The Impact of Digital Infrastructure on the Sustainable Development Goals

A Study for Selected Latin American and Caribbean Countries

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The GSMA represents the interests of mobile operators worldwide, uniting nearly 800 operators with more than 250 companies in the broader mobile ecosystem, including handset and device makers, software companies, equipment providers and Internet companies, as well as organisations in adjacent industry sectors. The GSMA also produces industry-leading events such as Mobile World Congress, Mobile World Congress Shanghai and the Mobile 360 Series conferences.

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Executive Summary

Scope and Introduction

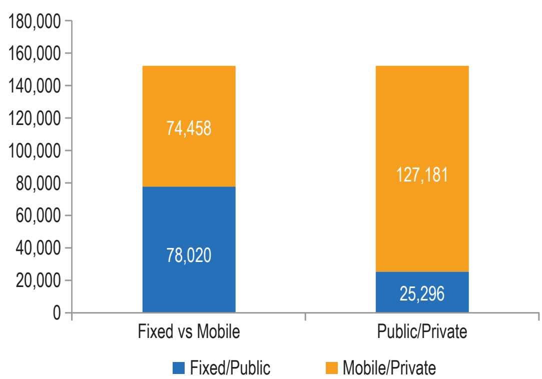
This study identifies the role of digital infrastructure in achieving the Sustainable Development Goals (SDGs) in 12 countries in the Latin American and Caribbean (LAC) region.[1] There is a gap between the outcomes achieved for each SDG in the LAC countries studied and those achieved in Organisation for Economic Co-operation and Development (OECD) countries. Moreover, LAC countries still have a long way to go to achieve the SDG targets set in the 2030 Agenda for Sustainable Development. This study explains how investment in digital (especially telecommunications [telecom]) infrastructure can help close the gap between the region and these two benchmarks (OECD countries and the SDG targets). It also quantifies the investment in telecom in the region between 2008 and 2017 and estimates the investment necessary to close these gaps.[2]

Key Findings

Telecom Investment

Mobile accumulated investment accounts for nearly 50 percent of total investment (US$74 billion) and increased in almost all countries between 2008 and 2017. By contrast, in almost half the countries considered in the study, investment in fixed telecom decreased over the period. Total accumulated investment over the period has reached US$78 billion. Eighty percent of this investment has been private, except in Costa Rica, where approximately two-thirds of the investment is public (Figure 1). The accumulated investment in telecom infrastructure in the LAC region between 2008 and 2017 was estimated at US$153

FIGURE 1. Accumulated Investment 2008–2017 (millions of US$)

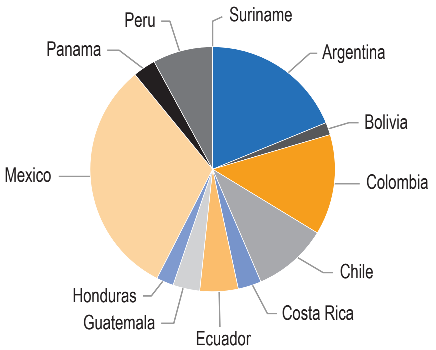


Sources: Frontier Economics, Infralatam, Telegeography, GSMA, and ITU.

[1] The countries are Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Honduras, Panama, Peru, and Suriname.

[2] This study complements other studies estimating the amount of investment needed to close the digital divide between the LAC region and OECD countries. These studies generally focus on the differences in broadband penetration, take-up of different technologies, and coverage. This study calculates the investment needed to close the gap with OECD countries with respect to achievement of the SDGs.

FIGURE 2. Accumulated Investment (2008–2017) by Country



Sources: Frontier Economics, Infralatam, Telegeography, GSMA, and ITU.

billion. Argentina, Colombia, and Mexico invested the most, while Bolivia, Honduras, and Suriname invested the least (Figure 2).

Table 1 lists the amounts invested by each country in fixed and mobile telecom by the public and the private sectors in the period 2008–2017.

Impact of Telecom Investment on the SDGs

According to the literature, investment in technology can improve social and development outcomes in a country through several channels. Internet access and enhanced telephone communication can improve access to information on employment and education, which will increase the chances that people can lift themselves out of poverty (SDG 1). Digital infrastructure and Internet of Things (IoT) technologies can enhance agricultural sustainability and improve food security (SDG 2). Telecom can also help reduce income inequality by connecting remote areas with cities and providing less developed countries and rural communities with work opportunities and free access to knowledge (SDG 10).

This analysis finds that digital infrastructure has a significant and measurable impact on several SDGs when the effects of other relevant variables are considered. The variable defining the SDG was correlated with several other variables, including investment in digital infrastructure, investment in other utilities,

TABLE 1. Accumulated (2008–2017) Telecom Investment in the Countries Studied (millions of US$)

	Investment				
Country	**Fixed**	**Mobile**	**Public**	**Private**	**Total**
Argentina	18,092	10,505	5,484	23,113	28,597
Bolivia	688	1,804	1,206	1,286	2,492
Colombia	8,496	11,682	3,778	16,400	20,178
Chile	4,429	10,556	150	14,835	14,985
Costa Rica	2821	1,860	2,879	1,802	4,681
Ecuador	3,983	3,704	1,461	6,226	7,687
Guatemala	1,998	3,397	5	5,389	5,394
Honduras	1,934	1,520	15	3,439	3,454
Mexico	30,618	17,407	9,127	38,897	48,025
Panama	2,241	2,317	866	3,692	4,558
Peru	2,529	9,525	253	11,801	12,054
Suriname	190	181	71	301	371
Total	**78,020**	**74,458**	**25,296**	**127,181**	**152,478**

Sources: Frontier Economics, Infralatam, Telegeography, GSMA, and ITU.

TABLE 2. **Summary of the Quantitative Impact of Telecom Infrastructure on Selected SDGs**

SDG	Results (ceteris paribus)
SDG 1: End poverty	An increase of 1 percent of total telecom investment leads to a reduction of the poverty rate (measured by percent of population under US$1.90 per day) by 0.0132 percentage points (pp). An increase of 1 percent in mobile investment leads to a reduction of 0.0135 pp. An increase of 1 percent in fixed telecom investment leads to a reduction of 0.0045 pp.
SDG 2: Zero hunger	An increase of 1 percent in total telecom investment leads to a reduction in the percentage of undernourished people of 0.011 pp. An increase of 1 percent in mobile investment leads to a reduction of 0.014 pp. No impact of fixed telecom investment.
SDG 3: Good health and well-being	An increase of 1 percent in total telecom investment increases life expectancy by 0.0095 pp. An increase of 1 percent in mobile investment increases it by 0.0145 pp. An increase of 1 percent in fixed telecom investment increases it by 0.0022 pp.
SDG 8: Decent work and economic growth	An increase of 1 percent of total telecom investment leads to an increase in GDP of 0.09 pp. An increase of 1 percent in mobile investment leads to an increase of 0.097 pp. An increase of 1 percent in fixed telecom investment leads to an increase of 0.023 pp.
SDG 10: Reduced inequalities (10.1)	An increase of 1 percent in total telecom investment leads to an increase in the income share held by the lowest 10 percent of 0.0013 pp. An increase of 1 percent in mobile investment leads to an increase of 0.0001 pp. An increase of 1 percent in fixed telecom investment leads to an increase of 0.0004 pp.
SDG 10: Reduced inequalities (10.2)	An increase of 1 percent in total telecom investment leads to an increase in the income share held by the lowest 20 percent of 0.0027 pp. An increase of 1 percent in mobile investment leads to an increase of 0.0019 pp. No impact of fixed telecom investment.
SDG 13: Climate action	An increase of 1 percent in mobile investment reduces CO_2 per capita by 0.09 pp. An increase of 1 percent in fixed telecom investment leads to a reduction of 0.015 pp. No impact of total telecom investment.

Source: Frontier Economics analysis.
Note: In all cases, the R-squared for these regressions is between 0.6–0.7 except for SDG 10, which has an R-squared between 0.5 and 0.6.

unemployment, and other specific variables which relate to the specific SDG, such as, public expenditure on health as a percentage of GDP. Table 2 shows those SDGs for which there is strong quantitative evidence of impact of digital infrastructure, as well as the measurement of that impact.

In practice, this would mean that, for example, if investment in digital infrastructure were increased by 10 percent in a year in all the countries in the study (all else being equal), around 375,000 people in the region under study would be lifted out of poverty[3] and around 360,000 people in the region would cease to suffer from hunger.[4]

We also find that, for many SDGs (SDG 1, 2, 3, and 10), the impact on achieving the SDGs of a marginal increase in mobile investment or investment in digital infrastructure is like (and in some cases even larger than) that of a marginal increase in expenditures on utilities. There is quantitative evidence of the effect of telecom infrastructure on achievement of SDG 4 (Quality Education), SDG 5 (Gender Equality), and SDG 9 (Industry, Innovation, and Infrastructure), although its magnitude is more difficult to measure from the available information. Nevertheless, the estimated coefficients for telecom infrastructure are statistically significant, which indicates that they have an impact on the SDG indicators. For the remaining SDGs, a qualitative analysis was developed based on case studies, which is summarized in Table 3.

[3] Poverty is measured as the share of the population living below the poverty line of US$1.90 per day (SDG 1).
[4] Hunger is measured as the percentage of undernourished people in the population (SDG 2).

TABLE 3. Summary of the Qualitative Impact of Digital Applications and Infrastructure on Several SDGs

SDG	Link	Examples in the LAC region
SDG 6: Clean water and sanitation	Digital infrastructure (through IoT) can provide tools to efficiently manage and monitor water consumption.	Still in an early phase. Projects in Chile (rationalization of consumption and detection of leakages) and Colombia (potabilization of systems).
SDG7: Affordable and clean energy	Smart grids and smart logistics reduce energy consumption. Smart meters provide households with a tool that improves awareness of energy usage. Connected washers and dryers (working with smart meters and IoT) could receive information about energy prices to delay cycles during peaks.	Examples in Chile and Mexico where the use of significant amounts of data collected through systems digitalization allows energy companies to increase efficiency. Chile and Colombia are leading the adoption of smart electricity meters.
SDG11: Sustainable cities and communities	The Sustainable Cities Index has identified digital infrastructure as one key metric to measure the progress of cities toward this SDG. Indicators include the availability of mobile transport applications, and the cost of broadband connections, mobile and broadband connectivity, among others.	Buenos Aires, Lima, Mexico City, and Santiago are in the "evolutionary cities" group. This group performs poorly in digital capabilities, which limits their overall performance in sustainability. Out of 100 cities (1 being the best and 100 the worst), they all rank between the 77th and 85th positions.
SDG12: Responsible consumption and production	Reducing the ecological footprint means achieving sustainable consumption and production. As one of the most water-consuming economic activities, agriculture will need to undergo significant changes to achieve this SDG. Technology and newer IoT solutions in agriculture can play a crucial role.	Colombia, one of the largest exporters of bananas worldwide, is developing a smart farming project using remote sensors in the plantations. Monitoring of climatic conditions optimizes water usage, prevents infestations and diseases, and reduces the consumption of fertilizers.
SDG14: Life under water	Some applications include internet and satellite maps which help to track the migration patterns of endangered animals; monitoring of global fish stocks, oxygen levels, algal blooms, temperature and ocean currents; and big data that assists the analysis of oceans in terms of biodiversity and pollution.	Nicaragua InvestEGGator: Global positioning system trackers against poachers represent the use of digital technologies to conserve marine environments and wildlife.
SDG15: Life on land	Digital applications include mobile sensors and IoT, which assist in the monitoring of terrestrial ecosystems, desertification, and others; satellite observation assists in the monitoring of water flows and climate, providing efficient early-warning systems to protect endangered species and fragile land areas; and mobile phones track illegal trafficking and poaching.	Tree Tag in Guatemala enables officials to report activities and volumes of logging and track suspicious activity. Another example is an e-mail warning system to detect fires in protected areas in South America.
SDG16: Peace, justice, and strong institutions	Governments and communities can use digital infrastructure to strengthen the rule of law and promote the institutions of good governance.	Many countries in the region, including Bolivia, Chile, Colombia, Costa Rica, Guatemala, and Peru, have introduced transparency portals to promote financial transparency and accountability.
SDG17: Partnerships for the goals	Efforts to digitalize different areas are driving partnerships between the public and the private sectors in LAC.	In 2017, the Brazilian Association of IoT was formed, which brought together public and private entities and academia to foster open innovation across different sectors of society. In Mexico, a partnership was created between IBM and the city council of Tequila to promote smart solutions at the municipal level.

Source: Frontier Economics analysis.

TABLE 4. Total Additional Telecom Investments Required to Meet the OECD Level (millions of US$)

SDG	1	2	3	8	10.1	10.2	Max
Argentina	0	2,645	15,611	2,839	28,986	24,243	28,986
Bolivia	1,959	6,588	6,706	1,241	5,432	4,473	6,706
Chile	542	1,365	393	4,060	14,510	12,360	14,510
Colombia	5,214	7,438	14,322	4,938	22,060	20,436	22,060
Costa Rica	208	1,634	0	1,614	6,512	6,182	6,512
Ecuador	1,584	6,500	3,576	765	7,242	5,979	7,242
Guatemala	N/A	8,418	6,525	1,868	N/A	N/A	8,418
Honduras	5,898	5,634	4,525	1,404	7,110	6,885	7,110
Mexico	5,909	6,113	16,925	9,586	24,360	19,566	24,360
Panama	396	2,332	905	1,763	5,147	5,115	5,147
Peru	N/A	7,983	11,400	5,322	16,218	14,028	16,218
Suriname	N/A	140	370	53	N/A	N/A	370
Total	**21,710**	**56,790**	**81,259**	**35,453**	**137,578**	**119,267**	**147,640**

Source: Frontier Economics analysis.
Note: The max column indicates the maximum investment required to fill the gap with OECD countries in all SDGs in each country. Results are not presented for SDGs 4, 5, and 9, for which the estimations are not statistically significant. For SDG 13, results are not presented because for its indicator (CO_2 emissions per capita) the OECD target has been achieved in all the countries studied. For SDG 8, the additional investment required to achieve twice the cumulated GDP growth in the period 2018–2023 is shown (as forecasted by the IMF). Thus, if, for example, the IMF forecasts that the GDP in Argentina in 2023 will be 6.8 percent higher than in 2018, the investment in telecom needed to make the GDP 13.6 percent higher in 2023 than in 2018 (i.e., to double the IMF forecast) is calculated. Therefore, this target only is calculated to 2023, the last year when GDP forecasts are available.
Countries with a zero-investment gap in any SDG have already achieved the target. Countries with N/A in any SDG do not have recent data for the indicator chosen (therefore, it is not possible to calculate the SDG gap and the investment gap). The totals for intervals including N/A values disregard the N/A observations.

Additional Investment Needed to Close the SDG Gaps

We have calculated the additional investment necessary to close the SDG gaps between the countries in this study, the SDG level attained in OECD countries, and the SDG 2030 official targets.[5] This is presented in Table 4 for the SDGs where a strong quantitative relationship was found.[6]

SDGs 1 and 2 are the two goals that require the least additional investment. This result indicates that investment in telecom is an important policy tool to improve the well-being of lower-income people.[7] According to these estimates, undernourishment could be reduced to 2.8 percent (SDG 2, OECD average level) by investing an additional US$56.8 billion in telecom infrastructure in the countries studied. Similarly, and for the countries for which data are available, investing an additional US$21.7 billion in telecom infrastructure, all people living on less than US$1.90 per day would be lifted out of poverty. Likewise, to achieve the OECD average life expectancy of 79.7 years (SDG 3), study countries would need to invest a total of US$81.3 billion in telecom infrastructure.

[5] For all those SDGs where either the target is not clearly defined or coefficient results are not statistically significant, this calculation is not possible.
[6] Typically, the level attained in the OECD (average) in the SDG indicators is smaller than the level set for the SDG agenda target. Therefore, reaching the OECD average level may be considered an intermediate step toward achievement of the SDG target.
[7] Each SDG can be measured across several dimensions, since they are multidimensional. For each SDG, one or two indicators (i.e., metrics) have been identified to measure them. In the case of SDG1 (End Poverty) the metric used is percent of the population living on less than US$1.90 per day, and for SDG2 (Zero Hunger), percent of undernourished people. Therefore, the amounts shown in Table 3 are those required to bridge the gap with the OECD on these metrics.

TABLE 5. Annual Additional Investment Growth Required to Meet OECD SDG Levels by 2030 (percent)

SDG	1	2	3	8	10.1	10.2	Max
Argentina	0	5	15	13	21	19	21
Bolivia	18	29	29	37	27	25	37
Colombia	11	13	18	26	22	22	26
Chile	3	6	2	30	22	20	30
Costa Rica	5	14	2	36	25	25	36
Ecuador	8	19	14	10	19	18	19
Guatemala	N/A	26	23	35	N/A	N/A	35
Honduras	26	26	24	38	28	28	38
Mexico	7	7	14	25	16	15	25
Panama	6	17	10	40	25	25	40
Peru	N/A	16	19	34	22	21	34
Suriname	N/A	14	22	18	N/A	N/A	22

Source: Frontier Economics analysis.
Note: The SDGs where the estimation had non-statistically significant results (SDGs 4, 5.2, 9.1, and 13) are not presented. For SDG 13, the results are not presented because for its indicator (CO_2 emissions per capita) the OECD target has been achieved in all the countries studied. For SDG 8, the annual additional investment required is calculated to achieve twice the cumulated GDP growth in the period 2018–2023 (forecasted by the IMF) over five years. This target only is calculated to 2023.
Countries with a zero percent have already achieved the target. Countries with N/A in any SDG do not have recent data for the indicator chosen (therefore it is not possible to calculate the SDG gap and the investment gap). The maximum for intervals including N/A values disregard the N/A observations.

Alongside these policy goals, some countries can achieve higher GDP growth by investing in digital infrastructure. According to the results for SDG 8 (Decent Work and Economic Growth), all countries in our study could obtain twice as much cumulated growth than the amount forecasted by the IMF in the period 2018–2023 just by investing in digital infrastructure to close the gap on other SDGs.

We also show the percentage by which investment in each country should increase yearly between 2019 and 2030 with respect to average investment in the last five years, to meet the OECD average and the SDG agenda target[8] (Table 5).

Table 5 shows that the increment in the annual investment is less than 10 percent in Chile, Costa Rica, Ecuador, Mexico, and Panama for SDG 1 (End Poverty), and for Argentina, Chile, and Mexico for SDG 2 (Zero Hunger). In these cases, investments in telecom at these levels could be fostered with sound economic regulation and promoting an increase in demand for telecom services.

Nonetheless, countries with results beyond 10–15 percent will need a significant investment effort to close the SDG gap, and additional measures are likely to be required. Specifically, countries such as Bolivia and Honduras would need to increase their annual investment substantially in the next 12 years to close the SDG gap with the OECD. Achieving the SDG target in this case will require a joint effort in terms of telecom investment as well as investment in other industries, along with the implementation of social policies. Investment in digital infrastructure can advance toward the target but cannot be the only driver.

[8] The annual average growth in investment is calculated as a compound annual growth rate (CAGR). The investment at the beginning of the period is measured by the average investment in digital infrastructure 2013–2017. The total investment required at the end of the period is proxied by the total investment at target (this is the level of investment in 2017 plus the incremental investment required, shown in Table 4). The average annual growth rate is calculated over a 12-year period, that is, the number of years left until 2030. Only for SDG 8, this is a five-year period, that is, the number of years left until 2023.

Recommendation

Due to the evidence showing that telecom infrastructure fosters sustainable development, these kinds of investments, and digital investments more broadly, should be strongly incentivized.

The Role of Public Institutions and Multilateral Organizations

There are numerous public policies in LAC countries that are funding the deployment of digital infrastructure, especially in less developed areas. Most of these plans are funded with industry revenues. Exceptions include the Telecommunications Development Fund (Fondo de Desarrollo de las Telecomunicaciones) in Chile and the Fund for Social Telecommunications Coverage (Fondo de Cobertura Social de Telecomunicaciones, or FONCOS) in Mexico, which are funded from the public budget (5G Americas, 2017). This reflects the fact that the macroeconomic environment in LAC does not favor substantial increases in investment funded by the public sector.

Concessional financing from international organizations and funds from multilateral development banks, such as the Inter-American Development Bank (IDB) and the Andean Development Corporation–Development Bank of Latin America (CAF), can be mobilized in areas where domestic public resources are insufficient, and the private sector is unable to provide adequate financing.

One area where these funds could focus their investment is rural areas. There is still a significant gap in rural areas with respect to the contribution of digital investment to sustainable development. The deployment of fixed, mobile, and broadband networks in these areas is a necessary condition for digital infrastructure to be able to contribute to achieving the SDGs.

Efficiency of Investment

Another way to promote investment is by removing policies that distort investment decisions, such as excessive regulation and inefficient taxation. Presently, the telecom market is regulated in almost all countries in the region. This means that the regulator has a role, by action or by omission, in the development of the sector. As underscored by Frontier Economics (2017), competition analysis, as currently carried out, raises several problems given the dynamic nature of the sector. To overcome these shortcomings, regulators in LAC should consider competition as determined by the existence of rivalry. Rivalry creates incentives for companies to reduce costs, lower prices, and invest in the development of new services.

Taxes can also distort consumption and investment. While taxes can have an economic rationale in terms of increasing welfare, the results of this study show that treasury departments must take additional care in the application of tax policy to the digital industry given the significant positive externalities that result from sustainable development.

Adoption of Digital Technologies

Penetration of digital services in LAC households is still low compared to the OECD average. Several actions could be undertaken to incentivize the adoption of digital technologies: applying policies to reduce the cost of purchasing telecom services, increasing the availability of local content, and undertaking digital literacy campaigns.

Investment in IoT

Digital infrastructure impacts some SDGs (12, 14, 15, 16, and 17) primarily through the adoption of new IoT and machine-to-machine (M2M) technologies. Therefore, the promotion of IoT investment is fundamental to achieve those SDGs. To this aim, it is crucial to investigate in depth the policies that foster investment in, and take up of, IoT adopted in other jurisdictions to understand how the countries in the LAC region could adapt them to their specific characteristics.

1 Introduction

This study identifies the impact of digital infrastructure on achievement of the Sustainable Development Goals (SDGs) in 12 countries in the Latin American and Caribbean (LAC) region.[9]

The 2030 Agenda for Sustainable Development, adopted by 193 heads of government at the United Nations General Assembly in September 2015, represents a holistic approach to transforming the world. It is designed as a plan of action for addressing the development challenges that affect mankind and the planet. As its bedrock, the plan encompasses a comprehensive set of 17 SDGs which integrate the economic, social, and environmental dimensions of sustainable development. The 17 SDGs are the following:

- SDG 1 – End poverty in all its forms everywhere
- SDG 2 – End hunger, achieve food security and improved nutrition, and promote sustainable agriculture
- SDG 3 – Ensure healthy lives and promote well-being for all at all ages
- SDG 4 – Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
- SDG 5 – Achieve gender equality and empower all women and girls
- SDG 6 – Ensure availability and sustainable management of water and sanitation for all
- SDG 7 – Ensure access to affordable, reliable, sustainable, and modern energy for all
- SDG 8 – Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all
- SDG 9 – Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation
- SDG 10 – Reduce inequality within and among countries
- SDG 11 – Make cities and human settlements inclusive, safe, resilient, and sustainable
- SDG 12 – Ensure sustainable consumption and production patterns
- SDG 13 – Take urgent action to combat climate change and its impacts
- SDG 14 – Conserve and sustainably use the oceans, seas, and marine resources for sustainable development
- SDG 15 – Protect, restore, and promote the sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
- SDG 16 – Promote peaceful and inclusive societies for sustainable development, provide access to justice for all, and build effective, accountable, and inclusive institutions at all levels

[9] The countries are Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, Honduras, Panama, Peru, and Suriname.

- SDG 17 – Strengthen the means of implementation and revitalize the global partnership for sustainable development

How the SDGs Are Measured

It is possible to measure each SDG across several dimensions. Each goal includes several sub-goals in different areas. To quantify the impact of digital infrastructure, for each SDG one or two indicators, or metrics have been identified to measure them. The metrics consist of either one of the suggested indicators in the official Knowledge Platform and United Nations Global SDG Database of the SDGs[10] or another indicator that best captures the multidimensionality of the SDG based on available data.

These metrics were used to proxy the SDG level in a given country and year. The same metric was then used to measure the SDG target level officially set in the 2030 Agenda and to measure average performance in OECD countries. These two benchmarks enable gaps between the selected LAC countries and OECD countries, and between the selected LAC countries and the targets in the 2030 Agenda to be identified. These metrics, shown in Table 1.1, are also the dependent variable in our econometric analysis.

TABLE 1.1. Summary of SDG Metrics Selected

SDG	Numbering	Metric
SDG 1	1	Poverty rate (% population living on less than US$1.90 per day)
SDG 2	2	Hunger rate (% undernourished people)
SDG 3	3	Life expectancy (years)
SDG 4	4	Secondary school enrolment (%)
SDG 5	5.1	Women in parliament (%)
SDG 5	5.2	Female secondary school enrolment (%)
SDG 6	6.1	Population using clean water supply (%)
SDG 6	6.2	Population using sanitation facilities (%)
SDG 7	7	Population with access to electricity (%)
SDG 8	8	GDP (US$)
SDG 9	9.1	R&D expenditures (as % of GDP)
SDG 9	9.2	Trademark applications (number)
SDG 10	10.1	Share of income in lowest 10% (%)
SDG 10	10.2	Share of income in lowest 20% (%)
SDG 13	13	CO_2 per capita (tons)

Source: Frontier Economics analysis.
Note: For the remaining SDGs, the metric is not presented as part of this analysis. They are analyzed separately in the case studies.

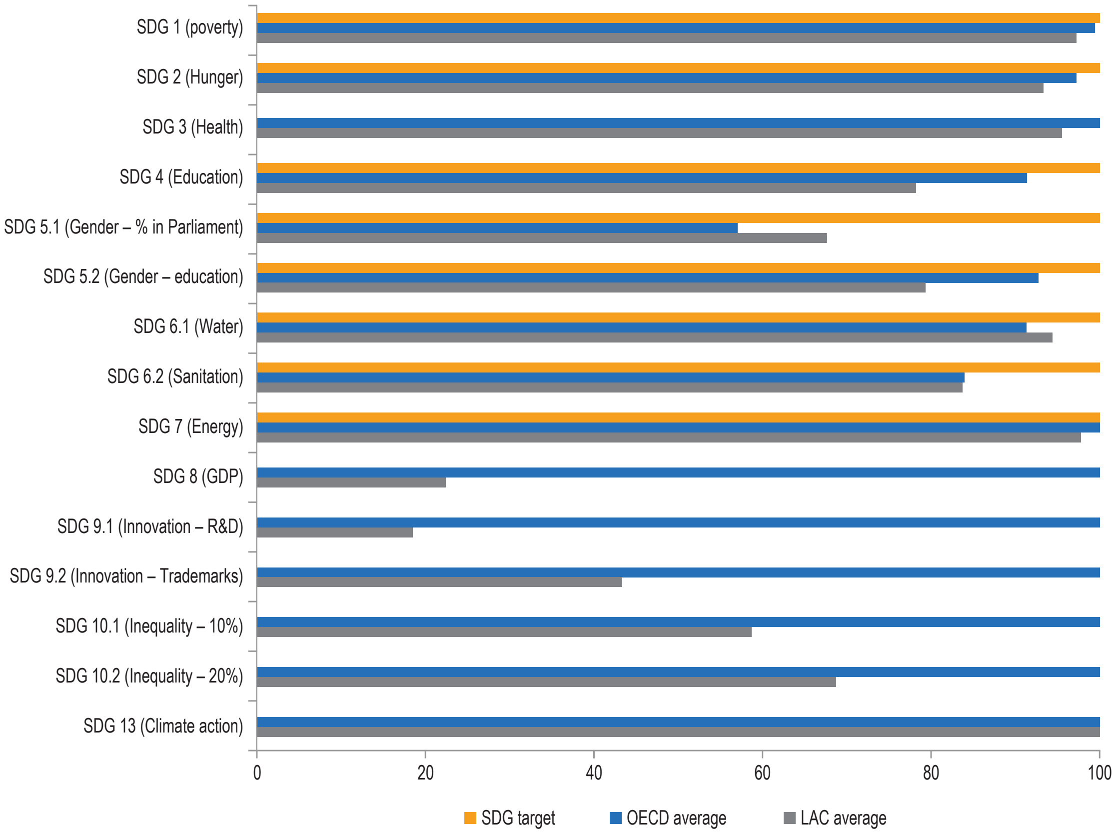
The SDG Gap

This section shows how the region's SDG indicators compare with those used in OECD countries and with the SDG official 2030 target. Figure 1.1 depicts these comparisons by objective. For each SDG, three data series are presented: the average level of the SDG indicator in the countries studied ("LAC average"), the average for the same SDG in the OECD countries ("OECD average"), and the final target set in the 2030 agenda ("SDG target").[11] For ease of interpretation, all values are indexed to the SDG target that is always represented as 100 percent.[12] This is to show the status of progress of the OECD and the LAC region on average toward completion of each SDG.

In most cases, there is a gap between the degree of attainment of the indicator in the study countries and the SDG target. Notably, the countries studied are performing worse than the OECD average in the education and income-related SDGs. Only in a few cases (SDG 5.1, SDG 6.1, and SDG 13), the countries studied outperform the OECD countries on average. These results are presented in Figures 2.1 and 2.2.

[10] https://sustainabledevelopment.un.org/ and https://unstats.un.org/sdgs/indicators/database/.
[11] Where applicable, not all the 2030 official SDG targets indicators used are quantifiable. When they are not, the OECD average is used as the target for LAC.
[12] This is because SDGs differ in the way the metric is measured (in percent or in numbers) and in the direction of improving the target (the target could be close to zero percent or 100 percent).

FIGURE 1.1. Performance of SDGs in the LAC Region as a Share of Target Completion*



Source: Frontier Economics analysis.
* The x-axis represents the % of completion of the target. The SDG target represents 100. When this is not available, the OECD average represents 100. All values are then indexed to 100.
Note: Values for SDG 8 are represented as GDP in constant 2010 US$, although the SDG gap is then estimated in % growth terms to avoid uninterpretable large results.

2

Public and Private Investment in Telecom Infrastructure in the Last 10 Years

Introduction

This section presents our estimation of the total investment in telecom for the 12 countries studied during the period 2008–2017. It disaggregates total telecom investment between public and private and fixed and mobile investment. The study relied primarily on GSMA data for the capital expenditure (capex) of the mobile industry and on information from Infralatam[13] and the International Telecommunication Union (ITU) for total investment in the telecom sector. It then estimated the missing information to produce a single, consistent database (see Annex B).

Total Accumulated and Per Capita Investment

This section presents the results of the estimated investment in the telecom sector in the countries studied. These estimates were used as inputs into the econometric analysis. The estimates are disaggregated as total (Figures 2.1 and 2.2) and per capita (Figure 2.3) annual investment and accumulated total investment (Figure 2.4) in telecom for the period (2008–2017). Total investment is presented in two figures for representation purposes only (figures have different scales).

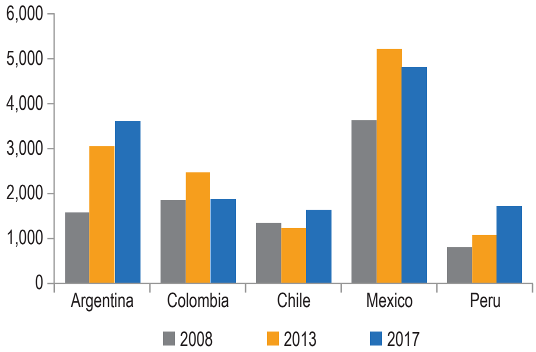
Since these data reflect annual investment flows, they can vary significantly from year to year, and it is difficult to draw clear-cut conclusions. Nevertheless, in most countries, investment has increased over the period, especially in Bolivia, Argentina, Costa Rica, and Peru (240, 127, 120, and 104 percent, respectively). The level of investment is lower in 2017 than in 2008 only in Panama and Suriname, by 61 percent and 18 percent, respectively.

Figure 2.3 depicts the per capita investment in telecom by country. As with aggregate investment, investment has increased in most countries over the period under study, especially in Bolivia and Argentina (195 and 107 percent, respectively). Only in Panama, Suriname, Ecuador, and Colombia, the level of per capita investment in 2017 was lower than in 2008, by 66, 25, 13, and 8 percent, respectively.

The accumulated telecom investment in the LAC region for the period 2008–2017 was

[13] http://www.infralatam.info/ Infralatam is an initiative of the IDB, CAF, and the Economic Commission for Latin America and the Caribbean (ECLAC). The objective of this project is to measure infrastructure investment in the LAC region.

FIGURE 2.1. Total Annual Telecom Investment in Larger LAC Countries (millions of US$)



Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.

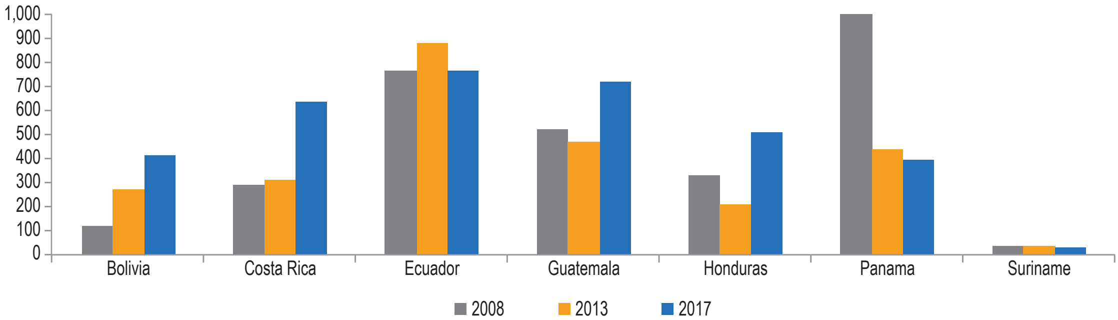
US$153 billion (Figure 2.4). Argentina, Colombia, and Mexico have invested the most, while Bolivia, Honduras, and Suriname have invested the least.

The Evolution of SDGs

Most SDG indicators in the selected countries have improved over the period 2008–2017. SDG 4 (quality education), for example, measured as the net secondary enrolment rate, jumped from 65 to 77 percent (Figure 2.5).

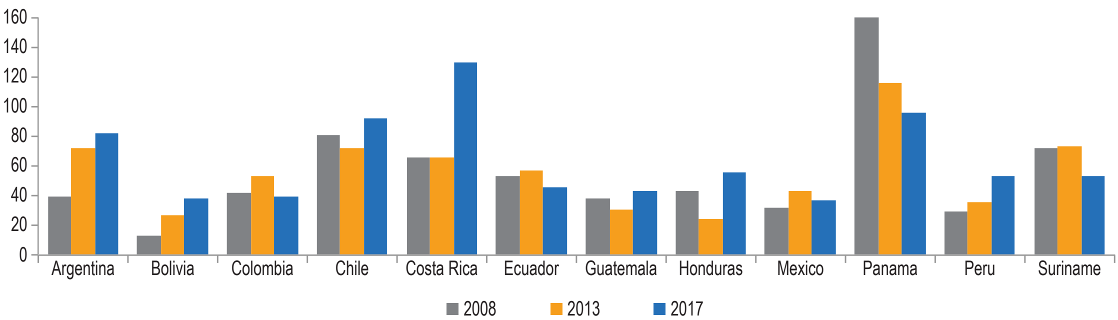
Although with these descriptive statistics is not possible to establish a relationship between investment in the telecom sector and achievement of the SDGs, both have improved in the countries studied.

FIGURE 2.2. Total Annual Telecom Investment in Smaller LAC Countries (millions of US$)



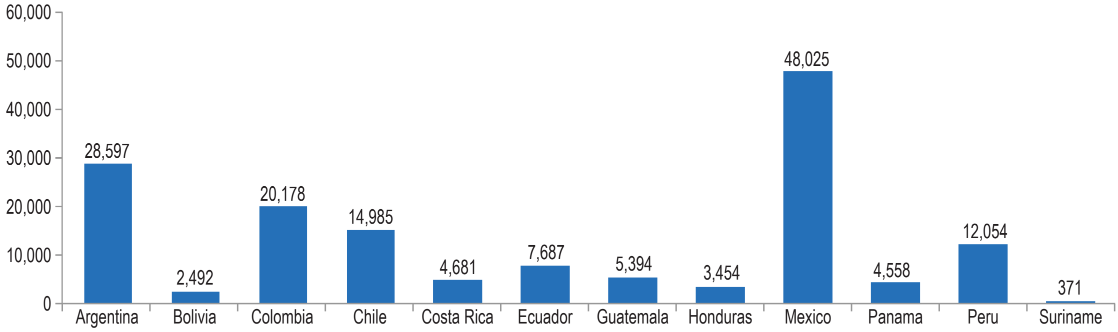
Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.
Note: For representation purposes the data series for Panama was truncated. The value of investment in Panama in 2008 was US$1 billion.

FIGURE 2.3. Total Annual Per Capita Telecom Investment in the LAC Region (millions of US$)



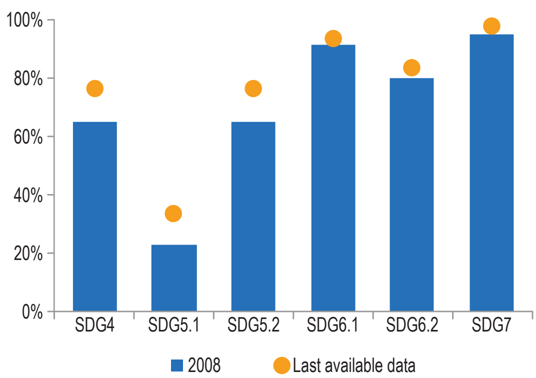
Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.
Note: For representation purposes, the data series for Panama was truncated. The value of investment in Panama in 2008 was US$286 million.

FIGURE 2.4. Total Accumulated Investment, 2008–2017, by Country (millions of US$)



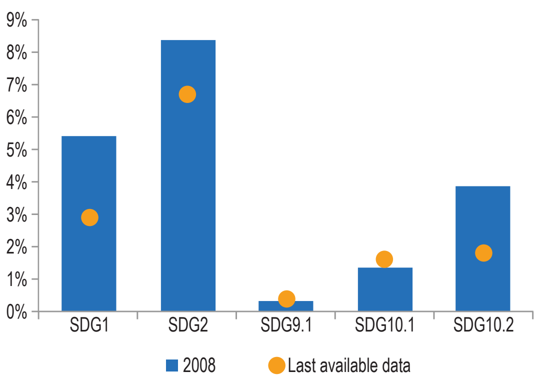
Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.

FIGURE 2.5. Evolution of SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 6 (Water and Sanitation), SDG 7 (Energy)



Source: Frontier Economics based on data from the World Bank and ECLAC.

FIGURE 2.6. Evolution of SDG 1 (Poverty), SDG 2 (Hunger), SDG 9 (Innovation), SDG 10 (Inequality)



Source: Frontier Economics based on data from the World Bank and ECLAC.

Investment in Technology

Figure 2.7 shows the increase in the proportion of investment in mobile telecom technology in 2017 compared to 2008 in the LAC region. Investment in mobile technology in 2008 represented 42 percent of total investment; while in 2017 it was 51 percent.

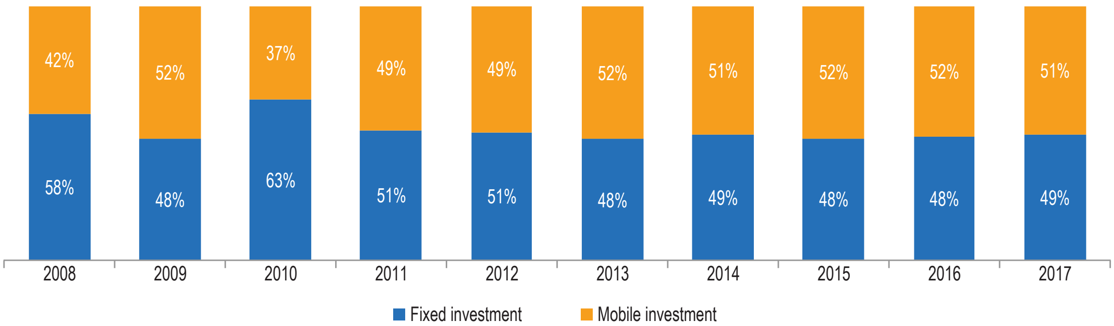
An analysis of the evolution of investment in mobile telecom technology by country reveals that in almost all countries, investment increased between 2008 and 2017 both in aggregate and

TABLE 2.1. Evolution of SDG 3 (years), SDG 8 (billions of US$), and SDG 13 (metric tons per capita)

SDG	2008	Last available data
SDG 3	74.5	75.8
SDG 8	522.5	638.7
SDG 13	3,174	3,159

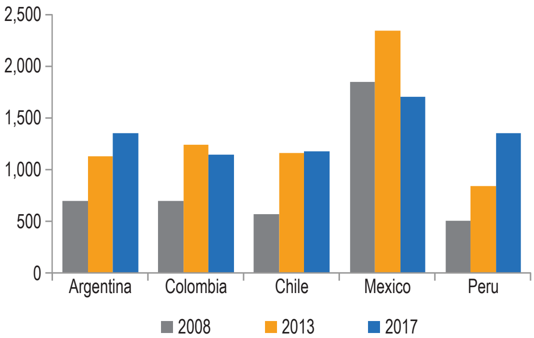
Source: Frontier Economics estimates based on data from the World Bank and ECLAC.
Notes: For SDG 3 the latest available data is from 2016, while for SDG 8 it is from 2017 and for SDG 13 it is from 2014.

FIGURE 2.7. Share of Investment in Fixed and Mobile Telecom Technology in the LAC Region, 2008–2017



Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.

FIGURE 2.8. Annual Mobile Telecom Investment in Larger LAC Countries (millions of US$)



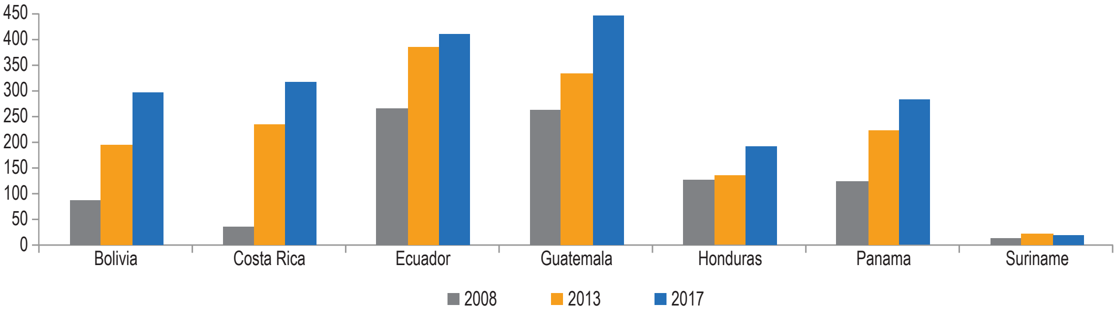
Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.

per capita terms (Figures 2.8 and 2.9). Investment increased the most in Costa Rica, Bolivia, Panama, and Peru. Only in Mexico did investment in mobile technology decline in 2017 relative to 2008, with oscillations in the interim years.

By contrast, in almost half of the countries considered in the study, investment in fixed telecom decreased between 2008 and 2017 (Figures 2.11 and 2.12). In Colombia, Chile, Guatemala, Panama, and Suriname, investment in fixed telecom technology decreased over the period. Per capita investments also decreased in Ecuador and Peru (Figure 2.13).

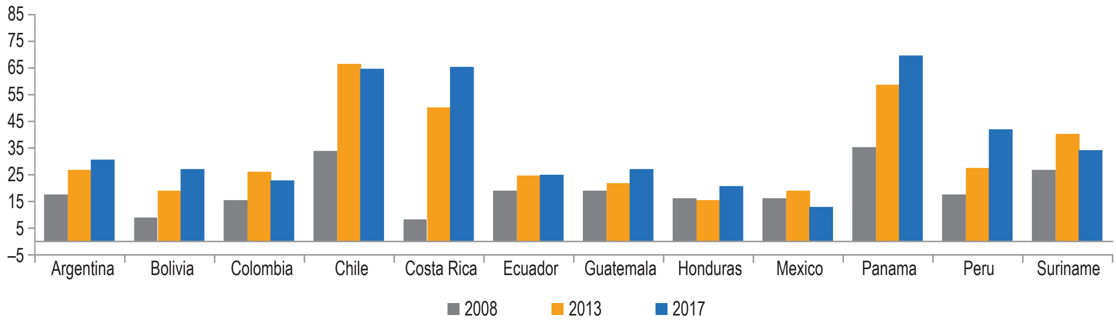
The evolution of investment in fixed and mobile telecom technology in LAC countries reveals the tilt

FIGURE 2.9. Annual Mobile Telecom Investment in Smaller LAC Countries (millions of US$)



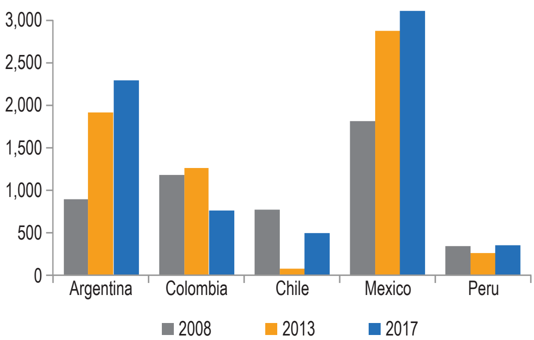
Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.
Note: For representation purposes, the data series for Guatemala has been truncated. The value of investment in Guatemala in 2017 was US$456 million.

FIGURE 2.10. Annual Per Capita Investment in Mobile Telecom Technology in the LAC Region (millions of US$)



Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.

FIGURE 2.11. Annual Investment in Fixed Telecom Technology in Larger LAC Countries (millions of US$)



Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.
Note: For representation purposes, the data series for Mexico was truncated. In 2017, Mexico invested US$3.1 billion.

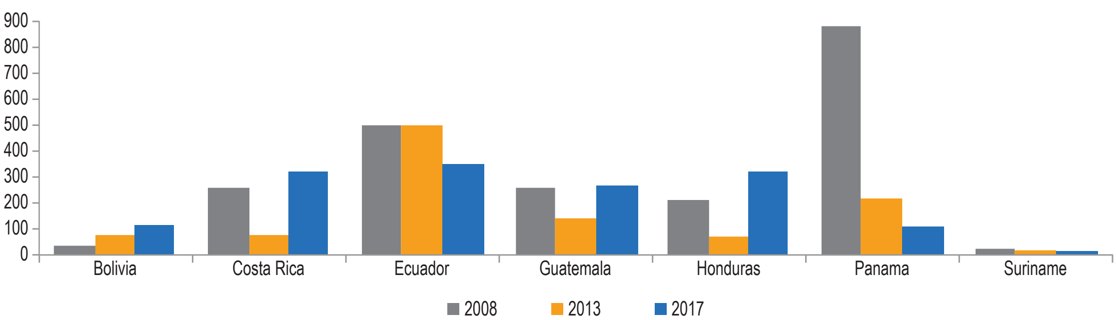
in accumulated investment in some countries toward one of the two technologies. Argentina, Costa Rica, and Mexico have invested more in fixed mobile telecom, while Bolivia, Chile, and Peru have invested relatively more in mobile telecom technology.

Public vs. Private Investment

In all the countries studied, the relative proportion of telecom investment made by private and public funding is around 80 percent and 20 percent, respectively (Figure 2.15) (see Annex B).[14] In all countries (except Costa Rica), a greater proportion of investment is

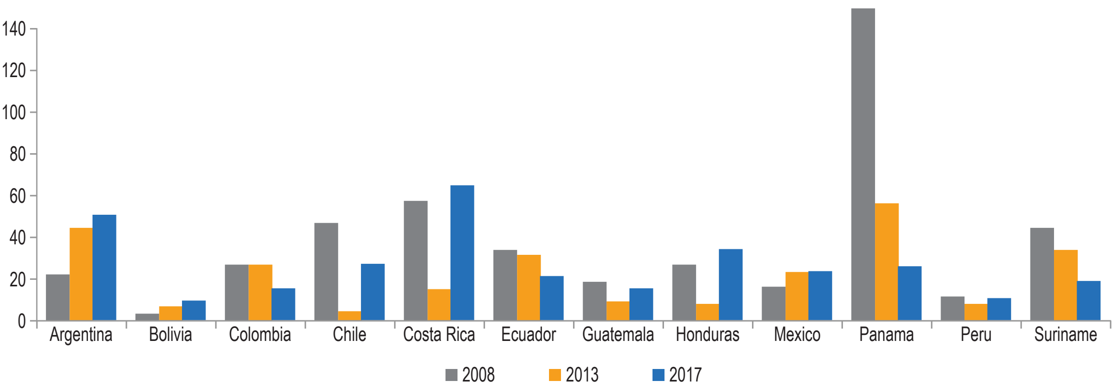
[14] See Annex B for total annual public and private investment.

FIGURE 2.12. Annual Investment in Fixed Telecom Technology in Smaller LAC Countries (millions of US$)



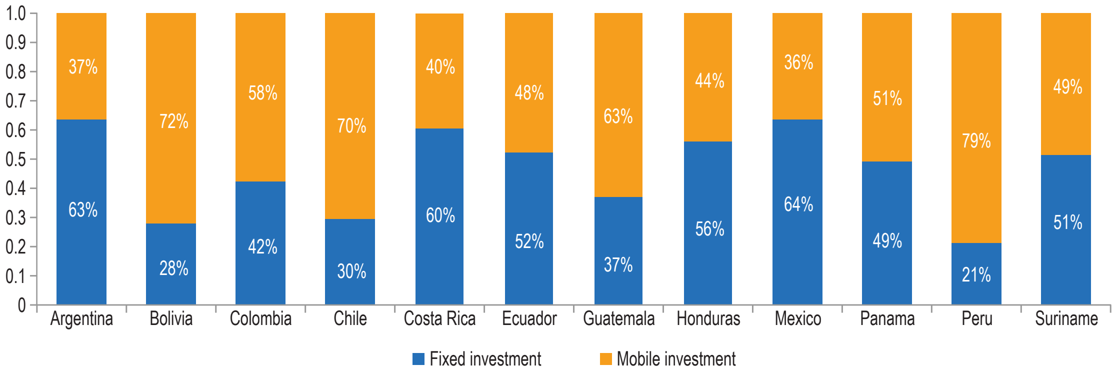
Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.

FIGURE 2.13. Annual Per Capita Investment in Fixed Telecom Technology in the LAC Region (millions of US$)



Source: Frontier Economics estimates based on data from Infralatam, GSMA ITU, and the World Bank.
Note: For representation purposes, the data series for Panama has been truncated. The value of investment in Panama in 2008 was US$251 million.

FIGURE 2.14. Proportion of Accumulated Investment in Fixed and Mobile Telecom Technology, 2008–2017, by Country



Source: Frontier Economics estimates based on data from GSMA ITU, Infralatam, and the World Bank.

private than public. In Costa Rica, public resources make up around 62 percent of the investment.[15]

Government Plans

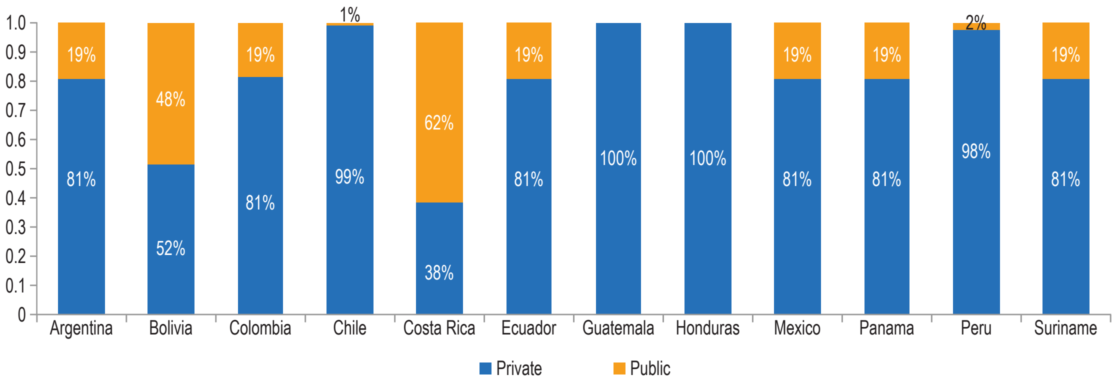
Although public investment is only a fraction of private investment, it is essential for connecting rural areas that are not covered by private sector. Other areas where public investment can have an impact are education and health. These public investment initiatives can be found in almost all LAC countries.[16] One example is backbone networks.

Backbone Networks

Backbone networks promote broadband connectivity. They offer backbone connectivity, while local Internet service providers (ISPs) provide last mile access. Presently, ISPs in LAC are in increasing demand for transmission capacity, because of the growth in the use of content available on the

[15] This is because the main broadband and wireless operator, Kolbi, is a state-owned company.
[16] See Annex E for examples of government plans.

FIGURE 2.15. Proportion of Accumulated Public and Private Investment, 2008–2017, by Country



Source: Frontier Economics based on data from Infralatam, GSMA, and the World Bank.
Note: Chile, Guatemala, Honduras, and Peru have a 1%, 0.1%, 0.4%, and 2.1% of public investment, respectively.

web (e.g., videos, video calling, social networks, etc.). There are examples of backbone networks in LAC countries, but they are still too new to assess their impact on achievement of the SDGs. They are fully operational only in Colombia and Peru (Table 2.2).

Backbone networks are developed under two types of financing schemes: public funds (Argentina) and public–private partnerships (PPP), where the construction, operation, and maintenance of the network are the responsibility of the concessionaire. A complementary form of public financing is requiring public entities to transmit all their internet traffic through these networks.

Summary

The amounts invested in telecom infrastructure by each of the 12 countries are listed in Table 2.3, disaggregated between fixed and mobile, as well as between public and private, according to the methodology described in Annex B. Table 2.4 lists the per capita investment in telecom infrastructure in the 12 countries studied.

TABLE 2.2. National Backbone Networks in Latin America

	Network	Km deployed	Concession year	Period of the concession	Type	Retail services	Investment (millions of US$)
Chile (Fibra Óptica Austral)	Transport (Regional)	3,953 (recently tendered)	2017	30 years	PPP	No	92
Argentina (Red Federal de Fibra Óptica)	Transport (National)	33,000 (partly constructed and in operation)	2015		State owned	No	1,329
Colombia (Proyecto Nacional de Fibra Óptica)	Transport and access (National)	19,000 (in operation)	2011	17.5 years	PPP	Yes	630
México (Red Troncal)	Transport (National)	25,650 (to be tendered)	2017	30 years	PPP	No	200
Perú (Red Dorsal Nacional de Fibra Óptica)	Transport (National)	13,400 (in operation)	2013	20 years	PPP	No	323

Source: OSIPTEL Informe Nº 00045-GPRC/2018 February 5, 2018, except for the investment amounts, which are based on information from national regulators.

TABLE 2.3. Accumulated (2008–2017) Telecom Investment in the 12 Countries Studied (millions of US$)

	Investment				
Country	Fixed	Mobile	Public	Private	Total
Argentina	18,092	10,505	5,484	23,113	28,597
Bolivia	688	1,804	1,206	1,286	2,492
Colombia	8,496	11,682	3,778	16,400	20,178
Chile	4,429	10,556	150	14,835	14,985
Costa Rica	2821	1,860	2,879	1,802	4,681
Ecuador	3,983	3,704	1,461	6,226	7,687
Guatemala	1,998	3,397	5	5,389	5,394
Honduras	1,934	1,520	15	3,439	3,454
Mexico	30,618	17,407	9,127	38,897	48,025
Panama	2,241	2,317	866	3,692	4,558
Peru	2,529	9,525	253	11,801	12,054
Suriname	190	181	71	301	371

Sources: Frontier Economics, Infralatam, Telegeography, GSMA, and ITU.

TABLE 2.4. Accumulated (2008–2017) per Capita Telecom Investment in the 12 Countries Studied (millions of US$)

	Investment				
Country	Fixed	Mobile	Public	Private	Total
Argentina	425	247	129	543	671
Bolivia	66	172	115	123	238
Colombia	180	248	80	348	428
Chile	256	605	9	853	861
Costa Rica	604	391	612	384	996
Ecuador	254	237	93	398	491
Guatemala	129	219	0.3	348	348
Honduras	224	177	2	398	400
Mexico	252	143	75	320	395
Panama	609	605	231	983	1,214
Peru	83	309	8	384	392
Suriname	355	334	131	558	689

Sources: Frontier Economics, Infralatam, Telegeography, GSMA, and ITU.

3

Contribution of Digital Infrastructure to the Achievement of the Sustainable Development Goals

This section demonstrates the impact of digital investment on SDGs. It uses two approaches: econometrics and case studies, depending on the information available and the nature of the SDGs.

The econometric approach is a "macro" approach. In it, the variable defining the SDG is correlated with a series of macroeconomic variables, including investment in digital infrastructure, investment in other utilities, unemployment, and other specific national variables which may relate to the specific SDG, such as public expenditure in health as a percentage of GDP, public expenditure in education as a percentage of GDP, public expenditure in social protection, and others (see Annex C for more details).

In principle, a different approach could have been adopted, which used micro data (at the household level) to measure the impact of digital infrastructure on the SDGs. This approach uses microeconomic relationships to further identify the channel by which digital infrastructure affects specific SDGs. For example, the expansion of digital infrastructure may lead to an increase in the adoption of specific technologies, such as telemedicine, to improve health outcomes. Using such an approach is not feasible given the absence of a database of consistent relevant variables at the micro level for all 12 countries studied.

Using the macro approach, the study finds that investment in digital infrastructure affects several SDGs when the effect of other relevant variables is considered. Even controlling for many variables that are expected to affect the SDG, for the reasons explained above, it is impossible to consider the effect of all relevant variables. Nevertheless, they provide evidence of the impact of digital infrastructure on SDGs.

For the other SDGs for which enough information was not available or for which a meaningful statistical impact was not found, case studies underscore the likely impact of digital infrastructure on achievement of some SDGs.[17]

The section defines the objective and the indicator used to measure the evolution of each of the 17 SDGs. It summarizes the evolution of

[17] In many cases, it is not surprising that no statistical evidence has been found, as the applications to influence the SDGs are nascent.

the indicator in the countries studied or in the LAC region. Finally, it describes the impact of digital infrastructure on those SDGs that have an econometric model or establishes a qualitative link between SDGs and the digital application and infrastructures in the case studies presented.

SDG 1: End Poverty

According to the World Bank, a person is considered poor if his or her income falls below the minimum level necessary to meet basic needs, such as food, clothing, and shelter.[18] This minimum level is called the poverty line.

What is considered necessary to satisfy basic needs varies across time and societies. Therefore, the definition of the poverty line has also varied across time and across societies. The poverty line can be defined either in relative[19] or in absolute terms.[20] This section is specifically concerned with absolute poverty. The UN Division for Sustainable Development Goals defines the international poverty line as US$1.90 per person per day using 2011 purchasing power parity (PPP).[21]

In the period from 2002 to 2017, the proportion of the global population living below the poverty line dropped dramatically, from 27 percent to 9 percent in 2017 (United Nations, 2018). Similarly, in LAC countries, the average share of people living on less than US$1.90 per day fell to 2.7 percent in 2016.[22] However, not all countries have experienced the same evolution. For example, while in Honduras (the country with the highest poverty rate in the sample in 2008), the proportion of people living below the poverty line declined by only 3 percent (from 16.5 percent to 16 percent), in Bolivia and Colombia, the countries with the second- and third-highest poverty rates in the LAC region in 2008, poverty declined by 36 percent and 57 percent, respectively. In recent years, some countries have experienced an increase in poverty compared to 2015 levels. This is the case for Bolivia, Ecuador, Honduras, and Panama (Figure 3.1).

Investment in technology is one tool that can break the cycle of poverty. Internet access provides free online educational resources and job portals that reduce the searching costs normally associated with finding a

[18] http://siteresources.worldbank.org/PGLP/Resources/povertymanual_ch3.pdf.

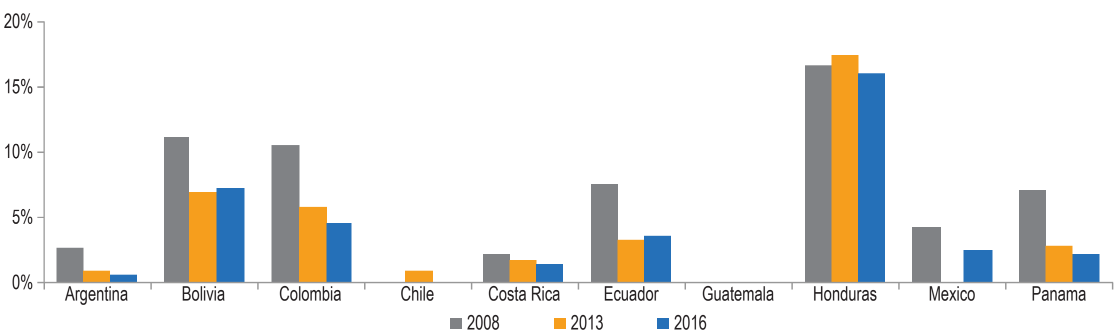
[19] Relative poverty is defined in relation to the economic status of other members of society. People are poor not only if they cannot meet their basic needs but also if they fall below prevailing standards of living in a given societal context.

[20] http://www.unesco.org/new/en/social-and-human-sciences/themes/international-migration/glossary/poverty/.

[21] https://unstats.un.org/sdgs/report/2016/goal-01/.

[22] Average calculated for the 12 LAC countries studied based on World Bank data.

FIGURE 3.1. Poverty Headcount Ratio at US$1.90 per Day, 2011 PPP (percent of population)



Source: Frontier Economics based on World Bank data.

job (GSMA, 2017). It provides access to digital tools related to financial services, such as mobile money and price comparisons. It also reduces transaction costs and information asymmetries by providing new opportunities (access to job information or education resources[23]) as well as access to lower prices with lower searching costs.

This study finds evidence that an increase in digital infrastructure investment reduces poverty. Specifically, an increase of 1 percent in mobile investment reduces the percentage of the population living below the poverty line by 0.0135 percentage points (pp) if all other variables are kept constant. An increase of 1 percent in investment in fixed telecom infrastructure also leads to a reduction (although to a lesser degree) of the poverty headcount ratio by 0.0045 percent, ceteris paribus. Finally, the analysis indicates that an overall increase of 1 percent of total telecom investment is associated with a reduction in poverty of 0.0132 percent. In relative terms, a marginal increase in mobile investment would have as much impact as a marginal increase in expenditure on utilities on decreasing the proportion of the population living below the poverty line in the LAC region.

SDG 2: Zero Hunger

Rapid economic growth and increased agricultural productivity in developing countries over the past two decades have seen the number of undernourished people drop by almost half.[24] While in 2000, 15 percent of the population was undernourished, in 2015 this percentage had fallen to 10.6 percent.[25] However, conflicts and natural disasters increased this rate to 11 percent by 2016 (United Nations, 2018).

LAC countries have all made significant progress in eradicating extreme hunger. Between 2008 and 2015, the percentage of the population that is undernourished (i.e., whose food intake is insufficient to meet dietary energy requirements) decreased by 20 percent on average in the region. Some countries made substantial progress: Panama and Peru experienced a reduction of 44 percent, while Bolivia and Colombia saw reductions of 28 percent and 25 percent, respectively. Costa Rica was the only country where the proportion of the population that is undernourished increased with respect to 2008 by 10 percent, to 5.6 percent (Figure 3.2).

IMPACT

Digital application and infrastructure investments can help ensure better conditions for agricultural sustainability (ITU, 2017a) and food security. For example, IoT[26] technology can monitor environmental and soil conditions, reducing potential crop damage and improving farm productivity using big data. It also allows farmers to access information and knowledge that can improve the productivity and yield of their crops, such as crop treatments and weather forecasts. The benefits that farmers get from IoT application in agriculture are twofold. First, these systems help farmers decrease production costs and waste by optimizing the use of inputs. Second, it can increase yields by improving farmers' decision making with more and accurate data.[27]

However, challenges to the use of IoT in agriculture persist in less developed regions. Remote areas tend to lack communication network

[23] Initiatives such as Vodafone's Instant Schools for Africa help people escape poverty by providing millions of young people in the Democratic Republic of Congo (DRC), Ghana, Kenya, Lesotho, Mozambique, South Africa, and Tanzania with free access to online learning materials. Vodafone and Arthur D. Little (2016): Connected Education.

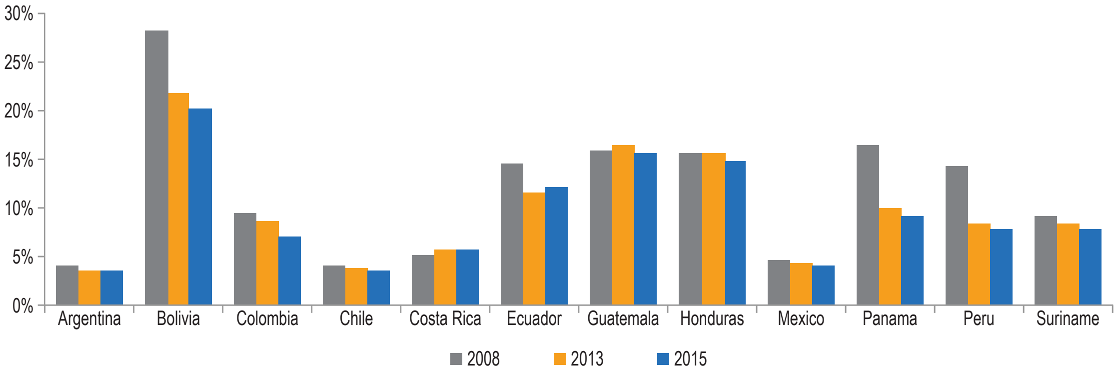
[24] http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-2-zero-hunger.html.

[25] http://www.fao.org/state-of-food-security-nutrition/en/.

[26] The Internet of Things envisages the networking of physical objects through embedded sensors that can make operations more efficient, increase productivity and boost output. It envisages a world of self-drive cars, smart homes, smart cities, and some others, maybe less fancy, but also important developments such as, fleet tracking, temperature monitoring and smart agriculture.

[27] https://blogs.worldbank.org/ic4d/agriculture-20-how-internet-things-can-revolutionize-farming-sector.

FIGURE 3.2. Prevalence of Undernourishment (percent of population)



Source: Frontier Economics based on World Bank data.

infrastructure. Farmers need to be presented with the right incentives to buy into IoT systems, whose upfront installation costs can be expensive.

This study finds evidence that investment in the digital infrastructure sector significantly lowers undernourishment. Specifically, an increase of 1 percent in total telecom investment is associated with a reduction in the percentage of undernourished people of 0.011 pp, while an increase of 1 percent in mobile investment is associated with a reduction in the same variable of 0.014 pp keeping all other variables fixed. In relative terms, a marginal increase in investment in mobile telecom technology would have a similar impact on the share of undernourished people as a marginal increase in investment in utilities.

SDG 3: Good Health and Well-being

3 GOOD HEALTH AND WELL-BEING

Child mortality has declined significantly in recent years thanks to improvements maternal health and advances in fighting HIV/AIDS, malaria, and other diseases.[28] In the early 19th century, life expectancy began to increase in the industrialized countries while it remained low in the rest of the world.[29] This led to significant disparities in health outcomes across the world: good health in wealthier countries and persistently bad health in poorer countries. Recent decades have seen rapid improvement in health outcomes. Since 1990, preventable child deaths have declined by more than 50 percent globally. Maternal mortality has also fallen by 45 percent worldwide. New HIV/AIDS infections fell by 30 percent between 2000 and 2013, and over 6.2 million lives were saved from malaria. Since 1900 the global average life expectancy has more than doubled and is now approaching 70 years.

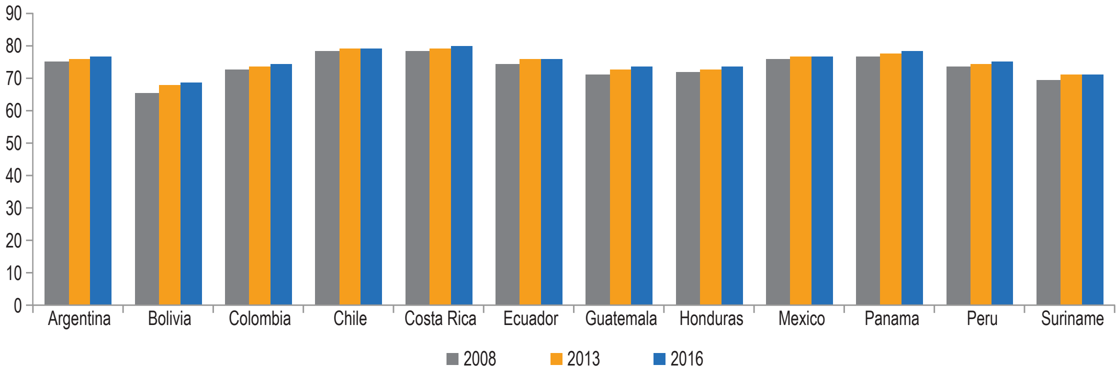
In the LAC region, life expectancy has increased because of improved health and economic conditions. Between 2008 and 2016, life expectancy at birth increased on average by 2 percent. In Bolivia and Guatemala, it increased by 6 percent and 4 percent, respectively (Figure 3.3).

IMPACT

Investments and innovations in IoT have introduced new communication systems that integrate health in those activities for which constant connectivity is guaranteed.

[28] http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-3-good-health-and-well-being.html.
[29] https://ourworldindata.org/life-expectancy.

FIGURE 3.3. Life Expectancy at Birth (years)



Source: Frontier Economics based on World Bank data.

The Organisation for Economic Co-operation and Development (OECD, 2010) notes that innovations in health care have given doctors new resources to improve their patients' health. Real-time patient monitoring can provide doctors with real-time data on patients' health situation, thus reducing costs, saving time, and supporting improved diagnostics.

The use of IoT technology to monitor and manage human health and fitness is expanding rapidly, with 130 million consumers worldwide estimated to use fitness trackers today (McKinsey, 2015). IoT health solutions have been successfully adopted in the LAC region, especially in Chile, Colombia, and Brazil (ICT Intelligence Service Americas, 2018). In the Dominican Republic, one of the LAC countries with the highest rate of maternal and neonatal deaths, IoT sensors monitoring up to 20 biometric parameters are used to detect preeclampsia pregnancy disorder and thus reduce infant mortality.[30] In Mexico, IoT applications have been used in physical rehabilitation.[31] Moreover, internet connections can provide online medical care in the most inaccessible rural areas (OECD, 2010). Access to information improves prevention by providing education on hygiene, thereby reducing the probability of contracting an infectious disease.

This study found evidence that investment in the mobile and fixed telecom sectors have a positive and significant impact on life expectancy within countries. Specifically, a 1 percent increase in mobile investment increases life expectancy by 0.0145 percent, whereas an increase of 1 percent in fixed telecom investment increases life expectancy by 0.0022 percent, if all other variables are kept fixed. Finally, an increase of 1 percent in total telecom investment increases life expectancy by 0.0095 percent, ceteris paribus. In relative terms, a marginal increase in mobile investment would have a very similar impact on life expectancy as a marginal increase in investment in utilities.

SDG 4: Quality Education

4 QUALITY EDUCATION

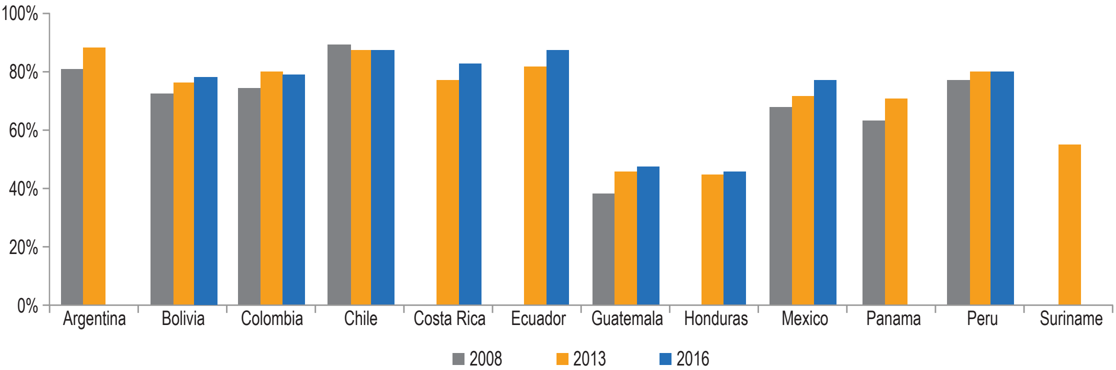
The contribution of education to development goals can be analysed from different angles. A first approach to education conceptualizes it as building human capital.[32] Education is an investment that creates skills and helps workers acquire knowledge that allows them to be more productive,

[30] http://www.libelium.com.

[31] http://www.libelium.com/mysignals-brings-physical-rehabilitation-to-people-with-disabilities-in-mexico-partnering-with-kinnov/.

[32] In the theory pioneered by economists Gary Becker and Theodore Schultz in the 1960s.

FIGURE 3.4. Net Enrolment of Girls in Secondary School (percent)



Source: Frontier Economics based on data from ECLAC.

thereby earning a higher wage.[33] The human capabilities approach developed by the economist Amartya Sen (Walker, 2005) moves beyond the human capital approach by linking development, quality of life, and freedom. Indeed, the UN specifically affirms in relation to SDG 4 that "obtaining a quality education is the foundation to improving people's lives and sustainable development."[34]

In general, there has been major progress toward increasing access to education at all levels and increasing enrolment rates in schools. For example, in the LAC region, net secondary enrolment of girls increased by 18 percent[35] on average between 2008 and 2016. Guatemala and Suriname[36] experienced growth of 24 percent and 27 percent, respectively (Figure 3.4).

There is a positive relationship between digital applications and infrastructures and quality education (ITU, 2017b). Access to connectivity and technology plays a vital role in enabling new educational opportunities. Mobile communication services already create opportunities for disadvantaged, low-income people, especially in less developed countries. Access to online educational platforms reduces one of the most important barriers to achieving universal quality education: lack of access to educational materials (Vodafone and Arthur D. Little, 2016). Apart from the Instant Schools for Africa, Vodafone also has e-schools in South Africa to provide learners ages 5 to 18 with access to free quality education at any time and from any place through a smartphone, tablet, or computer.

Fixed and mobile coverage are thus crucial for education. Digital investment in network coverage in rural areas allows local students to have access to the information available on the internet, attend online courses, and connect with other students in the same area. It provides affordable access to online learning services and enables access to primary and secondary schools in rural areas (GSMA, 2017).

In addition, schools that invest more in digital infrastructure can provide better quality education using new software updates or through media content. Digital infrastructure thus contributes to the

[33] https://www.econlib.org/library/Enc/HumanCapital.html.
[34] https://www.un.org/sustainabledevelopment/education/.
[35] Weighted average of the indicator and population for all the countries in the study less Suriname where there are not data available for 2008.
[36] In the case of Suriname, the year-over-year increase was calculated using data from 2009 to 2015.

increase in the availability of digital literacy content for primary and secondary education and improves the quality of this content (i.e., by providing more up-to-date teaching material) (GSMA, 2017).

This study evidences that investment in the mobile telecom sector has a positive and significant impact on the secondary net enrolment rate within countries. Specifically, an increase of 1 percent in mobile investment increases the secondary net enrolment rate by 0.031 pp, if all other variables are kept fixed.

SDG 5: Gender Equality

Gender inequality deprives women and girls of their basic rights and opportunities. Moreover, according to the UN, gender equality is not only a fundamental human right, but a necessary foundation for a peaceful, prosperous, and sustainable world, since providing women and girls with equal access to education, health care, decent work, and representation in political and economic decision-making processes will fuel sustainability and benefit economies.[37]

Gender equality is a broad objective. The multiple dimensions of discrimination cannot be measured with a single indicator. Women continue to suffer from discrimination in areas such as physical violence, unpaid domestic and caregiving work, and lack of representation in high positions in the government. Some of these areas have seen improvements. For example, the proportion of women in parliament increased from 13 percent in 2000 to around 23 percent by 2017 (United Nations, 2018). However, there are still areas which need to be improved. For example, according to the UN Division for Sustainable Development Goals,[38] in 2017 around 21 percent of women between 20 and 24 years were married or in an informal union before age 18.

This study attempted to capture multiple areas of discrimination. It includes as indicators the proportion of women in parliament and net enrolment of girls in secondary education. Education is a fundamental mean through which women can achieve equal opportunity. Education allows women to find fulfilling jobs that grant them economic independence. Education also changes social and cultural norms and values that help liberate women from traditional roles.

Although not in all countries, the percentage of women in parliament in the LAC region increased dramatically between 2008 and 2017 (on average by 47 percent).[39] In Bolivia, Colombia, and Mexico, it increased by 214 percent, 122 percent, and 84 percent, respectively. This indicates a significant change in cultural norms and in women's role in society (Figure 3.5).

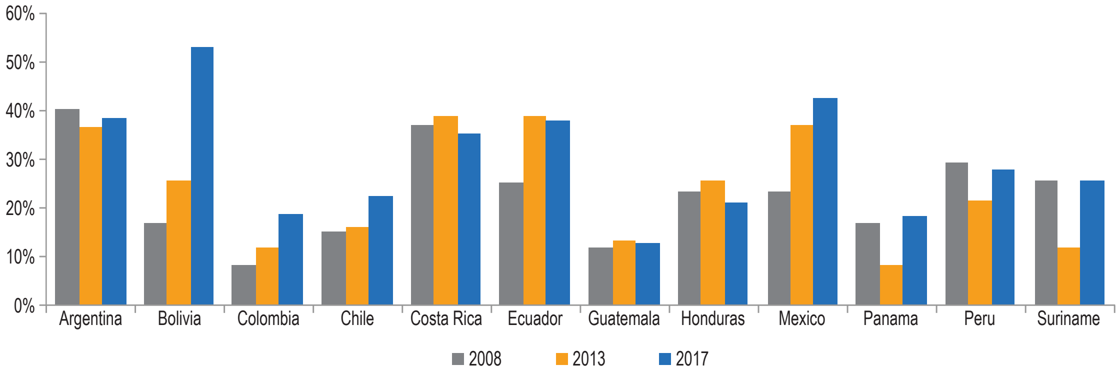
At the same time, as mentioned above, the net percentage of girls enrolled in secondary school in 2016 increased by 18 percent on average in the LAC region over 2008. Guatemala and Mexico improved the most in this regard, increasing 24 percent and 12 percent, respectively (Figure 3.6).

IMPACT

Access to information about the role of women in urban areas or in other countries where women are more empowered can promote gender equality and be a tool to empower women in communities.[40] Access to cable television has been found to help shape attitudes about gender roles and to change society's perception of women's role. The introduction of cable television is associated with improvements in women's status in India, including an increase in reported autonomy, a decrease in the reported acceptability of beatings, a decrease in reported preference for male children, an increase in female school enrolment, and a decline in

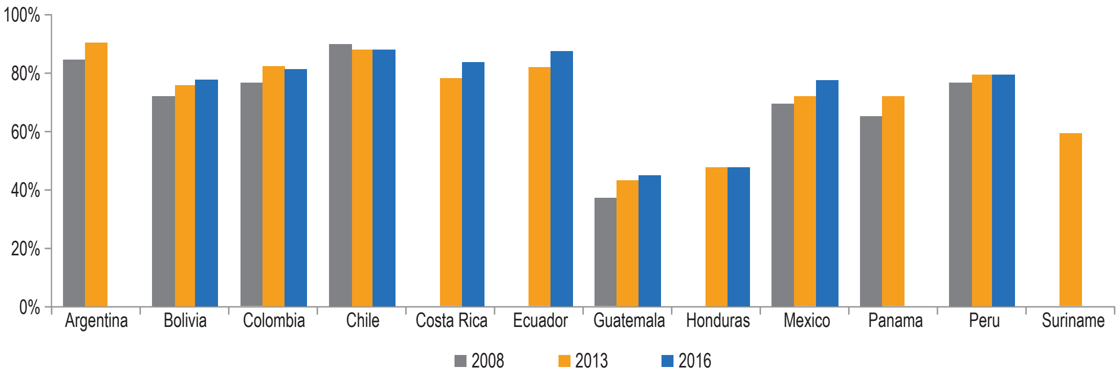
[37] https://www.un.org/sustainabledevelopment/gender-equality/.
[38] https://sustainabledevelopment.un.org/sdg5.
[39] Weighted average of the indicator and population for all the countries in the study.
[40] http://www.unwomen.org/en/news/stories/2017/7/reshaping-the-future-icts-and-the-sdgs.

FIGURE 3.5. Percentage of Women in Parliament



Source: Frontier Economics based on World Bank data.

FIGURE 3.6. Net Enrolment of Girls in Secondary School (percent)



Source: Frontier Economics based on data from CEPAL.

fertility (Jensen and Oster, 2007). Cable TV has been found to have a positive effect on gender equality also in Brazil. Exposure to soap operas, or *telenovelas,* provides women with alternative models of roles they might play in society both in the workplace and in relationships (Kottak, 1990; La Pastina, 2004; Pace, 1993). To sum up, television can change the framework of social interactions, increasing general world knowledge and changing people's perceptions of the role of women.

On the first indicator, this study finds evidence that investment in the fixed telecom sector has had a positive and significant impact on the proportion of seats held by women in national parliaments within countries. This is consistent with the evidence on the impact of cable television explained above. In particular, the analysis finds that a 1 percent increase in investment in fixed telecom infrastructure increases the proportion of seats held by women in national parliaments by 0.0221 pp. Total telecom investment also has a significant impact: an increase of 1 percent in total telecom investment increases women's presence in parliament by 0.0642 pp, *ceteris paribus.*

With respect to the education dimension, this study finds that investment in the mobile telecom sector has a positive and significant impact on achievement of SDG 5. A 1 percent increase in mobile investment increases the percentage of girls in secondary school by 0.0294 pp.

SDG 6: Clean Water and Sanitation

Safe water and adequate sanitation are indispensable for healthy ecosystems, reducing poverty, and achieving inclusive growth, social well-being, and sustainable livelihoods.[41] Water scarcity, poor water quality, and inadequate sanitation negatively impact food security, worsening hunger and malnutrition and reducing livelihood choices and educational opportunities for poor families across the world. The lack of clean water and proper sanitation facilities causes millions of people, most of them children, to die every year from diseases associated with inadequate water supply, sanitation, and hygiene.

In the LAC region, between 2008 and 2015, the proportion of the population that used improved sources of water supply (as defined by ECLAC) increased on average by 3 percent. Bolivia and Honduras experienced the highest growth, at 5 percent each (Figure 3.7).

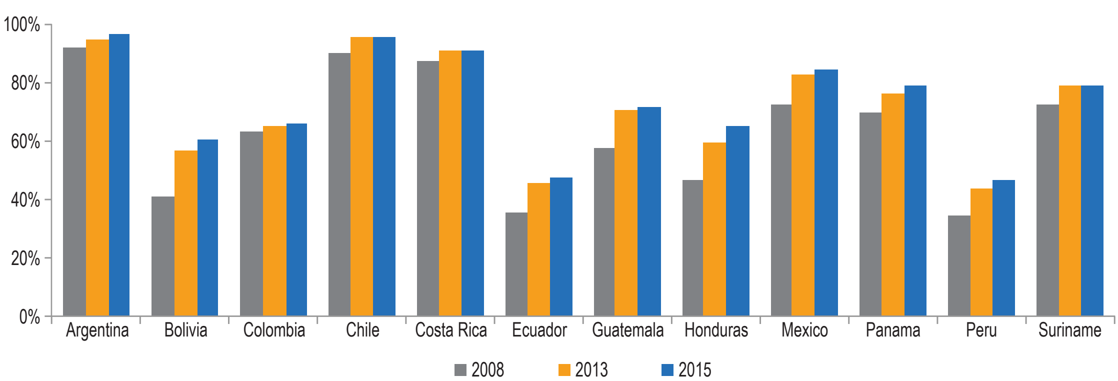
Similarly, in the LAC region, between 2008 and 2015, the proportion of the population that used improved sanitation facilities increased on average by 5 percent. Bolivia and Honduras experienced the highest growth, at 12 percent and 11 percent, respectively (Figure 3.8).

IMPACT

Digital applications and infrastructure are important tools to efficiently manage and monitor water consumption both in household and agricultural settings, especially through the IoT (ITU, 2018). In the context of ageing or insufficient water infrastructure leading to burst pipes and pipe leakages, smart water infrastructure can improve drainage or water supply plans, leakage detection services, network performance optimization, and geographic information system (GIS) management. For example, a smart water project (iWesla) developed in Spain aimed to optimize water consumption efficiency and safety and save up to 50 percent of water consumption (and related costs) thanks to the detection of abnormal water consumption.[42] Sensors detect overconsumption and alert the

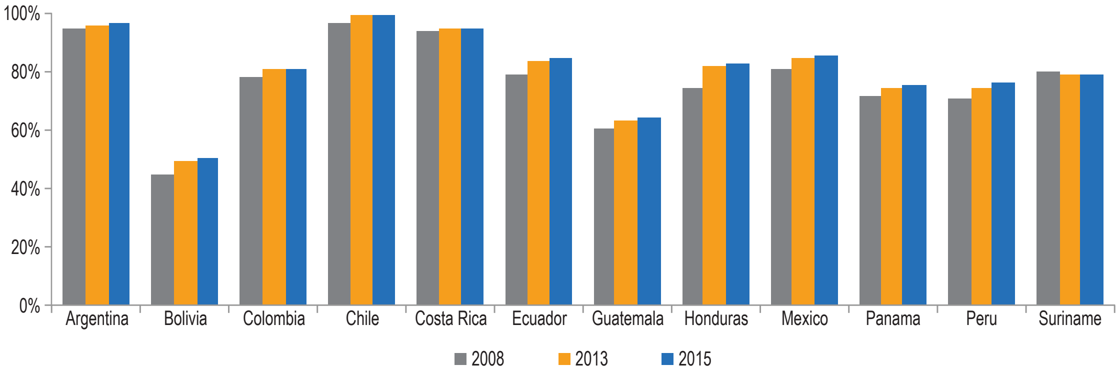
[41] https://www.un.org/sustainabledevelopment/water-and-sanitation/.
[42] http://www.libelium.com/saving-water-with-smart-management-and-efficient-systems-in-spain/.

FIGURE 3.7. Proportion of the Population that Used Improved Sources of Water Supply



Source: Frontier Economics based on data from ECLAC.

FIGURE 3.8. Proportion of the Population that Used Improved Sanitation Facilities



Source: Frontier Economics based on data from ECLAC.

user using alarms. Apart from the reduction in the water consumption, this early detection can lead to the reduction of potential damage caused by leaks or open taps.

In LAC countries, the application of the IoT for the efficient use of water is still in an early phase. In Chile, Telefonica, Huawei, and Kampstrump kicked off a project with the main water utility company to achieve more efficiency in water consumption through the application of NarrowBand IoT technology. This technology helps save water by measuring daily residential demand, detecting water leaks, and having updated information about the water supply that reaches final customers.[43] In the municipality of Olaya, in Antioquía, Colombia, IoT technology is being applied to the potabilization system. It helps to control water parameters, guaranteeing that consumers have access to potable water throughout the day and preventing water leakage.[44] There is still, however, a long way to go to develop digital capacity to achieve a more efficient use of water in LAC countries.

SDG 7: Affordable and Clean Energy

7 AFFORDABLE AND CLEAN ENERGY

Energy is fundamental for most activities in today's world. That is why it is crucial to increase energy efficiency and to increase the use of renewable energy such as solar, wind, and thermal.[45] Expanding infrastructure and upgrading technology to provide clean energy in all developing countries is a key goal that can contribute to job creation. It can also help the environment by reducing greenhouse gas (GHG) emissions, environmental degradation, and natural resource depletion.[46]

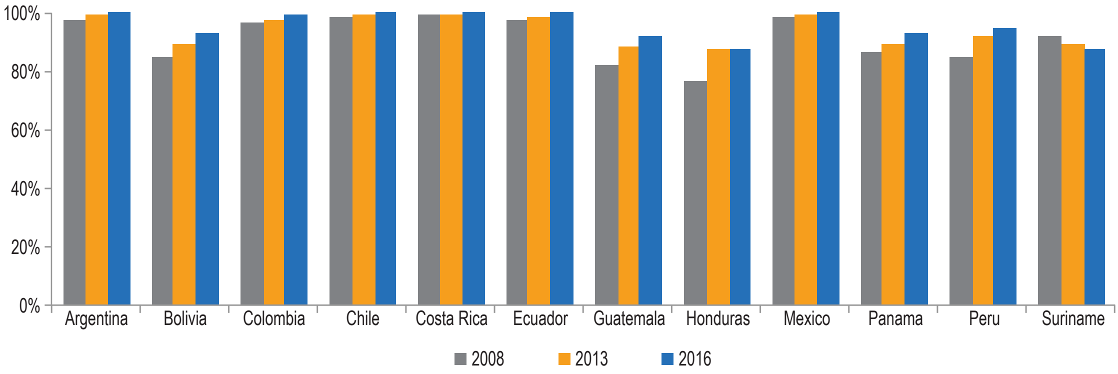
Between 1990 and 2010, the number of people with access to electricity increased by 1.7 billion. In LAC, the percentage of the population with access to electricity increased on average by 5 percent between 2008 and 2016. This increase was highest in Honduras, Guatemala, and Peru: 15 percent, 12.2 percent, and 12 percent, respectively (Figure 3.9).

IMPACT

Digital applications and investments can address the lack of enough clean energy by decreasing the energy intensity of sectors.

[43] https://www.networkworld.es/colaboracion/primer-proyecto-con-tecnologia-narrowband-iot-en-latinoamerica.
[44] https://telemetrik.co/project/primer-acueducto-regional-tecnologia-iot-colombia/.
[45] https://www.un.org/sustainabledevelopment/energy/.
[46] http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-7-affordable-and-clean-energy.html.

FIGURE 3.9. **Access to Electricity (percent of population)**



Source: Frontier Economics based on World Bank data.

For example, smart grids and smart logistics can promote energy efficiency by reducing energy consumption and transportation (Youngman, 2012). Specifically, smart meters that record consumption of electric energy aim to provide households with a user-friendly tool that improves awareness of energy consumption/use behavior in homes, enabling better management via the visualization of consumption, especially for low-income households (Podgornik et al., 2013). An effective metering and monitoring system can generate an immediate energy saving of 10 percent, and 30 percent over the long run.[47] Research has found that IoT applications could increase this impact: connected washers and dryers (working with smart meters installed by utility companies) could get information about energy prices to delay cycles during peak energy consumption periods. IoT technology could also collect useful information for generator companies that could help them reduce costs and achieve more energy efficiency (McKinsey, 2015).

The LAC region is beginning to digitalize energy use. An interesting case in point is a Chilean hydroelectric company, Enel Green Power, that is using IoT technology. With wireless weather sensors, it is collecting significant amounts of data (even in remote areas where there is scant access), which enables it to reduce costs and increase energy efficiency.[48] In Mexico, Siemens has introduced the first digitalization systems that allow it to optimize the use of electricity while reducing emissions of contaminated gasses.[49] Regarding smart electricity meters, which help households control and reduce power usage, Chile and Colombia are leading the adoption rates in the region.[50] All these projects are evidence of progress in energy saving and in the reduction of pollution during energy generation, thanks to the development of digital capacities in LAC.

SDG 8: Decent Work and Economic Growth

In general, the SDGs promote sustained economic growth, higher levels of productivity, and technological innovation. Encouraging economic growth is key to eradicating poverty, hunger, and reducing inequality.

[47] https://blog.schneider-electric.com/energy-management-energy-efficiency/2016/08/04/smart-meters-key-achieving-high-efficiency-buildings/.
[48] https://www.enelgreenpower.com/es/historias/a/2018/07/energia-hidroelectrica-egp-reto-de-la-innovacion.
[49] http://yucatan.com.mx/economia/industria/siemens-trae-mexico-sistemas-digitalizacion-cogeneracion-energetica.
[50] https://iot.telefonica.com/blog/m^{2}m-and-utilities-in-latin-america.

Before the 2008–09 financial crisis, in the least developed countries, per capita income growth accelerated from 3.5 percent in 2000–2004 to 4.6 percent in 2005–2009. However, after the crisis, overall average annual GDP growth in the least developed countries fell from 7.1 percent in 2005–2009 to 4.9 per cent in 2010–2015. The LAC region followed a similar trend, although to a lesser degree. While in the period 2000–2010 the region had an average growth rate of 4 percent, in the period 2010–2017 it slowed to 3.5 percent. Nevertheless, it is important to highlight that between 2008 and 2017, total GDP in the LAC region increased by 25 percent, an average growth of 34 percent per country, with Peru and Bolivia showing the highest rates of growth (72 percent and 53 percent, respectively) (Figures 3.10 and 3.11).

IMPACT

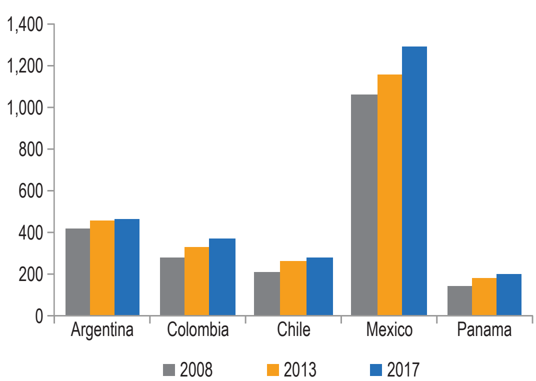
The impact of digital applications and infrastructure on economic growth and productivity has been long recognized. The tremendous growth in labor productivity in the United States since 1995 triggered a vast literature on the impact of digital technologies on the economy. Researchers tried to explain the difference in U.S. and European productivity growth rates by focusing on investment in ICT assets (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000). A similar impact on economic growth is now being assigned to the IoT: Frontier (Frontier Economics, 2018) estimates that a 10 percent increase in M2M connections would generate an increase in GDP of US$370 billion in Germany and US$2.26 trillion in the United States between 2018 and 2032. Similarly, 5G is expected to enable a global output of US$12.3 trillion globally by 2035 (4.6 percent of all real global output in that year) (IHS Economics and IHS Technology, 2018).

As the previous research underlines, digital infrastructure can impact the economy directly and indirectly:

- Direct impact. The development of ICT and IoT may lead to an increase in capital spending, as firms invest to take advantage of the new technology. Investment in ICT and IoT thus translates into a direct positive boost to GDP growth.
- Indirect impact. The development of ICT and IoT may also increase productivity and foster economic growth indirectly. Since technological investment increases the quality of capital and the skills of the average worker, innovation enables increased efficiency and improved productivity. In other words, technology and innovation increase multi-factor productivity, thus reflecting the greater efficiency with which labor and capital inputs are used together in the production process.

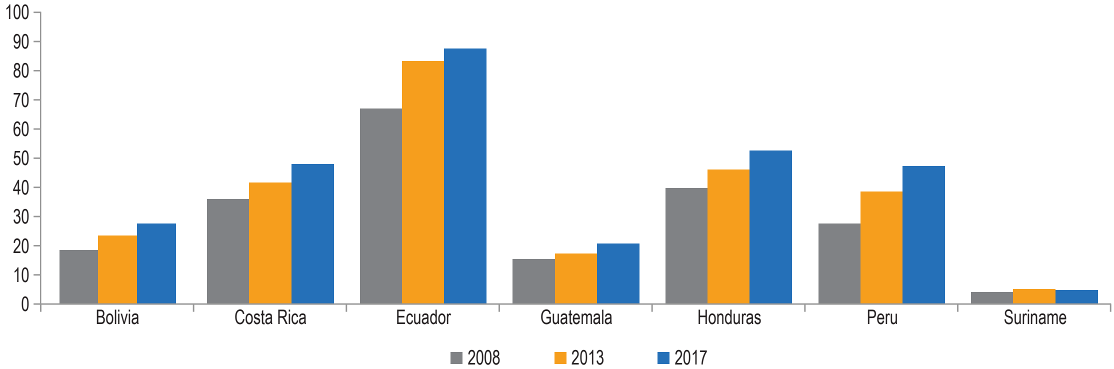
The ITU (2017b) highlights three main effects of ICT investment on economic growth and employment. First, the construction effect: the construction of a mobile and/or fixed network, as well as of data centers, directly and indirectly leads to an increase in employment, and thus of household income (which, in turn, can lead to more employment). Second, the spillover effect: fixed and mobile networks enable demand and thus increase market opportunities for businesses, thereby increasing economic

FIGURE 3.10. GDP Growth in Larger LAC Countries (billions of constant 2010 US$)



Source: Frontier Economics based on World Bank data.

FIGURE 3.11. **GDP Growth in Smaller LAC Countries (billions of constant 2010 US$)**



Source: Frontier Economics based on World Bank data.

growth and work opportunities. Third, the innovation effect: ICT research and development (R&D) leads to the development of new products and processes that can increase employment as well as productivity.

This study finds that investment in both the fixed telecom and mobile sectors have a positive and significant impact on GDP. Specifically, an increase of 1 percent in mobile investment increases GDP by 0.097 percent, if all other variables are kept fixed. Likewise, a 1 percent increase in fixed telecom investment leads to an increase in GDP of 0.023 percent, if all other variables are kept fixed. An increase of 1 percent of total telecom investment is associated with an increase in GDP of 0.09 percent.

SDG 9: Industry, Innovation, and Infrastructure

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Investment in infrastructure and innovation is a crucial driver of economic growth and development. With over half the world population now living in cities, mobile and fixed broadband networks, mass transportation, and renewable energy are becoming ever more important, as are the growth of new industries and ICT.[51]

Investment in digital applications and infrastructure can drive innovation as well as productivity. Two metrics were chosen for this study to measure innovation: R&D expenditure and number of trademark applications. R&D expenditure is critical to ensure innovation, economic growth, and development, but it is an indirect measure; the number of trademark applications is a direct measure of innovation.

Since 2000, the world's R&D expenditure has increased slightly, from 1.5 to 1.7 percent of GDP.[52] Although R&D expenditure in the LAC region as a percent of GDP has historically been low, it increased by 18 percent on average between 2008 and 2014 (with Ecuador and Costa Rica showing the highest growth, at 94 percent and 48 percent, respectively) (Figure 3.12).

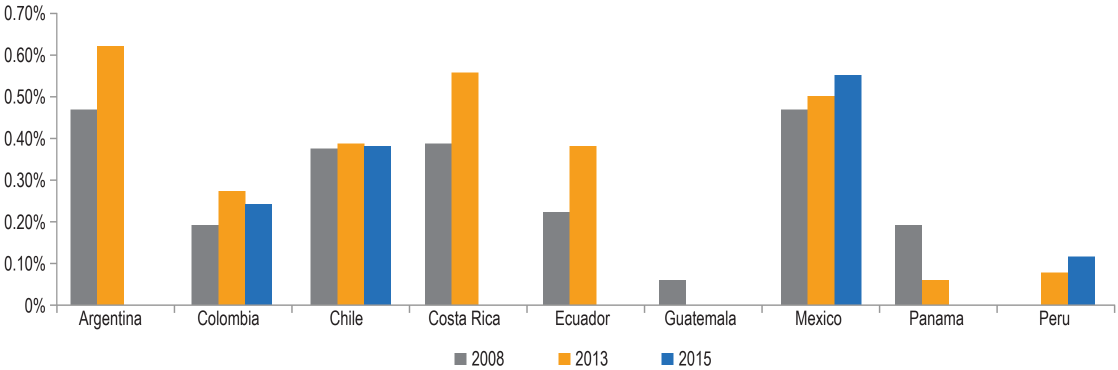
Trademark applications in the LAC region have increased by 28 percent[53] since 2008. Mexico, Suriname, and Bolivia have seen the largest growth with 55, 35, and 32 percent, respectively (Figure 3.13).

[51] http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-9-industry-innovation-and-infrastructure.html.

[52] https://sustainabledevelopment.un.org/sdg9.

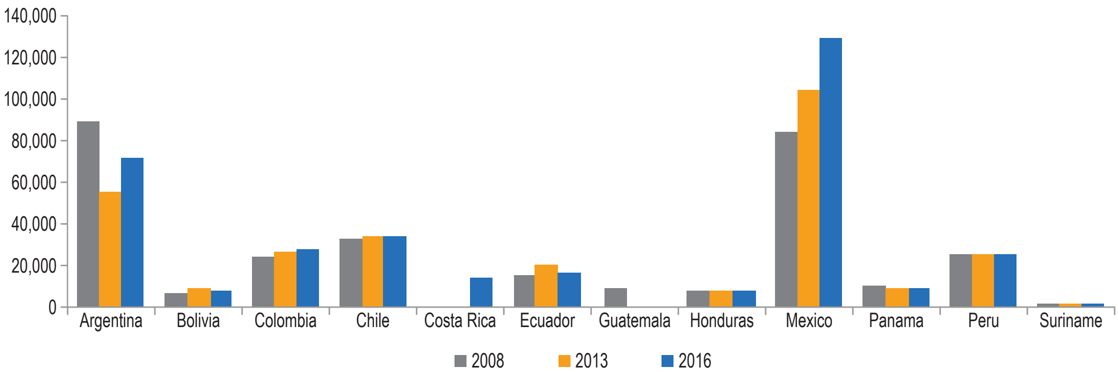
[53] Weighted average of the indicator and population for all the countries in the study.

FIGURE 3.12. R&D Expenditures (percent of GDP)



Source: Frontier Economics based on World Bank data.

FIGURE 3.13. Total Trademark Applications (number)



Source: Frontier Economics based on World Bank data.

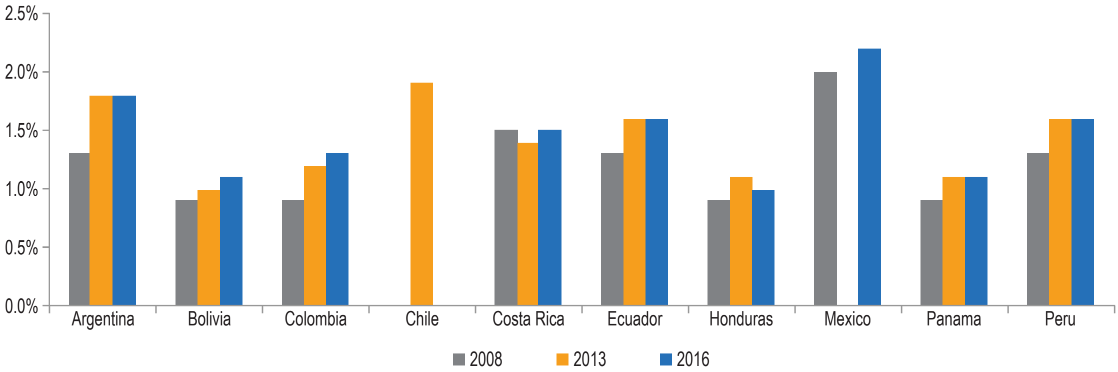
IMPACT

Investment in digital technology supports domestic technology development, research, and innovation in developing countries. ICT upgrades the technological capabilities of industrial sectors in developing countries by encouraging innovation and substantially increasing public and private R&D spending. There are many examples of how innovation in digital applications and investments can improve energy and water systems infrastructure (smart grids, smart buildings), reduce GHG emissions (through more energy-efficient appliances and lower transportation costs), and foster innovation by developing new products and expanding employment opportunities.

This study finds evidence that investment in the telecom sector may have a positive impact on R&D expenditure as a percent of GDP. However, the coefficients of the analysis are not significant,[54] which is not surprising given the relatively low level of R&D expenditure in the LAC region as a percent of GDP.

[54] This may be attributed to the limited amount of data available across year for each country, which reduces the sample of the panel data to 44 observations for 7 countries. See Annex C.

FIGURE 3.14. Share of Income Earned by Lowest 10 Percent Income Group



Source: Frontier Economics based on World Bank data.

By contrast, the study found evidence that investment in the telecom sector has a positive and significant impact on trademark applications. Specifically, an increase of 1 percent in total telecom investment increases trademark applications by 0.12 pp, ceteris paribus. Moreover, an increase of 1 percent in investment in fixed telecom infrastructure increases trademark applications by 0.06 percent.

SDG 10: Reduced Inequalities

According to the UN, economic inequality refers to how economic variables are distributed among individuals, in a group, among groups, in a population, or among countries.[55] This concept is at the heart of social justice theories. This study focuses on inequality of outcomes in material dimensions of well-being (e.g., level of income, educational attainment, health status) and that may be the result of circumstances beyond one's control (e.g., ethnicity, family of origin, gender).[56]

The inequalities within LAC countries have decreased in recent years. Figure 3.14 show that the income share held by the lowest 10 percent income group has increased on average between 2008 and 2016 by 22 percent, while the income share held by the lowest 20 percent income group has increased by 17 percent (Figure 3.15). Only Costa Rica experienced an increase in inequality, with a decrease of 2 percent of the income share held by the lowest 20 percent (while the income share of the lowest 10 percent remained constant).

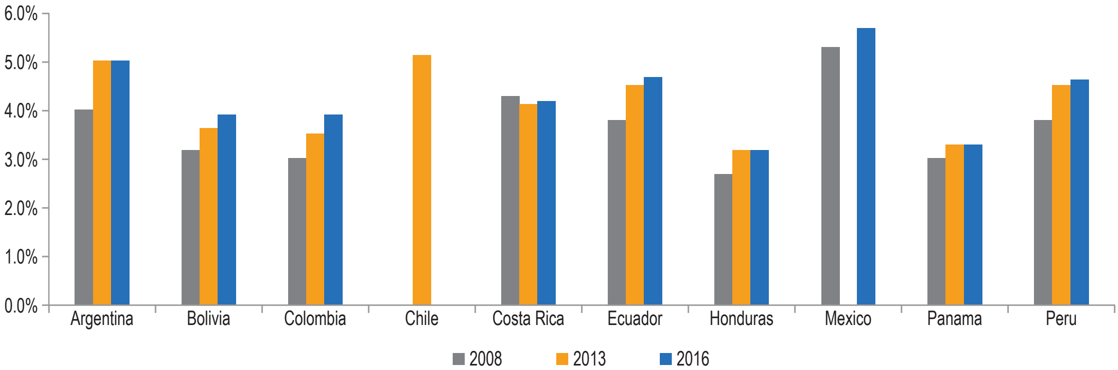
IMPACT

Given the findings described above, telecom investments could provide an opportunity to reduce poverty and income inequality (ITU, 2017c). Telecom investments are crucial in connecting unconnected areas, thus providing less developed countries and rural communities with new work opportunities and free access to knowledge (as underlined for SDG 4).

This study finds evidence that investment in the fixed and mobile telecom sectors has a positive and significant impact on the level of inequality within countries. Specifically, an increase of 1 percent in mobile telecom investment increases the income share held by the lowest 10 percent by 0.001 percent and the lowest 20 percent by 0.0019 percent. A

[55] http://www.un.org/en/development/desa/policy/wess/wess_dev_issues/dsp_policy_01.pdf.
[56] There is also a view concerned with inequality of opportunities, which focuses only on circumstances beyond one's control that affect potential outcomes, such as unequal access to employment or education.

FIGURE 3.15. Share of Income Earned by Lowest 20 Percent Income Group



Source: Frontier Economics based on World Bank data.

1 percent increase in fixed telecom investment leads to an increase in the income share held by the lowest 10 percent by 0.0004 percent. Finally, a 1 percent increase in investment in telecom infrastructure is associated with an increase in the income share held by the lowest 10 percent of 0.0014 and the lowest 20 percent by 0.0027 percent. In relative terms, a marginal increase in digital infrastructure investment would have as much impact as a marginal increase in expenditure in utilities on increasing the share of income of the bottom decile in the LAC region.

SDG 11: Sustainable Cities and Communities

11 SUSTAINABLE CITIES AND COMMUNITIES

Sustainable cities are urban areas where citizens enjoy a good quality of life. This includes enjoying economic prosperity and work opportunities, urban safety, good infrastructure, access to safe and affordable housing, and good sanitation and water supplies. A sustainable city also manages land and resources in a balanced way. These characteristics are increasingly important since more than half of the world's population lives in urban areas.[57] In 2014, there were 28 megacities, home to 453 million people. By 2050, that figure will have risen to 6.5 billion people—two-thirds of all humanity.

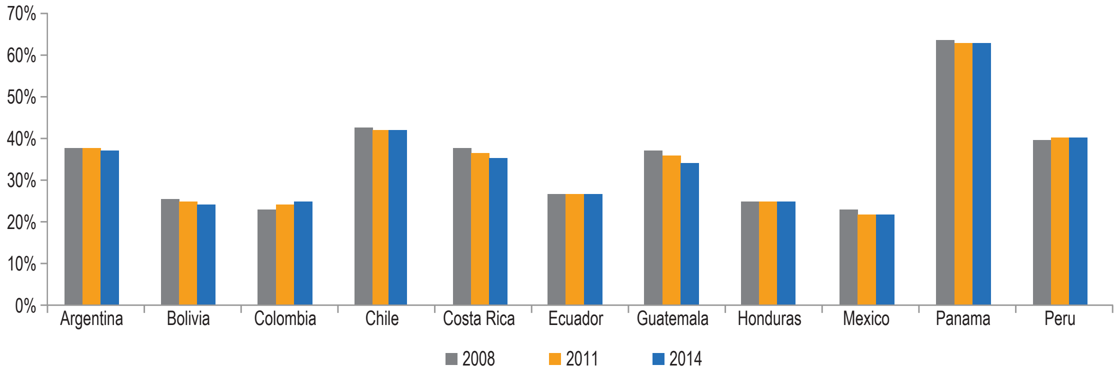
The proportion of the population living in the largest LAC cities has been decreasing, on average, by 2 percent per year between 2008 and 2015. Nonetheless, it remains one of the regions with the highest share of urban population (81 percent of the population lives in urban areas).[58] The LAC region is also one of the most unequal regions in the world in terms of income distribution, which challenges the possibility of achieving sustainable cities for issues such as growing slums.[59]

Figure 3.16 shows that for the 12 countries studied, the percentage of the population living in the largest cities is above 60 percent for Panama, and around 40 percent for Argentina and Peru. Except for Colombia, Honduras, and Peru, the percentage of the population living in the largest cities is declining at different rates.

Investments in digital infrastructure play an important role in achieving and maintaining sustainable cities. By fostering economic growth,

[57] http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-11-sustainable-cities-and-communities.html.
[58] In the countries studied, this percentage ranges from 52 percent in Guatemala to 92 percent in Argentina.
[59] https://www.iddri.org/en/publications-and-events/document-de-travail/sustainable-cities-latin-america.

FIGURE 3.16. Percentage of the Population Living in the Largest Cities



Source: Frontier Economics based on World Bank data.

digital infrastructure contributes to economic growth and job creation. It also helps to connect citizens and to provide them with quick, up-to-date information to better manage their time. Therefore, digital infrastructure improves people's quality of life. By developing digital capabilities, cities accelerate their safe and sustainable development.

The various channels through which digital infrastructure contributes to sustainability are well documented. The Sustainable Cities Index (2018)[60] has identified ICT as a key metric to measure the progress of cities toward this SDG.[61] This multidimensional index ranks cities according to their level of sustainability in the social, environmental, and economic realms. It is organized around three pillars, or sub-indices: people, planet, and profit. The first pillar, people, refers to social mobility and citizens' quality of life. The second pillar, planet, covers the management of energy use, emissions, and pollution. The third pillar, profit, covers economic performance and the business environment.

Each sub-index is a weighted average of various indicators. Each one includes at least one indicator related to the digital capabilities of the city. Under the "people" pillar, indicators include the availability of mobile transportation applications, the cost of broadband connections, digital public services, and availability of free wi-fi. Under the "planet" pillar, an indicator captures whether the city is equipped with digital early warnings for natural disasters. In the "profit" pillar, indicators include mobile and broadband connectivity and internet speeds.

In this study, Buenos Aires, Lima, Mexico City, and Santiago are part of the "evolutionary cities" group. With respect to digital capabilities, this group performs rather poorly, which strongly limits their overall performance in sustainability. Out of 100 cities (with 1 being the best and 100 the worst), they all rank between the 77th and 85th positions.

SDG 12: Responsible Consumption and Production

According to the United Nations Development Programme (UNDP), reducing the ecological footprint is a necessary step to achieve sustainable development.[62] Reducing

[60] https://www.arcadis.com/en/global/our-perspectives/sustainable-cities-index-2018/citizen-centric-cities/.
[61] https://www.weforum.org/agenda/2016/09/these-are-the-world-s-most-sustainable-cities/.
[62] http://www.latinamerica.undp.org/content/rblac/en/home/sustainable-development-goals/goal-12-responsible-consumption-and-production.html.

the ecological footprint means achieving sustainable consumption and production of resources by minimizing the use of natural resources, toxic materials, and emissions of waste and pollutants, while satisfying basic consumption needs.[63] As agriculture is one of the most water-consuming economic activities worldwide, significant changes will be needed to achieve this SDG. This will be increasingly challenging because the demand for food rises as the world population increases. Research by the Food and Agricultural Organization (FAO) suggests that by 2050 food production must increase by 70 percent to feed the world's 9.6 billion people.

IMPACT

Technology and newer IoT solutions in agriculture play a crucial role in improving the quantity and the quality of harvests. Since unpredictable weather conditions can affect crops and reduce yields, digital applications and infrastructure tools aid farmers to adjust their decisions on when to plant and which crop varieties to choose to achieve higher productivity. Moreover, they predict the optimal amount of water and agrochemicals that are necessary, contributing to a more sustainable agriculture.[64] They can also help monitor consumption and understand consumption patterns to raise awareness about the risk of unsustainable production and consumption of soil.

Because LAC economies rely heavily on agriculture, digital solutions in the agriculture sector may be especially important for their sustainable development. For example, Colombia, one of the largest exporters of bananas worldwide, is developing a smart farming project using remote sensors in the plantations. Monitoring different climatic conditions optimizes water usage, prevents plagues and diseases, and reduces consumption of fertilizers. These measures will significantly increase productivity and ensure that the largest banana-exporting country in the world achieves a sustainable production model.[65]

Colombia is also involved in a smart agriculture project with Honduras. From 2013, more than ten private and public organizations in both countries are participating in the project. They are providing about 300,000 farmers (most of them growing beans, maize, rice, coffee, and fruit trees) with digital applications to make climate-smart decisions. This project contributes to biodiversity by reducing the chances of soil erosion and achieving a more sustainable agriculture. It will also increase farmers' net income and food security by reducing crop loss.[66] Research shows that in Cordoba, Colombia, this project helped prevent a loss of 1800 hectares of irrigated rice, saving US$3.5 million in input costs in 2017.[67]

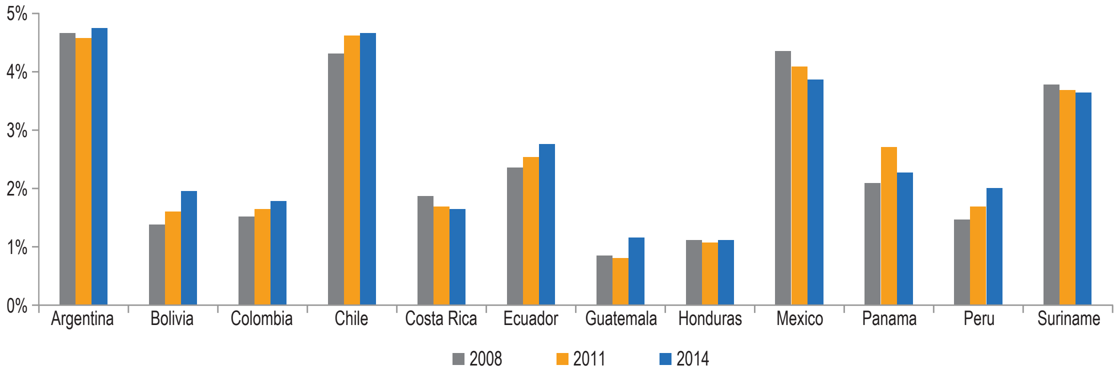
SDG 13: Climate Action

GHG emissions are continuing to rise, especially in developing countries, and are now more than 50 percent higher than their 1990 level.[68] Global warming is causing lasting changes to our climate system. Annual average losses from tsunamis, tropical cyclones, and flooding amount to hundreds of billions of dollars, requiring an investment of US$6 billion annually in disaster risk management alone.

CO_2 per capita has increased in most LAC countries since 2008 (Figure 3.17). However, some countries have managed to reduce CO_2 per capita. For example, Costa Rica and Suriname have decreased

[63] https://sustainabledevelopment.un.org/content/documents/LAC_background_eng.pdf.
[64] https://unfccc.int/climate-action/momentum-for-change/ict-solutions/icts-for-small-scale-farmers-a-game-changing-approach-to-climate-smart-agriculture-in-latin-america.
[65] http://www.libelium.com/improving-banana-crops-production-and-agricultural-sustainability-in-colombia-using-sensor-networks/.
[66] https://unfccc.int/climate-action/momentum-for-change/ict-solutions/icts-for-small-scale-farmers-a-game-changing-approach-to-climate-smart-agriculture-in-latin-america.
[67] https://publications.iadb.org/handle/11319/8966.
[68] http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-13-climate-action.html.

FIGURE 3.17. **CO_2 per Capita (metric tons)**



Source: Frontier Economics based on World Bank data.

per capita CO_2 by an average of 11 percent while the rest of the countries analyzed have increased their CO_2 emissions per capita.

Digital technology and investments can help reduce GHG emissions through more efficient energy, transportation, building, and industrial processes (European Parliament, 2009). ICT system can help monitor emissions from factories, producing real-time data on energy consumption and reducing energy consumption by buildings, as discussed in relation to SDG 7. For example, the Athens airport deployed an IoT platform to monitor air quality and reduce air pollution.[69] Air quality monitoring has also been used to reduce the environmental impact of logistics in ports.[70] Moreover, ICT reduces GHG emissions by substituting material products with virtual ones: using electronic books, for example, emits less GHG than using paper.

This study finds evidence that investment in both the fixed and the mobile sectors has a negative effect on CO_2 emissions per capita. Specifically, an increase of 1 percent in investment in mobile technology reduces CO_2 per capita by 0.09 percent, while a 1 percent increase in the investment in fixed telecom sector reduces CO_2 per capita by 0.015 percent.

All LAC countries have achieved this SDG indicator. However, as the economy of the LAC region grows, CO_2 emissions per capita may increase. Therefore, this estimation can illuminate ways that investment in telecom technology can foster sustainable economic growth.

SDG 14: Life Under Water

The temperature, chemistry, currents, and life in oceans are fundamental to enable habitability on earth. Moreover, more than 3 billion people depend on marine and coastal biodiversity for their livelihoods, which represents around 5 percent of global GDP.[71] Hence, the objective of SDG 14 is the conservation and sustainable use of the oceans, seas, and marine resources, preventing them from suffering the effects of overfishing, marine pollution, and climate change, including ocean acidification.

[69] http://www.libelium.com/athens-airport-trusts-exm-and-libeliums-iot-platform-to-reduce-noise-pollution-and-control-environmental-impact/.
[70] http://www.libelium.com/reducing-logistics-environmental-impact-by-air-quality-monitoring-in-the-baltic-sea-port-of-gdansk-poland/.
[71] http://www.latinamerica.undp.org/content/rblac/en/home/post-2015/sdg-overview/goal-14.html.

As in many other parts of the world, climate change and extreme natural events are challenging the sustainability of aquaculture and marine and inland fisheries in the LAC region. This is especially true in Central America, where sea temperatures are becoming warmer than in other locations and ocean acidification is a major concern. Both factors are strongly affecting biodiversity. Consequently, the production and the value chain of fisheries is being affected.[72]

IMPACT

Digital infrastructure and applications play a role in the achievement of marine conservation and sustainability, mainly by providing tools for the real-time monitoring of water masses. Digital applications for SDG 14 include internet and satellite maps which help to track the migration patterns of endangered animals and provide better understanding of lifetimes, loss, and predation; monitoring of global fish stocks, oxygen levels, algal blooms, temperature, and ocean currents; and big data that assists the analysis of oceans in terms of biodiversity, pollution, weather patterns, and ecosystem evolution to help plan mitigation and adaptation.

There are examples of projects in the region where digital technologies are used to conserve marine environments and wildlife. For instance, *InvestEGGator,* a project in Nicaragua, is positioning system trackers against poachers.[73] This is used to track the transit routes and final destinations of poached sea turtle eggs and related wildlife, to contribute to the long-term survival of four endangered marine turtle species.

SDG 15: Life on Land

15 LIFE ON LAND

The sustainable management of forests, wetlands, dry land, and mountains is crucial for human life. They are a source of food, clean air, and water. These functions are threatened by the increase in land degradation, deforestation, and desertification. These phenomena are leading to the loss of natural habitats and species. SDG 15 is aimed at conserving all kinds of ecosystems.

By 2017, the progress in preserving terrestrial ecosystems had been uneven, with advances in reducing the pace of forest loss, counterbalanced by declining rates in land biodiversity. Poaching remains a serious concern.

IMPACT

Digital applications and infrastructure can play a role in the conservation and sustainable use of terrestrial ecosystems and prevention of biodiversity loss. These include mobile sensors and IoT, which assist the monitoring of the state of the planet, terrestrial ecosystems, desertification, rainforests and flooding; satellite observation, which assists the monitoring of water flows, rain, snow, and wind patterns, providing efficient early-warning systems to protect endangered species and fragile land areas; and mobile phones, which can be used to track illegal trafficking and poaching of protected species and natural heritage.

The following are recent LAC experiences on the use of these applications to monitor and protect terrestrial ecosystems.

Smartphone Tree Tagging in Guatemala[74]

To overcome delays in annual forest harvesting, improve the capabilities to track timber along the value chain, and help reduce illegal logging, Consutel (Custodios de la Selva) developed Tree Tag. Tree Tag is a smartphone-based application that uses earth observation systems to track the location of logs transported from the forest to the mill. Only trees previously authorized for logging can enter the system. Tree Tag allows personnel to report activities and volumes, as well as

[72] http://www.fao.org/3/I9705EN/i9705en.pdf.
[73] https://investeggator.com/wildlife-crime-tech-challenge/.
[74] http://www.appsolutelydigital.com/ict_new/section_4_3_4.html.

disseminate alerts in the case of suspicious activity. In addition to the mobile app, satellite wireless and solar generators have been tested to provide connectivity and power to forest workers in remote areas.

E-mail Warning System for Fires in Protected Areas in South America[75]

NASA and Conservation International have contributed to the improved detection of fires using remote satellite sensing and GIS. Services such as the Fire Information for Resource Management System (FIRMS) and FireCast provide nongovernmental organizations (NGOs) and the governments in Bolivia and Peru with the tools to investigate active fires, fine landowners who violate forest management laws, and monitor trends in fire activity and the expansion of deforestation along the forest frontier. In addition, FireCast incorporates daily email alerts with active fire data in Bolivia, Colombia, Peru, and Suriname and provides daily flammability forecasts for the entire Amazonian region. Fire observation around the LAC region is made possible by Visible Infrared Imaging Radiometer Suite (VIIRS) and Moderate Resolution Imaging Spectroradiometer (MODIS) instruments aboard Terra, Aqua, and Suomi-PP satellites.

Monitoring and Early Warning System to Prevent Flooding – Colombia

In Colombia, after the La Liboriana river flood devastated the village of Salgar in 2015 causing 83 deaths, the National Unit for Disaster Risk Management designed a plan to monitor and compile information on the La Liboriana, La Clara, and Barroso rivers to prevent tragedies like the Salgar landslide. The project involved the installation of an early warning system in disaster management in the region based on a wireless sensor network that continuously monitored the river levels as well as the air temperature to alert the community in case of a potential flood or landslide.[76]

SDG 16: Peace, Justice, and Strong Institutions

Without peace, stability, human rights, and effective governance based on the rule of law, it is very difficult to achieve sustainable development.[77] High levels of armed violence and insecurity have a destructive impact on a country's development, affecting economic growth and undermining access to justice for all and effective, accountable institutions at all levels.

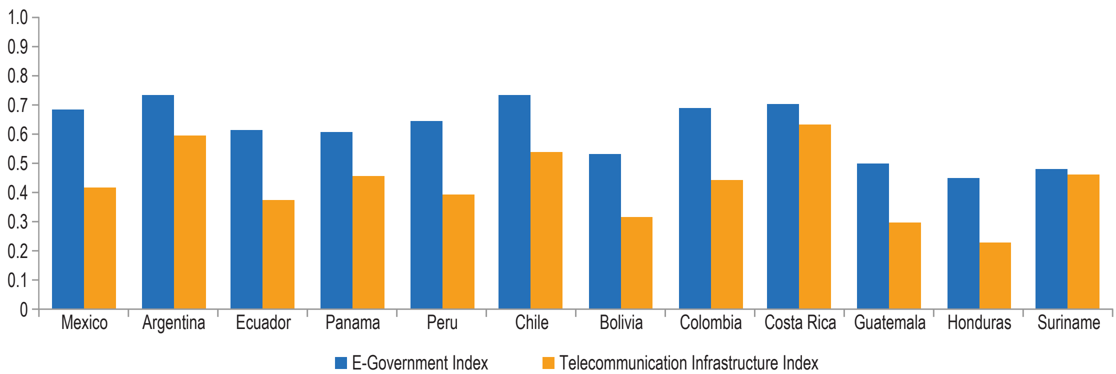
Although some regions enjoy sustained levels of peace, security, and prosperity, others fall into seemingly endless cycles of conflict, violence, and corruption. The LAC region suffers from high levels of corruption. According to Transparency International, in the 2017 Corruption Perceptions Index, the LAC countries in our study, out of 180 countries, rank as follows (position in parentheses): Argentina (85), Bolivia (112), Colombia (96), Costa Rica (38), Chile (26), Ecuador (117), Guatemala (143), Honduras (135), Mexico (135), Panama (96), Peru (96), and Suriname (117). Only Chile and Costa Rica present a low level of perceived corruption.

IMPACT

Governments and communities can use digital applications and platforms to promote human rights and institutions of good governance. Investment in digital infrastructure can impact institutions in three main ways. First, they can help promote mutual understanding between different cultures by fostering a multicultural society (Stauffacher et al., 2005).

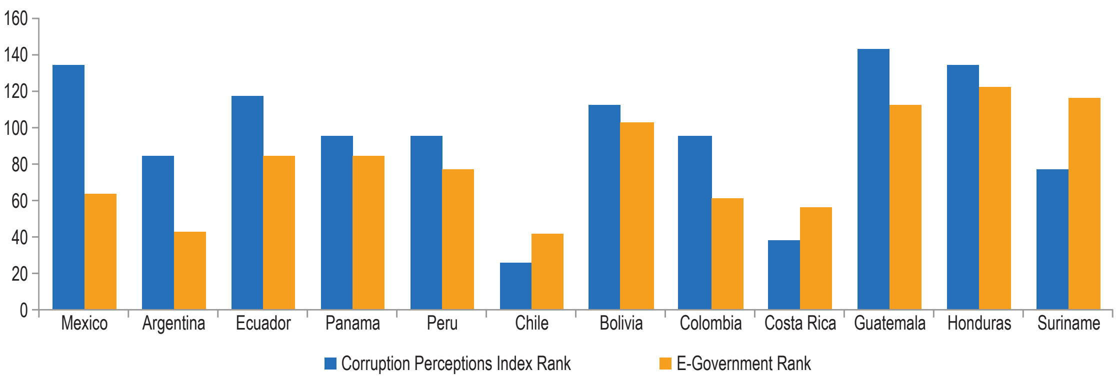
[75] http://firecast.conservation.org/.
[76] http://www.libelium.com/early-warning-system-to-prevent-floods-and-allow-disaster-management-in-colombian-rivers/.
[77] http://www.undp.org/content/undp/en/home/sustainable-development-goals/goal-16-peace-justice-and-strong-institutions.html.

FIGURE 3.18. E-Government and Telecom Infrastructure Indices



Source: UN e-government survey 2018.

FIGURE 3.19. Corruption Perceptions Index and E-Government Country Ranking



Sources: UN e-government survey 2018 and Transparency International.

Second, digital technology makes it easier to monitor government activity, thus increasing transparency and empowering societies. Third, digital infrastructure is indispensable for peacekeeping operations, as it facilitates logistics. Indirect empirical evidence supports this with respect to the LAC region. There is a positive relationship between digital infrastructure and applications and e-government (correlation of 0.77) (Figure 3.18). Moreover, e-government is negatively correlated with corruption (–0.60) (Figure 3.19).

There are many examples of how local and central governments in the region are seeking to increase transparency and reduce corruption by adopting e-government solutions. At the municipal level, for example, there are several cases of digital participatory budgeting in the region.[78] In Miraflores, Peru, a project called Neighborhood Participation (Participación Vecinal) manages the Digital Participatory Budget program, which provides citizens the opportunity to participate in selecting a portion of the works to be constructed by the municipality in the following year. In 2010,

[78] https://dl.acm.org/citation.cfm?id=1930328.

15,000,000 PEN (Peruvian soles) were invested in 12 projects, ranging from infrastructure to social projects. The website publishes the results and information about the election, as well as statistics on the winning projects. In Argentina, the city of Bella Vista conducted participatory budgeting for the first time in 2008 to choose projects with a limit of 100,000 ARS (Argentine pesos). All citizens above 14 years old could vote on any computer with internet access.

At the central government level, many countries in the region have introduced transparency portals to push forward financial transparency and accountability.[79] In short, these portals are websites devoted to publishing public financial information. Bolivia, Chile, Colombia, Costa Rica, Guatemala, and Peru have all implemented operations to increase transparency in public financial management. These portals aim to guarantee the right of access to information, especially in relation to the administration of public resources, to prevent and combat corruption. Through these portals, public budgets, contracts, and tenders are published periodically to make the actions of the public sector more visible.

SDG 17: Partnerships for the Goals

Sustainable development can be better achieved if there are partnerships between governments, civil society, and the private sector toward this common goal. Cooperation between actors across countries are also relevant in this respect. Digital applications and infrastructure can contribute to these alliances by facilitating coordination and communication between these actors and fostering their partnerships. Digital applications are modifying the relationships between citizens and governments by creating opportunities for public decision making through the digitalization of public services.

IMPACT

Though still incipient in many countries, digital infrastructure is facilitating partnerships between the public sector and civil society in the pursuit of the SDGs. There is potential to improve health and education through digitalization. The health sector has made strides in this area in many LAC countries. In Brazil, Chile, Colombia, and Costa Rica, there are more than 50 public centers that provide telemedicine. To improve air quality, Mexico City is using CleanSpace, an IoT sensor network that monitors air pollution.[80]

Efforts to digitalize processes in different areas are also driving partnerships between the public and the private sector in the LAC region. In 2017, the Brazilian Association of IoT emerged, joining together public and private entities, academia, telecom operators and startups to support and enable open innovation across different sectors of society.[81] In the City of Tequila, Mexico, a partnership has been created between IBM and the city council to enable smart solutions at the city level. At the regional level, CAF and Telefonica have created a partnership to enable projects related to the digitalization of LAC countries.[82]

There are also public–private partnerships across countries. As noted above, several public and private organizations from Colombia and Honduras are involved in a smart agriculture project to promote more sustainable and efficient food production in the two countries.

[79] http://www.egov4dev.org/transparency/case/laportals.shtml,https://halshs.archives-ouvertes.fr/halshs-00531527/document.

[80] https://www.idgconnect.com/abstract/21866/latin-america-a-hotbed-internet-things.

[81] https://iot.ieee.org/newsletter/july-2017/ipv6-and-internet-of-things-prospects-for-latin-america.html.

[82] https://www.eleconomista.com.mx/empresas/CAF-y-Telefonica-impulsaran-digitalizacion-en-Latinoamerica-20171030-0079.htm.

4

Quantification of the Additional Investment Necessary to Achieve the SDGs

This section presents a quantification of the investment necessary to close the SDG gap between the current outcomes in the countries studied, the level of achievement of the SDGs attained in the OECD countries, and the SDG 2030 targets. These estimates, based on the econometric results described in the previous sections, are presented for those SDGs where statistically significant values were found.

The estimates include the absolute additional investment in total digital infrastructure[83] required to close the gap for each SDG and country. The section also presents the estimated additional investments as a share of the average historic investment level, or the percentage by which investment in a given country should increase each year between 2019 and 2030 with respect to the average investment in the last five years, to meet the OECD average and the SDG agenda target. Finally, the section presents the mix of investments in mobile and fixed telecom infrastructure required to achieve the SDG targets.

Quantification of the Additional Investment Needed to Close the SDG Gap

Typically, the level attained in OECD countries (average) in the SDG indicators is smaller than the level set for the SDG agenda target. Therefore, reaching the OECD average can be considered an intermediate step toward completion of the SDG target.

The econometric findings presented in Section 3 were used to calculate the additional investment needed to improve the SDG metric (the "investment gap"). This means that for those SDGs where either the target is not clearly defined or coefficient results are not statistically significant, the calculation was not made.[84]

[83] As the base data for investment is telecom investment, the digital investment and telecom investment are used interchangeably.
[84] The estimates for digital investments in relation to SDG 5 (gender equality) are not reported. Despite the significance of the coefficient and the existence of a target, digital infrastructure is just one of many drivers of achievement of the target.

For these reasons, results of the investment gap with respect to the OECD for five SDGs were calculated, in the form of six specifications (SDG 10 has two specifications). These SDGs are: SDG 1 (End Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-being), SDG 8 (Decent Work and Economic Growth), and SDG 10 (Reduced Inequalities). With respect to the gap between achievement of the SDGs in the 12 LAC countries and the SDG 2030 targets, the study shows the required investment for SDG 1 and SDG 2.[85]

An improvement of one percentage point in the SDG metric does not have the same impact in every country. First, countries have attained different levels of achievement on a given SDG indicator (e.g., poverty, life expectancy, hunger rates, etc.). Second, the countries studied had different levels of digital investment in 2017. Therefore, the investment gap will be different for each country.

The investment gap is calculated as follows. First, the difference between the SDG target and the SDG level achieved is calculated for each country. Then this difference is divided by the elasticity of the SDG to investments in digital infrastructure. This ratio provides the percentage increase in investment required, ceteris paribus, to close the SDG gap. Finally, the percentage obtained is applied to the latest value of the investment available (i.e., 2017) to calculate the total investment gap.[86]

As explained above, the additional investment required is estimated as a percentage, which is then applied to the latest digital investment figure in each country. Therefore, the results for the total investment required may capture the effect of larger countries requiring historically larger investments in digital infrastructure. This is the reason why the investment gap is also calculated in per capita terms.

Tables 4.1 to 4.4 show the investment gap, or the incremental investment in digital infrastructure required to achieve the OECD and the SDG target levels in both total and per capita terms.

Table 4.1 shows that SDG 1 (End Poverty) and SDG 2 (Zero Hunger) require the least additional investment. This is a very important result, indicating that by investing in telecom policy makers can improve the well-being of poorer people. According to these estimates, undernourishment could be reduced to 2.8 percent (SDG 2, OECD average level) by investing an additional US$56.8 billion in telecom infrastructure across the countries studied. Similarly, to achieve the OECD average life expectancy of 79.7 years (SDG 3) study countries would need to invest a total of US$81.3 billion.

Alongside these policy goals, some countries can achieve greater GDP growth by investing in digital infrastructure. According to the results for SDG 8 (Decent Work and Economic Growth), all countries could obtain the double of the cumulated GDP growth forecasted in the period 2018–2023[87] just by investing in digital infrastructure to close the gap on other SDGs.

Table 4.2 shows the per capita level investment required to close the gap with the OECD.

The results in Table 4.2 show that Honduras and Bolivia require the two highest per capita additional investment levels in the region to reduce the percentage of people living below the US$1.90 per day poverty line (SDG 1), ceteris paribus. They will need to add US$637 and US$177 per capita, respectively, if they want to reach the OECD average at 0.9 percent and up to USS$673 and USS$202 per capita, respectively, if they want to eradicate it completely. However, for the other countries the per capita investment effort for the completion of this SDG is much smaller. For example, by investing an additional US$30 per capita (or

[85] The final SDG 2030 target cannot be quantified. The goals are expressed as “reducing” or “improving” but not as a numeric target.

[86] For example, in Argentina 0.6 percent of the population lives on less than US$1.90/day. The SDG target is to achieve 0 percent of people living below the poverty line by 2030. The beta coefficient of total telecom investment in the regression on this SDG is –1.3247. If all the other variables are kept constant, then the investment gap is equal to (0 percent–0.6 percent)/(–1.3247/100) = (–0.006)/ (–0.0132) = 45 percent. In Argentina in 2017, US$3.636 billion were invested in digital infrastructure. Therefore, the monetary amount of the investment gap is 45 percent * US$3.636 billion = US$1.647 billion, as shown in Table 4.3.

[87] This investment will be non-zero for all the countries in our study, as the target is fixed for each country. Source for forecasts: IMF https://www.imf.org/external/datamapper.

TABLE 4.1. Total Additional Telecom Investments Required to Meet the OECD Level (millions of US$)

SDG	1	2	3	8	10.1	10.2
Argentina	0	2,645	15,611	2,839	28,986	24,243
Bolivia	1,959	6,588	6,706	1,241	5,432	4,473
Colombia	5,214	7,438	14,322	4,938	22,060	20,436
Chile	542	1,365	393	4,060	14,510	12,360
Costa Rica	208	1,634	0	1,614	6,512	6,182
Ecuador	1,584	6,500	3,576	765	7,242	5,979
Guatemala	N/A	8,418	6,525	1,868	N/A	N/A
Honduras	5,898	5,634	4,525	1,404	7,110	6,885
Mexico	5,909	6,113	16,925	9,586	24,360	19,566
Panama	396	2,332	905	1,763	5,147	5,115
Peru	N/A	7,983	11,400	5,322	16,218	14,028
Suriname	N/A	140	370	53	N/A	N/A

Source: Frontier Economics analysis.
Notes: The results for the SDGs where the estimation was not statistically significant (SDG 4, SDG 5, and SDG 9) are not presented. The results for SDG 13 are not presented because for this indicator (CO_2 emissions per capita) the OECD target has been achieved in all the countries studied. For SDG 8, the additional investment required to achieve double the cumulated GDP growth in the period 2018–2023 (as forecasted by the IMF) is shown. Thus, for example, if the IMF forecasts that the GDP in Argentina in 2023 will be 6.8 percent higher than in 2018, the investment in telecom needed to make GDP 13.6 percent higher in 2023 than in 2018 (i.e., to double the IMF forecast) is calculated. Therefore, this target only is calculated to 2023. Countries with a zero-investment gap in a particular SDG have already achieved the target. Countries with N/A in a particular SDG do not have recent data for the indicator chosen (therefore it is not possible to calculate the SDG gap or the investment gap). The totals for intervals including N/A values disregard the N/A observations.

TABLE 4.2. Total Additional Telecom Investments Per Capita Required to Meet OECD Levels (US$)

SDG	1	2	3	8	10.1	10.2
Argentina	0	60	353	64	655	548
Bolivia	177	596	607	112	492	405
Colombia	106	152	292	101	450	416
Chile	30	76	22	225	804	685
Costa Rica	42	333	0	329	1,327	1,260
Ecuador	95	391	215	46	436	360
Guatemala	N/A	498	386	110	N/A	N/A
Honduras	637	608	488	152	767	743
Mexico	46	47	131	74	189	151
Panama	97	569	221	430	1,256	1,248
Peru	N/A	248	354	165	504	436
Suriname	N/A	249	657	93	N/A	N/A

Source: Frontier Economics analysis.
Note: Results for the SDGs where the estimation was not statistically significant (SDG 4, SDG 5, SDG 9) are not presented. For SDG 13, results are not presented because for this indicator (CO_2 emissions per capita) the OECD target has been achieved in all the countries studied. For SDG 8, the additional per capita investment required to achieve the double of the cumulated GDP growth in the period 2018–2023 (forecasted by the IMF) is shown. Therefore, this target only is calculated to 2023. Countries with a zero-investment gap in a particular SDG have already achieved the target. Countries with N/A in a particular SDG do not have recent data for the indicator chosen (therefore it is not possible to calculate the SDG gap or the investment gap). The totals for intervals including N/A values disregard the N/A observations.

TABLE 4.3. Total Additional Telecom Investment Required to Meet SDG Target (millions of US$)

SDG	1	2
Argentina	1,647	11,902
Bolivia	2,232	7,648
Colombia	6,463	12,282
Chile	1,638	5,613
Costa Rica	630	3,268
Ecuador	2,089	8,457
Guatemala	N/A	10,259
Honduras	6,237	6,948
Mexico	9,063	18,338
Panama	655	3,337
Peru	N/A	12,366
Suriname	N/A	217

Source: Frontier Economics analysis.
Note: Results for all those SDGs where either the target is not clearly defined, or coefficient results are not statistically significant are not presented. Countries with a 0 have already achieved the target.

TABLE 4.4. Total Additional Telecom Investment Per Capita Required to Meet SDG Target (US$)

SDG	1	2
Argentina	37	269
Bolivia	202	692
Colombia	132	250
Chile	91	311
Costa Rica	128	666
Ecuador	126	509
Guatemala	N/A	607
Honduras	673	750
Mexico	70	142
Panama	160	814
Peru	N/A	384
Suriname	N/A	386

Source: Frontier Economics analysis.
Note: Results for all those SDGs where either the target is not clearly defined, or coefficient results are not statistically significant are not presented. Countries with a 0 have already achieved the target.

up to US$91 per capita), Chile could catch up with the OECD average or eradicate poverty. Similarly, Argentina could eliminate poverty (defined as living on less than US$1.90 per day) by investing an additional US$37 per capita.

Tables 4.3 and 4.4 show the results for additional total and per capita investment to close the gap with the official SDG targets. As expected, the additional investment required, in absolute or in per capita terms, is significantly higher compared to the previous results, reflecting that the gap with the SDG targets is wider than with the OECD.

Quantification of Total Additional Annual Investment Required to Close the Gaps

This section presents a dynamic view of the previous results: how much additional investment is required annually to close the gap by 2030. It is expressed as the percentage of annual investment growth required to meet the OECD average and the SDG agenda target in the countries studied.

The average annual growth in investment is calculated as CAGR. The investment at the beginning of the period is measured by the average investment in digital infrastructure in the period 2013–2017. The total investment required at the end of the period is proxied by the total investment at target (i.e., the level of investment in 2017 plus the incremental investment required shown in Table 4.5). The average annual growth rate is calculated over a 12-year period, that is, the number of years left to 2030. For SDG 8 only, it is calculated for a five-year period, that is, the number of years left to 2023.[88]

[88] To illustrate the calculation, Argentina's average total investment in digital infrastructure was US$3.451 billion between 2013 and 2017. To close the gap with SDG 2, Argentina must invest an additional US$2.645 billion plus what Argentina already invested in 2017 (US$3.636 billion). The sum of these two is the total investment required in digital

TABLE 4.5. Annual Additional Investment Growth Required to Meet OECD SDG Levels by 2030 (percent)

SDG	1	2	3	8	10.1	10.2
Argentina	0	5	15	13	21	19
Bolivia	18	29	29	37	27	25
Colombia	11	13	18	26	22	22
Chile	3	6	2	30	22	20
Costa Rica	5	14	2	36	25	25
Ecuador	8	19	14	10	19	18
Guatemala	N/A	26	23	35	N/A	N/A
Honduras	26	26	24	38	28	28
Mexico	7	7	14	25	16	15
Panama	6	17	10	40	25	25
Peru	N/A	16	19	34	22	21
Suriname	N/A	14	22	18	N/A	N/A

Source: Frontier Economics analysis.
Note: The SDGs where the estimation had non-statistically significant results (SDG 4, SDG 5.2, SDG 9.1, SDG 13) are not presented. The same applies for the countries that show N/A results. For SDG 8, the annual additional investment required is calculated as the additional investment required to achieve the double of the cumulated GDP growth in the period 2018–2023 (forecasted by the IMF) over five years. Therefore, this target is only calculated to 2023. Countries with 0% have already achieved the target.

As shown in the Table 4.5, the percentages vary significantly within countries and between SDGs. Thus, it is difficult to generalize about them.

In some countries, such as Chile, Costa Rica, Panama and Mexico for SDG 1 (End Poverty), and for Argentina, Chile, and Mexico for SDG 2 (Zero Hunger), the increase in the annual investment is less than 10 percent. In these cases, investments in telecom, coupled with sound economic regulation and an increase in demand for telecom services, can contribute to achieving the SDG target.

Countries that require investment greater than 10–15 percent will need a significant investment effort to close the SDG gap. For example, Bolivia and Honduras would need to increase their annual investment substantially in the next 12 years to close the SDG gap with the OECD. Achieving the SDG target will require a shared effort, that is, investment in telecom and in other industries along with the implementation of social policies. Investment in digital infrastructure can help advance toward the target but cannot be the only driver.

For SDG 8 and SDG 10, the increases in annual investment required are substantial, reflecting the large economic gap between the region and the OECD (SDG 10) and the very ambitious (but hypothetical) target set for SDG 8.

Table 4.6 shows a similar panorama for SDG 1 and SDG 2. For each SDG, the percentage growth required is larger because the gap with the SDG target is greater than the gap with the OECD average.

The following scatter plots are a different representation of the same evidence. In Figure 4.1, the x-axis represents the level of per capita investment on average in the past five years and the y-axis represents the total incremental investment per capita required to close the SDG gap by 2030.

In the first set of figures, all the countries above the line[89] will require a per capita

infrastructure at target of US$6.281 billion. For this SDG, the investment growth is achievable over 12 years. Therefore, the CAGR is equal to (6,281/3,451)^(1/12)-1 = 5 percent.

[89] The dotted line shows the values where the incremental investment is equal to the last-five-year average investment.

TABLE 4.6. Annual Additional Investment Growth Required to Meet SDG Targets by 2030 (percent)

SDG	1	2
Argentina	4	13
Bolivia	19	30
Colombia	12	17
Chile	6	14
Costa Rica	8	19
Ecuador	10	21
Guatemala	N/A	28
Honduras	27	28
Mexico	9	14
Panama	8	21
Peru	N/A	20
Suriname	N/A	18

Source: Frontier Economics analysis.
Note: Results for all those SDGs where either the target is not clearly defined, or coefficient results are not significant are not presented.

incremental investment larger than the per capita investment level undertaken, on average, in the past five years. This may mean that these countries will require more than one year to close the SDG gap with telecom investments. For the few countries sitting at the bottom right-hand corner and underneath and further away from the dotted line, the necessary increment in investment required to eliminate the gap represents a smaller and likely more achievable proportion of the per capita levels of investment in the past. In the second set of figures, no dotted line is represented because all values (countries) lie above the line and therefore require an extremely large investment effort.

The main conclusion to draw from these figures is that the countries in this study are in different positions with respect to the difficulty of achieving the 2030 SDGs through an increase in digital investment. In relation to SDG 1, Bolivia and Honduras are lagging in terms of the investment in telecom required to fill the gap toward the OECD average or the 2030 official goal. To achieve the targets, they will require significant increases in investment in telecom infrastructure and in other industries. At the other extreme, in Argentina, Chile, and Costa Rica, the increase in investment needed is lower. For SDGs 8 and 10, the investments required would be slightly higher, given the large gap and the need to undertake horizontal policies beyond investment in telecom infrastructure.

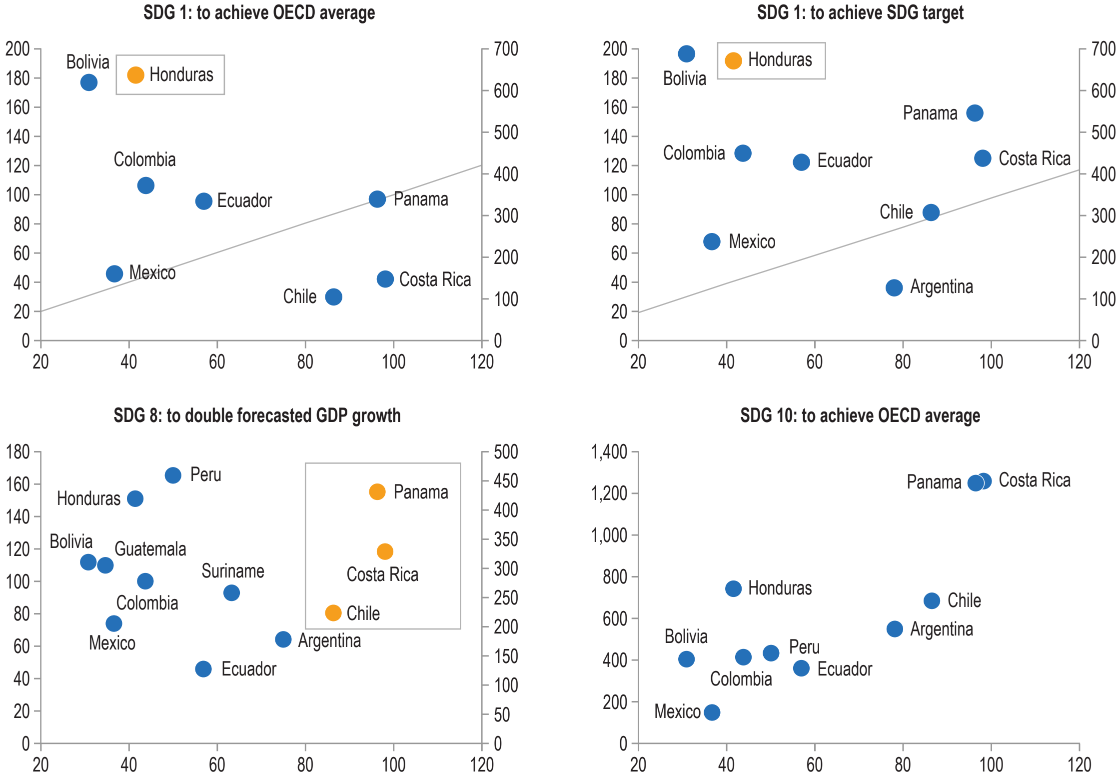
Estimation of the Required Mix of Investment in Fixed and Mobile Telecom Infrastructure

The econometric analysis in this study has estimated the impact of two other telecom investment variables on SDG outcomes: investments in fixed infrastructure and investments in mobile infrastructure. This section summarizes the impact of this separate econometric analysis and provide a brief interpretation.

Not all specifications of the estimated coefficients are statistically significant for either fixed or mobile investment. For some SDGs, either the coefficient for fixed telecom investment or the coefficient for mobile investment is statistically significant. In these cases, only increments in either the fixed or mobile investment can affect the SDG metric. This is the case of SDGs 2, 4, 5.1 and 5.2, 9.2, and 10.2.

For all the remaining SDGs analyzed (SDGs 1, 3, 8, 10.1, 13), investment in both fixed and mobile telecom infrastructure has a statistically significant impact on the SDG metric. However, the coefficient for mobile investment is consistently larger across all specifications: between three and seven times larger than the coefficient for investment in fixed telecom. This is especially true for SDGs 3 and 13, where the coefficient for investment in mobile telecom is respectively seven and six times larger than the coefficient for investment in fixed telecom. While these magnitudes should be taken as a broad approximation, they indicate that the impact of investment in mobile telecom is likely to be higher than for investment in fixed telecom.

FIGURE 4.1. Per Capita Historic Investment (x-axis) and Required Additional Investment Per Capita (y-axis) for Selected SDGs (US$)



Source: Frontier Economics analysis.
Note: Given their outlier nature, the countries denoted with yellow dots are represented on the secondary y-axis (on the right). SDG 10 is measured as the share of income in lowest 20 percent.

5

Recommendations

Given the evidence that shows that telecom investments foster sustainable development, telecom investments should be strongly incentivized. This is the main recommendation of this report. Other recommendations emanating from the results of this study focus on the following aspects:

- The importance of public institutions, specifically multilateral organizations, in providing funds to finance digital investment
- The need to remove unnecessary regulations and inefficient taxation
- The need to incentivize the adoption of digital services and IoT applications

Role of Public Institutions to Support Investment

Promoting investment in the telecom sector is fundamental to increase the contribution of digital infrastructure to sustainable development. To this end, public policies such as the funding of universal service obligations are a step in the right direction. Many countries in the region have public policies to fund the deployment of digital infrastructure, especially in less developed areas, as well as the deployment of fiber optic backbone networks. Most of these plans are funded from industry revenues. Chile and Mexico fund digital investment using public funds, specifically the Telecommunications Development Fund in Chile, and FONCOS in Mexico (see Annex A).

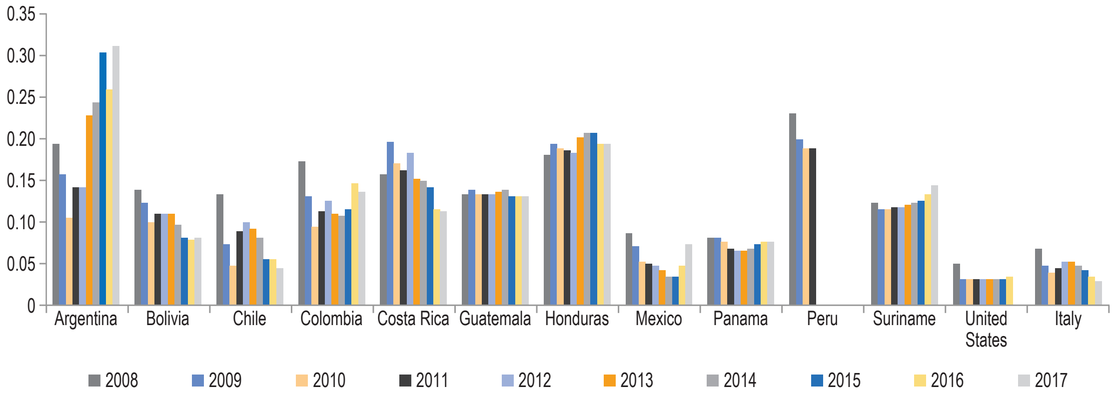
The macroeconomic environment in the LAC region precludes substantial increases in public investment in digital infrastructure. Public debt in almost all the countries considered in this study has steadily risen in recent years, which has led to negative fiscal deficits (5G Americas, 2017).[90] At the same time, it has become more expensive for private companies to incur debt to finance long-term investments. As Figure 5.1 shows, lending rates in the region are significantly higher than in more developed countries such as the United States and Italy.

Concessional international public finance and funds from multilateral development banks can be mobilized in areas where domestic public resources are insufficient, and business are unable to find adequate private finance. Several multilateral development banks are already providing funding for infrastructure projects that target the SDGs. In particular, the IDB and the Andean Development Corporation–Development Bank of Latin America (CAF) have been very active in this area. Therefore, it would be important for this activity to be continued and, where feasible, increased.

One area where these funds could focus is investment in rural areas. This study analyzed

[90] According to data from ECLAC the public debt (as a percent of GDP) has increased over the period 2008–2017 in the countries studied.

FIGURE 5.1. **Lending Interest Rates (percent)**



Source: The World Bank.

whether telecom investment has a different impact in countries where the percentage of rural population is higher.[91] In general, in countries with a high rural population, the impact of telecom infrastructure on the SDGs is generally not significant. This finding may be because countries which are more rural may have invested less in telecom because of the greater upfront investment required.

Efficiency of Investments

Another way to promote investment is by removing policies that distort investment decisions, such as excessive regulation and inefficient taxation. Presently, in almost all the countries of the region, the telecom market is regulated. This means that the regulator has a role in the development of the sector. The regulatory approach prevalent in LAC is increasingly based on market competition analysis. In this context, the regulatory framework is especially fundamental for incentivizing investments.

According to Frontier (2017),[92] competition analysis as currently carried out highlights several problems given the dynamic nature of the sector, including the following:

- Emphasis on static efficiency (vs. dynamic)
- Short-term time horizon
- Deterministic approach to competition analysis focusing on the market structure (number and share of operators)

This implies that regulators often only consider a market to be competitive where sharp price declines are observed. If this trend is not observed, regulators interpret it as a sign of insufficient competition because it occurs in a concentrated market. The problem with this static approach is that depressing prices may affect the return on future investment. That is, if investors expect prices to fall due to regulatory action, then they will not invest. This typically happens in contexts where regulatory uncertainty and scrutiny are higher.

To overcome these shortcomings, regulators in the region should consider competition as determined by the existence of rivalry. Rivalry creates incentives for companies to reduce costs, lower

[91] Specifically, two additional variables were included in the regressions detailed in Section estimating the impact of total ICT investment on the SDGs: the first variable is a dummy that assumes a value of 1 when the percentage of rural population is higher than 35 percent, and the second variable is an interaction between the rural population dummy and the total investment in ICT. This variable captures the impact on the SDG of investment in ICT in rural areas.

[92] https://cet.la/estudios/cet-la/analisis-competencia-mercados-dinamicos/.

prices, and invest and develop new services (if revenues expected from that investment exceed the risk-adjusted costs of the investment). In a dynamic market, competition understood as rivalry is not determined by a certain level of prices or by market shares below a given threshold, but by market conditions that indicate and facilitate the existence of rivalry, actual or potential, between companies.

Taxes can also distort consumption and investment. By making consumption more expensive, there is a reduction in services take-up and hence in the profitability of the investments. Taxes can also be levied on the investment itself (e.g., import duties on equipment goods or taxes levied to install mobile sites) which will impact network deployments. While taxes can have an economic rationale and increase welfare, the results of this study show that Treasury departments must take additional care in levying taxes on the digital industry given the significant spillover effects on sustainable development.

Incentivizing the Adoption of Digital Technologies and IoT

Adoption of Digital Technologies

One of the main obstacles to the contribution of the digital industry to the SDGs is the lower level of adoption of digital services among the LAC population relative to other regions. Penetration of digital services in the LAC region is still low with respect to the OECD average (CAF and Telecom Advisory Services, 2017).

The purchasing power of the population is severely limited in terms of the acquisition of service devices, such as PCs and smartphones. This is one of the main hurdles in the adoption of both fixed and mobile broadband in the LAC region, especially among the poorest segments of the population (Cet.la and Telecom Advisory Services, 2016).

In the case of fixed broadband, the demand gap in Latin America is on average 45 percent.[93] This percentage reflects households that cannot afford to access fixed broadband despite its availability where they reside. As mentioned above, one of the main causes of the demand barrier is the high cost of purchasing telecom services for individuals (for mobile broadband) or households (in the case of fixed broadband) relative to average income in the region. Public authorities should adopt policies that reduce the cost of acquiring broadband services (Cet.la and Telecom Advisory Services, 2016).

Another important element to incentivize the adoption of digital technology is the availability of local content (Rhinesmith, 2016). The LAC region had the lowest percentage of local content of any region in the world in 2013 (26.6 percent).[94] Generating local content may lead to an increase in the broadband penetration rate, as shown by OECD data for Europe and Asia, as well as the LAC region.[95]

Finally, digital literacy campaigns are extremely useful to increase the adoption of broadband services (Rhinesmith, 2016). Governments, NGOs, and the private sector should devise initiatives to increase the digital capacity of communities to participate online.

Investment in IoT

The impact of the digital industry on some SDGs, namely, SDGs 12, 14, 15, 16, and 17, is felt primarily through new IoT and M2M technologies. Therefore, promoting investment in IoT is fundamental to achieving those SDGs. Because IoT is still a nascent technology, digital infrastructure is not expected to have a strong impact on these SDGs yet. In the LAC region, IoT investment has been lower than in other more developed regions, which will delay the effects of this investment on achieving the SDGs. According to the ITU database, in 2015, Chile had 386,000 M2M connections, while in the

93 http://www.teleadvs.com/wp-content/uploads/BoP_.pdf.
94 As measured by the Popularity index, https://repositorio.ECLAC.org/bitstream/handle/11362/38916/1/ecosistema_digital_AL.pdf.
95 https://repositorio.ECLAC.org/bitstream/handle/11362/38916/1/ecosistema_digital_AL.pdf.

Czech Republic, there were 750,000. In Finland, a wealthier country with a smaller population, there were more than 1 million M2M connections.[96]

The revised Electronic Communications Code, the EU regulatory framework on electronic communications,[97] has triggered a debate on how best to foster investment in the EU for deploying the very high-capacity networks that are increasingly needed for 5G mobile services, as well as e-services such as e-health, e-administration, cloud computing, and connected cars. By 2025, the initiative plans to achieve 5G coverage for all urban areas and all major terrestrial transport paths. As approved in June 2018,[98] the new code amends the current regulatory framework to facilitate co-investment (i.e., when several investors agree to invest together) for building new high-capacity network infrastructure. Under the Commission's proposal, all types of co-investment (including the joint-venture model,[99] the reciprocal access model,[100] and the long-term access model[101]), could lead to an exemption from regulation if the predefined conditions of Article 74[102] are met.[103]

In addition, the Code introduces new rules on spectrum management: while previously managed at the national level, the Code introduces a framework for facilitating spectrum assignment in the EU. This aims to bring about the simultaneous release of spectrum frequencies throughout the EU's single market on the same technical conditions, thereby attracting simultaneous investments in 5G networks across the bloc. The Code seeks to incentivize and increase investment in spectrum—in part based on longer license durations (of 20 years)—and to provide clarity on license renewals. The goal is to ensure the rapid deployment of 5G technology across the EU starting in 2020.[104]

It is crucial to analyze the policies mentioned above, including the exemption from regulation for co-investment in high-capacity network infrastructure and new harmonized rules on spectrum management, to understand how the countries in the LAC region could adapt them to their specific characteristics.

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[96] Since data on IoT investment to measure IoT activity are not available, "machine to machine" (M2M) connections were used as a proxy for IoT capital investment. Although IoT and M2M are not entirely the same thing, they are related: many of the services that IoT are able to provide the connectivity that M2M provides through the interdependence of smart devices

[97] This framework sets common rules on how electronic communications networks and services such as telephony and internet broadband connections are regulated in the European Union (EU).

[98] http://www.consilium.europa.eu/en/policies/electronic-communications-code/.

[99] In the joint-venture model, a new entity jointly owned and controlled by the co-investors is established for developing and operating network infrastructure. The joint venture (JV) sells fiber access services to its partners and potentially to third parties on an access basis.

[100] In the reciprocal access model, co-investors are responsible for developing and operating their own network infrastructure (usually in geographically separate areas) and reciprocal access arrangements allow parties to the co-investment agreement to serve customers via each other's network infrastructure (through passive or active access).

[101] In the long-term access model, one party oversees the construction of the network infrastructure and a contractual agreement establishes how to provide access to new infrastructure and share costs, risks and profits between all the co-investors.

[102] Article 74 of the draft text requires that regulators refrain from imposing regulation with respect to 'new network elements' that a dominant operator 'has deployed' or 'is planning to deploy' when several cumulative conditions.

[103] http://www.europarl.europa.eu/thinktank/en/document.html?reference=EPRS_BRI%282018%29614693.

[104] https://www.globalpolicywatch.com/2018/08/iot-update-the-european-electronic-communications-code-developing-the-future-of-iot-in-the-eu/.

Annex A
Literature Review

This section contains a literature review, which will illustrate how previous studies have analyzed the contribution of digital infrastructure on sustainable development, and the conclusions they draw.

Impact of the Mobile and Fixed Telecom Sectors on the SDGs

Previous literature shows that broadband, both fixed and mobile, but especially mobile, plays a crucial role in fostering sustainable development by providing access to essential information and communication services in rural and underserved areas. Access to information is crucial to provide people in developing countries with higher standards of education, medical care, and financial services.

- GSMA (2016) was the first report to offer critical insights into the transformative impact of the mobile industry on individuals, societies, and economies in developed and developing country markets. It establishes a benchmark through which the industry can assess its success in contributing to the SDGs and serves as a blueprint for other industries as they commit to achieving the SDGs. The report maps out the industry drivers that influence the SDGs, links the mobile industry's activities to the SDGs and their targets, and assesses the impact of these activities on the SDGs. The mobile telecom industry impacts all SDGs to varying degrees, with the greatest impact being felt on SDG 9 (Industry, Innovation and Infrastructure), SDG 1 (End Poverty), SDG 4 (Quality Education), and SDG 13 (Climate Action). The industry activities that drive the impact are spread across the value chain: 30 percent are operational activities, 27 percent are related to the primary output of the industry (connectivity), 32 percent are related to services or content that are based on that connectivity, and 11 percent are assessed as non-core. This body of evidence is then used to reflect the implications of current trends and what the industry can do to enhance the impact.
- GSMA (2017) updates GSMA (2016) and shows the progress the digital industry has made in terms of impacting each SDG. The industry's impact increased across all 17 SDGs.[105] GSMA underscores that three underlying trends explain much of the improvement in the industry's impact across all 17 SDGs in 2016. First, mobile operators invested heavily in expanding infrastructure and improving the quality of service. Second, operators continue

[105] Each SDG has a score out of 100, with a higher score representing increased impact. A score of 0 would mean no impact at all, while a score of 100 would mean the industry is doing everything possible to influence that SDG.

to connect the unconnected. The economic and social benefits of this are wide-ranging, with connectivity driving improvements in economic growth through improved productivity, infrastructure development, and efficiency. Finally, users are becoming increasingly sophisticated in how they use their mobile phones and are starting to access more advanced mobile-enabled services such as mobile money and government services. Nevertheless, the mobile industry is still far from realizing its potential impact. The reasons for this include: the increased cost of connecting the unconnected, constraining regulation, and cultural barriers. Operators therefore still have much to do to realize their full potential and contribute to achieving the SDGs.

- GSMA (2018a) shows how the mobile industry proved to be an important lifeline during the 2017 hurricane season in the Caribbean. Nearly 60 per cent of people in the Caribbean subscribe to a mobile service, relying on their mobile phones to access essential information and communication services. Mobile operators were thus crucial in saving lives by delivering early warning messages about approaching hurricanes, updating people regularly on restoration efforts, and offering free or reduced-price SMS, calls, and data, as well as free wi-fi and charging facilities in certain locations to ensure consistent access to communication. The report highlights that pre-positioning and setting up support systems and necessary regulator support prior to a disaster are essential for the immediate initiation of community support services. The destructive force of Hurricanes Irma and Maria exposed gaps in stakeholder coordination and communication and highlighted multiple interdependencies. Therefore, the report recommends that, as the region undergoes reconstruction, the mobile industry and other stakeholders, from government agencies to vendors, commercial power suppliers and other multinational organizations (MNOs), strengthen and enforce coordinating procedures. For MNOs in high-risk regions, reassessing investment priorities will be vital not only to protect business assets but also to provide a communication lifeline for vulnerable communities in their operating regions.
- GSMA (2018b) focuses on the contribution of the mobile industry to economic growth in Sub-Saharan Africa. It finds that in 2017, mobile technologies and services generated 7.1 per cent of GDP across Sub-Saharan Africa, a contribution that amounted to US$110 billion of economic value-added. The mobile ecosystem also generated almost 3 million jobs in 2017. In addition, the mobile sector made a substantial contribution to the funding of the public sector, with almost US$14 billion raised in 2017, including general taxation and sector-specific levies on the consumption of mobile services.
- Latif et al. (2017) explore the relationship between the diffusion of ICT and environmentally sustainable development in South Asian countries during the 2005–2015 period. The study assesses the contribution of five pertinent ICT indicators (landline, mobile, and fixed broadband subscriptions, internet users, and number of secure severs) in the composite sustainable development and growth index (SusD) via the generalized method of moments. The report finds a direct relationship between most of the indicators and the SusD and highlights the role of ICT in achieving the SDGs. The effect of fixed broadband was not found to be statistically significant for the South Asian economies. A potential reason for this may be the low purchasing power in the countries in the area, which reduces individuals' capacity to pay the monthly internet charges.
- CAF (2017) argues that broadband, both fixed and mobile, directly and indirectly stimulates economic growth. Three types of economic effects are identified: direct, indirect, and induced. The creation of employment and the improvement of economic growth are direct effects. Broadband also indirectly increases a country's productivity. Finally, in an induced way,

broadband generates new business activities by encouraging entrepreneurship. The report also finds that broadband has a social impact, mainly in education, health, and rural development.

The report calculates the economic benefits derived from the expansion of broadband at national and subnational levels in Colombia, Mexico, and Peru, using the multiplier method. The report estimates a cumulative impact by 2020 of:

- US$17.880 billion (equivalent to 2 percent of GDP) and nearly 500,000 additional jobs (1.9 percent of the economically active population) in Colombia;
- US$29 billion (1.8 percent of GDP) and about 1.3 million jobs (2 percent of the economically active population) in Mexico; and,
- US$4.7 billion (1.4 percent of GDP that year) and about 250,000 jobs (1.4 percent of the economically active population) in Peru.

The IDB's (2015, 2016) Internet and Broadband Connectivity reports offer valuable insights into the development of ICT in the 12 countries studied. The reports analyze the countries' capacity to exploit the opportunities offered by ICT to improve competitiveness and well-being. They provide an in-depth examination at the district/municipal level of the relationship between broadband access and various socioeconomic and infrastructure development indicators. To assess the correlation between broadband penetration and the set of development indicators, the IDB reports rank each country's territorial districts for each indicator. Then, they compare broadband penetration against the indicators to create a correlation matrix. Table A1 shows the IDB's findings.

Impact of the Digital Sector on the SDGs

Previous research has found that progress on ICT promotes sustainable development, especially in developing countries, by enabling people to use online services such as e-payment, m-banking, e-learning, e-health, e-government, e-commerce, and others. To store and process all the data that these services generate, significant networking, storage, and processing infrastructure, including data centers, need to be developed.

- Huawei (2017) explores the relationship between ICT and sustainable development. This study identifies ways that entities can contribute to achieving the SDGs. The report: (i) investigates six SDGs which have a clear link to ICT performance and thus are most likely to be achieved by 2030 with support from ICT; (ii) explores the performance of 15 developed and developing countries on SDGs and ICT development; and (iii) highlights lessons from national initiatives with country case studies. Huawei draws the following conclusions:
    - ICT is highly correlated with country-level SDG performance (89 percent), suggesting that countries that perform well on ICT also perform well on the SDGs. While this does not prove causality, it suggests a strong relationship. The correlation between ICT development and SDG progress is particularly high for SDG 9 (Infrastructure, Industrialization, and Innovation), SDG 4 (Quality Education), and SDG 3 (Good Health and Well-being).
    - Overall, developed countries generally have higher ICT scores than SDG scores, indicating that ICT development is outpacing progress on sustainable development, whereas the reverse is true for developing countries. This means that while developed countries should try to direct ICT investment toward the achievement of SDGs, developing nations may benefit from policies that aim to increase investment in ICT and improve ICT infrastructure.

TABLE A.1. IBD Results from Broadband Penetration Country Studies

	Population	GDP per capita	Health	Education	Crime	Computer penetration	Internet penetration	Mobile internet penetration	Water & sanitation	Electricity	Gas	Railway	Roads
Argentina	Weak	Strong	Moderate	Moderate	Weak	Strong	Strong		Moderate	Weak	Moderate	Weak	Weak
Bolivia	Weak	Moderate	Strong	Strong	Moderate	Strong	Moderate	Strong	Strong	Strong	Strong	Weak	Weak
Chile	Weak	Strong	Weak	Strong	Strong	Strong	Strong	Weak	Strong	Weak	Moderate	Moderate	Moderate
Colombia	Moderate	Weak	Moderate	Weak	Weak	Weak	Strong		Weak	Moderate	Weak		
Costa Rica	Moderate	Strong		Strong	Moderate	Strong	Strong	Strong	Moderate	Moderate		Moderate	Strong
Ecuador	Strong	Moderate	Weak	Strong	Moderate	Strong	Strong		Strong	Moderate		Weak	Moderate
Guatemala	Moderate	Weak	Strong	Moderate	Weak	Strong	Strong		Moderate	Moderate			Strong
Honduras	Strong	Strong	Weak	Strong	Moderate	Strong	Strong	Strong	Moderate	Strong			Weak
Mexico	Strong	Moderate	Weak	Moderate	Moderate	Strong	Strong	Moderate	Weak		Weak	Weak	Moderate
Panama	Strong	Moderate	Weak	Moderate	Weak	Strong	Strong		Moderate	Weak		Weak	Weak
Peru	Strong	Weak	Moderate	Strong	Moderate	Strong		Strong	Strong	Strong		Moderate	Weak
Suriname	Moderate	Moderate	Moderate	Strong	Moderate	Strong	Strong		Strong	Strong			

Source: IDB broadband studies per country (Informes de Conectividad de Internet y Banda Ancha, 2015–2016).

- Ono, Iida, and Yamakazi (2017) explain how the SDGs relate to corporate activities, and presents the Fujitsu Group's thinking, assessment methods regarding its contributions to achieving the SDGs through the provision of ICT service, and specific examples. The paper highlights the efficiency improvements that have been realized in areas such as energy consumption and the production and consumption of goods. The Fujitsu Group has provided ICT services that will contribute to the 17 SDGs. The paper names, for example, smartphone-based disaster information sharing systems (SDG 11), the provision of low power consumption and energy management services (SDGs 7 and 13), and food and agriculture cloud services (SDG 12).
- ICC (2018) argues that ICT is equipping populations with tools to alleviate poverty, access education, provide healthcare, and reduce CO_2 emissions. The report focuses on several SDGs and describes the ways that ICT can have a substantial impact.
  - With respect to SDG 1, a mobile phone-based platform for money transfer and financial services provides marginalized and remote communities access to a range of services, such as loans.
  - With respect to SDG 5, access to ICT can impact gender equality by allowing women to participate more easily in the labour market.
  - ICT can impact SDG 6 in the form of smart water meters that provide information on water usage, especially during times of drought or flooding, as well as real-time monitoring of communities' sanitation status.
  - ICT enables infrastructure expansion and technological upgrades for supplying sustainable energy (SDG 7), for example, by facilitating platforms such as smart meters.
  - ICT can enable the design and management of smart cities (SDG 11) by capturing vast amounts of data using sensors that monitor road traffic, mitigate congested roads, and prevent fuel wastage and carbon dioxide emissions.
  - With respect to SDG 12, the ICC argues that smart grids and meters, cloud computing, and reduced energy consumption of ICT have a positive impact on reducing consumption.
  - Through improved monitoring and reporting, ICT can play an integral role in the prevention of biodiversity loss and conservation and the sustainable use of terrestrial ecosystems (SDG 15).
  - Finally, ICT is transforming the relationship between citizens and government through digitalization of public services and increasing opportunities for public participation in decision making (SDG 17).
- Ericsson and Earth Institute (2017) argue that ICT, especially mobile broadband, will be the essential infrastructure platform for the SDGs. They identify five major ways that this will occur: (i) accelerated upscaling of critical services in health, education, financial services, smart agriculture, and low-carbon energy systems; (ii) reduced deployment costs addressing urban and rural realities; (iii) enhanced public awareness and engagement; (iv) innovation, connectivity, productivity and efficiency across many sectors; and (v) faster upgrading in the quality of services and jobs.
- Garcia Zaballos and Iglesias (2017) argue that ICT provides services that help achieve the SDGs, such as e-payment, m-banking, e-learning, e-health, e-government, e-commerce, and others. The big datasets that result from these types of services require reliable storage, security, low latency, and software analytics tools for data transfer and storage. Processing and managing big data require specially tailored ICT solutions and significant networking, storage, and processing infrastructure, including data centers.

Government Plans

Several LAC governments have developed plans to improve ICT infrastructure and/or connect the unconnected. These plans will directly or indirectly help achieve some of the SDGs. Some examples are the following:

- **Argentina**: In 2010, Argentina launched the National Argentina Connected Plan (Plan Nacional Argentina Conectada). The aim of the plan was to build and deploy fiber optic networks to reach 97 percent of the population by 2015 and bring high-speed Internet and free digital TV to unconnected regions. The main driver to meet the goal was the roll-out of a national fiber optic network, Federal Fiber Optic Network (Red Federal de Fibra Óptica, or REFEFO). The project was awarded to ARSAT, the Argentine public satellite public company. REFEFO has more than 30,000 km of fiber deployed.

  At a later stage, the Ministry of Communications introduced the Federal Internet Plan (Plan Federal de Internet), also awarded to ARSAT. The aim was to expand the national fiber optic network and to connect remote locations to the national backbone network. More than 1,300 locations and 29 million inhabitants are expected to be connected to the backbone network in 2018.

  In April 2018, the Ministry of Modernization issued a subsidy program to promote internet access in towns with up to 5,000 inhabitants. Up to 80 percent of the required access network investment in the towns will be subsidized (up to 3 million pesos per town). ARSAT will provide the required wholesale transport service to connect the network deployed in the towns to the backbone network.
- **Bolivia**: The government has developed a digital agenda and an associated Broadband Plan to digitalize all sectors of the population, providing broadband connectivity and connection devices and providing digital skills to the population.

  The Bolivian regulatory authority the Telecommunications and Transport Authority (Autoridad de Telecomunicaciones y Transporte, or ATT)[106] provided the required funding. The project was executed by PRONTIS. PRONTIS[107] has developed several projects to extend mobile coverage in rural areas, and to bring Internet access, communication services and satellite TV to schools, health centers, and rural populations.

  By 2023, the goal is to provide communications services to more than 16,000 rural towns and connect more than 3 million people currently unconnected.
- **Chile**: For the period 2013–2020, Chile has developed the Digital Agenda (Agenda Digital).[108] It covers five main areas: rights for digital development, digital connectivity, digital government, digital economy, and digital skills.

  Digital connectivity is intended to lead to a higher level of coverage (90 percent of households connected) and speeds (internet speed averages of 15–20Mbps).

  The plan aims to extend connectivity and free Wi-Fi zones together with regional and municipal governments to narrow the digital gap. A special effort is being made to connect educational entities, low-income urban areas, and rural and isolated towns.

  To accomplish these targets, the government developed a National Infrastructure Plan. The plan establishes an institutional, technical, and regulatory framework with the objective of increasing fiber optic networks in the country.

  One of the most important parts of this plan is the Austral Fiber Optic Network (Red de Fibra Óptica Austral),[109] a public-private

[106] Autoridad de Regulación y Fiscalización de Telecomunicaciones y Transportes (ATT): https://www.att.gob.bo.
[107] PRONTIS: http://prontis.gob.bo.
[108] http://www.agendadigital.gob.cl.
[109] https://foa.subtel.gob.cl/proyecto-fibra-optica-austral-2/.

national backbone fiber network awarded in 2018 to connect the country with a very high capacity transport network. The aim is to allow operators and entities to expand their coverage and service capacity. With more than 3,000 kilometers, this optical network will connect the two extremes of the country. The project will be supplemented with US$100 million by the government through the Telecom Development Fund (Fondo de Desarrollo de Telecomunicaciones).[110]

The Telecom Development Fund subsidizes operators to increase telecom service coverage. Thanks to this fund, communication service coverage increased from 70 percent in 2009 to 95 percent in 2015 with more than US$110 million of public funding.

- **Colombia**: Colombia Live Digital Plan (Plan Vive Digital) 2010–2014 was named one of the best public policy plans for ICT in the region. The plan was renewed for the period 2014–2018 as Vive Digital. Plan Vive Digital's main targets include widespread use of the internet, ICT technology development, increase of ICT jobs to reduce unemployment and poverty, increase competitiveness, and strengthen democracy.

  A very successful initiative of Plan Vive Digital is Kioskos Vive Digital. Under this initiative, 7,600 access points were installed in 2014, providing access to citizens in 5,300 towns and rural areas and providing free ICT skills development. More than 550 billion pesos (COP) were invested by 2014.

  Plan Vive Digital also aimed to encourage students to pursue degrees and jobs in science, technology, engineering, and mathematics (STEM). The result has been a threefold increase in the number of ICT jobs in the period of the plan, with direct benefits for the ICT sector and other sectors and the economy. As part of the Plan, subsidies (lower taxation) to purchase personal computers and internet services (fixed and mobile) were provided to low-income citizens.

  Vive Digital (2014–2018)[111] has continued to promote digital inclusion through ICT development and encouragement of STEM degrees.

- **Mexico**: Mexico established a National Digital Plan[112] for the period 2013–2018 with the following targets: government transformation, digital economy, education, universal health, and citizenship involvement.

  To achieve these goals, the plan identified several enablers: connectivity, inclusion and digital skills, interoperability, legal framework, and open data.

  The "connectivity" and "inclusion and digital skills" enablers are key to developing digital infrastructures and connecting the unconnected.

  For the connectivity enabler, there are two major projects with public-private participation: "Red Troncal,"[113] a national fiber transport network over the infrastructure of the Federal Electricity Commission (Comisión Federal de Electricidad, or CFE) and Shared Network (Red Compartida)[114] a wholesale mobile network for 4G services in the 700 MHz band to provide coverage to at least 92 percent of the Mexican population by 2024.

  Red Compartida is meant to provide wholesale 4G coverage in populated and urban areas already served by current mobile operators, as well as in rural areas not currently served by operators and unlikely to be served in the short to medium term due to the lack of economic viability. Red Compartida will be the first wholesale mobile network in the world. Total investment will exceed US$7 billion. Public participation mainly consists of the award of 90 MHz in the 700 MHz spectrum band. In March 2018, the network

110 https://www.subtel.gob.cl/quienes-somos/divisiones-2/fondo-de-desarrollo-de-las-telecomunicaciones/.
111 www.mintic.gov.co/portal/604/articles-8247_recurso_4.pdf.
112 https://www.gob.mx/mexicodigital/.
113 http://www.telecomm.gob.mx/rtroncal/.
114 http://www.sct.gob.mx/red-compartida/index.html.

started operating with coverage of 30 percent of the population.

Red Troncal is a public-private project to provide a national wholesale fiber transport network so that telecom operators can benefit from a high-capacity transport network to meet their increasingly high data demand and to connect to and from places not currently served with affordable high-capacity transport networks. The wholesale operator will manage the network with resources from CFE (fiber cables, passive infrastructure, and rights of access). Current assets to be provided as wholesale services include 25,600 km with two (dark) fiber threads. The award will be granted in 2019 and the winner will have to expand the network and invest around US$200 million.

For the inclusion and digital skill enabler, an important effort has been made in the period 2013–2018 to connect the unconnected and bring digital access to the rural population, schools, and public areas. The project, called Connected Mexico (Mexico Conectado),[115] aims to ensure that all citizens have access to the internet, which is a constitutional right. The federal government, together with state and local governments, is implementing the program. So far, 101,000 places have been connected (schools, public places, clinics, government buildings, etc.) with a different set of technological solutions: terrestrial networks, satellite, and high capacity networks. Sixty-percent of these places have public wi-fi so that all citizens may use their devices freely. The estimated amount of public investment to reach the goal of 250,000 connected sites is around 400 billion pesos.

- **Panama**: In Panama, the National Authority for Innovation[116] developed a Digital Agenda for the period 2014–2019. The aim of this plan is to provide 100 percent connectivity and broadband for the whole population by 2024. One of the main drivers of this plan is the Strategic Broadband Plan, initiated in 2013. A national broadband network began in 2012 to bring free connectivity and Internet to public places in 41 cities and 1,105 locations.
- **Peru**: In 2013, Peru launched the National Fiber Optic Backbone Network (Red Dorsal Nacional de Fibra Óptica, or RDNFO).[117] This is a public-private partnership designed to reduce the digital divide and expand digital services and high-capacity networks to almost all the provincial capitals and regional cities. It has been one of the most important ICT projects in the country.

RDNFO consists of a wholesale national network built and operated by a private entity, with the government guaranteeing the project's viability. The total estimated investment is over US$330 million with 13,500 km of fiber optic cable deployment by connecting 180 cities (out of 196 provinces) and 22 regional capitals (out of 24 regional capitals). PROINVERSIÓN is the public entity in charge of the RDNFO project.

Along with the RDNFO project, there are 21 regional projects to extend the fiber optic network from the RDNFO points to district capitals (1,516, or 82 percent of district capitals). The objective is to provide a regional transport network with over 30,000 km of fiber optic deployment as well as an optical access network reaching 6,000 towns and public entities, including educational institutions, health centers, government premises, and others. These regional projects are established by the Telecom Investment Fund (Fondo de Inversión en Telecomunicaciones, or FITEL)[118] of the Ministry of Communications and awarded to telecom operators that can provide wholesale services and retail end user services. The total amount of investment associated with these regional projects, conducted by FITEL, is expected to be above US$1.8 billion.

[115] http://www.mexicoconectado.gob.mx.
[116] Autoridad Nacional para la Innovación Gubernamental. Panamá: http://innovacion.gob.pa/documentos.
[117] www.proinversion.gob.pe/RedDorsal/.
[118] http://www.fitel.gob.pe.

Annex B
Estimation of Investment

Methodology to Estimate Total Public and Private Investment in Fixed and Mobile Telecom Infrastructure

This section describes the methodology followed in Section 4 to improve and correct investment data for some years and countries from the original data sources.

Infralatam does not collect data for Suriname.[119] Therefore, Suriname's investment was estimated based on a regression of telecom investment on GDP (World Bank), per capita GDP (World Bank), and total population (GSMA). Because this regression was used to predict the values of past investment for Suriname, the aim was not to determine causality but rather correlation. GDP and population were chosen as variables of interest because of their very high correlation with investment (Pearson correlation coefficient of 0.86 for GDP and 0.78 for population). Population density was included to control for the cost of fixed network investment and IoT connections to take forward-looking investments into account. With an adjusted R squared of 74 percent, the predictions are robust.

Additionally, when comparing GSMA mobile capex and the total investment provided by Infralatam, for a few years in a few countries, total investment as provided by Infralatam appeared to be lower than mobile-only investment provided by GSMA. This was because for Infralatam, total data is the sum of public and private telecom investments. Often, either private or public data was missing for a country. This means that total investment as provided by Infralatam can be inferred because it lacks one of its components. This was especially problematic for countries that lacked information on private investment (which on average represents approximately 85 percent of total ICT investment in LAC[120]). This was corrected for as follows:

- First, the implied fixed telecom investment was calculated by subtracting mobile capex (as provided by GSMA) from total investment. As expected for some observations, the implied fixed telecom investment was negative, given that total investment as provided by Infralatam was infra-estimated.
- Then, the average ratio of mobile to total investment was calculated for each country. Only those observations for which both

[119] At first, this study complemented Infralatam data with ITU's data, for which information for Suriname is available. However, the data provided by ITU are very different from that of Infralatam. Therefore, the two databases could not be used as complementary.

[120] As estimated based on Infralatam data (using only observations for which the data was complete, that is, both public and private investment were considered).

public and private investment were available were included.

- In cases where the implied fixed telecom investment was negative, and thus total investment was infra-estimated, total investment was calculated as that investment which reflected the average ratio[121] of mobile to total investment.[122] In other words, if, for example, in Colombia, mobile investment represented on average 60 percent of total ICT investment, the total investment values of Colombia that were infra-estimated were corrected by assuming that total investment in that year respected the average ratio of mobile to total investment. For instance, in 2015 total investment in Colombia was only around US$300 million, according to Infralatam. However, mobile capex was more than US$1 billion the same year, according to GSMA. The total value was thus estimated at US$1.8 billion.

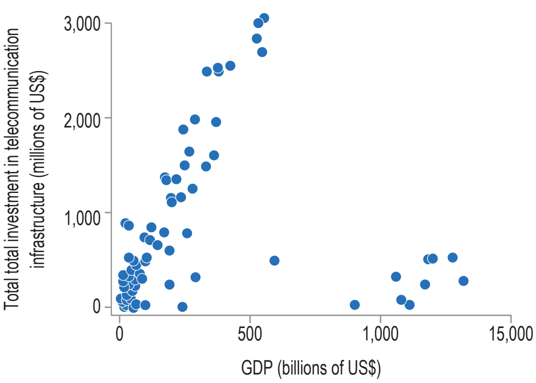
However, this methodology was not sufficient to solve the issues of three countries (Mexico, Ecuador and Panama), for which the whole series of either private (Mexico and Ecuador) or public (Panama) investment was missing from the Infralatam database. This issue was resolved as follows:

- For Mexico, public investment data provided by Infralatam were augmented by data on investment in ICT, with private participation data provided by the World Bank. For the years for which data from the World Bank were missing, an average of the available data was used.
- The same method was not possible for Ecuador since the World Bank does not have data for this country. World Bank data could not be used for Panama since the public investment data were missing. The values for Ecuador and Panama were infra-estimated in the Infralatam database using averages (without considering outliers).

The comparison of the correlation coefficient of the total investment variable (as first provided raw by Infralatam) and GDP to the correlation coefficient of the total investment variable (as estimated according to the methodology used for this study) shows that the estimation is robust. Indeed, while the former was only 25 percent over the whole sample, and 86 percent without considering Mexico (which was an outlier because of its very low value of investment because Infralatam did not account for private investment), the latter is 96 percent over the whole sample. The following scatterplots show the previous dispersion of investment with respect to GDP and the current dispersion after these estimations. It is clear from the graphs that the dispersion has diminished thanks to these estimations.

These estimations were checked for consistency with data publicly available. For Mexico, the country for which the Infralatam data were the least complete, the Federal Telecommunications Institute (Instituto Federal de Telecomunicaciones,

FIGURE B.1. Scatterplot of Raw Investment Data and GDP

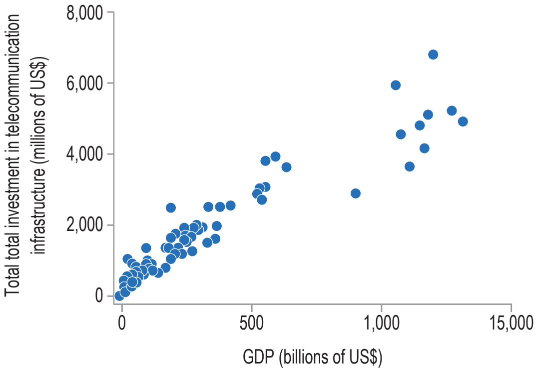


Sources: Infralatam, the World Bank, and the author's estimations.

[121] As estimated based on GSMA mobile capex data and Infralatam total investment data (using only observations for which the data were complete. That is, both public and private investment were considered).

[122] It is possible that when the implied fixed telecom investment is positive, total investment can be estimated by Infralatam, although to a lesser degree. However, this analysis tackles the main issues related to the data, as the R^2 of the regressions and the scatterplot analysis shown in this section confirm.

FIGURE B.2. Scatterplot of Estimated Investment and GDP



Sources: Infralatam, the World Bank, and the author's estimations.

or IFT) publishes statistics on the total investment of the ICT sector. The IFT considers that in the first three quarters of 2017, US$2.685 billion were invested in fixed telecom (IFT, 2017). As presented below, this value is close to and smaller than the US$3.104 billion estimated here.

Infralatam also provides investment data disaggregated into public and private investment. However, as the discussion above highlights, this disaggregation is not available for all years and countries. Therefore, to fill in the gaps for those years in which disaggregated data was missing, the average proportion of public to private investments in the country was assumed, based on the years for which Infralatam data were available. For those countries for which there was no disaggregation in Infralatam, the average proportion of the whole sample was assumed.

Matrix Tables of Investment in the LAC Region

The following tables detail the total investment in telecom in the LAC region in the period 2008–2017, disaggregated into mobile, fixed, fiber optic, public, and private.

TABLE B.1. Total Telecom Investment (millions of US$)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Argentina	1,599	1,486	2,549	3,011	2,695	3,054	2,841	3,926	3,800	3,636
Bolivia	122	140	172	178	174	274	304	327	385	416
Colombia	1,883	1,156	1,985	2,478	1,955	2,498	2,534	1,870	1,917	1,903
Chile	1,347	1,357	1,346	1,497	1,643	1,252	1,639	1,551	1,684	1,669
Costa Rica	292	289	317	519	858	311	300	551	602	642
Ecuador	769	513	480	630	567	888	961	769	1,342	769
Guatemala	526	474	452	467	542	477	464	600	669	723
Honduras	335	277	362	207	352	208	214	465	518	516
Mexico	3,648	2,891	5,940	5,106	6,799	5,220	4,909	4,150	4,558	4,802
Panama	1,007	395	395	395	395	445	344	395	395	395
Peru	845	705	662	788	1,014	1,101	1,142	1,603	2,471	1,722
Suriname	37	39	38	38	41	40	40	38	30	30

Sources: Frontier Economics, Infralatam, Telegeography, and ITU.

TABLE B.2. Fixed Telecom Investment (millions of US$)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Argentina	898	875	1,893	1,950	1,583	1,918	1,832	2,468	2,389	2,286
Bolivia	34	39	48	49	48	75	84	90	106	115
Colombia	1,187	28	853	922	631	1,257	1,335	750	769	764
Chile	777	776	447	158	226	89	490	464	504	499
Costa Rica	255	229	225	402	687	73	55	275	300	320
Ecuador	499	169	152	306	197	498	545	363	904	351
Guatemala	258	175	167	172	200	139	151	221	247	267
Honduras	208	131	225	74	218	72	76	289	322	321
Mexico	1,802	1,873	4,884	3,600	4,388	2,875	2,955	2,433	2,705	3,104
Panama	882	195	201	139	190	219	73	110	125	107
Peru	346	144	159	57	215	262	121	339	523	364
Suriname	23	21	23	25	26	18	17	15	9	11

Sources: Frontier Economics, Infralatam, Telegeography, and ITU.

TABLE B.3. Mobile Investment (millions of US$)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Argentina	701	611	656	1,061	1,112	1,135	1,009	1,458	1,411	1,350
Bolivia	89	101	125	129	126	198	220	237	279	302
Colombia	696	1,128	1,132	1,556	1,324	1,241	1,198	1,120	1,148	1,139
Chile	570	581	900	1,339	1,417	1,163	1,149	1,087	1,180	1,170
Costa Rica	37	60	92	117	171	238	245	276	302	322
Ecuador	270	344	328	324	370	390	416	406	438	417
Guatemala	268	299	285	294	342	339	313	378	422	456
Honduras	127	146	137	134	133	136	138	176	196	196
Mexico	1,847	1,018	1,056	1,506	2,411	2,345	1,954	1,718	1,854	1,698
Panama	125	199	194	255	205	226	271	285	270	287
Peru	499	561	503	731	800	839	1,021	1,264	1,948	1,357
Suriname	14	17	15	13	14	22	23	23	21	19

Sources: Frontier Economics, Infralatam, Telegeography, and ITU.

TABLE B.4. Estimated Private ICT Investment (millions of US$)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Argentina	1,580	1,319	1,728	2,425	2,082	2,343	2,344	3,210	3,108	2,974
Bolivia	63	72	89	92	90	141	157	169	199	215
Colombia	1,691	900	1,658	2,096	1,532	1,994	1,904	1,520	1,558	1,547
Chile	1,342	1,342	1,317	1,478	1,636	1,244	1,623	1,536	1,667	1,652
Costa Rica	108	107	117	170	444	104	90	204	222	237
Ecuador	623	416	389	510	459	719	779	623	1,087	623
Guatemala	525	473	452	466	541	477	464	599	668	723
Honduras	334	275	361	206	350	207	213	463	516	514
Mexico	2,955	2,341	4,811	4,136	5,507	4,228	3,976	3,361	3,692	3,890
Panama	816	320	320	320	320	361	279	320	320	320
Peru	842	684	642	774	993	1,081	1,112	1,570	2,418	1,685
Suriname	30	31	31	31	33	32	32	31	24	25

Sources: Frontier Economics, Infralatam, Telegeography, and ITU.

TABLE B.5. Estimated Public ICT Investment (millions of US$)

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Argentina	19	166	821	586	613	711	498	715	693	663
Bolivia	59	68	83	86	84	132	147	158	186	202
Colombia	192	256	327	382	423	505	629	350	358	356
Chile	5	15	29	19	7	8	17	16	17	17
Costa Rica	184	182	200	349	414	207	210	348	379	405
Ecuador	146	98	91	120	108	169	183	146	255	146
Guatemala	1	0.5	0.4	0.5	0.5	0.04	0.2	0.6	0.6	0.7
Honduras	1	1	2	1	2	1	1	2	2	2
Mexico	693	549	1,129	971	1,292	992	933	789	866	913
Panama	191	75	75	75	75	85	65	75	75	75
Peru	3	21	20	15	21	20	30	34	52	36
Suriname	7	7	7	7	8	8	8	7	6	6

Sources: Frontier Economics, Infralatam, Telegeography, and ITU.

Annex C
Econometric Estimate

Overview

The steps undertaken to estimate the impact of the digital industry on the SDGs by using econometrics for those SDGs for which enough information was available (i.e., SDGs 1–5 and SDGs 8, 9,10, and 13) are as follows:

- First, the appropriate metric was selected to measure the impact of the digital industry on the SDGs.[123] This is the dependent variable in each regression.
- The main explanatory variables of interest include total investment in ICT and investment disaggregated into fixed and mobile (as estimated in the previous section). Using investment in telecom as the independent variable of interest is very useful to determine the total investment required to reach the OECD average and the investment required to achieve the 2030 target.
- To avoid confounding the effect of investments in telecom infrastructure with other kinds of investments being carried out in the countries under study, investment in utilities (which includes investment in transport, electricity, and water, as provided by Infralatam) is included in the regressions as a control variable. Socio-economic variables (mainly provided by the World Bank and ECLAC), such as the unemployment rate, GDP growth, and GDP per capita, are also included to control for macroeconomic evolution in the country.
- Finally, some specific variables in each SDG are used to control for factors which may also affect the SDG indicator beyond the macroeconomic variables:
    - In the case of hunger (SDG 2), public expenditure in health as percentage of GDP, public expenditure in education as percentage of GDP, and proportion of the population living in rural areas are included.
    - For health (SDG 3), public expenditure in health as a percentage of GDP and net percentage of children enrolled in secondary school are included.
    - For education (SDG 4), public expenditure in social protection is included.

[123] In some SDGs, the same indicator cannot be used as the official metric for the objectives presented by the UN Division for Sustainable Development Goals because the indicator has missing data for years between 2008–2015 and/or missing data in the countries analyzed. This is true for SDGs 3, 4, 5.2, 8, 9.2, 10, and 13. However, in all these instances the available indicator that is as close as possible to the targets was used. Official targets were consulted at: https://unstats.un.org/sdgs/indicators/database/.

- In the case of the first specification for gender equality (SDG 5), measured as the proportion of seats held by women in national parliaments (percent), the percentage of girls enrolled in secondary education is included.
- For economic growth (SDG 8), the analysis was based in a theoretical model specification (Jorgenson and Stiroh, 2000; Oliner and Sichel, 2000). Therefore, its structure differs from the rest of the estimations.
- For innovation (SDG 9) gross enrolment rate in tertiary education and public expenditure in education as a percentage of GDP were used for the first model specification.
- For inequality (SDG 10), in both specifications, public expenditure on housing and community services were used.
- For climate change (SDG 13), renewable electricity consumption (percent) and expenditure in R&D as a percentage of GDP were included.

The final database, composed of panel data, has, in most cases, observations across the 12 selected countries and between 2008–2017.[124] This enables a methodology fixed effects model in all the regressions to be employed, thereby controlling for unobserved aspects which may affect the level of the SDG within each country. For example, aspects such as government policy and the strength and quality of institutions determine people's ability to socially progress (and thus the level of poverty, hunger, and inequality). Aspects such as environmental regulations, green consciousness, and the availability of clean natural resources determine the attractiveness of renewable energy production and consumption. Cultural norms and values have an impact on gender equality. These aspects are specific to each country and determined by their history and culture, and do not display variation in time when considering a relatively short period of 10 years.

Finally, dependent and independent variables are measured both in logarithms or as a percentage. The variables used in this study related to telecom investment are always in logs. Therefore, it proposes two potential model specifications:

- For SDGs 3, 8, and 13, dependent variables are also transformed into logs. In these cases, the coefficients can be directly interpreted as perceptual changes. If the coefficient of mobile investment is 0.05, this would imply that an increase of 1 percent in mobile investment increases the SDG by 0.05 percent.
- The dependent variables for the remaining SDGs are measured as a percentage, while the telecom independent variables are in logs. Thus, the coefficient should be interpreted (dividing its value by 100) as the percentage point increase in the SDG caused by a 1 percent increase in investment in telecom.

We have attempted to control for as many variables affecting the SDGs as possible given the available data. In the following sections, the econometric results are presented for the selected SDGs. The following tables summarize the main descriptive statistics of the data.

124 Some of the relevant variables are missing data for some countries and/or some years.

TABLE C.1. Descriptive Statistics – Investment Variables

Variable	No. obs	Mean	Std. dev.	Min	Max
Fixed telecom investment (millions of US$)	120	650	936	9	4,884
Mobile telecom investment (millions of US$)	120	620	573	13	2,411
Total telecom investment (millions of US$)	120	1,271	1,405	30	6,799
Investment in utilities (millions of US$)	86	5,291	5,356	236	22,995

Source: Frontier Economics analysis.

TABLE C.2. Descriptive Statistics – Dependent Variables

Variable	No. obs	Mean	Std. dev.	Min	Max
Poverty headcount ratio at US$1.90 a day (2011 PPP) (%)	71	5.68	4.86	0.6	19.6
Prevalence of undernourishment in the population (%)	96	10	6	3	28
Life expectancy at birth (years)	108	74	3	65	80
Net secondary enrolment rate (%)	94	72	14	38	89
Proportion of seats held by women in national parliaments (%)	120	25	11	8	53
Girls net enrolment in secondary school (%)	94	73	14	37	91
GDP constant prices 2010 (millions of US$)	120	214,000	314,000	4,030	1,280,000
Trademark applications (number)	96	29,175	31,350	472	128,902
R&D expenditures GDP (%)	62	0.33	0.18	0.04	0.64
Share of income in the bottom 10% of the population (%)	80	1.37	0.32	0.8	2.2
Share of income in the bottom 20% of the population (%)	80	4	0.70	2.7	5.7
CO_2 per capita (number emissions)	84	2.56	1.31	0.78	4.77

Source: Frontier Economics analysis.

TABLE C.3. Descriptive Statistics – Control Variables

Variable	No. obs	Mean	Std. dev.	Min	Max
Unemployment rate (%)	105	6	2	2	12
GDP real growth (%)	119	0.21	1.86	–0.96	19
Rural population (number of inhabitants)	120	6,096,746	6,781,835	172,683	26,100,000
Education expenditure GDP (%)	87	4	2	1	7
Health expenditure GDP (%)	87	1.60	0.98	0	4.41
Social protection expenditure GDP (%)	87	3.44	2.43	0.48	10.84
Labour force (number of workers)	120	12,300,000	14,500,000	191,461	58,100,000
Gross fixed capital minus ICT (millions of US$)	110	49,000	68,400	1,600	269,000
GDP per capita (US$)	120	9,714	11,061	959	48,443
Gross enrolment rate in tertiary education (%)	66	49	21	18	90

Source: Frontier Economics analysis.

Estimation Results

SDG 1: End of Poverty

TABLE C.4. Impact of Digital Infrastructure on SDG 1

Poverty headcount ratio at US$1.90 per day (2011 PPP) (%)	(1)	(2)
Variables	**Disaggregated**	**Total**
Fixed telecom investment (natural logarithm)	–0.4520** (0.1865)	
Mobile telecom investment (natural logarithm)	–1.3503*** (0.4550)	
Investment in utilities (natural logarithm)	–1.3493*** (0.3753)	–1.8158*** (0.3205)
Unemployment rate (%)	0.4563*** (0.1196)	0.4022*** (0.1209)
Real GDP growth (%)	–0.0143 (0.0608)	–0.0518 (0.0625)
Total telecom investment (natural logarithm)		–1.3247*** (0.4591)
Constant	24.3383*** (3.2442)	26.5823*** (4.0338)
Observations	60	60
R-squared	0.639	0.603
Number of countries	10	10
Standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		
Fixed-effects model		

Sources: Frontier Economics estimations and data from ECLAC, GSMA, Infralatam, and the World Bank.

SDG 2: Zero Hunger

TABLE C.5. Impact of Digital Infrastructure on SDG 2

Prevalence of undernourishment in the population (%)	(1)	(2)
Variables	**Disaggregated**	**Total**
Fixed telecom investment (natural logarithm)	–0.2433 (0.1933)	
Mobile telecom investment (natural logarithm)	–1.4292*** (0.5294)	
Investment in utilities (natural logarithm)	–1.6836*** (0.3777)	–2.1518*** (0.3098)
Unemployment rate (%)	0.2119* (0.1236)	0.2392* (0.1239)
Rural population (natural logarithm)	–14.4977** (6.5241)	–7.9056 (5.6225)
Real GDP growth (%)	–0.0447 (0.0554)	–0.0686 (0.0562)
Education expenditure GDP (%)	0.4743 (0.3681)	0.3198 (0.3670)
Health expenditure GDP (%)	–0.0542 (0.4718)	0.1560 (0.4595)
Total telecom investment (natural logarithm)		–1.0999** (0.4498)
Constant	253.4327** (101.6170)	153.5370* (87.7808)
Observations	80	80
R-squared	0.604	0.585
Number of countries	11	11
Standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		
Fixed-effects model		

Sources: Frontier Economics estimations and data from ECLAC, GSMA, Infralatam, and the World Bank.

SDG 3: Good Health and Well-being

TABLE C.6. Impact of Digital Infrastructure on SDG 3

Life expectancy at birth (natural logarithm)	(1)	(2)
Variables	**Disaggregated**	**Total**
Fixed telecom investment (natural logarithm)	0.0022** (0.0010)	
Mobile telecom investment (natural logarithm)	0.0145*** (0.0032)	
Investment in utilities (natural logarithm)	0.0047** (0.0022)	0.0075*** (0.0022)
Unemployment rate (%)	0.0004 (0.0009)	–0.0010 (0.0009)
Real GDP growth (%)	–0.0002 (0.0003)	–0.0001 (0.0003)
Enrolment in secondary education (%)	0.0007** (0.0003)	0.0011*** (0.0003)
Health expenditure GDP (%)	0.0018 (0.0023)	–0.0004 (0.0023)
Total telecom investment (natural logarithm)		0.0095*** (0.0025)
Constant	4.1150*** (0.0281)	4.1144*** (0.0309)
Observations	69	69
R-squared	0.664	0.616
Number of countries	11	11
Standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		
Fixed-effects model		

Sources: Frontier Economics estimations and data from ECLAC, GSMA, Infralatam, and the World Bank.

SDG 4: Quality Education

TABLE C.7. Impact of Digital Infrastructure on SDG 4

Net secondary enrolment rate (%)	(1)	(2)
Variables	**Disaggregated**	**Total**
Fixed telecom investment (natural logarithm)	0.5325 (0.3970)	
Mobile telecom investment (natural logarithm)	3.1044** (1.3474)	
Investment in utilities (natural logarithm)	1.5901* (0.8954)	2.2643*** (0.8459)
Unemployment rate (%)	0.2739 (0.3973)	–0.0599 (0.3691)
Social expenditure GDP (%)	0.4788 (0.6075)	0.7706 (0.6034)
Total telecom investment (natural logarithm)		1.4300 (0.9965)
Constant	34.4963*** (10.8235)	42.5811*** (10.9415)
Observations	70	70
R-squared	0.271	0.211
Number of countries	11	11
Standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		
Fixed-effects model		

Sources: Frontier Economics estimations and data from ECLAC, GSMA, Infralatam, and the World Bank.

SDG 5: Gender Equality

TABLE C.8. Impact of Digital Infrastructure on SDG 5

	Proportion of seats held by women in national parliaments (%)		Girls net enrolment in secondary school (%)	
	(1)	(2)	(3)	(4)
Variables	**Disaggregated**	**Total**	**Disaggregated**	**Total**
Fixed telecom investment (natural logarithm)	2.2082** (0.9404)		0.3081 (0.3638)	
Mobile telecom investment (natural logarithm)	4.7739 (3.2448)		2.9413** (1.1985)	
Investment in utilities (natural logarithm)	2.8576 (2.1699)	3.3350 (2.0368)	1.3997* (0.8233)	2.1062** (0.7898)
GDP growth (%)	–0.3047 (0.2798)	–0.2377 (0.2771)	0.0107 (0.1090)	0.0203 (0.1142)
Unemployment rate (%)	1.4310 (0.9299)	1.2219 (0.8375)	0.2642 (0.3604)	–0.0603 (0.3450)
Girls enrolment in secondary education (%)	0.8720** (0.3494)	0.9794*** (0.3272)		
Total telecom investment (natural logarithm)		6.4285*** (2.2941)		0.8103 (0.9389)
Constant	–115.3297*** (29.6255)	–127.4889*** (30.2299)	41.8249*** (10.0354)	52.5467*** (10.2449)
Observations	70	70	70	70
R-squared	0.353	0.363	0.256	0.180
Number of countries	11	11	11	11
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				
Fixed-effects model				

Source: Frontier Economics analysis.

SDG 8: Decent Work and Economic Growth

The empirical model presented below is based on the theoretical neoclassical exogenous growth theories of Solow (1956) and Swan (1959). Solow and Swan used aggregate production functions to describe the empirical relationship between specified outputs and inputs at the aggregate country level. As described by Barro and Sala i Martin (2004), in the Solow–Swan model total production depends on labour (L), capital (K) and a measure of long-term technological change (A). The simplest way to describe the Solow-Swan model is by using the Cobb-Douglas production function, where: (i) Y equals total production, L equals labour input, K equals capital input, and A is a productivity parameter that reflects the current state of knowledge; (ii) α is strictly less than one, so that there are diminishing returns to individual capital accumulation and the function displays constant returns to scale.

$$Y(t) = K^{\alpha}(A(t)L(t))^{(1-\alpha)}$$

The analysis uses the aggregate production function to construct economy-wide estimates of output and its sources. The objective is to estimate the output elasticity of ICT capital, that is, the responsiveness of output to a change in the level of ICT inputs, all other things being equal.

TABLE C.9. Impact of Digital Infrastructure on SDG 8

GDP constant prices 2010 US$ (natural logarithm)	(1)	(2)
Variables	**Disaggregated**	**Total**
Fixed telecom investment (natural logarithm)	0.0228*** (0.0064)	
Mobile telecom investment (natural logarithm)	0.0969*** (0.0144)	
Gross fixed capital minus ICT (natural logarithm)	0.2638*** (0.0285)	0.3016*** (0.0297)
Labour force (natural logarithm)	0.7212*** (0.0836)	0.8261*** (0.0866)
Total telecom investment (natural logarithm)		0.0874*** (0.0151)
Constant	5.5251*** (1.0700)	4.4309*** (1.1201)
Observations	110	110
R-squared	0.896	0.876
Number of countries	12	12
Standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		
Fixed-effects model		

Sources: Frontier Economics estimations and data from ECLAC, GSMA, Infralatam, and the World Bank.

SDG 9: Industry, Innovation, and Infrastructure

TABLE C.10. Impact of Digital Infrastructure on SDG 9

	R&D expenditure GDP (%)		Trademark applications (natural logarithm)	
	(1)	(2)	(3)	(4)
Variables	Disaggregated	Total	Disaggregated	Total
Fixed telecom investment (natural logarithm)	0.0109 (0.0076)		0.0574** (0.0245)	
Mobile telecom investment (natural logarithm)	0.0067 (0.0259)		–0.0018 (0.0835)	
Investment in utilities (natural logarithm)	0.0244 (0.0276)	0.0274 (0.0272)	0.0557 (0.0568)	0.0572 (0.0599)
Unemployment rate (%)	–0.0050 (0.0065)	–0.0050 (0.0055)		
Gross enrolment rate in tertiary education (%)	0.0027* (0.0016)	0.0022 (0.0015)		
GDP per capita constant prices 2010 US$ (natural logarithm)	–0.3288 (0.2963)	–0.3064 (0.2478)	0.2891 (0.4266)	0.1156 (0.3900)
Education expenditure GDP (%)	0.0741*** (0.0191)	0.0713*** (0.0182)		
Total telecom investment (natural logarithm)		0.0306 (0.0196)		0.1178* (0.0664)
GDP growth (%)			–0.0082 (0.0068)	–0.0073 (0.0070)
Constant	2.7241 (2.4792)	2.4188 (2.0849)	6.6501** (3.0727)	7.6735*** (2.8030)
Observations	44	44	74	74
R-squared	0.601	0.602	0.212	0.174
Number of countries	7	7	11	11
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				
Fixed-effects model				

Source: Frontier Economics analysis.

SDG 10: Reduced Inequalities

TABLE C.11. Impact of Digital Infrastructure on SDG 10

	Share of income in the bottom			
	10% of the population (%)		20% of the population (%)	
	(1)	(2)	(3)	(4)
Variables	Disaggregated	Total	Disaggregated	Total
Fixed telecom investment (natural logarithm)	0.0354* (0.0181)		0.0590 (0.0370)	
Mobile telecom investment (natural logarithm)	0.0998** (0.0444)		0.1868** (0.0906)	
Investment in utilities (natural logarithm)	0.1074*** (0.0371)	0.1331*** (0.0297)	0.2729*** (0.0756)	0.3215*** (0.0600)
Unemployment rate (%)	–0.0270** (0.0118)	–0.0237** (0.0112)	–0.0617** (0.0240)	–0.0553** (0.0226)
Housing and community expenditure GDP (%)	0.1122 (0.0738)	0.1313* (0.0709)	0.2029 (0.1507)	0.2357 (0.1432)
Total telecom investment (natural logarithm)		0.1380*** (0.0406)		0.2700*** (0.0820)
Constant	–0.1865 (0.3186)	–0.5431 (0.3552)	0.6468 (0.6503)	–0.1431 (0.7173)
Observations	68	68	68	68
R-squared	0.511	0.535	0.556	0.587
Number of countries	11	11	11	11
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				
Fixed-effects model				

Source: Frontier Economics analysis.

SDG 13: Climate Action

TABLE C.12. Impact of Digital Infrastructure on SDG 13

CO_2 emissions per capita (natural logarithm)	(1)	(2)
Variables	**Disaggregated**	**Total**
Fixed telecom investment (natural logarithm)	–0.0146* (0.0083)	
Mobile telecom investment (natural logarithm)	–0.0897*** (0.0239)	
Investment in utilities (natural logarithm)	0.0284 (0.0244)	0.0509** (0.0213)
GDP per capita constant prices 2010 US$ (natural logarithm)	0.7526*** (0.1794)	0.3071*** (0.0992)
Renewable electricity consumption (%)	–0.0090*** (0.0028)	–0.0087*** (0.0030)
R&D expenditure GDP (%)	–0.1445 (0.1411)	–0.2607* (0.1522)
GDP growth (%)	0.0038* (0.0021)	0.0040* (0.0023)
Total telecom investment (natural logarithm)		–0.0079 (0.0243)
Constant	–5.0662*** (1.3842)	–1.9056** (0.7899)
Observations	56	56
R-squared	0.683	
Number of countries	10	10
Standard errors in parentheses		
*** p<0.01, ** p<0.05, * p<0.1		
Fixed-effects model		

Source: Frontier Economics analysis.

Annex D
Impact of Data Centers, Satellite, and Backbone Networks on Sustainable Development

Data Centers

Data centers are facilities that centralize an organization's IT operations and equipment, and the location where it stores, process, manages, and disseminates its data. A single data center comprises servers, routers, and firewalls, as well as supporting components such as backup equipment, fire suppression, and air conditioning. Data centers can be integrated as part of a shared facility or built as stand-alone units. Major data center users include banking, financial services, and insurance (BFSI) companies, as well as the IT industries and healthcare.

There are three types of services traditionally provided by data centers: housing (or co-location), hosting, and cloud services. Housing services provide the customer the ability to locate and manage their own servers, while the data center provides support in the form of ICT, power, and cooling infrastructure. In a hosting service, the data center owner also locates (hosts) and maintains the client's servers. Cloud services provide clients with virtual computing resources via broadband network access, which can be delivered in the form of private, community, public, or hybrid deployment models.

Latin American Data Center Market

The growth of the Latin American data center market is being fueled by the continued investment from local and global services providers. The increasing demand for cloud-based services and platforms such as Amazon Web Services, Microsoft, Google, Oracle, and IBM will transform the market in the coming years. Major investors for new facilities in LAC are primarily large telecom companies such Entel, Telefonica (Vivo), AmericaTel, Telecarrier, and América Movil. The data center power market in LAC is projected to generate revenues of around US$490 million by 2023, and it is anticipated to grow at a compound annual growth rate of 11.87 percent during the 2018–2023 period.[125]

The major regional contributors are Brazil (47.6 percent), Mexico (25.8 percent), Chile (8.5 percent), Colombia (7.6 percent), Argentina (6.7 percent), and Peru (3.8 percent), with Brazil largely dominating the market in the

[125] https://www.arizton.com/market-reports/data-center-power-market-latin-america.

2016–2017 period. In 2016, the data center market was US$2.87 billion. Projections indicate that the regional data center market will account for US$4.37 billion by 2021.[126]

According to the IDB research on the current data center environment in the LAC region, the best countries for the construction of such facilities are Argentina, Bahamas, Brazil, Chile, Costa Rica, Panama, and Uruguay. The evaluation was assessed via the Data Center Development Index, which evaluates the following criteria: (1) economic development, (2) fundamental infrastructure, (3) connectivity, (4) data center infrastructure, and (5) critical infrastructure protection (CIP) (Garcia Zaballos and Iglesias, 2017).[127]

The construction and maintenance of new data centers in the region are constrained by high investment (capex) and operational cost (opex), in addition to the lack of qualified personnel and unreliable power capacity and connectivity.[128]

Data Centers and Sustainable Development

Sustainable data centers can assist the achievement of SDG 13 (Climate Action) by reducing the environmental effects of ICT and data facilities. Data centers consume a considerable amount of electricity and saving energy is a major challenge. To reduce data center consumption and decrease their CO_2 emissions, strategies like the consolidation of servers in data centers and virtualization have been proposed. For instance, in Japan, the estimated annual GHG emissions from 1.02 million servers located in Tokyo in 2012 was 1,700 tons. According to the Japan Data Center Council, by consolidating the set of data centers, annual GHG emissions could be reduced by 15 percent (250,000 tons). Furthermore, additional virtualization and consolidation of data centers would lead to an estimated 40 percent (680,000 tons) reduction in emissions.[129]

In addition, the deployment of state-of-the-art data centers, such as software-defined data centers, would yield the following benefits: carbon reduction due to the replacement of older/obsolete ICT infrastructures and mitigation of problems created by the lack of skilled ICT engineers through the centralized management of data resources.

Satellite

Satellite technology is currently available throughout the LAC region to provide a broad range of services, including telecom and surveillance. In 2016, there were 12 communication satellite operators in the region, which included companies operating globally, regionally, and domestically.

Domestic satellite programs have been established to complement the existing communication infrastructure and reduce the digital divide. The following are recent experiences of LAC governments in the operation of state-owned communication satellites:

- Agencia Boliviana Espacial (Bolivia): Acquired Tupac-Katari (TKsat-1) satellite (2013) aiming to improve access by Bolivian citizens to teleconnection and media services. Currently, multiple television and radio stations use this satellite, as well as Bolivia's customs service and state-owned oil company YPFB.[130] However, high service prices have deterred various telecom companies to use Tupac Katari broadband services. Notwithstanding this, mobile carriers, such as VIVA, use the KT-1 satellite to provide broadband in rural and insolated areas.[131]
- ARSAT (Argentina): Argentina built and deployed ARSAT-1 and ARSAT-2 satellites in 2014 and 2015, respectively. ARSAT-1 supports mobile carriers, improves the penetration and

126 http://www.avilatinoamerica.com/201805015353/noticias/empresas/mexico-se-destaca-como-mercado-estrategico-para-data-centers.html.
127 http://dx.doi.org/10.18235/0000692.
128 https://www.cisco.com/c/dam/global/es_mx/solutions/datacenter/next_gen_tech/pdf/fs_white_paper_cisco_es.pdf.
129 https://www.dir.co.jp/report/research/capital-mkt/esg/09073101law.pdf.
130 http://www.thespacereview.com/article/3413/1.
131 https://www.viva.com.bo/viva/vernoticia/663.

quality of open digital television (TDA) service, and connects 2500 rural schools via broadband as part of the Build Equality (Construir Igualdad) initiative.[132] With ARSAT-1, ARSAT-2, and the future deployment of ARSAT-3, Argentina is the eighth country to develop and build its own geostationary satellites.

Regional-based operators offer telecom solutions to governments and companies throughout the region, including mobile backhaul services, video broadcasting, Very Small Aperture Terminal (VSAT) platforms, and satellite internet. One example of such services is the use of HISPASAT's (HISPAMAR) satellite fleet by Telefonica's Media Networks Latin America (MNLA). MNLA uses Amazonas-3's Ka band to offer residential broadband in suburbs of major cities in South America.

In recent years there has been interest in deploying the new generation High-Throughput Satellite (HTS), which is particularly suited for broadband. By mid-2016 only two satellite operators offered HTS capabilities in LAC: Telsat/Viasat, through the Anik-F2/WildBlue-1 satellite; and, HISPASAT/ HISPAMAR through the Amazonas-3 satellite.[133] In future years, the regional HTC services will be expanded with the deployment of the following satellites:

- HISPAMAR / HISPAMAT: Amazonas 5 (2017)
- TELEBRAS: SDGS-1
- EUTELSAT: EUTELSAT 65 W (2016)
- Star One (Embratel): Start One-D1 (2016)

Satellite Communications in the Achievement of the SDGs

Satellite technology can assist and monitor the achievement of each of the SDGs in multiple ways. Earth observation satellites provide accurate and reliable information on the state of the atmosphere, oceans, rivers, soil, crops, built infrastructure, and others, as well as changes over time.[134] These observations help to monitor and understand the effects of climate change (SDG 13), improve natural resource management (SDG 2), and help to prevent threats to biodiversity in land and oceans (SDGs 14 and 15). According to Eumetsat estimates, the benefits of weather forecasting based on satellite observation reaches €64.5 billion per year in the European Union alone.[135]

Satellite-based technology can also improve communications and data-sharing capabilities in critical situations or places where communication infrastructure is lacking, as well as support disaster relief and mitigation.[136,137] Satellite communications can also promote health and well-being (SDG 3) through tele-medicine and e-health applications, which allow specialists to monitor the health of patients in remote villages. In addition, satellite communications can bring educational resources (e-learning) and internet connectivity to remote and vulnerable communities (SDG 4). The following are examples of the uses of communication satellites to achieve the SDGs:

- **Kioskos Digitales in Colombia.** In mid-2014 Colombia's Ministry of Information and Technology (MinTic) launched Kioskos Digitales as part of the national communications plan Vive Digital (2014–2018). The initiative aimed to establish more than 5,300 internet access points (kioskos) within schools and communities in rural areas of more than 100 people. Kioskos provide internet connection and other ICT and mobile services via VSAT platforms

[132] https://www.minutouno.com/notas/341068-para-que-sirve-y-cual-sera-la-funcion-del-satelite-arsat-1.
[133] https://publications.iadb.org/bitstream/handle/11319/7843/The-Provision-of-Satellite-Broadband-Services-in-Latin-America-and-the-Caribbean.pdf?sequence=1&isAllowed=y.
[134] http://eohandbook.com/sdg/files/CEOS_EOHB_2018_SDG.pdf.
[135] https://news.itu.int/how-can-satellites-help-to-achieve-the-sdgs/.
[136] https://www.weforum.org/agenda/2017/07/using-space-to-help-global-development/.
[137] http://unesdoc.unesco.org/images/0023/002346/234674e.pdf.

TABLE D.1. Backbone National Networks in Latin America

	Network	Km deployed	Concession year	Period of the concession	Type	Retail services	Investment (millions of US$)
Chile (Fibra Óptica Austral)	Transport (Regional)	3,953 (recently tendered)	2017	30 years	PPP	No	92
Argentina (Red Federal de Fibra Óptica)	Transport (National)	33,000 (partly constructed and operated)	2015		State owned	No	1,329
Colombia (Proyecto Nacional de Fibra Óptica)	Transport and access (National)	19,000 (in operation)	2011	17,5 years	PPP	Yes	630
Mexico (Red Troncal)	Transport (National)	25,650 (to be tendered)	2017	30 years	PPP	No	200
Peru (Red Dorsal Nacional de Fibra Óptica)	Transport (National)	13,400 (in operation)	2013	20 years	PPP	No	323

Source: OSIPTEL Informe Nº 00045-GPRC/2018 February 5, 2018, except for the investment amounts which are based on information from national regulators.

with the support of HISPASAT, Intelsat SA, and Gillat Satelite Networks.[138,139]

- **Brazil SEDUC Project**. HugesNet partnered with the Secretariat of Education (SEDUC), State of Amazonas (Brazil), to provide satellite broadband for educational purposes in rural areas. The project aimed to bring interactive learning experiences to 20,000 students in 300 rural schools, leveraging Brazil-wide HugesNet satellite service, in addition to IPTV, to transmit classes from Manaus to 700 classrooms all over the State of Amazonas.[140,141]
- **SATMED e-health Platform.** SATMED is an initiative funded by SES and the government of Luxembourg to use satellite communications to enhance public health in emerging countries. It offers and integrates a broad range of digital applications, including e-recordings, e-consultancy, e-surveillance, e-learning, and video conferences, as well as satellite broadband and cloud-based tools. SATMED has assisted with Ebola relief efforts in Sierra Leona and the development of a virtual clinic for training and workforce management in Eritrea.[142]

Backbone Networks

Backbone networks are developed to promote broadband connectivity. These networks offer backbone connectivity, while local internet service providers (ISPs) deploy the last mile access. Indeed, at present, ISPs in LAC experience an increasing demand for transmission capacity, because consumers make increasing use of the contents available on the web (videos, video call, social networks, etc.).

There are some examples of these networks in the region, although only in Colombia and Peru are the projects fully operative. Therefore, these backbone networks are too new to assess their impact on SDGs.

[138] https://unesdoc.unesco.org/ark:/48223/pf0000234674.
[139] https://www.hispasat.com/contenidos/notas-de-prensa-es/0/185–1.pdf.
[140] https://publications.iadb.org/bitstream/handle/11319/7843/The-Provision-of-Satellite-Broadband-Services-in-Latin-America-and-the-Caribbean.pdf?sequence=1&isAllowed=y.
[141] http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=37306758.
[142] https://satmed.com/project_sierraleone.php.

Backbone networks are developed under two types of financing schemes: public funds (Argentina) or public-private partnership (PPP), where the construction, operation, maintenance, and operation of the network are the responsibility of the concessionaire. Another complementary form of public financing consists of requiring public entities to transport all their internet traffic through these networks.

The fact that they are publicly funded indicates that the business case for only private investment is groundless. However, in some instances, network duplication in areas where private investment has deployed its own infrastructure is also an issue. For instance, about 70 percent of the nodes of the National Backbone Fiber Optic Network (Red Dorsal Nacional de Fibra Óptica, or RDNFO) in Peru operates in areas where there is competition and are located at close distances from the infrastructure of the companies competing with RDNFO, which affects the ability of these networks to generate revenue.

The analysis undertaken in Peru reveals several key elements that affect the success of these networks:

- Deployment focused in areas where there are no alternatives.
- Reduction in transaction costs. Contracts may include clauses that make it unnecessarily difficult for clients to agree on the terms or perform the contracts.
- Tariff and product flexibility. Especially when these networks face competition from private networks, tariff rigidity may be problematic. Even if there are no competing networks, tariff and product flexibility is helpful to accommodate different demands, as it allows the operator to adapt its commercial to volume or time of commissioning, among other attributes.
- Regulation. Different types of regulatory design provide the network operator with different incentives. One of the issues faced in Peru is that the network operator has total certainty on the revenues to be received over the concession period. In other words, revenues are guaranteed by the State. The Peruvian regulator claims that this distorts the incentives of the network operator as it has less incentives to promote demand.

Annex E

Case Studies to Identify Potential Ways to Fulfill the Digital Contribution to the SDGs

This section presents several international benchmarks to identify how other regions and countries inside and outside of the LAC region are using digital infrastructure to achieve the SDGs. The case studies presented show how both LAC countries and countries outside LAC have adopted policies to overcome the obstacles identified in Section 5, namely, the lower contribution of ICT investments in sustainable development in rural areas, in the fixed sector, and with regard to specific SDGs (SDGs 12, 14, 15, 16, and17).

Successful Benchmarks Outside the LAC Region

This section focuses successful stories outside the LAC region.

We have identified several projects that aim to improve connectivity in rural areas. These projects may be a useful guide to overcome the gap identified in the previous section and achieve the full potential of the digital industry's contribution to sustainable development in rural areas.

- **GiGA Project**: The GiGA project, launched in October 2014, aims to connect and enable access to ICT in remote locations within the republic of Korea, including rural areas and islands. The project was based on the cooperation between Korea Telecom, local governments, and residents. This project benefited the local communities by opening channels that enhance culture, education, farming, and health, as well as facilitating communication between remote islands and the mainland (ITU and UNESCO, 2015).
- **Broadband China Orientation**: The Chinese government aims to expand broadband coverage across rural and urban areas. Broadband is seen as a major foundation to promote development and foster emerging industries and international trade. Proposed strategies seek to achieve a 98 percent broadband coverage in administrative villages by 2020 and provide fixed broadband connections to 50 percent of Chinese households by 2015. In addition, the government is planning to bring Gigabit internet speeds to mayor cities. These

initiatives are supported by multiple projects, such as the Broadband Countryside Project and the Broadband Network Optimization and Acceleration Project (ITU and UNESCO, 2015).

- **Collaborating with the Power Companies**: Infrastructure-sharing between telecom and power companies represents a powerful alternative to promote the expansion of broadband in rural areas. Power companies often already have assets in place that can be adapted for the rollout of telecom networks, such as towers and ducts. Several examples suggest that infrastructure-sharing reduces costs. For example, Orange Poland saved 14 percent of its fiber investment and 12 months of time by fully sharing pipe, infrastructure, labor, and deployment costs with a power company. Norway Altibox achieved 30 percent cost savings by cooperating with 42 regional electricity companies. According to Huawei's statistics, around 160 power companies in 65 countries have already started or intend to start investing in broadband (ITU and UNESCO, 2015).
- **Global "GiGA Island" Project in Bangladesh**: To replicate the success of the Korean 'GiGA Island Project", the government of Bangladesh, with the aid of Korea Telecom, the International Organization for Migration, and NGOs, has launched the Digital Island project. This program aims to empower residents of rural communities in Moheshikhal Island with ICT solutions, including: Teachers Portal, Telemedicine, Agriculture Information and Communication Center, as well as an Integrated Pest/Crop Management. Digital Island promotes the achievement of various SDGs, including SDG 1 (End Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), SDG 4 (Quality Education), and SDG 9 (Good Jobs and Economic Growth). One of the project objectives is the creation of a replicable development model for developing countries (ITU and UNESCO, 2016).

We also identified several projects that seek to improve the ICT industry's contribution to SDG 17 by enabling PPPs to foster sustainable development through ICT.

- **Saudi Arabia's Vision 2030 – Transformation Program 2020**: Vision 2030 is a blueprint for the digital transformation and sustainable economic development of the Kingdom using PPPs to drive business models and solutions in the digital economy. To achieve Vision 2030's goals, the Kingdom launched the Transformation Program 2020, composed of 10 strategic goals and 19 initiatives. The program targets include: (i) increase in the high-speed broadband access, (ii) increase in internet penetration within Saudi Arabia from 63.7 percent to 85 percent, and (iii) increase in the ICT industry's contribution to the non-oil GDP from 1.12 percent to 2.24 percent. The results of the PPPs are already visible. For example, internet user penetration has grown from 41 percent in 2010 to 70.4 percent in 2016 and 74.9 percent in 2017 (ITU and UNESCO, 2016).
- **Centre for Digital Innovation and Capacity in the UAE**: The Centre for Digital Innovation (CoDI) of the government of the United Arab Emirates (UAE) was the winner of the C4 category for Capacity Building at the WISIS Awards (2015). The center promotes innovation by providing capacity building, quality assurance, and consulting services. The CoDI contributes to the achievement of multiple SDGs, particularly SDG 4 (Education), SDG 16 (Strong Institutions and Governance) and SDG 17 (Multi-stakeholder Partnerships). The center provides the following services: (i) testing mobile applications developed for UAE government entities, (ii) provisioning, testing, and demonstration of new and innovative tools and technologies, and (iii) training for government employees, the university community, and job seekers (ITU and UNESCO, 2017).

Initiatives from the Public and Private Sectors to Maximize the Impact of Investment on the SDGs in the LAC Region

This section identifies successful case studies, including governmental and private sector initiatives, in some of the largest economies in the LAC region. These initiatives show how governments and private actors in the LAC region have sought to overcome certain gaps (i.e., low contribution of the fixed sector, low impact in rural areas, and low impact on SDGs 12, 14–17). These case studies provide examples of policies that if fully implemented and taken forward, can significantly help reduce the gaps previously described.

Argentina

In recent years, Argentina has successfully implemented policies and initiatives to increase optical fiber broadband coverage and quality and promote its use to provide government and education services. The initiatives were integrated into Connected Argentina (Argentina Conectada 2011–2015), the national ICT development plan. The plan aimed to reach a 97 percent national fiber broadband coverage and achieve complete internet penetration in public schools.

The plan sought to promote digital inclusion and equity in access to ICT, infrastructure, and connectivity, as well as training and research in ICT. To incentivize digital inclusion, the government launched the Connect Equality Plan (Plan Conectar Igualdad), which distributed laptops to students and teachers in public schools. Connected Argentina also established around 250 Knowledge Access Nuclei (Nucleos de Acceso de Conocimiento, or NAC), specialized centers that provide free internet access and training in digital technologies and trades.

By 2015, Connected Argentina had deployed around 30,000 km of fiberoptic cable (out of the 58,000 km planned), 25,800 km of federal backbone network, and 6,524 km of provincial network.[143] In addition, it generated 27,000 direct and 20,000 indirect jobs around the country.

Chile

Three complementary governmental programs aim to expand and integrate the ICT sector in Chile:

- National Telecommunications Fund (Fondo Nacional de Telecomunicaciones, or FDT). The FDT subsidizes public initiatives to promote connectivity in impoverished urban and rural areas.
- Digital Agenda (Agenda Digital, 2013–2020). It aims to achieve full household internet penetration, 50 percent coverage of high-speed internet, and to improve digital skills among the population. It is focused on five ICT axes including education, innovation, services, and applications. The Digital Agenda seeks to reach a 10 percent ICT contribution to GDP.
- National Plan for Infrastructure and Telecommunications (Plan Nacional de Infraestructura y Telecomunicaciones, or PNIT). The PNIT aims to develop ICT by improving the infrastructure, based on public-private partnerships. The PNIT seeks to reduce the digital gap by increasing the national bandwidth, establishing a national telecom network, and developing digital access networks. Its most important projects are:
  - Austral Fiber Optic Network: installation of 3000 km of fiber optic cable from Puerto Montt to Puerto Williams, providing connectivity to the southernmost areas of the country.[144]
  - Connectivity for Education: an initiative to increase ICT services in low-income rural and urban areas. By 2015, the project had benefited 2,850,000 students in 8,055 education centers.

143 https://www.opengovpartnership.org/sites/default/files/Versi%C3%B3n%20final%20II%20Plan%20de%20Acci%C3%B3n%20-%20traducci%C3%B3n.pdf.
144 https://foa.subtel.gob.cl/proyecto-fibra-optica-austral-2/.

All Chile Connected (Todo Chile Comunicado) is a good example of a private initiative to expand ICT infrastructure to achieve the SDGs and reduce the digital gap. Entel has brought mobile and broadband services to more than 1,400 rural and isolated areas and towns. The project received funding from the Ministry of Transportation and Telecommunications.

Colombia

The development of mobile and broadband coverage and ICT services was one of the milestones of the Colombian government between 2010 and 2018. These objectives were addressed through two consecutive ICT plans: Live Digital (Vive Digital 2010–2014) and Vive Digital 2014–2018.

Vive Digital (2010–2014) focused on the growth of digital coverage and the promotion of ICT to generate employment, reduce poverty and increase the country's competitivity. To decrease the digital gap, the government promoted the installation of Live Digital Kiosks (Kioskos Vive Digital), community centers that provide internet access and free training in digital skills. By 2014, 7,621 kiosks had been installed, benefiting 5,300 rural municipalities. In addition, the government funded technical, undergraduate, and graduate studies on ICTs through Digital Talent (Talento Digital). Related initiatives subsidized computers and tablets for the low-income population. The number of computers per 100 inhabitants increased from 16.8 percent in 2010 to 34 percent in 2014.

Vive Digital has also encouraged the development of web applications through initiatives like App.co. By 2015, 2,000 new applications had been created. Seventeen laboratories for digital innovation had been established through this program.

Finally, the government also sought to promote e-government. By 2014, 52 percent national and territorial entities had a high level of digital governance.

Mexico

The development of broadband was one of the milestones of the National Development Plan for Mexico (2013–2018).[145] One of the plan's objectives was the democratization of telecom services, based on three principles: (i) achievement of universal coverage of ICT services, (ii) make ICT services and products affordable by promoting competition, and (iii) improvement in the quality of ICT services and contents.

To achieve the objectives, the government launched a complementary digital strategy—the National Digital Strategy (Estrategia Nacional Digital 2014–2018), which focused on six ICT applications, including government transformation, digital economy, health, education, and citizen security. The IDB supported these initiatives with US$550,000 in technical cooperation for national broadband development.

In addition to the Digital Strategy, the government launched Connected Mexico (Mexico Conectado). This project aims to offer free broadband access in public spaces such as public schools, hospitals, and libraries. By May 2015, around 66,000 access points had been covered out of the initial goal of 250,000. Furthermore, the project sought to reduce the digital gap by establishing community centers for training and digital education. These community centers had 79,000 associates and 30,000 students by March 2015.

Peru

In Peru, Telefónica is working with Facebook[146] on multiple projects using new technologies and operating models to make wireless broadband deployment more cost-effective. This is part of a

[145] The contribution of ICT in Mexico's GDP was 3.2 percent in 2014 and accounted for 110,000 employees.
[146] Telefónica press note (2018): https://www.telefonica.com/es/web/sala-de-prensa/-/telefonica-presenta-internet-para-todos-un-proyecto-colaborativo-para-conectar-a-los-no-conectados-en-latinoamerica.

project called Internet for All (Internet para Todos), an initiative to connect more than 100 million people in LAC to the internet.

These projects are already making high-speed mobile internet available to tens of thousands of Peruvians across the highlands and in the Amazonian rainforest. Using an open approach to network deployment, both companies are empowering rural mobile infrastructure operators, local entrepreneurs, and communities to collaborate in delivering high-quality connectivity efficiently and sustainably.

These cases show that providing sustainable rural connectivity relies on complementary connectivity policies and highlights the positive steps taken by the Peruvian government to foster investment in rural areas. Peru's commitment to rural access connectivity is reflected in its telecom legislation. One of the steps taken allows the creation of the rural mobile infrastructure operators (operadores de infraestructura móbil rural, or OIMR), local companies that own mobile infrastructure but use spectrum allocated to other operators. OIMRs can use their infrastructure to extend the reach of traditional mobile carriers covering last mile access in rural areas.

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