source of operational efficiency and social legitimacy.

Unlike multilevel governance models based on voluntary coordination and negotiation [\(12\)](#), this model incorporates a coercive component as an empirical response to fragmentation in Colombia, and adds sustainability as a central regulatory pillar, absent in previous frameworks [\(5,14\)](#).

When contrasting this model with the cases studied, it is observed that Chile and Brazil approach this ideal, showing strengths in the first two pillars. Mexico, for its part, compensates with exceptional strength in the sharing pillar, supported by a top-down mechanism. Colombia, in contrast, shows a structural decoupling among the three elements. Together, this theoretical proposal integrates dimensions traditionally analyzed separately —policy, engineering, and sustainability— offering a testable analytical framework to diagnose and redesign public policies in regions facing similar challenges.

The findings indicate that accelerating sustainable deployment in Latin America requires more than creating national laws. It requires eliminating multilevel fragmentation, actively incentivizing sharing, and making sustainability a guiding principle of regulation. These actions, addressed together, are fundamental to achieving social legitimacy and economic efficiency. The study provides comparative empirical evidence and an integrative model that serves as a guide for public policies capable of promoting an inclusive and resilient digital transformation in the region.

Conclusions

This study has shown, through a mixed-methods design applied to four Latin American countries, that the interaction between multilevel governance architecture and infrastructure sharing models is a fundamental determinant of the effectiveness, speed, and sustainability of wireless network deployment. The evidence points to the main bottleneck being not technical or financial in nature, but institutional.

Three key empirical findings emerge from the research:

The quality of intergovernmental coordination (regulatory harmonization) functions as the most consistently associated factor with performance. Those countries with coercive and centralized mechanisms (Brazil, Chile) achieve 5G coverage and infrastructure density metrics significantly higher than those with regulatory fragmentation (Colombia), consistent with the structural challenges identified in Colombia's digital transformation agenda [\(22\)](#).

The existence of a “regulatory paradox” is confirmed, whereby legal enablement of active sharing (MORAN/MOCN) is insufficient for its adoption, since it requires proactive incentives and the presence of neutral actors (such as the Red Compartida in Mexico) to overcome “strategic distrust” and become an engine of efficiency and inclusion.

Environmental and social sustainability, although still basic in regulatory frameworks, acts as a positive moderator. Its early integration —through energy efficiency or “shared value” models— increases social legitimacy and operational efficiency, aligning technological deployment with principles of energy justice.

The main theoretical contribution of this work is the proposal of an Adaptive Governance Model. This framework synergistically integrates three pillars that the literature often analyzes separately: (1) coercive multilevel coherence, (2) incentive-driven sharing, and (3) sustainability as an endogenous criterion (5,13,14). The model provides a conceptual framework with analytical potential to diagnose and redesign policies in emerging contexts, with potential application in other regions facing similar challenges of institutional fragmentation and digital divide.

Practical implications and policy recommendations

The findings offer concrete guidelines for modernizing sector regulation in Latin America during the transition to 5G/6G networks:

Strengthen multilevel coherence: It is imperative to adopt framework laws at the national level that establish fixed deadlines and limit the regulatory discretion of local governments, transforming municipalities from “bottlenecks” into facilitating partners, following the example of Brazil’s Antenna Law.

Incentivize active sharing through asymmetric mechanisms: Regulators could implement instruments that alter market logic, such as priority spectrum access for shared projects or the promotion of neutral infrastructure operators. This is key to reducing CAPEX and extending coverage to low-profitability areas.

Integrate sustainability as a central regulatory pillar: Regulation must evolve to include mandatory energy efficiency standards and early community participation protocols that offer “shared value” (e.g., infrastructure for public services). This could mitigate social opposition and align digital development with climate commitments.

Limitations and research prospects

Although the multiple-case design and methodological triangulation lend robustness to the conclusions, the study has limitations that delimit its scope and suggest future lines of research. First, the number of national units (n=4) precludes statistical generalizations; therefore, the reported correlations should be interpreted as descriptive trends that require validation with larger samples. Second, the cross-sectional nature of the qualitative data does not capture the dynamic

evolution of governance mechanisms. Future studies could employ panel analysis with an expanded sample of Latin American countries to more precisely quantify the causal impact of regulatory harmonization on sharing adoption. Longitudinal research is needed to track the trajectory of these mechanisms in the face of technological evolution (Open RAN, 6G) and new challenges such as cybersecurity, digital sovereignty, and the growing influence of global actors on regional infrastructure. Finally, the proposed Adaptive Governance Model should be tested and refined in additional contexts, including countries from other regions facing similar challenges of institutional fragmentation and digital divide.

Final reflection

This work shows that building sustainable wireless infrastructure in Latin America is essentially an institutional design challenge. The convergence of technical analysis, political economy, and governance studies reveals that bridging the digital divide requires far more than capital and technology: it demands political will to align incentives across all levels of government and to translate regulatory ambitions into tangible and equitable outcomes. Given its demographic and economic potential, the region has the opportunity to become a reference for resilient and inclusive connectivity. This study provides both the diagnosis and the conceptual tools necessary to undertake that transformation.

References

1. GSMA. The Mobile Economy Latin America 2024 (Internet). London: GSMA Intelligence; 2023. Available from: <https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-economy/wp-content/uploads/2024/06/The-Mobile-Economy-Latin-America-2024.pdf>
2. Jung J, Melguizo A. Rules, institutions, or both? Estimating the drivers of telecommunication investment in Latin America. *Journal of Cyber Policy*. 2022;7(1):5-23. <https://doi.org/10.1080/23738871.2022.2034910>
3. Sánchez-Suárez G, Sierra-Daza CA. Análisis comparativo de los marcos regulatorios para la implementación de infraestructura inalámbrica sostenible: estándares internacionales y el caso de Colombia. *Respuestas*. 2025;30(2):82-96. <https://doi.org/10.22463/0122820X.5134>
4. Cano L, Capone A, Sansò B. On the evolution of infrastructure sharing in mobile networks: A survey. *ITU J Future Evolving Technol*. 2020;1(1):1-18. Available from: https://www.itu.int/dms_pub/itu-s/opb/itu-jnl/S-ITUJNL-JFETF.V1I1-2020-P10-PDF-E.pdf
5. Williams L, Sovacool BK, Foxon TJ. The energy use implications of 5G: Reviewing whole network operational energy, embodied energy, and indirect effects. *Renew Sustain Energy Rev*. 2022;157:112033. <https://doi.org/10.1016/j.rser.2021.112033>
6. 5G Americas. Telecommunications Policy Reforms in Latin America <https://www.5gamericas.org/wp-content/uploads/2024/10/WP-Telecommunication-Policy-Reforms-in-Latin-America-ENG.pdf>
7. GSMA Intelligence. The Mobile Economy Latin America 2024 (Internet). London: GSMA Intelligence; 2024

<https://www.gsmaintelligence.com/research/the-mobile-economy-latin-america-2024>

8. International Telecommunication Union. Specification of 5G network sharing and co-construction adapting to climate change mitigation. ITU-T Recommendation L.1391; 2024. Available from:

https://www.itu.int/ITU-T/workprog/wp_item.aspx?isn=18387

9. Creswell JW, Plano Clark VL. Designing and conducting mixed methods research. 4th ed. Los Angeles: SAGE Publications; 2025. Available from:

<https://www.sagepub.com/shop/buy-a-book/designing-and-conducting-mixed-methods-research-4-269004>

10. Fetters MD, Curry LA, Creswell JW. Achieving integration in mixed methods designs: principles and practices. Health Serv Res. 2013;48(6 Pt 2):2134-2156.

<https://doi.org/10.1111/1475-6773.12117>

11. Yin RK. Case study research and applications: design and methods. 6th ed. Los Angeles: SAGE Publications; 2017. Available from:

<https://uk.sagepub.com/en-gb/eur/case-study-research-and-applications/book250150>

12. Hooghe L, Marks G, Schakel AH, et al. Measuring regional authority: a postfunctionalist theory of governance. Oxford: Oxford University Press; 2020. Available from:

<https://global.oup.com/academic/product/measuring-regional-authority-9780198728870>

13. Kora AD. Towards sustainable 5G networks: A proposed coordination solution for macro and pico cells to optimize energy efficiency. IEEE Access. 2023;11:50794-50804.

<https://doi.org/10.1109/ACCESS.2023.3278209>

14. International Telecommunication Union. Environmental key performance indicators for digital infrastructure adapting to climate change. ITU-T Recommendation L.1510; 2025. Available from:

<https://www.itu.int/rec/T-REC-L.1510>

15. Bauer JM, Bohlin E. Regulation and innovation in 5G markets. Telecomm Policy. 2022;46(4):102260.

<https://doi.org/10.1016/j.telpol.2021.102260>

16. Calzada I, Pérez-Batlle M, Batlle-Montserrat J. People-Centered Smart Cities: An exploratory action research on the Cities' Coalition for Digital Rights. J Urban Aff. 2023;45(9):1537-1562.

<https://doi.org/10.1080/07352166.2021.1994861>

17. Patton MQ. Qualitative research and evaluation methods: Integrating theory and practice. 4th ed. Thousand Oaks, CA: SAGE Publications; 2015. Available from:

<https://uk.sagepub.com/en-gb/eur/qualitative-research-evaluation-methods/book232962>

18. Hannig Núñez S. 5G networks in Latin America. In: Caught in a global geopolitical competition. London: Routledge; 2025. 211-230. <https://doi.org/10.4324/9781003489450-11>

19. Bornachera Zarate LS, Vargas González ID, Ardila Sánchez IA. The 5G race: is Colombia lagging behind in implementation and information security? Ing. Solidar. 2024;20(1):1-37.

<https://doi.org/10.16925/2357-6014.2024.01.08>

20. Jung J, Katz R. Exploring the heterogeneous link between broadband investment and coverage expansion using unconditional quantile regressions. Telecomm Policy. 2023;47(9):102623.

<https://doi.org/10.1016/j.telpol.2023.102623>

21. Jung J. Mandated sharing and telecom investment in Latin America and the Caribbean. *J Regul Econ*. 2019;56(1):85-103.

<https://doi.org/10.1007/s11149-019-09391-y>

22. Sánchez-Suárez G, Ríos-Bocanegra JC. Transformación digital como política de recuperación postpandemia: Lecciones internacionales y desafíos para Colombia. *Rev Virtual Univ Catol Norte*. 2026;78:379-407. Available from:

<https://revistavirtual.ucn.edu.co/index.php/RevistaUCN/article/view/1882>