DEVELOPMENT IN THE AMERICAS

FROM STRUCTURES TO SERVICES

The Path to Better Infrastructure in Latin America and the Caribbean

Edited by
Eduardo Cavallo
Andrew Powell
Tomás Serebrisky

IDB

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Preface

Every year the Inter-American Development Bank (IDB) presents in its flagship publication, *Development in the Americas* (DIA), an in-depth investigation into one of the main economic and social challenges facing Latin America and the Caribbean. The themes covered have ranged from savings, productivity, housing and debt to productive policies, quality of life, and taxation.

In the 2020 edition, we decided to focus on infrastructure, a key element for the prosperity and growth of the region. While most of the book was written before the coronavirus pandemic struck, its content and arguments are more relevant today than ever. As you will see in the following pages, rethinking our infrastructure will be vital for helping us to overcome the crisis triggered by COVID-19, and to lay the foundation for a sustained recovery.

This year we present the book in a context where our countries are not only facing all the problems they had before the pandemic—among them, inequality—but also a health crisis and an unprecedented economic collapse.

What should Latin America and the Caribbean do in this new situation? Although the challenges we face today are deeper than those we faced a few months ago, the evidence on how to foster growth and development has not changed. We know that investing in infrastructure is one of the best ways to stimulate growth. As governments focus on the health emergency, they must also deal with the demands their citizens were already expressing when this crisis erupted. The discontent that drove the street protests in many cities in the region in late 2019 has not disappeared during the pandemic, and that discontent is primarily due to the lack of economic opportunities and the poor quality of basic services.

Instead of postponing the investments needed to deal with these demands, the COVID-19 crisis is making us think more strategically about how and where we can build the infrastructure we need to recover from the economic effects of the crisis. But it also gives us the opportunity to anticipate the needs of a world with a more uncertain climate, with populations that are less young, and with technologies that will transform every aspect of our daily lives.

Since I took over the presidency of the IDB in 2005, two major paradigm shifts have impacted the sector, which are captured in this book and will surely define the next era of infrastructure. These are the focus on services and the urgent need to develop sustainable infrastructure.

All of this plays out in the context of a digital revolution that promises to open up enormous opportunities for improving services and that will place consumers at the center, with a much more active role in determining the quantity and quality of services.

The first of these transformations marks the end of what we might call "the era of concrete." In 2005, the great challenge in Latin America and the Caribbean was still the enormous gap in coverage of basic services. We wanted to extend the road, electricity, and water networks to bring development to the most remote villages and the most disadvantaged areas of our cities.

Today we can be proud of having invested billions of dollars to expand the reach of these services. In the last 15 years we have connected 110 million people to clean water grids for the first time. We have extended electrical grids to more than 100 million people, many of them in low-income rural and peri-urban areas.

Countries like Paraguay have doubled the percentage of paved roads. Investment in public transport, especially in the bus rapid transit systems invented in Brazil, have grown exponentially in the region and globally. And subway networks were also expanded.

Digital technology has proved to be an indispensable complement to investment in the strategy to expand access to services to more people and to new services. It seems incredible, but in 2005 only 34% of our people used the Internet at home. Today we have more mobile phones than people, the vast majority get their information online, many use carpooling applications, and we spend more hours on social networking sites than anyone else in the world. In times of quarantine, this is a blessing that has enabled us to stay connected even when we are physically separated. After the emergency, digital connectivity and its applications will be the bridge to a better future in infrastructure services.

As the book shows, we have significantly reduced the access gaps. And in that respect, the "era of concrete," when we focused on building structures to increase coverage, was a vital chapter for our countries. But clearly, we have not yet succeeded in closing all these gaps and there is still a lot of work to do. Universalization of services must be a priority that we continue working on until all households in the region have water, electricity, and sanitation.

But today people's expectations are not the same as they were 15 years ago. Many of the social protests we experienced in 2019 were set off by increases in subway fares or the price of gasoline. We could say that these protests express popular discontent, not with the state of our infrastructure as such, but with the quality and cost of the services that people receive from that infrastructure.

No longer is it enough to have access to a modern bus, if the bus is late and—in times when we should be practicing social distancing—overcrowded, and if the fare over a month exceeds 10% of a minimum wage. No longer is it enough to have a tap in the kitchen if the quality of the liquid is so dubious that it is necessary to buy bottled water for drinking and cooking. No longer is it enough to be connected to the power grid if there are power cuts every week which cause inconvenience and damage appliances.

But the quality of service is not the only source of frustration. In many of our countries, paying for services requires a major financial effort. Low-income families spend 15% of their income on water, electricity, and public transport services, which is almost 5 percentage points of income more than in emerging Asia. This book argues that the prices consumers pay can be reduced by more efficiency and smart regulation that allows companies to recover the costs of providing quality services.

All this leads us to the conclusion that we need to replace the "era of concrete" with the "era of services," with emphasis on closing the remaining gaps to access, and above all working much harder to improve the quality and affordability of services. This will be a new era in which we will move "from structures to services" with a focus on the user, on customer service, and on modern and smart regulation.

It is not that new structures do not need to be built. Rather, to operate successfully in the future, both governments and companies will have to listen to the demands of users and propose new ways of serving them better, at an affordable price.

There are many examples in the region that show we have the capacity to do this. Argentina does it with a transport and social protection program known as SUBE. The program places direct subsidies on the transport cards of the poorest travelers, easing the burden of transport spending for one in three Buenos Aires residents.

In Colombia, Empresas Públicas de Medellín (EPM) has been a recognized leader in customer service for many years. EPM not only offers flexible programs to facilitate payment of water and electricity services by low-income households; it also helps them buy more efficient and environmentally friendly appliances, so that family expenses are lower and the service network is more sustainable. With IDB support, EPM has been investing in wastewater treatment plants for 25 years. As a result, the Medellín river is one of the cleanest urban rivers in the hemisphere, and its banks have become places of recreation and meeting for all the city's inhabitants.

Along with the shift in focus from investment in assets to services, the second major paradigm shift since I took office as President of the IDB is the concept of infrastructure sustainability. Climate change, the value of biodiversity, and new expectations of social participation have altered forever the definition of a sustainable project.

Today we cannot build a road in a coastal area without first anticipating how it might be affected by the rise in sea level. Or we cannot propose a hydroelectric plant that involves displacement of indigenous communities, without obtaining their authorization in a completely transparent process.

And we cannot continue to plan the infrastructure of the future without taking into account the commitments made to combat climate change in the context of the Paris Agreement. These commitments oblige us to start developing clean infrastructure today, creating an energy matrix with zero net carbon emissions. We must exploit the solutions and potential provided by renewable energy sources, such as wind and solar. We also need to explore how natural infrastructure can replace the services provided by gray infrastructure.

If we do not act sustainably and fight climate change, we are putting our future at risk.

How can we achieve this? The answer is more and better investment. Due to lack of investment, every year the region is growing by one point less than it could. That's why it is even more important to invest in infrastructure now, precisely to boost economic recovery once the pandemic lockdowns are behind us.

The good news is that we no longer have to go to New York or Tokyo to attract investment. The pension funds in our own region now manage over US$3 trillion. But at present, these funds are investing only 1% of their assets in infrastructure. This has to change.

The irony is that we have the funds and the technology to multiply these projects, but we lack the ambition and creativity to get them off the ground. I am convinced that the new paradigms are opening the door to a new era in infrastructure.

This book offers a fresh look at the future of transport, energy, and water and sanitation services. Technological revolutions—such as 5G telephony, autonomous vehicles, and home-generated solar power—are emerging that will force us to abandon many of the assumptions of the previous era. This revolution, part of which is already underway, opens up great opportunities. But we must manage it well.

The challenges we face are colossal, but so are the opportunities. Investment in infrastructure will help kick-start economies once the coronavirus pandemic has passed. But this book shows that by focusing efforts on improving services and embracing the opportunities provided by new technologies, we can also create the infrastructure and deliver the services our societies deserve to come out of this crisis stronger and more resilient.

Luis Alberto Moreno
President
Inter-American Development Bank

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Part 1 Setting the Scene

1

Services: The Forgotten Side of Infrastructure

The word *infrastructure* means different things to different people. Most associate it with structures such as ports, airports, roads, sewerage, and power plants. Fewer people associate it with the services those structures deliver, even though they depend on those services. Electricity, transportation, water, and sanitation are indispensable services in modern societies, enabling people to be productive, healthy, and pursue their aspirations.[1]

The focus of this book is on the infrastructure services that consumers need and demand but that are so often overshadowed by the traditional brick and mortar structures of infrastructure. Consider water, for example. Consumers understand the need for water treatment plants and pipes, and the rest of the physical infrastructure that transports water to their homes. But what they really want is to be able to turn on the faucet at any time of day or night and get clean, potable water at the right pressure.

An analysis of social media conversations confirms that the quantity and quality of services is far more important to users than the availability or construction of assets.[2] The cloud of most mentioned words in water and sanitation confirms the predominance of words related to the provision of services, such as *continuity* and *potability* (Figure 1.1).

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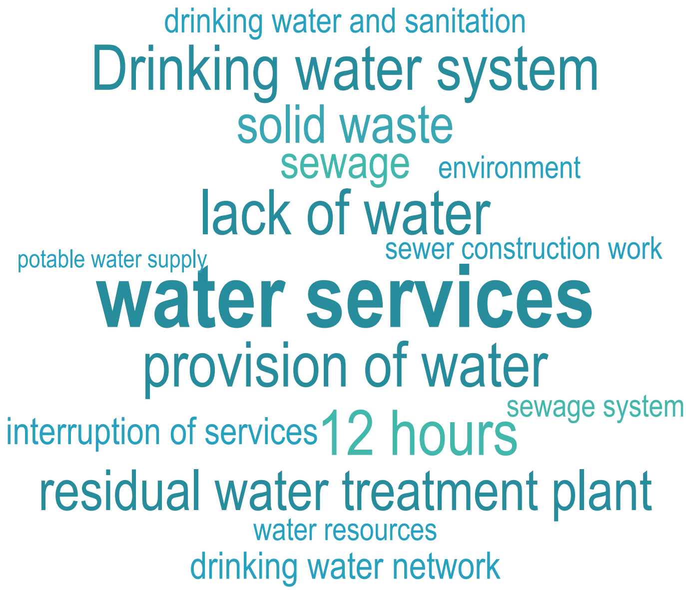
1 In this book, the term *infrastructure* refers exclusively to economic infrastructure (energy, transportation, telecommunications, and water and sanitation). Social infrastructure—schools, hospitals, courts, and the services they provide—presents many of the same characteristics and challenges as economic infrastructure, but is not dealt with in this book.

2 Analysis of Twitter conversations conducted in Spanish between 2016 and 2018. Quality, continuity, and access are top concerns in energy and water, whereas affordability and pollution dominate digital conversations about transport services. The analysis excluded the accounts of service providers and public officials in order to better reflect consumers' priorities.

Figure 1.1
Digital Conversations about Water Services in Latin America and the Caribbean



Source: Calderón, Fernández Gómez Platero, and Wanner (2020).
Note: The Knowledge, Innovation and Communication Sector (KIC) of the IDB conducted an analysis of social media messages (on Twitter) in Latin America and the Caribbean between 2016 and 2018 to identify key words that social media users utilized when posting messages related to infrastructure services. The main goal was to characterize the interactions in order to assess whether the attention of users was directly connected with the provision of services.

Infrastructure services are as essential for firms as for individuals. They are indispensable inputs in firms' production processes; supply problems, poor quality, and unreliability directly affect costs and competitiveness. Table 1.1 presents the percentage of firms in Latin America and the Caribbean that identify the supply of electricity, water, and transport services as a major constraint on their productive activities. In the case of electricity, firms that suffer power outages are markedly less productive and profitable than those that enjoy uninterrupted access to electricity. Firms that experience electric outages report annual sales losses of 2.4 percent, while firms that suffer the highest incidence of blackouts (the top 10 percent of enterprises most affected by electrical supply interruptions) record annual sales losses of up to 3.4 percent (Acevedo, Borensztein, and Lennon, 2019).

Most debates in the policy arena and reports produced by academia, think-tanks, and multilateral development institutions focus on the need to invest more in infrastructure in Latin America and the Caribbean to improve the quantity and quality of infrastructure services. The focus on investment is to be expected because the region has invested less in infrastructure in recent decades (see Chapter 3). This book recognizes the urgent need to boost infrastructure investment but argues that simultaneous and decisive policy action must be taken on two additional fronts: the efficiency of the infrastructure investment process and regulation of services. Latin America and the Caribbean has ample room to improve the efficiency of investment in infrastructure, that is, the capacity to generate more assets and better services with the resources it currently allocates to infrastructure. The region also faces the challenge of improving the regulatory policies, institutions, and instruments that set the rules of the game for service providers to increase the availability and quality of services.

Table 1.1
Infrastructure Problems Identified by Firms

	Percentage of firms experiencing electrical outages	Percentage of firms identifying electricity as a major constraint	Percentage of firms experiencing water insufficiencies	Percentage of firms identifying transportation as a major constraint
Europe and Central Asia	**38.0**	**20.1**	**6.7**	**10.2**
East Asia and the Pacific	**48.0**	**15.0**	**10.2**	**13.4**
Middle East and North Africa	**51.6**	**34.1**	**19.0**	**17.6**
Latin America and the Caribbean	**59.2**	**32.2**	**15.9**	**23.7**
Panama (2010)	21.6	4.2	7.6	0.5
Bolivia (2017)	35.1	23.6	18.5	29.7
Chile (2010)	42.6	30.1	1.8	27.2
Mexico (2010)	45.1	46.7	9.2	26.2
Brazil (2009)	45.8	46.0	6.4	27.9
El Salvador (2016)	47.6	19.1	24.3	16.0
Costa Rica (2010)	49.4	63.2	13.0	54.3
Nicaragua (2016)	49.9	25.1	26.3	10.5
Peru (2017)	52.2	27.5	10.0	28.8
Colombia (2017)	53.9	50.1	8.2	42.4
Dominican Republic (2016)	54.1	37.6	13.9	13.8

(continued on next page)

Table 1.1
Infrastructure Problems Identified by Firms *(continued)*

	Percentage of firms experiencing electrical outages	Percentage of firms identifying electricity as a major constraint	Percentage of firms experiencing water insufficiencies	Percentage of firms identifying transportation as a major constraint
Guatemala (2017)	54.4	11.7	11.6	19.2
Barbados (2010)	55.6	47.3	22.3	18.3
Uruguay (2017)	56.6	55.0	21.3	36.4
Grenada (2010)	59.5	16.9	15.1	14.8
Ecuador (2017)	62.4	27.4	18.8	21.6
Venezuela (2010)	64.6	54.2	24.7	20.5
Argentina (2017)	65.1	47.2	10.4	22.8
Trinidad and Tobago (2010)	65.7	14.6	12.5	11.6
Honduras (2016)	69.8	34.5	23.3	26.5
Bahamas (2010)	75.0	24.6	12.6	14.3
Belize (2010)	78.4	36.3	20.7	56.1
Jamaica (2010)	80.9	33.7	4.8	11.8
Guyana (2010)	81.8	43.0	17.8	21.5
Paraguay (2017)	83.0	30.9	11.4	26.7
St. Vincent and the Grenadines (2010)	83.3	25.4	8.4	12.0
Suriname (2018)	86.0	28.2	8.4	13.5
St. Kitts and Nevis (2010)	94.0	63.7	11.2	30.9
Antigua and Barbuda (2010)	95.5	45.1	3.0	24.4
St. Lucia (2010)	99.8	55.7	0.0	21.1
Dominica (2010)	100.0	66.1	0.0	11.8
South Asia	**66.2**	**46.1**	**11.3**	**21.1**
Sub-Saharan Africa	**77.5**	**40.5**	**22.7**	**25.8**

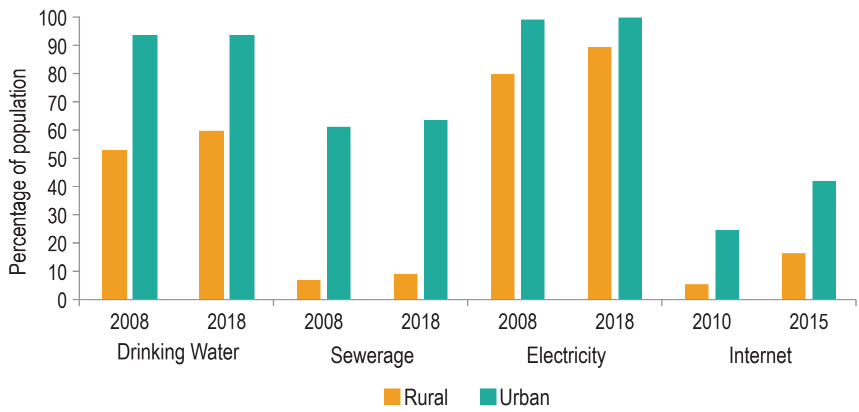
Source: World Bank Enterprise Survey 2019.

This chapter introduces several themes that run through the book. It begins with a description of the challenges of providing infrastructure services in the region and then introduces a framework that describes how the interplay between infrastructure assets (hardware) and regulatory instruments, management practices, and consumer behavior (software) determines the quantity and quality of infrastructure services.

The Potholes in Providing Electricity, Transport, and Water Services

The benefits of infrastructure services depend first on access. In the past decade, Latin America and the Caribbean has expanded access significantly (Figure 1.2). The gap between urban and rural areas is narrowing, especially in water and electricity. The region has not attained universal coverage, however, and reaching that target will require more financial resources and technological innovation (for instance, mini-grids or distributed energy solutions). The region still has a long way to go to achieve universal access to the Internet, an essential input in an increasingly digitalized economy.

Figure 1.2
Access to Infrastructure Services, 2008 and 2018

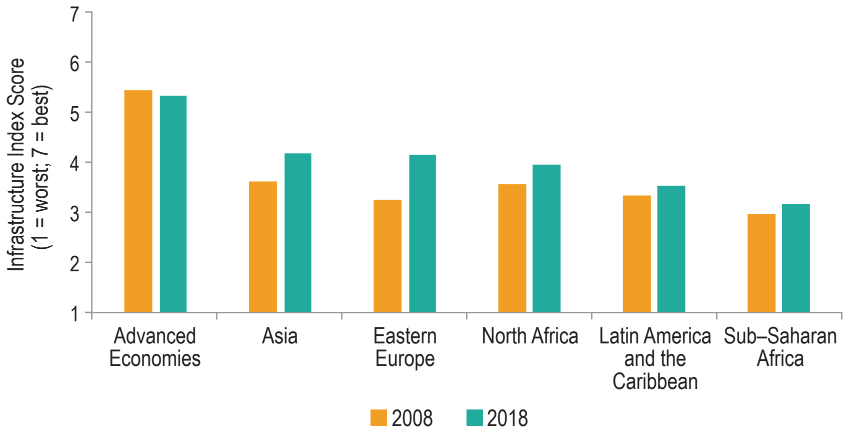


Source: Socio-Economic Database for Latin America and the Caribbean (CEDLAS and World Bank), 2018 data; and World Telecommunication/ICT Indicators Database 2018 (International Telecommunication Union).
Note: Data on access to drinking water, sewerage, and electricity are based on country household surveys and drawn from the database of SEDLAC. The data express the share of households with access to the respective service. Internet data are from the International Telecommunications Union and refer to the percentage of the population with access to Internet.

ACCESS HAS GROWN, BUT UNIVERSAL ACCESS IS NOT YET A REALITY.

While Latin America and the Caribbean has advanced admirably to universalize access, it has failed to provide infrastructure services of good quality. According to the World Economic Forum, an independent international organization that compiles a highly cited index on the quality of infrastructure services, quality improved between 2008 and 2018 in Latin America and the Caribbean, as it did in all developing regions. However, quality is lower in Latin America and the Caribbean than it is in every region except

Figure 1.3
Quality of Infrastructure by Region, 2008 and 2018



Source: WEF (2019).
Note: The information in this figure is based on the "overall quality of infrastructure" indicator in WEF's *Global Competitiveness Report*. This indicator ranges from 1 (worst) to 7 (best), based on stakeholders' answers to the following question: "How do you assess the general state of infrastructure (e.g., transport, communications, and energy) in your country? [1 = extremely underdeveloped—among the worst in the world; 7 = extensive and efficient—among the best in the world]."

THE QUALITY OF INFRASTRUCTURE SERVICES HAS IMPROVED BUT REMAINS LOW COMPARED WITH OTHER REGIONS.

Sub-Saharan Africa, and the gap with other regions, particularly Asia and Eastern Europe, is growing (Figure 1.3). Given that infrastructure services are essential for growth and competitiveness, reversing this trend is imperative.

The single quality indicator reported for Latin America and the Caribbean masks notable differences in countries' income, physical, and institutional realities. Countries in the region are not only diverse in their income per capita—a wealth indicator that explains, to a great extent, the quantity and quality of services that a country can afford—they are also diverse in other fundamental characteristics that determine the provision of infrastructure services. Some of them are physical, like geography, urbanization, and climate, while others depend on the efficiency of institutional factors (rule of law, transparency, effectiveness of government agencies) that are also important determinants of the quantity and quality of infrastructure services. Table 1.2 presents the evolution of each country's quality indicator between 2008 and 2018. Chile remains the best performer but most countries in the region improved, and some did so remarkably (Bolivia, Ecuador, Nicaragua, and

Table 1.2
Evolution of the Quality of Infrastructure Services in Latin America and the Caribbean, by Country, 2008 and 2018

	2008	2018	Percentage Change
Chile	5.01	4.73	–6%
Panama	4.24	4.70	11%
Ecuador	2.75	4.52	64%
Jamaica	3.76	4.17	11%
Mexico	3.45	4.07	18%
Honduras	3.40	3.59	6%
Uruguay	3.67	3.59	–2%
Dominican Republic	3.39	3.55	5%
Nicaragua	2.45	3.51	43%
Guatemala	3.61	3.36	–7%
El Salvador	4.56	3.30	–28%
Argentina	3.10	3.25	5%
Brazil	2.69	3.14	17%
Colombia	2.83	3.11	10%
Costa Rica	2.40	3.09	29%
Peru	2.50	3.09	24%
Bolivia	2.06	3.01	46%
Paraguay	1.87	2.56	37%
Haiti	—	2.02	

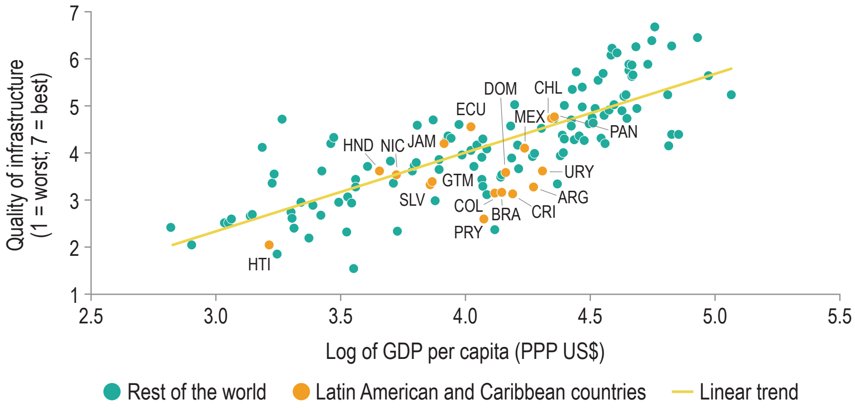
Source: IDB calculations based on WEF (2019).

SEVERAL COUNTRIES HAVE IMPROVED THE QUALITY OF INFRASTRUCTURE SERVICES—SOME REMARKABLY; CHILE LEADS IN THIS AREA.

Paraguay).[3] However, progress cannot mask a stark reality: the quality of services in Latin America and the Caribbean is lower than expected given its income. The vast majority of countries in the region are below the predicted line that links income per capita and quality of services. Very few countries in the region stand out (Chile, Ecuador, and Panama), and several are well below where they should be (Figure 1.4).

[3] Unfortunately, the available information on how the quality index is built does not allow for identifying the drivers (change in investment, improvement in management of services, more effective regulation schemes, among others) that explain increases or decreases in the value of the quality index. A subsection of this chapter titled "Investment Inefficiency: a Regional Problem" links the evolution of investment with the evolution of quality and provides efficiency rankings.

Figure 1.4
Perceived Quality of Infrastructure by GDP per Capita



Source: WEF (2019).

THE QUALITY OF INFRASTRUCTURE SERVICES IN MOST COUNTRIES IS LOWER THAN IT SHOULD BE GIVEN THEIR INCOME LEVEL.

Transportation: Congestion and Lost Productivity

Latin America and the Caribbean is the most urbanized region in the developing world; more than 80 percent of its people live in cities. Therefore, urban transportation is vital for access to jobs, health care, and education. Yet the average commuting time in the region's megacities is close to 90 minutes (Serebrisky, 2014). For those who spend that much time commuting, transportation trails only public safety as the top priority for improving the quality of life. The distances traveled in Latin America and the Caribbean are shorter than those of commuters in the most advanced economies, but they take longer: According to Moovit, a mobility app, the average trip on public transportation is 7.3 km, almost a kilometer shorter than the average trip in advanced economies, but lasts 13 minutes longer. Longer commutes are, to a large extent, a consequence of increasing congestion. According to the INRIX 2019 Global Traffic Scorecard database, Bogotá, Mexico City, São Paulo, and Rio de Janeiro are among the top 10 most congested cities in the world. This, in turn, is the result of fast-growing motorization; vehicle ownership in the region increased 63 percent between 2005 and 2015, from 127 to 201 vehicles per 1,000 inhabitants (Rivas, Suárez-Alemán, and Serebrisky, 2019a). Interurban transport also poses challenges. In the region, 85 percent of cargo (by weight) is transported by road (only Brazil and Mexico carry a sizable share by train), but the productivity of the trucking industry leaves much to be desired: yearly kilometers traveled by a truck in Latin America and the Caribbean are 40 percent lower than in the United States or the European Union[4].

Water and Sanitation: Too Little and too Dirty to Drink

The region's water and sanitation services present enormous shortcomings. In 2018, IDB/LAPOP 2019 data showed that the average Latin American and Caribbean household received water 18 hours a day, with residents of some countries enjoying almost uninterrupted service (Costa Rica), while others received water only 13 hours a day (Guatemala). Although piped water coverage stood at around 80 percent in most countries, less than 60 percent choose piped water for drinking, with Mexico being the extreme case: only 16 percent of Mexicans report drinking the tap water, despite 81 percent coverage. The message is that quality in water service depends on appropriate treatment, both of piped water and of wastewater. If sanitation services discharge untreated wastewater into clean waterways, water supply companies are fighting a losing battle. And the region lags in water treatment services: only 22 percent of wastewater is safely managed, compared with the world average of 39 percent, although Chile (85 percent) and Uruguay (63 percent) have made significant advances.[5] On a regional basis, only Sub-Saharan Africa and South Asia trail Latin America and the Caribbean in wastewater treatment.

Electricity: Darkness and Demand

The frequency and duration of blackouts in Latin America and the Caribbean is much lower than in Sub-Saharan Africa but no better than in Asia or Eastern Europe. The region faces rapid growth in demand for electricity, fueled by economic activity and a growing middle-class consuming power for devices such as air conditioners and washing machines. A comparison of the electricity consumption basket of Brazil and France provides insights on the potential growth in demand. Households in the lowest decile of the income distribution in France consume the same amount of electricity (1,500 kWh per year) as the fifth decile in Brazil (Grottera et al., 2018).

4 Beyond congestion, growing challenges for the transport sector are emissions (with high incidence of local pollution levels in several Latin American and Caribbean cities) and road safety, which is the largest cause of death for those under 15 years of age in the region. For details on the evolution of transport emissions, see Chapter 7; for road safety, see Chapters 4 and 10.

5 See WHO/UNICEF's global database on water supply, sanitation and hygiene (WASH).

Overall, the average consumption per household (2,000 kWh per year) is only about half the average consumption in Europe (3,700 kWh per year). If economies comply with climate commitments, transportation and heating, among other activities, will run on electricity, for which demand will increase substantially. On the plus side, Latin America and the Caribbean is still the region with the cleanest energy mix, thanks to the long-standing presence of hydroelectric power, which accounts for half of all electricity generated, and the growth of nonconventional renewables (wind and solar), which increased their role in generation from almost zero in 2010 to 75,000 GWh in 2017, reaching 5 percent of all electricity generated. At the same time, the pursuit of energy security propelled the growth of nonrenewable sources, chiefly natural gas, which doubled its role in generation between 2000 and 2017. As in the case of water, defining quality of service beyond reliability (no blackouts) to include environmental concerns will increase pressure to expand the use of renewable sources and, simultaneously, invest in energy efficiency to reduce demand.

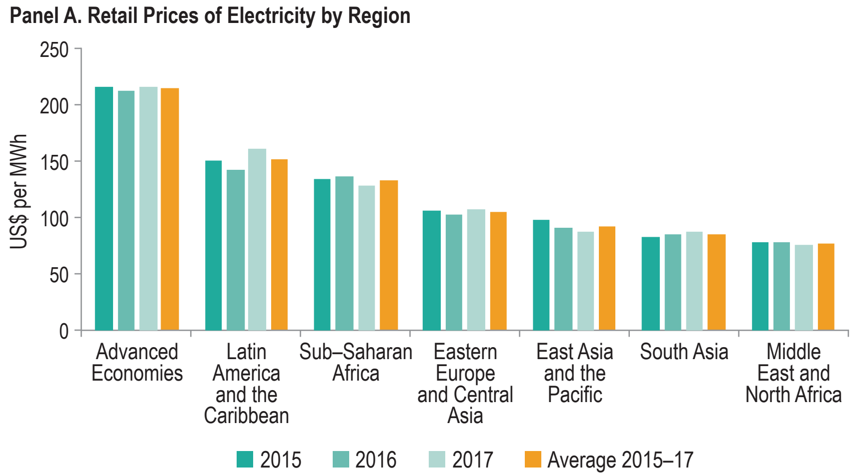
The Ideal vs. Reality: Cost and Quality Explain the Difference

High-quality services produced at the lowest possible cost and delivered at low prices represent the ideal for consumers. Unfortunately, reality is quite different in Latin America and the Caribbean: service quality is low, and prices are high, at least when compared to other developing regions.

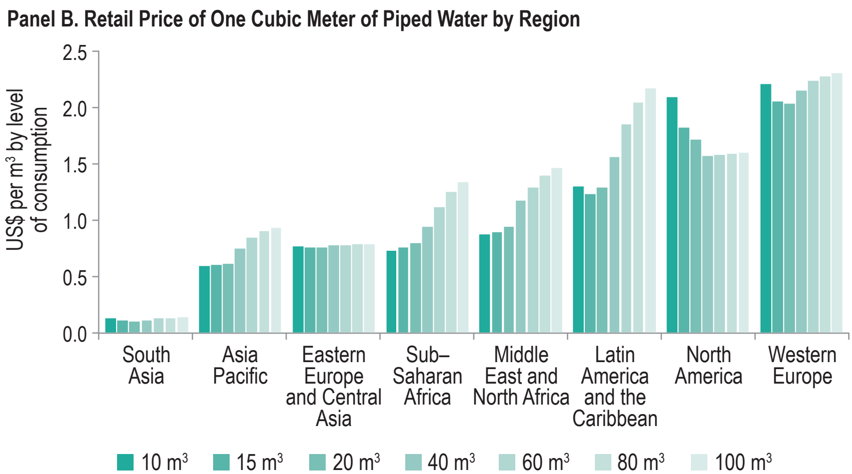
Electricity and water prices are higher in Latin America and the Caribbean than in other developing regions, although they are lower than in advanced economies (Figure 1.5).

Electricity, transport, and water are essential services. When prices are high, consumption accounts for a large share of households' income and eventually leads to consumption below what is necessary to fulfill basic needs. In Latin America and the Caribbean, people in the lower half of the income distribution spend a larger share of their income on infrastructure services than in all other developing regions (Figure 1.6). For the poorest, the difference is even more pronounced, providing evidence that affordability is a problem in the region. Complementary and more circumstantial evidence shows that people consume less than what they would if they could pay for the services. According to the results of a question added to the Latinobarometro survey in 2018, a large share of the population in Latin America and the Caribbean suffer from the heat or the cold. This likely reflects both a lack of access to equipment (for instance air conditioning) and lower demand for services (electricity in the case of air conditioning) than what would be required to be comfortable. Evidence

Figure 1.5
Prices of Electricity and Water by Region, 2015-17



Source: Bloomberg New Energy Finance (BNEF), 2019.

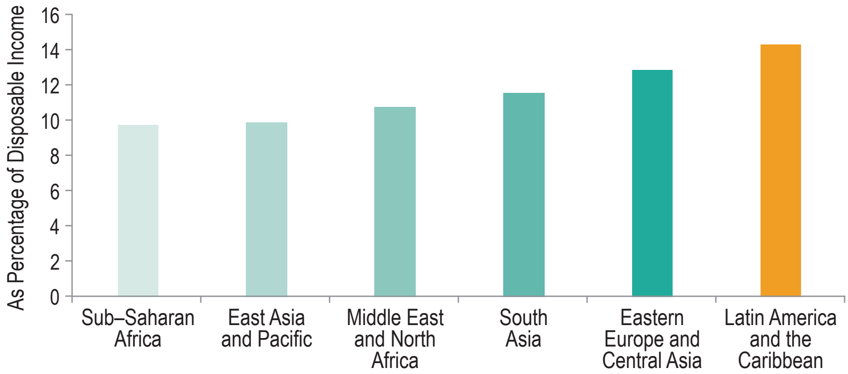


Source: Brichetti (2019). Based on information for the year 2017 from the GWI Global Water Tariff Survey 2018.

ELECTRICITY AND WATER TARIFFS ARE HIGHER THAN IN OTHER DEVELOPING REGIONS.

for the transport sector indicates the poor cannot afford the services they need. Rivas, Serebrisky, and Suárez-Alemán (2018) report significant differences across income deciles in the share of walking vs. other forms of transport used. In Cali, the difference in the share of walking between the

Figure 1.6
Share of Income Spent on Infrastructure Services by Relative Position on Global Income Distribution



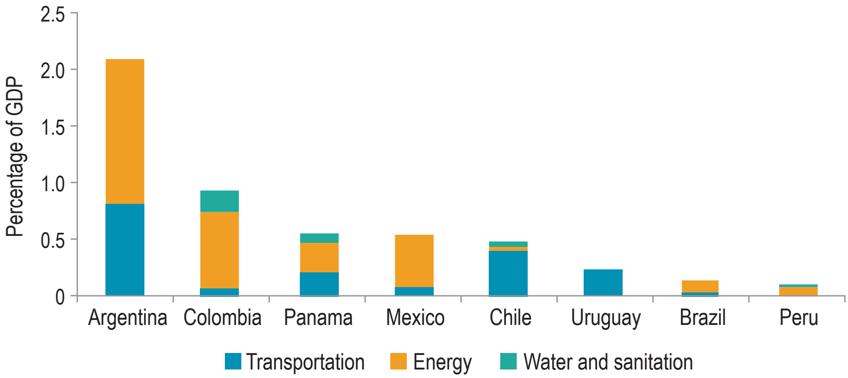
Source: Estache, Bagnoli, and Bertomeu-Sánchez (2018).
Note: Infrastructure services in this figure include water and sanitation, public transportation, energy, and communications.

lowest income decile and the highest is 32 percent while in Montevideo the difference is 31 percent and in Chile, 28 percent. Even though affordability is a problem, especially for the poor, few targeted subsidy schemes exist in the region (Cont and Navajas, 2019).

Consumers aren't the only ones left disappointed by the state of services. Providers of infrastructure services are also left wanting as they are unable to fully recover costs. Obtaining data on the cost recovery of infrastructure service providers is difficult for a number of reasons: few service providers are listed on stock markets where they would be required to release information on costs; regulators usually do not have regulatory accounting systems and do not request cost data from firms; and accountability of state-owned firms is weak. The scant available evidence indicates that difficulty recovering costs is most widespread in water and urban transport, and less so in electricity. With regard to public transportation, formal service providers in cities rarely recover operational costs with fare revenues. For instance, Buenos Aires covered only a third and Panama half of their operational costs (data for 2015 collected by Scorcia, 2018). The immediate consequence of poor cost recovery is the inability to access commercial financing which, in addition to enabling timely investments, provides incentives to improve performance and increase transparency and accountability. For only one in five water utilities in Latin America and the Caribbean, cash revenues exceed operational costs by enough to allow them to access commercial financing (Fay et al., 2017).

Government transfers to service providers are an indication that they do not recover costs (Figure 1.7). An analysis of subsidies in eight countries of the region shows that transfers reach on average 0.7 percent of GDP (Brichetti and Rivas, 2019b). It should be highlighted that the inability of service providers to recover costs and the granting of subsidies are not exclusive to Latin America and the Caribbean. On the contrary, operational subsidies are widespread, even in developed countries and in particular for public transit (Cont and Navajas, 2019).

Figure 1.7
Government Subsidies (excluding Capital Transfers) to Infrastructure Services, 2018



Source: Brichetti and Rivas (2019b).
Note: This graph refers to governmental transfers to institutions, businesses, and individuals not associated with capital investments. Subsidies were calculated using budgetary information at the national level, with the exception of Brazil, which includes information for the five states with the highest GDP. The estimate may underestimate subsidies as it does not include state-owned enterprise deficits not financed by direct government transfers or subsidies provided by local governments (the most prevalent financing source of water utilities in Latin America and the Caribbean). Fiscal credits that may act as subsidies are also not incorporated unless they were explicitly stated as subsidies in the budgetary information. Data for all countries is from 2018, except in the cases of Panama and Uruguay, for which it is from 2017.

Low service quality, higher prices than in other developing regions, and limited cost recovery mean the infrastructure sector in Latin America and the Caribbean must increase its efficiency. Efficiency has several dimensions: efficiency of investment to generate more assets; the capacity of service providers to make the most of their existing assets to provide services; and the effectiveness of regulatory institutions to generate incentives for service providers to reduce costs and improve quality. Chapter 4 provides an in-depth diagnostic of access, quality, and affordability of infrastructure services in the region as well as examples of regulatory policies that have achieved tangible progress in service provision.

The next section presents a framework for understanding the relationship between the hardware (infrastructure assets) and software (governance, management, regulation) of infrastructure by focusing on the roles of government, providers, and consumers.

Infrastructure Assets and Services: A Framework for Understanding the Links

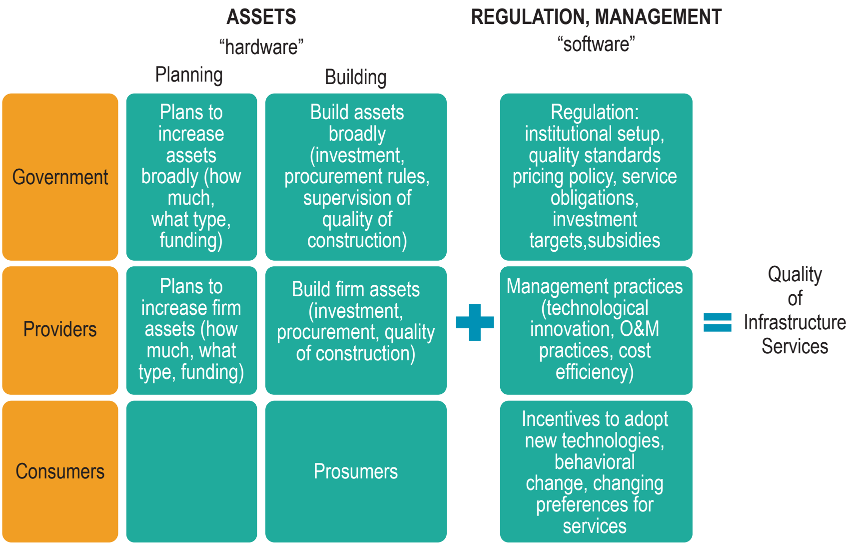
To a large extent, the shortcomings in providing infrastructure services in Latin America and the Caribbean reflect a lack of investment in infrastructure. In fact, the supply of infrastructure has not kept pace with economic growth, urbanization, and the growing middle class, all of which have raised demand for services.

Lack of investment is, however, only part of the problem. One of the key messages of this book is that the infrastructure agenda should focus on the complementarities between investment and the less tangible determinants of quality infrastructure services. The management of infrastructure assets, the regulation and performance of firms that operate them, and even consumers' behavior are fundamental determinants of the availability and quality of infrastructure services. Surprisingly, these "soft" factors have received far less attention than they deserve—far less, certainly, than that devoted to estimating the investments required to close the infrastructure assets gap.

The relationship between investing in infrastructure assets and providing infrastructure services is direct: services are possible only in the presence of assets of adequate capacity and condition. Providing electricity to houses and industries depends on the existence of power plants and transmission lines; freight services need railways and roads. The level of demand for services may fall below or exceed what the available assets are capable of producing. For example, a road built under erroneous assumptions about potential demand may be underused. On the other hand, it may become congested if needs were underestimated or if circumstances change over time (e.g., with population growth, motorization, or industrial activity). On that same road, fleets of trucks belonging to truck companies can provide transport services with high or low levels of efficiency. Either way, the provision of infrastructure services clearly depends not only on the quantity and quality of physical infrastructure, but also on other factors, including the efficiency of the firms that use it to provide services. Understanding how assets and services interact is key to measuring infrastructure's contribution to the economy.

The framework used in this book to analyze how infrastructure assets and services interact, and the roles that government, service providers, and consumers play in securing high-quality infrastructure services, is illustrated in Figure 1.8. Subsequent chapters analyze each of the framework's components.

Figure 1.8
Roles of Government, Service Providers, and Consumers in Securing Infrastructure Services of High Quality



Source: IDB staff elaboration.

Historically, governments have decided how much and what type of infrastructure to build. This need not be the case. Increasingly, governments are allowing the private sector to choose how, where, and what technology to use to supply infrastructure services. Such is often the case with electricity, where service providers choose technologies (wind, solar) and the best place to build generation facilities, typically within guidelines and according to rules set down by governments. But governments retain the responsibility to forecast and plan how to respond to aggregate demand, to comply with international agreements, to provide permits for the use of land, and to address social and environmental conflicts.

Today, most of the region's infrastructure is built by the private sector. The government often pays for the infrastructure, but, even in this case, the actual construction is contracted out to private firms. Increasingly, services, too, are provided by private firms. Governments participate to varying degrees in the governance and operation of services.[6] Box 1.1 provides data that show the private sector provides most of the region's transportation services and plays a leading role in energy generation, but its role is much smaller in water and sanitation.

Box 1.1

Who Provides Infrastructure Services in Latin America and the Caribbean: The Private or the Public Sector?

No public database reports the ownership of firms that provide infrastructure services in the region. Given this lack of information, a best guess estimate was carried out for the preparation of this book in 2019. In the results reported below, public firms are state-owned enterprises in which a government entity is the majority shareholder. Private firms are either wholly private or a government entity is a minority shareholder.

Transport

- All *trucking services* are provided by private firms.
- 18 of the 20 largest *port terminals* are operated by private firms.
- 15 of the 20 largest *airports* are operated by private firms. Only one of the 20 largest airlines is state-owned.

Electricity

- *Generation* is highly varied, from no private sector generation (in Paraguay, for example) to 100 percent in Chile. Private firms generate about half of the region's electricity.
- Most *transmission* is under the control of state-owned firms, except in Chile and Argentina.
- Few countries allow private firms to *distribute* electricity. The major exceptions are Chile and Argentina. Private firms play some role in distribution in Mexico and Costa Rica.

Water and sanitation

- 40 of the 45 largest water utilities are state-owned. Chile, where most of the water utilities are private companies, is an outlier.

Government: Setting the Rules of the Game

In addition to guiding how much, where, and what assets to build, the government plays a fundamental role in framing the technical and economic

[6] For a detailed recent analysis of the characteristics and performance of state-owned enterprises in Latin America, see Musacchio and Pineda Ayerbe (2019).

regulation of services. Regulating quality standards, pricing policy (tariff level and structure), service obligations, and investment commitments are fundamental tools governments use to provide incentives for quality infrastructure services.

Strong planning institutions and processes are needed to assess how much additional infrastructure a country needs and where to build it. As shown in Chapter 2, many opportunities exist to improve the policies, institutions, instruments, and human resources employed in the region's public investment systems. A key dimension often neglected in selecting infrastructure projects is the interaction among different types of assets. This reflects the silo structure and mentality in most countries, which have sector-specific ministries and no central agency to take a comprehensive and holistic approach to infrastructure planning. Providing efficient services requires well-planned interaction among assets. Multimodal logistical services, for example, require seamless interaction among roads, railroads, and port facilities. For urban mobility it is crucial to coordinate land use planning and zoning with the supply of transit services. In Latin America and the Caribbean, these activities are often controlled by separate institutions (usually ministries of housing and transport). Understanding those interactions depends on ever-more complex processes managed by multidisciplinary teams.

Determining what type of infrastructure to build is becoming increasingly important. Climate change and technology are shaping those planning decisions. Planning must take into account the uncertainty of climate change and the need to make new infrastructure as resilient as possible to a range of climate-related threats. New infrastructure (especially in the energy and transportation sectors) should also contribute to a country's climate-mitigation targets. Although infrastructure that is resilient to climate change may be more expensive to build, it may be economically justified over its life cycle (Chapter 6). Technological change will make infrastructure services more interdependent (digitalization of services, electrification of transportation), and cybersecurity will have to be embedded in planning and regulation (Chapters 9, 10, and 11).

The life cycle approach to infrastructure is also relevant for planning, designing, and operating infrastructure; governments must prioritize maintenance, avoiding the current bias in favor of new investment by implementing sound asset management policies. Chapter 2 provides examples of the bias against maintenance in policy, practice, and even data collection, to the point where it is impossible to document how much Latin American and Caribbean countries invest in maintenance.

Going beyond what type of infrastructure to build, governments must also improve policies and practices that determine how efficiently infrastructure is built. Corruption, insufficient competition, and weak supervision lead to inefficiencies in public investment that amount to 0.65 percent of the region's GDP (see Chapter 2).

Though they may not provide infrastructure services directly, governments establish institutions (ministries, commissions, independent regulatory agencies), processes, and instruments that define rules and incentives to guide firms providing services. Governments' most important objective in regulating infrastructure is for services to satisfy demand, meet minimum quality standards, and be delivered at affordable rates. Governments also want infrastructure service providers to achieve the highest levels of operational efficiency so they can deliver services at the lowest possible cost.

The most powerful instruments governments have to achieve their mandate are *tariffs* (the prices charged for services according to the level of consumption or the status or location of the customer), *standards* of quality (for example, that water is potable or electricity is of the right voltage), and *incentives* to induce the service provider to invest in equipment and facilities that will provide services at the lowest possible cost. Some regulatory instruments are specific to a single sector (e.g., subsidies for the purchase of electric buses); others are economywide (e.g., reductions in import tariffs to lower the cost of adopting renewable energy). These and other regulatory instruments that governments use are detailed in Chapters 5 and 13.

As detailed in the chapters that present scenarios for the future of electricity, transport, and water services (Chapters 9, 10, and 11), technology disruption will change how services are provided and affect the relationship between infrastructure assets and infrastructure services. Those changes will oblige governments to develop regulatory institutions capable of setting flexible and responsive rules to enable consumers and service providers to derive maximum benefit from technological changes.

Service Providers: The Link between Assets and Consumers

Service providers are key determinants of the quality of infrastructure services. They are the link between assets and consumers. Increasingly, through a range of different legal agreements, from management contracts to full privatization, service providers are involved in the whole project cycle of infrastructure assets and service provision: design, construction, and operation of infrastructure. In many countries, service providers also play an important role in financing infrastructure (Chapter 3).

Service providers must comply with the regulations set forth by government. Properly designed regulations give service providers room to increase efficiency. For instance, when asset construction and operation are bundled—a typical arrangement in road concessions—service providers have the incentive to build a high-quality asset (road) to reduce maintenance needs, which translates into benefits for the users of the infrastructure (private vehicles and trucking fleets).

Technological innovation provides opportunities for service providers to increase efficiency while simultaneously providing better and more affordable services to users. Smart energy metering is a case in point, as it allows consumers to shift a fraction of their electricity demand to hours of the day when it is cheaper, thereby reducing their energy bill. The change in consumer behavior also benefits the service provider by reducing the need to invest in additional energy generation capacity. The implementation of smart payment methods is another example of an innovation that benefits the bottom line of service providers while improving affordability of services; consumers can pay for the quantity they can afford instead of paying a fixed amount regardless of the quantity they consume.

The behavior of service providers, far and beyond compliance with regulations, can go a long way toward improving the quality of services. Data sharing and reporting of service performance are a good example: commercial airlines in the United States began a voluntary reporting system for mishandled luggage in the early 2000s that was subsequently made mandatory by the Department of Transportation.

Nontraditional aspects influencing the quality of infrastructure service are receiving increasing attention and service providers are taking action. Gender and accessibility are concrete examples. Infrastructure is being designed and retrofitted to facilitate access, frequency of service in urban transport is increasingly designed to take into account the different mobility needs of women and men, and personal security features like cameras, panic alarms, and more public lightning are being installed. Several infrastructure service providers are implementing active employment policies to increase the number of women in jobs where their participation has traditionally been low. Although progress is being made, faster and more decisive action is required.

Consumers: An Evolving Role

The role of consumers in shaping the quantity and quality of services has been neglected, but this is changing. New technology is allowing, for the first time, a blurring of the frontier between consumers and service providers. In the framework presented in this section, consumers can play a meaningful role in the endowment of infrastructure. The energy sector is leading this transformation. Households equipped with solar panels now generate electricity for their own use and sell any excess to the network. They are transitioning from being consumers only to being producers as well (that is why households that produce electricity are referred to as prosumers). Other infrastructure services are being transformed as well, like transportation, where individuals can provide services through platforms with their own infrastructure equipment (Uber is the best-known example).

The environmental concerns of households, cities, and industries are changing the type of infrastructure that is being built. Consumers are no longer indifferent to the source of their electricity. They demand not only cleaner sources but also policies to increase the efficiency of energy consumption. A similar trend is underway in urban transport due to the increasing level of pollution.

As computer users know, hardware and software are interdependent: neglecting the role of regulation is equivalent to forgetting to upgrade the software to get the most out of new hardware. Of course, the converse applies as well: hardware must be intermittently upgraded to take advantage of new software developments. The message from the framework presented in this chapter and its application in Latin America and the Caribbean is clear: to date, infrastructure policies and debates in the region have focused disproportionately on hardware (investment in assets) and largely ignored the software of regulation and choice. Correcting this asymmetry and striking the right balance is the challenge facing the region today.

2

Toward More—and More Efficient—Investment

Few public policies generate greater consensus in Latin America and the Caribbean than the need to invest more in infrastructure. Insufficient physical assets, inadequate maintenance, and poor infrastructure services add up to low service quality throughout the region. But no consensus exists on how much the region should invest, or for how long, in order to close the infrastructure gap.

Measuring the size of the infrastructure gap has absorbed the attention of academics and development banks since the early 2000s. The most influential reports estimate annual investment needs between 4 and 7 percent of GDP.[1] Different methodologies and demand scenarios explain the wide range of estimates.

While the size of the gap may be up for discussion, everyone agrees that the region is investing less than it should. From 2008 to 2017, the countries of the region invested an average 2.8 percent of their GDP in infrastructure, of which 2.3 percent was public and 0.5 percent private.[2] Investment in infrastructure in Latin America and the Caribbean is well

1 The most cited reports are those from Calderón and Servén (2003), Fay and Yepes (2003), Kohli and Basil (2011), Perrotti and Sánchez (2011), Bhattacharya, Romani, and Stern (2012), Ruiz-Nuñez and Wei (2015), and Sánchez et al. (2017). The most recent reports are Castellani et al. (2019) and Rozenberg and Fay (2019). The latter incorporates for the first time scenario modelling and the need for infrastructure to be compatible with climate targets. It finds that the region will need to invest 3.3 percent of its GDP in the next decade to achieve the infrastructure-related Sustainable Development Goals and stay on track to limit global warming to 2°C.

2 Public investment data produced with a comparable methodology for a large sample of countries in Latin America and the Caribbean are not available before 2008. See Infralatam (www.infralatam.info). Private investment level was obtained from Infrastructure Journal Database and the Private Participation in Infrastructure database of the World Bank (see Chapter 3 for detailed information on private investment).

below that of other emerging economies: 5.7 percent in East Asia and the Pacific, 4.8 percent in the Middle East and North Africa, and 4.25 percent in South Asia (Fay et al., 2019). Absolute numbers help put the differences into perspective. Latin America and the Caribbean invested around US$125 billion per year from 2008 to 2017 while China, a country that has assigned infrastructure investment a top policy priority, invested US$450 billion each year during the same period. On a per capita basis, China invests US$330, 65 percent more than the US$200 Latin America and the Caribbean invests per year in infrastructure.

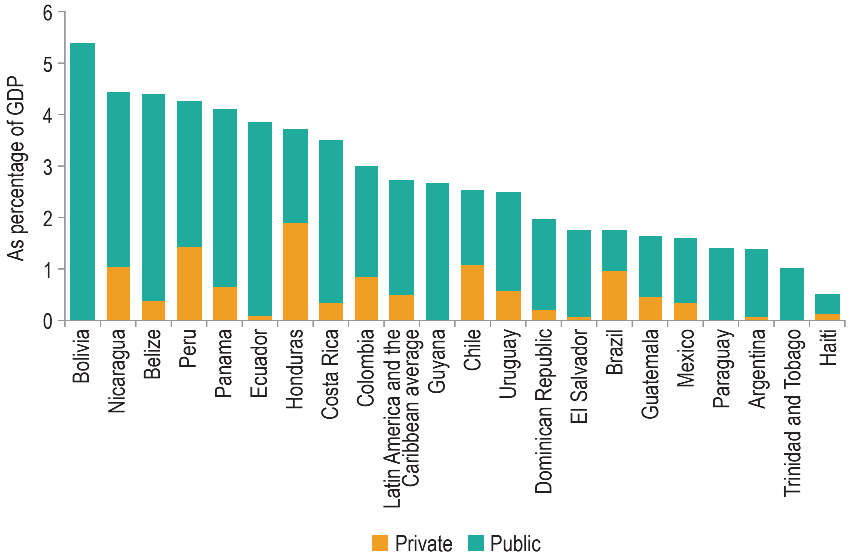
While regional numbers may raise awareness, actionable policies require country-level analysis. Countries must produce and update sound estimates of infrastructure investment needs and establish priorities that reflect social aspirations and a realistic assessment of available resources. Those estimates and priorities must result in well-prepared investment projects. Unfortunately, few countries estimate infrastructure investment needs on a regular basis. And the estimates that do exist are largely generated by academics or private firms rather than governments. Recent examples include estimates of annual investment needs for Bolivia (9 percent), Chile (5 percent), Colombia (4.5 percent), and Peru (4 percent).[3]

Actual investment levels between 2008 and 2017 vary widely across countries (Figure 2.1). While some countries invest significant amounts (Belize, Bolivia, Nicaragua, and Peru), the largest economies—Argentina, Brazil, and Mexico—invest far less as a percentage of GDP.

Closing the infrastructure gap in Latin America and the Caribbean will require a surge in both public and private investment. The role of public investment in the surge is undeniable. But governments can also improve the regulatory environment to attract more private investment wherever it makes economic sense to do so—that is, for projects with high social rates of return and where the private sector can deliver services of better quality and with greater efficiency. The potential for private financing is significant (see Chapter 3). Institutional investors in the region have US$2.7 trillion in assets under management (close to 50 percent of regional GDP) but allocate less than 1 percent of that total to infrastructure (Baghai, Erzan, and Kwek, 2015).

[3] References for the reported investment needs are: Bonifaz (2016), Bonifaz et al. (2015), Grijalva, Ponce, and Rojas (2017), CChC (2018), Bonifaz et al. (2019), and Yepes (2014). In 2019, the Government of Peru published an updated version (Peruvian Ministry of Economy and Finance, 2019) of the study of Bonifaz et al. (2015) that reported an infrastructure gap of 8 percent of GDP. The estimates of investment needs in infrastructure were reduced to 4 percent a year. The lower needs reflect several years of investment over 5 percent of GDP that greatly reduced infrastructure access gaps in Peru.

Figure 2.1
Average Investment in Infrastructure, 2008–17



Source: Infralatam (www.infralatam.info) for public investment and Private Investment in Infrastructure (PPI) database for private investment.
Note: Public investment data for all countries are from 2008–17 with the following exceptions: Dominican Republic, 2009–17; Ecuador, 2008–16; El Salvador, 2008–15, and; Haiti, 2012–16.

Sadly, a pronounced increase in public infrastructure investment, however desirable, seems unlikely in light of fiscal constraints and the low priority that has been given to infrastructure. The record of public expenditure in Latin America and the Caribbean shows a bias against capital spending, of which infrastructure is a major component. Since 1995, current expenditures in the region have grown almost without interruption. Capital spending, on the other hand, has been more volatile, including prolonged periods of cuts. Total primary public spending in the region increased 5.2 percent of GDP between 2000 and 2016, but 88 percent of it was current expenditures; only 12 percent went to longer-term investments (Izquierdo, Pessino, and Vuletin, 2018). In fact, infrastructure spending in the region is procyclical and suffers disproportionately large cuts in difficult times (Ardanaz and Izquierdo, 2017).

The impact of infrastructure investment goes beyond the provision of more and better-quality services. Investment in infrastructure matters for economic growth. Cavallo and Powell (2019) compare the projected growth rate of six economies in Latin America and the Caribbean with the growth rate those economies would have achieved if investment in infrastructure just covered depreciation of the existing capital stock (that is, no new asset is built). After 10 years, the rate of economic growth of the six economies declines: Peru (–29 percent), Bolivia (–14 percent), Costa Rica (–12 percent), Chile (–7 percent), Argentina (–4 percent), and Jamaica (–2.5 percent).

Investing more in infrastructure must go hand-in-hand with investing more efficiently. Efficiency in the delivery of *public* infrastructure can increase 35 percent in the region according to IDB estimates presented below. In simple terms, this means that the region could build 35 percent more assets without spending a penny more of public funds. To grasp the magnitude of the prevailing inefficiencies, consider that of the 2.3 percent of GDP of public investment in Latin America and the Caribbean, 0.65 percent of GDP is lost to inefficiencies. If the region does not improve the efficiency of its investment, closing the infrastructure gap will take longer and will be much more difficult to achieve.

So, where to start? What policy actions will increase and improve infrastructure investment? The rest of this chapter identifies the gains to be had from better planning, better performance (in terms of cost and time), greater selectivity (building only what is necessary), and better use of existing assets (through maintenance). Corruption and ways to curb it are also discussed. It concludes with concrete policy recommendations. Chapter 3 complements this chapter by delving into the options for developing and implementing instruments to attract more private sector participation and financing to infrastructure.

Investing in the Investment Process

Generating more and better investment in infrastructure demands a more efficient public sector that can streamline project cycles and attract the private sector. Efforts to "invest in the investment process" can play a key role in raising returns on public and private investment, and in ensuring that investment pays growth dividends, all while maintaining fiscal and debt sustainability. Choosing the right combination of projects to provide the infrastructure services growing economies need depends on strong upstream planning. When done properly, upstream planning allows countries to select the projects with the highest economic and social rates of return.

The importance of planning goes far beyond choosing projects with the highest economic returns. Social and environmental concerns are increasingly important as well. The best way to avoid conflicts and mitigate the negative effects of infrastructure projects is to consider those concerns early on in the upstream planning process. The costs of ignoring the social dimension in upstream planning were quantified by Watkins et al. (2017). In a sample of 200 projects in Latin America and the Caribbean, 36 were cancelled because of social conflicts, while 162 faced delays, and 116 suffered cost overruns. Given the very real threats to infrastructure assets posed by climate change, planning should incorporate tools for decision-making under scenarios of deep uncertainty (see Chapter 6). The international community is developing standards to build more sustainable infrastructure. Japan's presidency of the G-20 in 2019 focused on quality infrastructure, a concept that in practical terms implies adopting the high standards needed to develop resilient and inclusive infrastructure.[4] The approach begins with *choosing the right project* and then investing in *doing the project right*.

To what extent does the region presently optimize the processes involved in the project cycle of infrastructure investment? Have its countries developed the proper environment to attract the private sector? Multilateral development banks (MDBs), the Global Infrastructure Hub, and other organizations, have tried to answer these questions with indices that benchmark countries' institutional performance in infrastructure (Table 2.1).

Country rankings vary because the indices rely on different methodologies and information sources. The indices do not allow for identifying with precision which institutional arrangement leads to better planning outcomes or even what is the ideal path of institutional reform. The absence of a sound body of evaluations that link institutional reforms to the performance of infrastructure planning and management institutions give these indices an informative role, and, consequently, rankings should be understood as a first step toward in-depth country analysis. Despite the difference among rankings and the diversity among Latin American and Caribbean countries in the performance of their infrastructure institutions, Chile, Colombia, and Peru stand out as consistently top performers. Chile is well known for the solid foundations of its National System of

[4] The IDB developed in 2018 a framework that defines the term *sustainable infrastructure* and proposes methodologies to incorporate the dimensions of sustainability (economic, financial, environmental, and social) in planning and project design (Watkins et al., 2017). The Center for Strategic and International Studies, an American bipartisan think tank, prepared a report with recommended policy actions for the U.S. government (Runde, Yayboke, and Ramanujam, 2019). The report highlights that an emerging critical mass of countries could provide alternatives for meeting infrastructure needs while establishing sound international principles for quality, affordability, sustainability, resiliency, and social responsibility.

Table 2.1
Selected Indicators of Institutional Capacity for Infrastructure Delivery, 2016–19

	PIMA[a] (0 = worst, 4 = best)	Infrascope[b] (0 = worst, 100 = best)						Benchmarking Public Procurement (BPP)[c] (0 = worst, 100 = best)					Infracompass[d] (low = worst, very high = best)	
Country	PIMA overall score	Infrascope overall score	Regulations	Institutions	Maturity	Investment and business climate	Financing	BPP overall score	Preparation of PPPs	Procurement of PPPs	PPP contract management	Unsolicited proposals	Delivery	Planning
Argentina	2.66	49	66	40	50	49	37	59	27	56	74	79	Medium	Low
Bolivia	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Brazil	—	71	63	88	67	69	69	64	47	80	76	54	Medium	Medium
Chile	3.03	80	94	80	81	83	63	80	67	72	87	92	Medium	High
Colombia	2.66	77	95	80	78	61	73	83	90	79	72	92	Medium	High
Costa Rica	1.76	71	84	78	69	67	60	41	28	44	50	—	Low	Low
Dominican Republic	3.03	50	82	11	33	82	49	55	42	82	38	58	Low	Low
Ecuador	2.66	59	74	36	67	74	43	47	52	35	43	58	Low	Low
El Salvador	1.76	68	88	78	67	67	40	70	42	67	90	79	Low	Low
Guatemala	2.35	69	81	93	68	64	41	67	55	78	68	—	Low	Low
Haiti	—	—	—	—	—	—	—	45	50	59	54	17	Low	Low
Honduras	2.35	70	84	56	86	56	63	58	56	53	66	58	Low	Low
Jamaica	—	74	78	90	81	76	42	64	71	59	44	83	Low	Low
Mexico	2.66	66	79	56	73	53	64	81	81	82	84	75	Medium	Very high
Nicaragua	2.35	59	80	66	66	45	36	66	30	73	68	92	Low	Low
Panama	1.76	58	60	29	71	71	54	47	32	72	56	29	Low	Low
Paraguay	1.76	52	68	60	56	43	32	83	89	80	83	79	Low	Low
Peru	3.03	77	70	67	77	85	85	81	81	66	78	100	Low	Very high

(continued on next page)

Table 2.1
Selected Indicators of Performance of Infrastructure Institutions, 2016–19 *(continued)*

	PIMA[a] (0 = worst, 4 = best)	Infrascope[b] (0 = worst, 100 = best)						Benchmarking Public Procurement (BPP)[c] (0 = worst, 100 = best)					Infracompass[d] (low = worst, very high = best)	
Country	PIMA overall score	Infrascope overall score	Regulations	Institutions	Maturity	Investment and business climate	Financing	BPP overall score	Preparation of PPPs	Procurement of PPPs	PPP contract management	Unsolicited proposals	Delivery	Planning
Trinidad and Tobago	—	53	52	43	56	71	43	26	20	41	31	13	Low	Low
Uruguay	2.35	70	76	87	62	62	68	72	77	73	68	71	Medium	Low
Venezuela	—	8	16	0	10	4	8	—	—	—	—	—	Low	Low
Latin America and the Caribbean average	2.41	62	73	60	64	62	51	63	55	66	65	66	Low	Low
World average	1.57	57	60	59	60	62	44	56	51	64	54	56	—	—

Legend:

PIMA	Infrascope	BPP	Infracompass
0–1	0–25	0–25	Low
1–2	26–50	26–50	Medium
2–3	51–75	51–75	High
3–4	76–100	76–100	Very high

Source: IMF, The Economist Intelligence Unit, World Bank, Global Infrastructure Hub.
Note: PPP = public-private partnership; — = no value reported.

[a] The International Monetary Fund's Public Investment Management Assessment (PIMA) was adapted to Latin America and the Caribbean by the IDB. The PIMA index captures the institutional environment underpinning public investment management systems at four project stages: appraisal, selection, implementation, and evaluation. It scores from 0 (worst) to 4 (best). See more at https://www.imf.org/external/np/fad/publicinvestment/.

[b] The Infrascope index is a benchmarking tool that evaluates countries' capacity to implement sustainable and efficient PPPs in infrastructure. It evaluates readiness and capacity by dividing the PPP project life cycle into five components: enabling laws and regulations; the institutional framework; operational maturity; investment and business climate; and financing facilities for infrastructure. It scores from 0 (worst) to 100 (best). See more at https://infrascope.eiu.com/.

[c] The Benchmarking Public Procurement indicator (BPP) reflects the private sector's perspective on the public procurement cycle. It assesses procurement life cycles in 180 economies, which it scores from 0 (worst) to 100 (best). See more at https://bpp.worldbank.org/en/BPP-data.

[d] Developed by the Global Infrastructure HUB, Infracompass aims to provide a better understanding of a country's infrastructure market by identifying policies and practices that lead to sustainable and equitable infrastructure through efficient markets, better decision-making, and delivery. It scores from low (worst) to very high (best). See more at https://infracompass.gihub.org/overview.

Investment (Gómez-Lobo, 2012). Colombia has a long-standing tradition of planning at the national level through the National Planning Department and has recently reformed its infrastructure structuring institution to improve the project cycle of infrastructure delivery (National Infrastructure Agency, ANI) and to attract private financing (*Financiera de Desarrollo Nacional,* FDN). Peru is well known for having strong economic regulators and innovated when it set up a national multisectoral transport regulator.

Several countries have made concerted efforts to improve their infrastructure planning institutions. Perhaps the most important innovation has been the development of national systems of public investment regulated by an agency that is usually hosted in the finance ministry, given its key role in prioritizing projects.[5] To enhance the quality of infrastructure assets and services, these institutions regulate the processes of public investment that guide projects from the early stages of formulation and feasibility to post-completion evaluation. However, few evaluations suggest how such institutions might be improved and shielded from the persistent political pressure to eliminate them (Contreras et al., 2016).

With respect to private sector involvement, where does Latin America and the Caribbean stand? How many of the region's countries enjoy the macroeconomic, institutional, and regulatory environment needed to attract the private sector into public-private partnerships (PPPs)? Various indicators have been developed in recent years to assess the PPP environment in the region and to identify potential barriers to private participation in infrastructure. Of these, Infrascope, a benchmarking tool that evaluates a country's capacity to implement sustainable and efficient PPPs, is the most thorough and frequently cited.[6]

According to Infrascope, Latin America and the Caribbean has made a significant effort in recent years to boost infrastructure PPPs by implementing new laws and policies, creating new PPP units, updating PPP registries, and publishing contracts, documentation, and project evaluations (EIU, 2017). Taking the results of all Infrascope editions, Colombia, Chile, Peru, and Brazil have the strongest institutional environment for

5 As of 2019, several countries set up National Systems of Public Investment (SNIPs; "Sistemas nacionales de inversión pública" in Spanish): Argentina, Bolivia, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, and Uruguay. The Economic Commission for Latin America and the Caribbean (ECLAC) set up a portal dedicated to SNIPs that includes links to countries' web portals and papers that evaluate the performance of SNIPs (https://biblioguias.cepal.org/c.php?g=159547&p=1044441).

6 See more at https://infrascope.eiu.com/.

PPPs (EIU, 2017). However, taking the region as a whole, there is still a significant gap between theory and practice. While overall legislation and regulation are relatively well established compared to other developing economies, deficiencies are notable in institutional capacity, maturity, and investment and business climate. The Caribbean countries—with the notable exception of Jamaica—are still very far from the regional average in terms of PPP development. Beyond the indices, the region must develop the ability to systematically assess when to implement PPPs and when to stay with traditional public provision.

Filling the Potholes: Improving the Efficiency of Infrastructure Delivery and Maintenance

Delivery of infrastructure is a complex endeavor riddled with procedural, administrative, and operational potholes. The size of projects, the number of actors involved (designers, construction firms, supervisors, regulators), and the lack of adequate and transparent information over the project cycle frequently come together to open a gap between the expected (planned) result and the actual outcome. Even assuming that the outcome of the planning process is the set of the best possible infrastructure projects, do countries use the most updated engineering specifications to match supply and demand? The evidence required to answer that question definitively is unavailable in Latin America and the Caribbean, but anecdotal information points to ample room to improve. A study of the engineering designs of potabilization plants in South America (Páez, Alberti, and Rezzano, 2019) shows that the demand parameters contained in the regulations that set engineering specifications were outdated. Consequently, countries' overinvestment in infrastructure ranged from 12 to 26 percent. In turn, overinvestment in capacity increased maintenance costs by 10 percent. Clearly, correct sizing of projects could be a source of efficiency and savings. Other ways to improve efficiency and reap savings include reducing cost overruns, avoiding delays in project implementation, and maintaining existing assets properly.[7]

Reducing Cost Overruns

Cost overruns are often blamed on perverse incentives and illegal behavior (for example, bids with prices under costs to win contracts and corruption

[7] Serebrisky et al. (2017) lay out in more detail the methodology, data, and results related to the efficiency gains reported in this chapter.

in project delivery). However, the high and varied risks inherent in infrastructure development often produce contingencies that are hard to anticipate at the outset of a project. Among the contingencies that may increase project costs are geological conditions that are more complex than expected, archaeological remains, or the absence of well-defined property rights, which can delay land acquisition. While these contingencies may be partially anticipated and mitigated through proper project evaluation and contract design, residual risk may remain and cause cost overruns. Thus, it is simply untrue that cost overruns are always explained by corruption or the inefficiency of public agencies.

Cost overruns are ubiquitous in the development of infrastructure, though few studies present evidence of cost overruns for comparable projects across countries and regions.[8] Flyvbjerg, probably the best-known scholar in the field of measurement of cost overruns, showed in 2016 that, at the global level, cost overruns account for 28 percent of the total cost of infrastructure investment. This means that the average infrastructure project could be built with 28 percent fewer financial resources. Even countries such as Australia—usually one of the best performers in infrastructure development, according to a wide range of indicators—incurs cost overruns of 12 and 35 percent for PPP and public procurement contracts, respectively (Duffield and Raisbeck, 2007).

How does Latin America and the Caribbean compare to the rest of the world in cost performance? The answer is not encouraging. Overruns in the region are almost double the world average (48 percent) (Flyvbjerg, 2016). Indeed, Latin America and the Caribbean is the only region in the world where cost overruns have been systematically increasing over time; in other regions, including Europe and Asia, they have been declining (Flyvbjerg and Sunstein, 2016).[9] Other sources confirm the unfavorable standing

8 A vast literature shows that infrastructure construction is associated with substantial cost overruns (Flyvbjerg, 2007, 2016; Flyvbjerg, Skamris Holm, and Buhl, 2002, 2003, 2004; Ahsan and Gunawan, 2010; Cantarelli et al., 2010). The literature points to four dimensions that explain cost overruns in infrastructure projects: technical, economic, political, and sociological (Flyvbjerg and Sunstein, 2016). The technical drivers of cost overruns are forecasting errors and risks, which, in infrastructure projects are complex and difficult to specify and quantify. Economic drivers include principal–agent problems between the public officials who decide what projects to build and the society that is the intended beneficiary. The objectives of public agents and societies are not always aligned, so the decisions of public agents may not maximize social welfare. There is also a sociological/psychological driver, known as "appraisal optimism." Agents tend to think that the costs, risks, and execution time of projects will be lower or shorter than they have proved to be in similar projects (Flyvbjerg, Skamris Holm, and Buhl, 2004).

9 For a description of the database, see Flyvbjerg (2016).

of the region. According to Guasch, Suárez-Alemán, and Trujillo (2016), 75 percent of Latin American infrastructure projects suffer cost overruns. Dams have the highest overruns: 95 percent worldwide, 103 percent in Latin America and the Caribbean. The greatest differences in overruns between Latin America and the Caribbean and the world are found in road development: 23 percent worldwide, 53 percent in Latin America and the Caribbean (Flyvbjerg and Sunstein, 2016). Bonifaz (2019) confirms the excessive cost overruns in Latin America and the Caribbean.

As noted, even after avoidable risks are properly accounted for in project costing, residual risk may cause cost overruns, implying the existence of a minimum technical average cost overrun that should be understood as the natural result of carrying out complex construction projects. Is Latin America and the Caribbean close to that minimum technical average? Or is there room for addressing cost overruns by improving processes in the project cycle?

To answer this question, this chapter presents the result of the following exercise: First, the cost overruns of infrastructure projects financed by multilateral development banks (MDBs) in the region are calculated. MDBs have generally high standards for project preparation and implementation, which translate into more stringent practices relating to feasibility, procurement, transparency, and supervision than most national systems in the region. In projects developed under these higher standards, contingencies should be better identified, measured, and managed.[10] Consequently, cost overruns in MDB-financed projects could be expected to represent a best-case scenario: they are likely to be lower than in other infrastructure projects. The second step of the exercise was to compare the cost overruns found in MDB-financed projects with the overruns reported in the specialized literature. The difference provides an estimate of how much could be saved in infrastructure investment. That is, it offers a measure of the inefficiency of public investment in infrastructure in Latin America and the Caribbean.[11]

10 As an example, throughout the process of infrastructure delivery, MDBs use standardized processes to generate estimated construction costs in the planning phase and have a mandate to report actual construction values at the end of the construction phase. Some countries generate similar information, but national reporting systems are heterogeneous and seldom used to evaluate infrastructure project performance.

11 Given that the sample only includes public financing of infrastructure (loans that are made to governments and have sovereign guarantee for its repayment), the calculation of inefficiencies corresponds to public investment.

The sample of MDB-financed projects includes 83 IDB infrastructure projects implemented from 1996 to 2015 and 148 World Bank projects carried out in the region from 1985 to 2010.[12] By sector, these 231 projects break down as follows: 142 road transport projects involving new construction, maintenance, or rehabilitation (48 IDB, 94 World Bank); 73 water and sanitation projects involving treatment plants or improvement and expansion of distribution networks (24 IDB, 49 World Bank); and 16 energy projects involving generation or transmission (11 IDB, 5 World Bank).

In the sample, 82 percent of IDB projects and 53 percent of World Bank projects had cost overruns. On average, cost overruns represented 22 percent (IDB) and 17 percent (World Bank) of total project costs. By sector, on average, transport projects have slightly higher overruns than water and sanitation while energy projects have lower cost overruns in both institutions (Table 2.2).[13] However, the difference is statistically insignificant.

Table 2.2
Cost Overruns in Infrastructure Projects Financed by the IDB and the World Bank, by Subsector (percent)

	Transport	Energy	Water and sanitation
IDB average	23	16	19
World Bank average	18	9	17
IDB standard deviation	33	21	28
World Bank standard deviation	38	19	34
IDB maximum	144	93	138
World Bank maximum	191	47	174

Source: Authors' elaboration based on IDB and World Bank project data.

12 The IDB sample is geographically distributed as follows: 35 percent of the projects were developed in Brazil, 7 percent in Colombia, 6 percent in Haiti, 6 percent in Peru, 6 percent in Uruguay, and 5 percent in Bolivia. The remaining 35 percent is distributed among Argentina, The Bahamas, Barbados, Belize, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Jamaica, Mexico, Panama, Paraguay, and Trinidad and Tobago. The World Bank sample is geographically distributed as follows: 26 percent of projects were developed in Brazil, 10 percent in Argentina, 7 percent in Colombia, 6 percent in Peru, 5 percent in Honduras, 4 percent in Haiti, and 4 percent in Mexico. The remaining 29 percent is distributed among Chile, Guatemala, Paraguay, Uruguay, Bolivia, Ecuador, Guyana, Jamaica, Nicaragua, Panama, Belize, Dominican Republic, St. Lucia, Costa Rica, El Salvador, and Venezuela.

13 At the IDB, the Transport Division recently developed a manual for estimating and tracking the final cost of an infrastructure program (Monteverde, Pereyra, and Pérez, 2016).

Comparing cost overruns reported in the literature (48 percent) with those in MDB-financed infrastructure projects (20 percent, the average of cost overruns in IDB and WB financed-projects) suggests that if proper infrastructure policies, like standardized project preparation processes and high-quality supervision, were applied over the project cycle, Latin America and the Caribbean could save around 25 percent of total project costs.[14] Recently, public investment in infrastructure in the region has averaged 2.3 percent of GDP. Extrapolating from that level, avoiding 25 percent of cost overruns could save up to 0.45 percent of regional GDP. In other words, by keeping cost overruns to a minimum, Latin America and the Caribbean would need to spend only 1.85 percent of GDP to achieve the same output (measured in terms of construction of assets) as it currently gets from investing 2.3 percent of GDP. The opportunity for public policy is ample and full of potential benefits.

Time Is Money

How much is lost when infrastructure assets take longer to build than they should? This question has pressing policy relevance in Latin America and the Caribbean because, as noted, the region has invested much less than it should in infrastructure. The best way forward for a region that does not invest much is to do it efficiently—and delays reflect inefficiency in spending.

Spending less than what has been budgeted, in turn, clearly indicates that investment projects are being delayed. It is also a symptom of poor planning. Izquierdo, Pessino, and Vuletin (2018) explain that under-execution of budgets in the region is not specific to infrastructure and encompasses all public investment. The difference between allocations and actual capital expenditure is significant in the region, ranging from 20 to 53 percent (Figure 2.2).

Time delays are common in infrastructure delivery. The reasons range from cumbersome procedures to obtain permits and approvals to contingencies arising during construction, whether caused by bad planning, the self-serving behavior of construction firms, weak supervision, or unforeseen events such as obstacles not shown on maps. Delays immobilize valuable resources, including physical and financial capital, thereby

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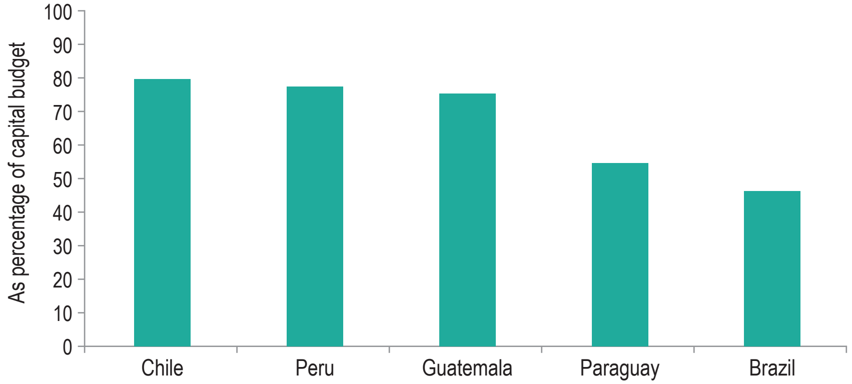
[14] The savings of 25 percent is the rounded difference of the cost overruns reported in the literature (48 percent) and the average cost overruns found for World Bank– and IDB-financed projects.

Figure 2.2
Execution of Capital Budgets in Five Latin American Countries, 2015



Source: Boost Open Budgets Portal, World Bank; Ministry of Economics and Finance of Peru; Integrated Budget Planning System of Brazil; Ministerio de Obras Públicas, Chile (2012–14).
Note: The data for Brazil and Guatemala include only the federal government and the central government, respectively.

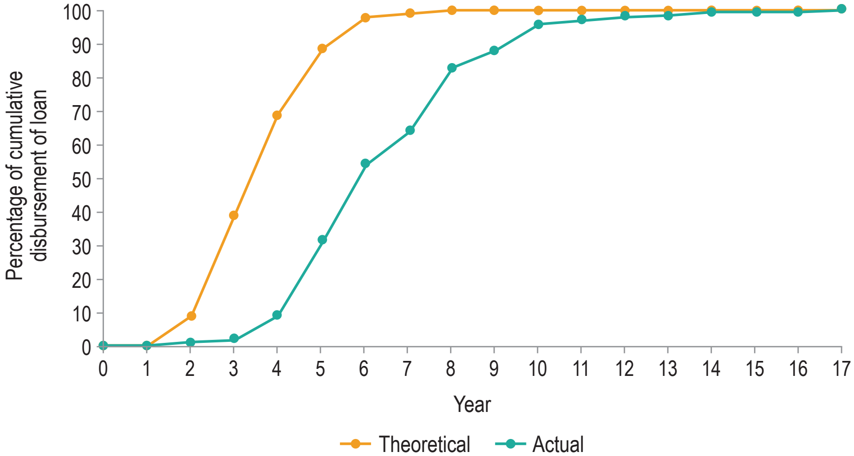
increasing a project's financial costs in a variety of ways: unit prices may increase, trained staff may leave the project, and the needs and priorities of the beneficiaries may change (Leurs, 2005).

To assess the cost of time delays, this chapter relies on IDB data on the execution of infrastructure projects to compare a theoretical disbursement curve with actual disbursements. Comparing the curves allows for assigning a monetary value to the savings that could be achieved by the timely implementation of infrastructure projects. The theoretical disbursement curve was constructed after reviewing more than 100 project appraisal documents containing detailed information on implementation schedules between 2003 and 2016. The second curve was constructed from the actual pattern of disbursement of a sample of 317 infrastructure projects. All disbursements were standardized using their approval date as year 0, with disbursements tracked on a yearly basis. Figure 2.3 compares the curves, revealing a significant gap between the theoretical and the actual. By way of example, the theoretical curve predicts that at Year 5, almost 90 percent of the loan should be disbursed. In practice, however, only 30 percent has been disbursed by then.

What are the financial costs of these delays? Deviations from the schedule set at the time of project approval have opportunity costs in the form of resources that could be allocated to alternative uses. The interest that could be earned on the immobilized capital is one way to measure those costs.

To estimate the financial costs of time delays, the exercise compared the difference in disbursement schedules between the actual and theoretical

Figure 2.3
Theoretical vs. Actual Cumulative Disbursement Curve, 2003–16



Source: Authors' elaboration based on IDB project data.
Note: Both curves have an "S-shape" in time, which graphically depicts how infrastructure projects behave. The start of the curve is the moment zero, which is the approval year. At the beginning, the curve takes time as project implementation begins. This period runs between approval and eligibility (government ratification or congressional authorization,) which lasts approximately two years. Once the first disbursement is made, the curve increases in slope because costs increase cumulatively, while toward the end of the project, these accumulated costs make up the greater part of the project disbursements.

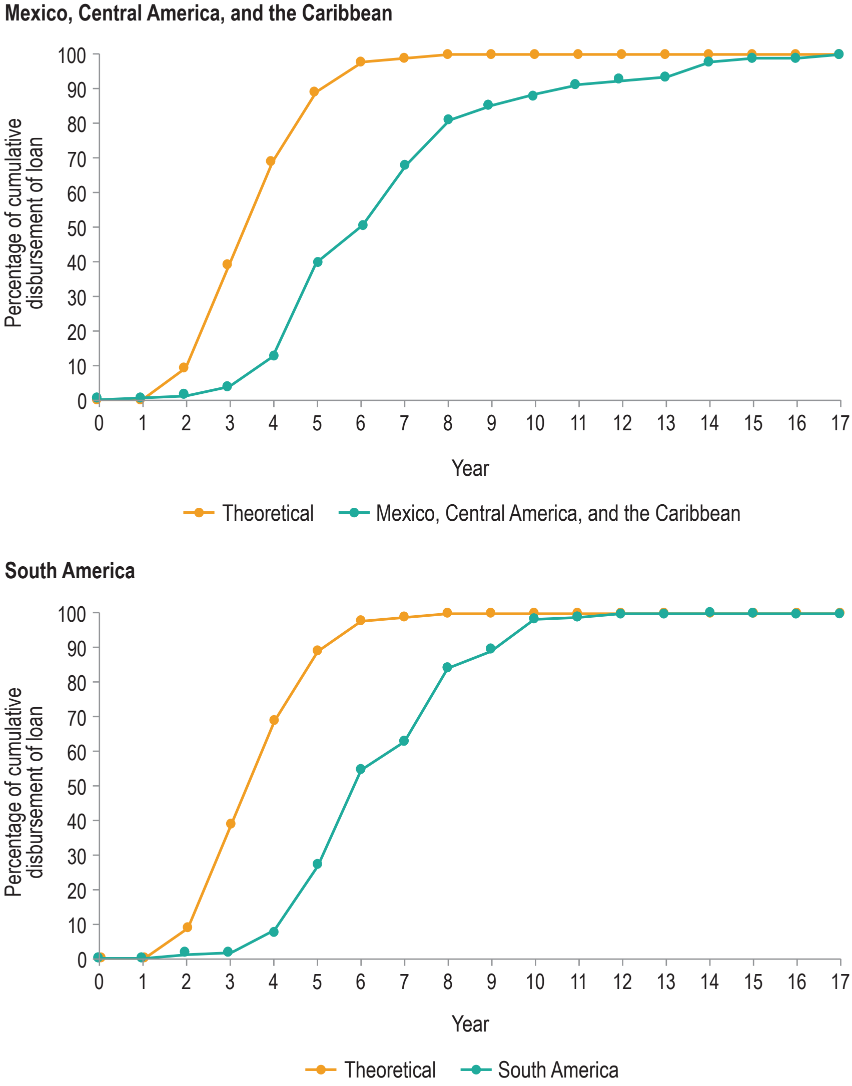
curve and applied the prevailing IDB lending rates. Based on the average interest rate over the period of analysis (4.2 percent), disbursement inefficiencies added 10.5 percent to project costs. Depending on the interest rate, these costs range from 2.8 percent, based on the lowest rate the IDB has charged since 1997 (0.99 percent), to 19.7 percent, based on the highest rate charged (7.03 percent). Using the average of the minimum and maximum interest rate suggests a potential savings equal to 10 percent of the total amount of the project. Given that 2.3 percent of public investment in Latin America and the Caribbean has gone to infrastructure, savings from avoiding time delays could reach up to 0.2 percent of regional GDP.

Transport, water and sanitation, and energy show similar patterns in time delays. While all countries in Latin America and the Caribbean fall below the theoretical curve, the countries of Central America and the Caribbean perform worse than those of South America (Figure 2.4).

The good news is that time performance is improving.[15] Between 2008 and 2016, the actual disbursement curve moved closer to the

15 In contrast to the conclusion reached for cost overruns.

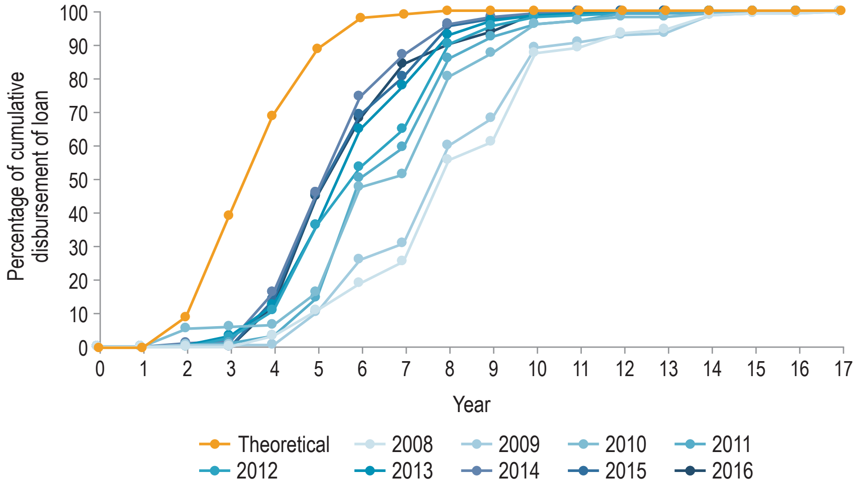
Figure 2.4
Theoretical vs. Actual Cumulative Disbursement Curve by Subregion, 2003–16



Source: Authors' elaboration based on IDB project data.

theoretical one (Figure 2.5). If the results for IDB-financed projects are extrapolated to all other infrastructure projects, the prognosis is good: With the same budgets, more infrastructure can be built.

Figure 2.5
Theoretical vs. Real Cumulative Disbursement Curve by Year, 2008–16

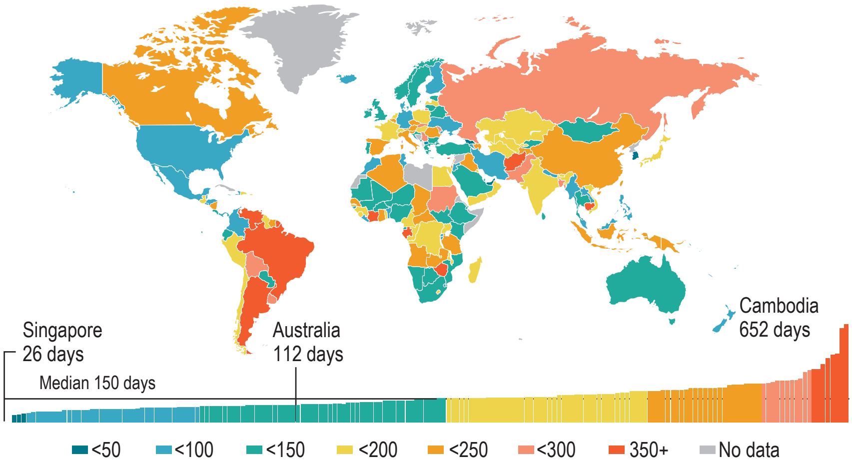


Source: Authors' elaboration based on IDB project data.

Ideally, this exercise should be done with project execution data from Latin American and Caribbean countries. But very few countries report such data; when they do, methodologies vary and include only a few projects. Given this limitation, the exercise carried out on IDB projects should be considered an approximation of the magnitude of time delays in the region. As in the case of cost overruns, assuming the IDB follows detailed supervision procedures, the estimated time delays should be considered a minimum.

Permitting and approval processes, a key determinant of project delays, take 25 percent longer in Latin America and the Caribbean than in OECD countries (McKinsey Global Institute, 2017; Figure 2.6). Latin America and the Caribbean is the worst performer among developing regions. Singapore is the top performer worldwide; completing all permitting and approval procedures takes only 26 days. In Latin America and the Caribbean, the average is 181.3 days. Colombia has the shortest delays in the region (73 days). Between 2009 and 2011, Colombia eased construction permitting by improving the electronic verification of prebuilding certificates, introducing regulations that categorize building projects on the basis of risk, allowing electronic verification of several documents, fully adopting the "silence means consent" rule, and introducing a new, unified application form for building permits.

Figure 2.6
Days Required to Complete All Permitting and Approval Procedures for Infrastructure Projects, by Country



Source: McKinsey Global Institute (2017) and World Bank.

LATIN AMERICA STANDS OUT AS THE REGION WITH SOME OF THE LONGEST PERMITTING DELAYS IN THE WORLD.

Giving Maintenance Its Due

The need to invest in maintenance is obvious: maintenance keeps existing infrastructure in working order. Infrastructure experts and policymakers understand that infrastructure deteriorates in a nonlinear way: skimping on maintenance makes assets deteriorate faster and accelerates the need for future maintenance. At the extreme, improperly maintained assets will have to be rehabilitated, or even replaced. And what is obvious to policymakers and experts is also evident to users of infrastructure. Potholes damage cars and increase the likelihood of accidents, breaks in water mains and an unreliable electrical grid deny basic services. Poorly maintained infrastructure can also require firms to invest in back-up equipment, diverting resources from their main activity and reducing their competitiveness.

Lack of proper maintenance has clear political and institutional roots. Government agencies and private infrastructure firms know the technical importance of maintenance and its impact on the cost of assets over their life cycle. Thus, there are no technical constraints to implementing optimal maintenance strategies. On the other hand, the nontechnical drivers of insufficient investment in maintenance are many (and often occur simultaneously). Opportunities for political payoffs rise when new assets are built and inaugurated. Profits from construction projects are higher than those from maintenance. Transparency is lower and complexity higher with new construction, leaving room for rents and corruption (Jaffe, 2015).

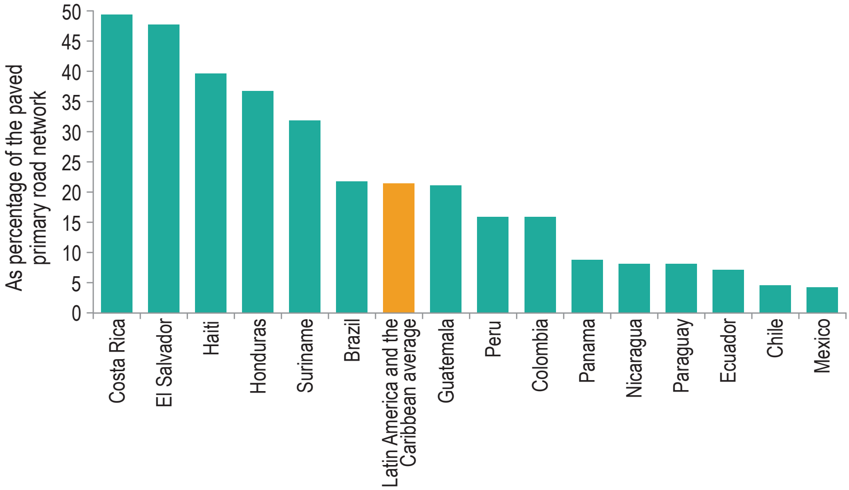
Clearly, countries systematically invest too little in maintenance. Yet substantiating this conclusion is not easy given the dearth of information on maintenance spending. This problem is not unique to Latin America and the Caribbean. Data on maintenance are scarce in developed and developing nations alike. A logical source of information about investment in new assets and maintenance would be countries' national accounts. However, countries use different methodologies that complicate the identification and reporting of maintenance expenditures. This explains why data on infrastructure investment do not report spending on maintenance.

What can be said about Latin America and the Caribbean's relative performance in maintaining its infrastructure? The scant and partial evidence shows that maintenance is far from optimal. Much of the primary road network is in poor condition (Figure 2.7). Interruptions in electricity vary enormously across countries and suggest that some countries have plenty of room to improve maintenance (Figure 2.8). Water losses—especially technical losses, which are reported by only a few countries—are also pervasive in the region.[16] Better maintenance could bring them closer to the best practice benchmark, which in the case of water is Singapore with only 5 percent of water losses (Figure 2.9). Even without detailed maintenance data or sector-specific information on types of investment, it is clear that the region is underinvesting in maintenance.

Some countries in Latin America and the Caribbean have taken steps to reduce maintenance backlogs. One example, implemented in the late 1990s in Argentina, Brazil, Chile, and Uruguay, is performance-based contracts between road agencies and private firms that bundle rehabilitation and maintenance. Evaluations of these contracts are few, and most do not use rigorous econometric techniques. An exception is Pérez and Pereyra (2019). Relying on data for performance-based contracts in Uruguay, the authors found that the International Roughness Index, a measure of pavement quality, had better values on roads administered under performance-based contracts than on those maintained conventionally (usually contracts based on inputs).

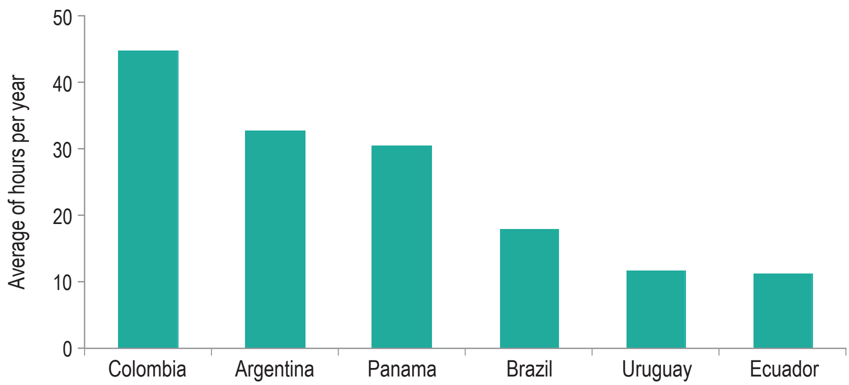
[16] Data on losses mix two types of losses: (i) technical or physical (when electricity or water is lost between the plant and customer) and (ii) commercial (when users illegally connect to the network or when the utility does not charge users). To assess if there is a maintenance backlog, the variable to study is technical losses. The notable variance in total losses is still a good proxy for lack of maintenance in countries with the highest total losses.

Figure 2.7
Paved Primary Road Network in Poor Condition



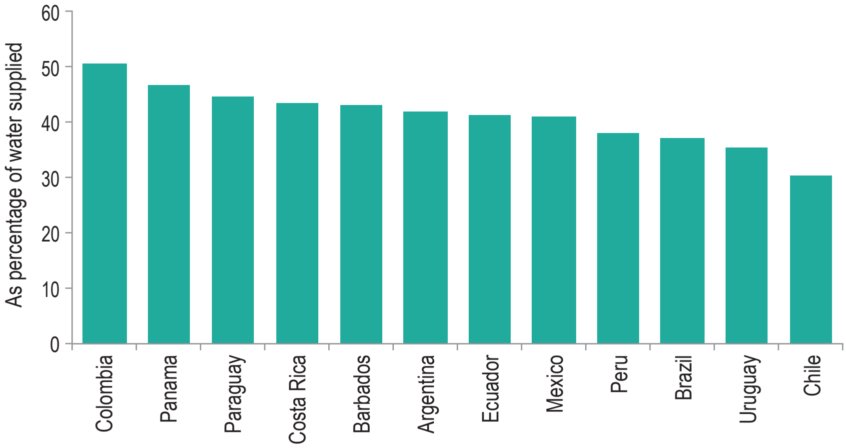
Source: Pastor (2019).
Note: Poor condition is determined by a score on the International Roughness Index (IRI) that exceeds a certain threshold, which changes from country to country. Chile has the minimum threshold in the region. The roads covered in each country are as follows: in Chile, Costa Rica, Ecuador, El Salvador, Honduras, and Peru, paved primary roads; in Guatemala and Nicaragua, total paved roads; in Brazil, federal and major state paved roads; in Colombia, excludes concessioned paved primary roads; in Panama, paved interurban roads; in Haiti and Mexico, paved and unpaved primary roads; in Suriname, total paved roads under control of the Road Authority. Data for countries vary between 2012 and 2019.

Figure 2.8
Duration of Electrical Service Interruptions, 2015



Source: Sanin (2019).
Note: The average per country is calculated as a weighted average using the available data of distribution companies.

Figure 2.9
Water Losses



Source: Pastor (2019).
Note: Data for countries vary between 2015 and 2018.

The Elephant in the Room: Corruption

Corruption touches everyone in the region. The Latinobarómetro survey reported in 2016 that 53 percent of the population believed their governments were fighting corruption poorly. In 2017, 62 percent of citizens in the region thought corruption had grown; in 2018, that number had risen to 65 percent (Corporación Latinobarómetro, 2018). Efficiency in the use of resources depends crucially on its management. Recent scandals lay bare the effect corruption can have on the development and management of infrastructure assets and services.[17]

Corruption leads to waste, scarcity, and inflated prices, while creating bottlenecks in project management. The combined result of these effects is to lower the quantity and quality of public goods and services, hurting the citizens who rely on them. The magnitude of corruption in public procurement in the region is particularly worrisome. According to World Bank Enterprise Surveys, Latin American and Caribbean firms pay more than twice as much in bribes to public officials for contracts as do their counterparts in OECD countries. In the 2017–18 Global Competitiveness Index,

[17] Though most recent scandals have involved infrastructure projects, it would be a mistake to assume that corruption is limited to this sector. In fact, there are also cases involving health services and education, among other sectors.

Latin America and the Caribbean scored below East Asia, Europe, North America, the Middle East, South Asia, and Sub-Saharan Africa on indicators of diversion of public funds, favoritism in the decisions of government officials, and inefficiency of public spending.[18]

Considerable data—at both the global and regional level—support the notion that publicly tendered infrastructure projects are especially vulnerable to corruption. An estimated 10–25 percent of the value of public contracts is lost to corruption (ABD, 2018). This information is consistent with the numbers reported in this chapter for the inefficiency of public spending on infrastructure.

Latin America and the Caribbean has not sit idly by in the fight against corruption. On the contrary, most countries have advanced on various fronts, including national legislative and institutional reforms, civil society initiatives, and adoption of international transparency and governance standards. At the national level over the past two decades, countries have bolstered their legal frameworks and institutional capacity to enhance transparency and fight corruption (Casas-Zamora and Carter, 2017). In addition, they have tried to raise standards to international levels to promote integrity, especially in high-risk areas such as the extractive industries, construction, and finance. Standard-setters include the Extractive Industries Transparency Initiative (EITI), the Construction Sector Transparency Initiative (CosT), and the Financial Action Task Force (FATF).

Countries in the region have also strengthened autonomous government audit organizations and expanded access to information.[19] These legal mechanisms have provided a critical resource for civil society organizations and investigative journalists, playing a crucial but often unheralded role in exposing major corruption episodes in the region (de Michele, 2017).

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18 Kahn, Barón, and Vieyra (2018) offer a detailed description of the state of corruption in public investment and public procurement in Latin America and the Caribbean, including statistical information, recent technological developments, national legal and regulatory reforms, and policy recommendations. This section relies heavily on that paper, produced as a background note for this report.

19 During the 1990s and 2000s, 16 Latin American and Caribbean countries passed legislation enhancing the institutional standing and bolstering the competencies of government audit organizations, which have been crucial to identifying systemic corruption risks in countries such as Brazil, Chile, and Colombia. Since 2002, 18 Latin American and Caribbean countries have approved legislation to expand access to information. In Chile and Mexico, among others, independent agencies have been created to ensure compliance across public agencies and help train officials to apply new norms.

But improvements to date are incommensurate with actual and perceived levels of corruption. Legal and institutional reforms are a necessary, but not a sufficient, condition for promoting integrity and fighting corruption. The main challenge is ensuring the effectiveness of such mechanisms. The low effectiveness of anti-corruption institutions can be traced to insufficient enforcement, which in turn reflects lukewarm political commitment, insufficient financial and human resources, and problems of interinstitutional coordination. Addressing the inefficiencies inherent in the fight against corruption will require perseverance and action in all sectors of the economy.

Beyond much-needed improvements in the legal framework and its enforcement, progress in the fight against corruption can be achieved through targeted interventions. New initiatives and solutions based on innovations in information and communication technologies have great potential to increase the transparency, oversight, and efficiency of public resources in the region. Applications of digital technology include open data initiatives, the use of big data and data mining to enhance management of public investment, and social media platforms to encourage citizen participation in the public investment cycle. These new tools build on and complement the legal and institutional measures just described.

Data analysis techniques are expanding the tools available to auditors and oversight agencies. Data mining enables public sector auditors to subject massive numbers of transactions to systematic scrutiny and, potentially, to identify corruption risks in real time. Brazil's Observatory of Public Spending, a unit within the country's Office of the Comptroller General, has implemented data mining tools that allow officials to audit US$5 billion in public spending. In 2015 alone, the unit raised red flags in more than 7,500 cases amounting to contracts worth US$104 million (Moreno, 2017).

In 2016, the IDB launched the MapaInversiones regional initiative (www.iadb.org/mapainversiones), an online platform that allows users to monitor the physical and financial progress of public investment projects through data visualizations and geo-referenced maps. MapaInversiones was first developed in Colombia in 2013 to monitor mining and hydrocarbon royalties paid to local governments. In 2018, platforms were launched in Costa Rica, Paraguay, and Peru.

The first external evaluation of a similar, earlier platform, MapaRegalías (Lauletta et al., 2019), provided evidence that the project completion rate increased by 11 percentage points. In addition, since MapaRegalías' launch, the number of irregularities detected and referred to a control institution (mainly the attorney general) in Colombia increased from 57 in 2013, to more than 1,000 in 2016. MapaInversiones was developed to deepen and expand those results.

Solid legal frameworks remain an important requirement for effective management of public investment. As the example of MapaInversiones shows, robust legal provisions, budget transparency, technology, and incentives for citizens to use the information made available to them, make up a complete package. Reforms must be accompanied by robust regulations to prevent conflicts of interest, especially in public procurement, and to ensure cooperation and coordination among agencies responsible for preventing, detecting, and punishing fraud, public funds waste, and corruption.

Paving the Way to More and Better Infrastructure: Regulation, Data, and Technology

The region can achieve impressive gains in efficiency *today*. Those gains will be even larger if countries embrace and foster disruptive technologies that are already available (see Chapter 5). Machine learning can help improve cost estimates. Digital tools, drones, and satellite-based data can improve planning, engineering designs, land acquisition, and resettlement. Emerging technologies can reduce construction costs between 10 and 50 percent (Milner and Yayboke, 2019). Augmented and virtual reality, for example, can facilitate design and construction. Worksite sensors can track materials. Eventually, new technologies will change the type of infrastructure that is built. In many cases emerging business models will make infrastructure redundant (for instance and likely in the short term, coal power plants). And new construction materials could bring cost savings of unknown proportions. Flexibility, agility, and an institutional setup that accommodates technological change should be top priorities in public sector infrastructure institutions in the region.

Taken together, the estimated gains from more efficient public spending obtained by reducing cost overruns and time delays (25 and 10 percent respectively) represent 35 percent of public investment in infrastructure in the region. Public investment in Latin America and the Caribbean between 2008 and 2017 was 2.3 percent of GDP per year, but given the prevailing inefficiency, this level of investment is equivalent to investing 1.65 percent of GDP without inefficiencies. That is, 0.65 percent of GDP is lost to inefficiencies in the production of infrastructure assets. Additional gains can be achieved by strengthening the institutional and regulatory framework to adequately plan infrastructure, choosing the projects with the highest impact on growth and quality of life.

The following outlines a number of policy recommendations that aim to increase the efficiency of infrastructure investment in the region.[20]

Establish National Centers of Infrastructure Expertise

Conscious of the need to improve the efficiency of infrastructure delivery, several developed countries have embarked on a reform agenda, anchored in the development of new institutions. Australia, Canada, and the United Kingdom have created special centers of infrastructure expertise known as infrastructure bodies (i-bodies; see Box 2.1). Countries in Latin America and the Caribbean could follow these countries and build similar institutions. The *Consejo de Politicas de Infraestructura* in Chile is the only institution in the region that shares some design features of the infrastructure bodies of those countries.

Box 2.1

Centers of Infrastructure Expertise: I-Bodies

Infrastructure Australia is an independent statutory body with a mandate to prioritize and advance infrastructure of national significance. It is responsible for strategically auditing such infrastructure and developing 15-year rolling plans that specify national and state priorities. The first national infrastructure audit was released in 2015 and provided the first-ever independent, comprehensive review of Australia's existing infrastructure and future needs across transport, water, energy, and telecommunications. A second audit, focused on the role of technology in infrastructure service provision, was released in 2019.

Infrastructure Canada is a federal department established to (i) provide long-term, predictable support to help Canadians benefit from world-class, modern public infrastructure; (ii) make investments, build partnerships, develop policies, deliver programs, and foster knowledge about public infrastructure in Canada; and (iii) address complex challenges such as the rapid growth of cities, climate change, and threats to water and land. Infrastructure Canada is also responsible for drafting Canada's long-term vision for infrastructure development, the Investing in Canada Plan.

To guide Britain's infrastructure implementing agencies, the U.K. government created the Infrastructure and Projects Authority (IPA) and the National

[20] It must be acknowledged that for some of the recommendations (be it the creation of institutions, policies, or use of instruments) the evidence base is thin. Considering the need to improve the investment process, the recommendations should be considered promising but will require experimentation followed by operational research to gauge their effectiveness.

Infrastructure Commission (NIC). The IPA, reporting to The Treasury and the Cabinet Office, defines the overarching framework for project preparation in the United Kingdom. This guidance sets the standards under which contracting authorities develop projects. IPA also undertakes quality assurance reviews for major projects, and supports capacity development and delivery support. Established in 2015 through the merger of Infrastructure U.K. and the Major Projects Authority, IPA has a long history of managing and delivering major infrastructure projects through its founding institutions.

To shape a vision for the future of the United Kingdom's economic infrastructure, the Treasury created the NIC. NIC is charged with delivering to each new Parliament a National Infrastructure Assessment setting out long-term infrastructure needs and offering recommendations for fulfillment of those needs. Between assessments, it prepares in-depth studies of the United Kingdom's most pressing infrastructure challenges. It monitors the government's progress in delivering the infrastructure projects and programs it has recommended. NIC prepared its first National Infrastructure Assessment in 2018, outlining a strategic vision for the next 30 years and offering related recommendations. The vision is to be realized through the annual National Infrastructure Plan, a four-year pipeline of prioritized projects. Implementation of the pipeline is monitored by IPA.

While the I-bodies in the three countries have different functions, they offer common benefits: (i) greater strategic coherence to whole-of-government infrastructure policy; (ii) reduced political risk; (iii) improved market and investor certainty; and (iv) stronger public confidence in infrastructure delivery. Most I-bodies produce independently assessed lists of infrastructure projects based on an audit or assessment of infrastructure needs and performance.

I-bodies are at an early stage of institutional development, and it is too soon to measure their impact and to identify what worked and what has not. But for countries in Latin America and the Caribbean they offer a possible way to choose the *right projects* and *do the projects right* while pushing an agenda to make the most of existing assets. The experiences of Australia, Canada, and the United Kingdom highlighted here need not—indeed should not—be copied slavishly. Each country should carefully identify the characteristics that best suit its legal, institutional, and cultural settings.

Produce Comprehensive National Infrastructure Plans

Countries in Latin America and the Caribbean do not have comprehensive infrastructure plans. Plans are usually sector specific and ignore the linkages and interdependencies of infrastructure systems. More worrisome is that they tend to be plans produced by each new administration, sometimes ignoring consistency with previous plans. The region needs plans that are the outcome of consensus-building exercises. And these plans need to be flexible enough to change when change is called for and to embrace the new drivers of climate change and technological innovation.

Before and After: Invest in Project Preparation and Evaluation

The few evaluations available suggest that investing in pre-investment carries a high rate of return. However, political demands to deliver projects within the term of an administration create incentives to accelerate project preparation. In recent years, myriad project preparation facilities and platforms have emerged, some commercial and others supported by MDBs as public goods. Several combine the need to improve engineering designs and add sustainability dimensions (social, environmental, and economic).[21] Countries should build project preparation facilities and accompanying platforms, giving them the budget resources they need to be effective. Efforts to strengthen national systems of public investment should continue making sure all projects go through sound cost benefit analysis. And the region urgently needs to set up a system to conduct sound ex-post evaluation of projects' impacts not only to increase accountability but also to improve project preparation.

Use Available Tools for Better Costing and Fewer Delays

Recognizing that cost overruns are a natural outcome of infrastructure construction, several tools have been developed recently to help governments improve costing and project delivery.[22] Use of these tools should be accompanied by persistent efforts to: (i) increase the transparency of procurement processes and (ii) work closely with regulators, anti-corruption authorities, and competition agencies to foster competition in the design of contracts and bidding processes.

Latin America and the Caribbean ranks poorly in permit approvals. Without compromising compliance with rigorous social and environmental standards, the region can certainly improve. One possible path is to create a national single window for permit approval.

[21] In 2019, the German aid agency, GIZ, unveiled a website named "Sustainable Infrastructure Tool Navigator" that serves as a hub for project preparation and sustainability platforms (https://sustainable-infrastructure-tools.org/). The effectiveness of project preparation facilities is explained in Fioravanti, Lembo, and Deep (2019).

[22] The most relevant tools include risk assessment at all levels; project management tools; peer-reviewed gateway processes; life-cycle guidelines (such as benefit evaluations); frameworks for managing total project costs; reassessments of demand forecasts; value engineering; infrastructure performance reviews; and integrated asset inventories that identify key trends and expected needs (Alberti, 2019).

Delivery can be made more efficient by speeding up approval processes, investing heavily in the early stages of project planning and design, and structuring contracts to encourage time and cost savings. Contracts, too, can bring cost savings—for example, by encouraging the adoption of advanced construction techniques, such as prefabrication and modularization.

Proper Maintenance to Ensure High-Quality, Durable Infrastructure

How can countries change the dynamics of suboptimal investment in maintenance? The first change must occur in institutions outside the infrastructure arena. Census and statistics bureaus must improve the methodologies they use to collect and report spending on maintenance. In parallel, state-owned enterprises and private infrastructure operators (utilities and firms operating under public-private partnerships) must be required to provide accurate data on maintenance. Strong sector-wide institutions can help improve the reporting of maintenance data and monitor the implementation of maintenance plans that prioritize preventive (as opposed to corrective) maintenance. At the sector level, government agencies must generate and publish information about the state of infrastructure assets and the maintenance instruments used.

Technology is playing a positive and growing role in reducing maintenance costs. The use of sensors, drones, and satellite imagery, for example, has lowered maintenance costs in water and energy utilities. These technologies allow utilities to pinpoint the location of leaks in pipes and of overheating in distribution lines. Drones and satellite images are being used to assess the condition of roadways. Rather than relying on time- and labor-intensive ground-based surveys and maps, drones provide rich, accurate, and actionable data in real time. An interesting example is the application of Watson, IBM's artificial intelligence system, to help the airline industry optimize performance by using sensors in airplane engines. Information transmitted from planes in flight is analyzed in real time, helping identify potential failures and focus maintenance efforts. Korean Air shortened the lead times for analyzing maintenance defects by 90 percent thanks to Watson (eSolutions, 2018; Tech Wire Asia, 2017).

Fight Corruption with Transparency

Beyond reforms, dedicated institutions, and the adoption of powerful tools and instruments, the secret to an effective process for planning, delivering, and maintaining infrastructure is to increase transparency. Transparency rests on data and information. Given the massive amounts of data generated and the potential of artificial intelligence and machine learning to improve infrastructure services, the paucity of information available on the complete infrastructure project cycle is alarming. Accessible, digestible information is needed to elicit meaningful participation from stakeholders (from construction firms to consumers), to reduce corruption, and to ensure that service providers meet their commitments.

One of the main challenges in reducing the opportunities for corruption rests on the principle of making information available to all. Technology plays a vital role in making this principle a reality. Technological tools such as interactive web platforms, mobile apps, and data visualization can ensure that the information provided by public agencies reaches citizens in an intuitive, user-friendly format. An example is geo-referenced maps, which use GPS technologies to show the location of public investment projects. These maps allow citizens to identify how resources are being spent in their jurisdiction and compare that with neighboring locales. The combination of incentives for more vigorous monitoring by citizens and better management and oversight of data can exert a sizeable impact on efficiency. In Peru, greater monitoring of projects through INFOBRAS, a web portal with data on more than 70,000 public works hosted by the country's Office of the Comptroller General, cut project costs by half (Lagunes, 2017).

Make Infrastructure a Top Policy Priority

No reform or policy action by itself will be a silver bullet. Infrastructure lasts for decades. Inescapably, it binds the generation that builds it to those that follow. And that is precisely why it should be carefully planned and should reflect political consensus and social aspirations. Infrastructure should be a policy priority managed at the highest level of government.

3

The Changing Face of Financing

Infrastructure is financed by many actors including governments, state-owned enterprises, banks, private companies (including private regulated utilities), multinational entities, and investment funds. Different actors have different governance structures and those structures play an important role in determining service quality. Governance structures are intimately related to financing, thereby creating a strong link between financing and service quality. Financing is, therefore, not just important for the quantity of the infrastructure assets but also, through governance, for the quality of the services provided by those assets.[1]

It is important to draw a distinction between financing and funding. Financing generally refers to who puts the money down up front. Infrastructure projects normally imply large capital outlays, with income only appearing several years down the road.[2] That income may come from a variety of sources that determine how the project is funded. Final users (consumers) may entirely fund some projects through fees to use a road, or to consume electricity, water, or sewage services. An intermediary such as an electricity distribution company might sign a contract to buy power from a new project but then resell to firms and households, in which case once again users may end up funding the project. But income could come in part (or in whole) from government transfers in the form of direct subsidies for each mile of road built, each kilowatt of power produced, or each liter of water supplied. Payments might be made by users, but then subsidies for electricity or water might be targeted to households depending on

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1 Governance is used here in a general way referring to the governance of firms and projects as well as government rules and regulations.

2 Financing may be required at other points during the project life cycle and, as discussed below, projects may be refinanced particularly after a construction phase when the pattern of risks changes.

income levels or to firms to boost production of certain items, such as food or innovative goods for exports. Funding may then be shared between users and government. Still, if some funding comes from general government sources, then that implies funding through taxation, as in the end governments must find a way to pay their bills. This income is then used to pay the financiers the capital they invested plus interest or dividends, depending on the form of the financing obtained. While this chapter focuses on financing, it is important for financiers to know how they will be repaid, as to a large extent this will determine the perceived risks.

As reviewed in Chapter 2, the perceived quality of services delivered by infrastructure in Latin America and the Caribbean remains low, in part due to low investment. Public investment has been falling and fiscal positions remain stretched.[3] But infrastructure is financed in many ways. State-owned enterprises and private companies (such as utility companies) finance infrastructure. And employing project finance techniques (perhaps through the use of special purpose vehicles sometimes under the auspices of legal frameworks for public-private partnerships, PPPs) has become popular in some countries to attract private financing. PPPs may appear particularly attractive for fiscally strained governments, but they may have serious implications for public accounts.[4] This chapter reviews the state of public infrastructure investment, the roles of state-owned enterprises and private regulated companies, as well as recent trends in private investment.

Public Financing: The Need to Reverse the Trend

Traditionally, large infrastructure projects have been financed by governments. Such projects include roads, ports, bridges, electricity grids, dams, large power-plants and water and sanitation infrastructure.[5] But public investment in infrastructure (and public investment in general) has been low and if anything, has been falling. Figure 3.1 illustrates the average and median investment in public infrastructure across countries in Latin America and the Caribbean as a percentage of GDP. Average public investment in infrastructure fell from about 2.3 percent of GDP in 2013 to an estimated 1.7 percent of GDP in 2019. However, as the distribution of this investment

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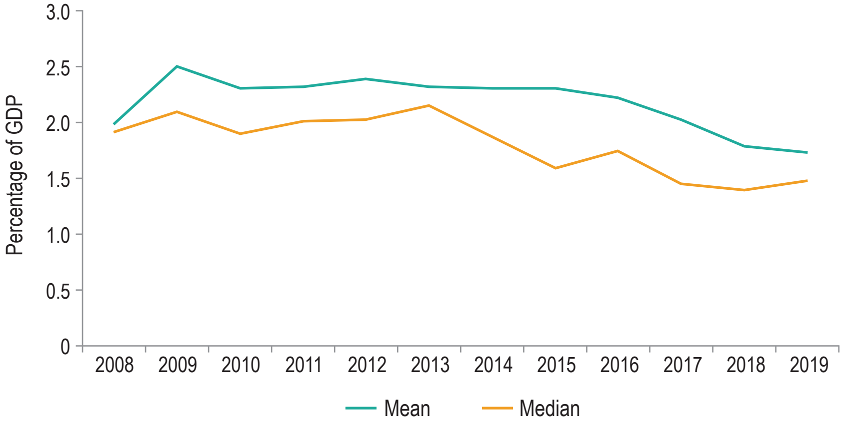
[3] See Nuguer and Powell (2020) for a recent analysis of fiscal balances in the region.

[4] Infrastructure is financed by other actors as well, such as state and municipal authorities. The discussion in Chapter 2 on institutional capacity as a constraint is particularly relevant for subnational authorities. Fiscal and other implications of PPPs are discussed in Box 3.4.

[5] In some countries, private financing has grown significantly, particularly for ports, airports, and energy.

Figure 3.1
Public Infrastructure Investment in Latin America and the Caribbean



Source: Infralatam and World Economic Outlook.
Note: Actual figures for public investment are not available for 2019. The estimates employ projections for gross fixed capital formation (GFCF) and historical ratios of infrastructure investment to GFCF for 2019 and other years where data are missing.

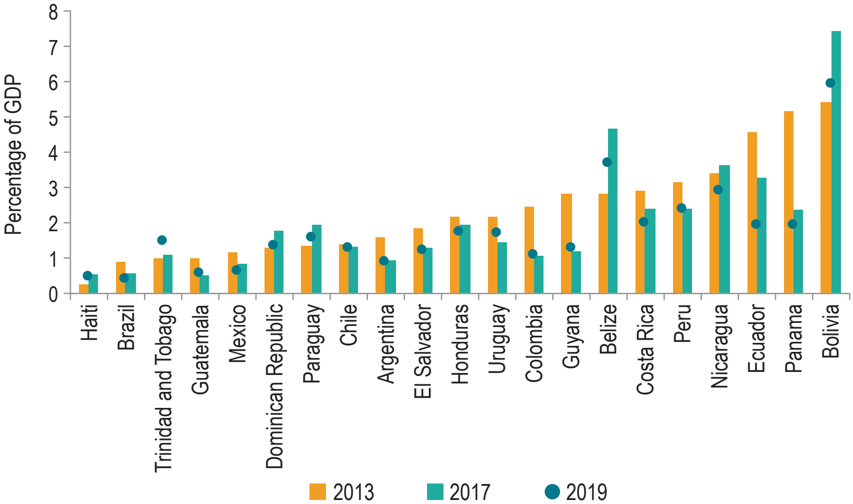
across countries is skewed (a few countries invest significantly more than the average and there is a longer tail for countries with low investment levels), the median is likely a better measure than the mean; and for the median country, public investment in infrastructure fell from about 2.1 percent in 2013 to an estimated 1.5 percent of GDP in 2019.

Considering public infrastructure investment in 2013, the governments of Bolivia, Ecuador, Nicaragua, Panama, and Peru all invested 3.0 percent of GDP or more. However, between 2013 and 2017, investment declined significantly in all these countries, except Bolivia. And most countries have seen declines to estimated 2019 levels. The governments of 12 countries invested an estimated 1.5 percent of GDP or less in 2019. In Brazil, investment dipped to under 0.5 percent of GDP (Figure 3.2).

In those countries where public investment remains significant, there is considerable space to improve the efficiency of that spending (see Chapter 2). Where public investment is low, improving efficiency in other aspects of public spending may allow governments to boost investment, even within current spending envelopes. Reducing spending inefficiencies in the areas of energy, social programs, and tax expenditures could result in overall savings of up to 2 percent of GDP for the average country—and as high as 4 percent of GDP in some cases.[6] For the Andean

[6] See Izquierdo, Pessino, and Vuletin (2018).

Figure 3.2
Public Infrastructure Investment in Selected Countries



Source: IDB staff elaboration based on Infralatam and IMF World Economic Outlook.
Note: The figures for 2013 and 2017 are from Infralatam. The 2019 figures are an estimate harnessing the historical relation between infrastructure investment and gross fixed capital formation.

countries, recent estimates suggest that public infrastructure investment could be increased to as much as 7 percent of GDP on average by 2038, given a mixture of ambitious tax and spending reforms.[7] Ensuring the right projects are selected and capacities are in place such that assets can be constructed and managed efficiently should be a prerequisite for any substantial boost in public investment.

In addition, public sectors in Latin America and the Caribbean have many assets that are not managed in a way that realizes their full financial potential. Indeed, in some cases those assets are not even recorded or valued in any systematic way, let alone exploited. A cataloging and review of public sector assets to consider how they may become significant net revenue earners could yield enormous gains to governments in the region.[8]

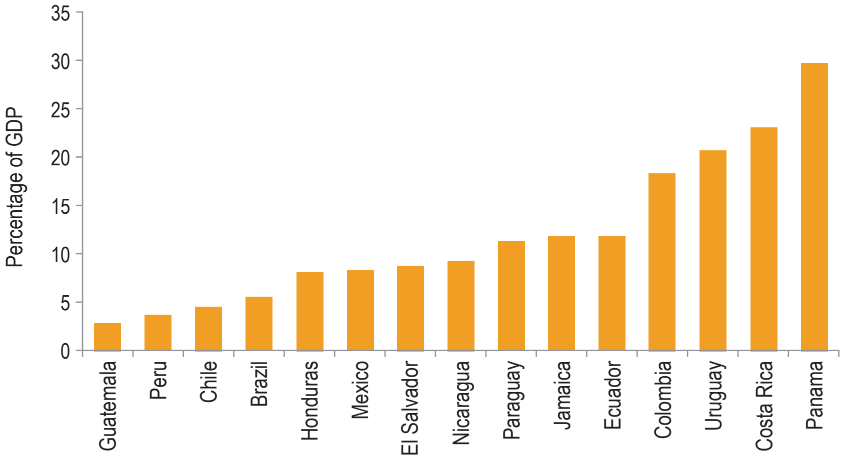
State-Owned Enterprises: Filling in the Hole

Many publicly owned companies also invest in infrastructure. Unfortunately, there is no systematic database on the infrastructure investment of

7 See De la Cruz, Manzano, and Loterszpil (2020).
8 See Detter and Fölster (2015, 2017).

such firms; consequently, this important sector is frequently ignored. Yet in some countries, these firms play a very important role. Figure 3.3 illustrates the total assets of a set of the larger state-owned enterprises (SOEs). While the data may not be comprehensive and likely underestimate the total, for four countries the assets of such companies amount to more than 15 percent of GDP and for all 15 countries included in this analysis, the average is 12 percent of GDP.

Figure 3.3
The Assets of State-Owned Enterprises in Selected Countries, 2016



Source: IDB staff elaboration based on Musacchio and Pineda Ayerbe (2019).
Note: Data may not be comprehensive and so likely represent an underestimate. Data is from 2016 for all countries with the following exceptions: Panama, 2015; Brazil, Costa Rica, Ecuador, Jamaica, and Uruguay, 2014; and Colombia, 2011.

Recent analysis of the governance of SOEs in both advanced and emerging economies traces how governance impacts financial performance and, in some cases, the quality of investment.[9] Recent work at the Inter-American Development Bank argues that governance lies at the heart of the poor performance of SOEs in Latin America and the Caribbean (see Box 3.1). Problems in governance not only affect financial performance but surely feed through to the poor selection and execution of investment. Countries may wish to create centralized mechanisms to oversee such enterprises

9 See OECD (2015), World Bank (2014a) and the World Bank's 2012 toolkit at: https://openknowledge.worldbank.org/handle/10986/20390?show=full&locale-attribute=es.

Box 3.1

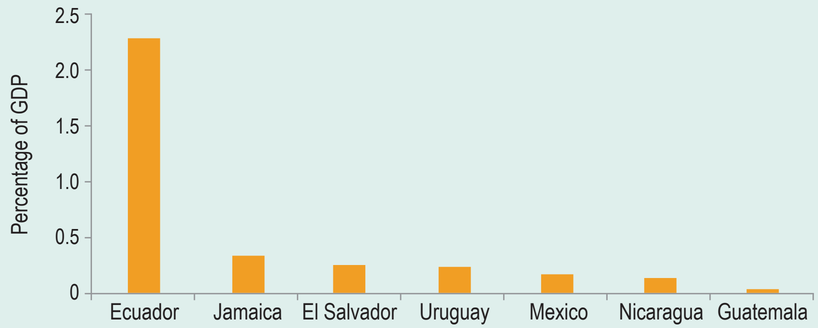
On the Role of State-Owned Enterprises (SOEs)

Analyzing SOEs in Latin America, three issues emerge: i) SOEs are large relative to their home economies, ii) financial performance is inferior to private comparators and raises risks for their respective governments, and iii) political power complicates monitoring and control, and SOE behavior may reflect short-term or partisan political priorities rather than enhancing efficiency and reducing the quality of the services they provide.[a]

SOEs operate in key infrastructure sectors, such as electricity, mining, ports and airports, and oil and gas. On average, there are about 20 SOEs per country in Latin America and almost a quarter of those have assets over US$1 billion. Assets are over 20 percent of GDP across several countries. SOE revenue is about 8 percent of GDP and around 30 percent of government tax revenues or spending. Still, countries vary widely across the region. Over 70 percent of total SOE revenues come from SOEs located in Mexico and Brazil. While there is no consistent data on SOE investment in infrastructure, it can be inferred that they are important players and the quality of that investment and the services offered is affected by the issues raised here.

Around 30 percent of the SOEs analyzed face fiscal losses (and this is already net of "normal fiscal transfers"). In Honduras, Nicaragua, and El Salvador, this figure is as high as 70 percent of SOEs. Explicit or implicit government guarantees may weaken performance incentives through moral hazard, and some of the larger SOEs may now be so large as to threaten the fiscal sustainability of the state if a serious bailout is required. Figure 3.1.1 shows the average regular fiscal transfers to SOEs across seven countries with available data. Fiscal transfers are significant in all the countries analyzed and particularly large in Ecuador.

Figure 3.1.1
Average Fiscal Transfers to SOEs in Selected Countries, 2010–16



Source: Authors' elaboration based on Musacchio and Pineda Ayerbe (2019).
Note: These figures do not include exceptional transfers or capital injections.

While SOEs may have different objectives, Musacchio and Pineda Ayerbe (2019) argue that poor financial performance also reflects poor governance, undue political influence, and inefficiency. SOEs are often harnessed to implement policies such as energy subsidies, credit grants, and redistribution and may also be used as a means of patronage, for example through the creation of public sector jobs. All this may take attention away from a focus on higher-quality service provision.

Given their size and substantial political influence, many SOEs are difficult to manage, monitor, and control, let alone reform. Are there any solutions? SOEs with smaller boards (less likely to be populated by political appointees), more independent directors, and explicit codes of governance and ethics tend to exhibit better financial performance. In countries with centralized SOE agencies, that facilitate monitoring and control, financial performance appears to be better and debt lower. Such systems are likely more effective at exerting control over smaller SOEs.[b] In the case of larger SOEs, it may be that only market incentives or a willingness by national governments, perhaps sparked by pressure from citizens, will exert influence to limit debt and provoke reform measures to improve the quality of investment and service provision.

[a] See Musacchio and Pineda Ayerbe (2019), as well as IMF (2020) for an analysis of SOEs around the world.
[b] See also Navajas (1991).

through either a holding company or alternative structures where performance can be monitored and controlled. Transparency, both in terms of objectives and performance indicators, can assist in this process, and control potential problems of corruption.

Investment by Private Corporations

Private corporations also invest in infrastructure. Such corporations include regulated utilities in the energy and water sectors as well as construction companies in transport and large companies (often in oil, gas, and mining) that need infrastructure as an input to their main activities. Once again, no homogeneous database details investment in infrastructure by private firms.

To shed some light on this area, a database was created of firms that operate in three sectors—electricity, gas, and water—in six countries (Argentina, Brazil, Chile, Colombia, Mexico, and Peru) covering their main balance sheet items and financial ratios. Interestingly, comparing firms in Latin America and the Caribbean to their European counterparts (in France, Germany, and Spain), the return on sales (otherwise known as net income on sales) tends to be higher in the region (see Box 3.2). This is consistent with the tendency for margins to be high, as discussed in Chapter 2. Asset turnover (the amount of sales generated by a level of assets, a measure of efficiency) is somewhat lower in the region, as is leverage. The product of return on sales, asset turnover, and leverage is return on equity. For 2017, return on equity for most electricity utilities in the region was higher than for European counterparts. The evidence suggests margins are high, although returns are moderated by lower levels of efficiency and lower leverage.

Box 3.2

Utility Companies: A Missing Link in the Analysis of Infrastructure

The vast majority of studies on infrastructure investment consider projects undertaken by governments and private sector finance-structured investments. However, infrastructure is also financed by firms from their own retained earnings or through corporate equity or debt issuance. The absence of a consistent database on such investments suggests that infrastructure investment may be seriously underestimated. Considering the energy and water sectors, utility companies listed on stock markets are important players. Moszoro (2019) makes progress in this area by analyzing the sources and uses of these companies' funds. General results are summarized here.

The data consist of an unbalanced panel of, on average, 74 listed firms in six countries over the period 2003 to 2017 in three sectors: electricity, natural gas, and water.[a] First, these firms play an important role in the sectors concerned. Second, assets grew at a rate of about 3.6 percent per year, indicating that these firms were investing.[b]

The amount of investment varies across sectors and over time. Investment has been highest in the gas sector (4.7 percent of assets per annum) followed by water and electricity. Investment was very strong in the period 2003–08 (over 20 percent of assets each year) but during the global financial crisis and its aftermath (2008 to 2012), investment fell to 8 percent of assets annually. Between 2013 and 2017, a period of lower commodity prices, low growth, and fiscal pressure in several countries, investment was lower, but still averaged about 2 percent of assets per year.

A Dupont decomposition allows for a comparative analysis of some aspects of firm performance. The Dupont decomposition breaks down return on equity into net income divided by sales (an indicator of efficiency), sales divided by assets (an indicator of margins), and assets divided by equity (a measure of leverage):

$$ROE = \underbrace{\underbrace{\frac{NI}{Sales}}_{ROS} \times \underbrace{\frac{Sales}{Assets}}_{AT}}_{ROA} \times \underbrace{\frac{Assets}{Equity}}_{Leverage}$$

Compared to European counterparts, Moszoro (2019) finds that Latin American utilities have somewhat lower net income divided by sales, indicating that they are not so efficient. This suggests costs are high due to i) structural characteristics (e.g., lack of scale or complicated geography), ii) X-inefficiency (poor management or managerial incentives that are not profit maximizing and a lack of monitoring and control), or, iii) regulatory measures.[c] Moreover, leverage is also relatively low. However, on average return on equity is higher than in Europe as sales divided by assets tends to be relatively high. This suggests that margins are relatively high in the region. This analysis echoes evidence presented elsewhere in this report that infrastructure services tend to be expensive.[d]

[a] For water, only three countries were included as the sample was restricted by imposing the minimum requirement of data being available for at least three firms in each sector. As the dataset consists of listed firms, these are likely to be among the larger and better-performing utility companies in the region.
[b] Note that this would correspond to accumulated investment net of depreciation and valued using the accounting principles in force in each country over that period.
[c] Such measures might include pushing firms to service unprofitable areas or invest more in unprofitable activities.
[d] This may also reflect a high cost of capital or regulation that allows firms to charge high tariffs to compensate for perceived high risks.

However, there is considerable heterogeneity across countries and significant volatility over time. While assets grew substantially from 2003 to 2008, investment appears to have fallen since. This volatility is also evident in returns. The volatility suggests significant risks, which may also imply a high cost of capital, greater margins, and higher average returns over time. These findings illustrate the trade-offs between private and public management of infrastructure services. While private management may bring greater efficiency, a firm's owners seek compensation for perceived risks.

A Hybrid: Infrastructure Project Financing

Apart from purely public financing, or financing by state-owned enterprises (SOEs) and by private corporations, a popular way to attract private finance is through project finance techniques. These normally involve setting up a specific governance mechanism and a special purpose vehicle (SPV).

Project-level SPVs typically consist of a level of equity (the owners of the project), debt holders who have loaned money to the project, and possibly other types of financial support; for example, the project could count on guarantees for specific project aspects from governments or other official or private institutions. Moreover, there may be different types of debt holders. SPVs might, for example, have what is called a mezzanine level of debt that may be subordinated, which means that if the project runs into difficulties, losses would accrue first to holders of that debt and, consequently, those instruments may offer higher yields.

Some projects may count on support from governments and the private sector. If the private sector bears significant risk and its rewards are related to performance, then these projects are referred to as public-private partnerships (PPPs),[10] or they may be purely private. However, even purely private investments in infrastructure may have a relation to a public entity, either through regulation or a contract for services provided. Given many different potential structures, the range of possibilities is wide and the term PPP is itself very broad.[11] Some countries have passed so-called PPP laws that attempt to spell out a framework for such arrangements.

Conceptually, nothing is inherently better or worse about private versus public financing. Whether service quality and financial outcomes improve depends largely on whether the governance structures employed to bring in private financing promote more efficient management, sharpen incentives, or spread risks more effectively. But there are also dangers. For example, private investors will be attracted if governments agree to high tariffs or if governments provide subsidies or blanket guarantees. But this may then not be best for society as a whole or may create substantial liabilities for the public sector (see Box 3.3).

Box 3.3

On Public-Private Partnerships

The label public-private partnerships (PPPs) has become popular to describe governance and financing arrangements that count on government support and bring in private sector management expertise with the aim of enhancing efficiency in the development of public infrastructure projects.[a] PPPs do not turn bad projects into good ones and much of the analysis in Chapter 2 is relevant, irrespective of the procurement modality. Instead, the question is, under what

[10] According to the multilateral development bank reference guide, a PPP is a long-term contract between a private party and a government entity, to provide a public asset or service, in which the private party bears significant risk and management responsibility and remuneration is linked to performance (PPP Reference Guide, 2017).

[11] For a detailed discussion on what is and what is not a PPP, see https://ppp-certification.com/ppp-certification-guide/2-private-participation-public-infrastructure-and-services-what-and-not-ppp.

circumstances might PPPs improve viable projects in terms of service quality and efficiency?[b] PPP schemes are shaped around how to share risks and how to improve performance. Where the advantages of risk transfer and enhanced performance outweigh the increased costs of contracting and financing, then PPPs may be desirable.

PPPs can improve outcomes through several mechanisms including i) pure efficiency gains by better planning, development, and maintenance of assets, ii) better alignment of incentives, iii) improved risk management throughout the life cycle of the project, and iv) mobilization of additional financing. On pure efficiency, PPPs may improve project selection and filter out white elephants, while narrowly focused private sector management teams might improve the planning and execution of projects. Harnessing tools such as cost-benefit analyses within the procurement process may improve decision-making. Performance-based contracts may align the incentives of the private and public actors, leading to better maintenance and higher service provision quality.[c] Contracts that allow the builder of a project to then operate (and maintain) it sharpen the incentives to ensure construction is both timely and of good quality. Additionally, PPPs can serve as a tool to improve risk management (identification, allocation, and mitigation).[d]

While it may be attractive for cash-strapped governments to use PPPs, unless there are some underlying economic gains, private financing provides no advantage from a fiscal sustainability standpoint.[e] Indeed fiscal sustainability might be worsened if there are no efficiency gains and interest rates paid to private investors are higher than the government's cost of funding.

At the same time, the challenges for governments to manage large infrastructure are well known and some are detailed in Chapter 2. Ultimately, PPPs should be regarded as a tool to improve public infrastructure provision, with the potential for reducing delays and cost overruns and improving maintenance. The pertinent question is, then, whether there are good reasons to think that outcomes will be better when projects are managed by private entities and how to best shape PPP frameworks and governance structures toward that aim.[f]

But there are also potential pitfalls. Private firms may be reticent to invest in fixed assets, fearing a government may take action that then reduces the value of the sunk investment. This is referred to as the hold-up problem and may even stop contracts being awarded. There needs to be agreement on the rules of the game ex ante and an expectation that they will not be changed opportunistically. But hold-up can also occur in the other direction. A firm may bid low, win a contract, and then when it becomes costly for the government to switch to another provider, seek to renegotiate. These problems may be present in other procurement modalities too, as when governments manage projects and procure directly from the private sector. Renegotiations seem to be all too frequent, even within the construction phase.[g] If this local monopoly power is too great, the government may have little option but to agree to the firm's demands.

As there is relatively frequent renegotiation, clearly contracts are being signed. However, it is hard to know how many projects were considered but then a final agreement was not reached. Public officials may have an incentive to focus on seemingly competitive bidding and be seen as improving public services during their time in office, thereby prompting over-optimistic or myopic behavior. Even worse, it has been argued that renegotiation is related to corruption in some cases. However, in an analysis of renegotiation and corruption in Latin America, no significant difference between public and private provision was found.[h]

In contrast, there is evidence that PPPs have improved outcomes. For example, analysis suggests private participation has enhanced efficiency and productivity in ports, reducing transport costs and boosting trade and competitiveness. About 90 percent of container cargo in the region is moved through PPP ports. Similarly, three out of four air passengers pass through airports operated through PPPs in Latin America and the Caribbean. And the costs for road rehabilitation and maintenance are some 25-30 percent lower, comparing PPPs to traditional procurement.[i] These examples indicate that when deployed in an appropriate fashion, PPPs can lower costs and alleviate fiscal constraints.[j]

Since 2010, many countries in the region have strengthened frameworks to pursue PPPs. In 2009, only one country in the region had the required institutions at international standards. Ten years on, 16 countries have created specific agencies to implement PPPs, provide technical support, and monitor private participation in infrastructure.[k] Harnessing private financing for infrastructure does not translate into automatic benefits and does not mean governments should have less capacity. Arguably, identifying good projects for private financing, managing a bidding process, selecting and negotiating contracts, and monitoring private sector players require an even more sophisticated skill set than directly managing projects. The region has made much progress and there is considerably more potential to increase private financing for infrastructure by further developing the necessary institutions for PPPs.

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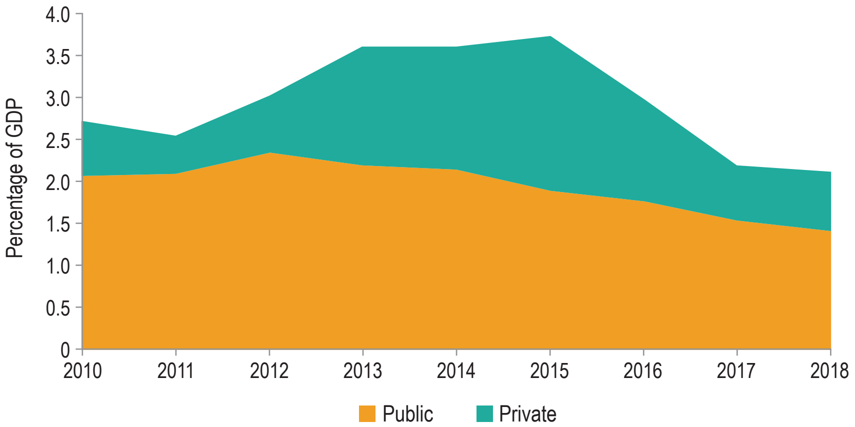
[a] Governments support large projects by identifying and developing opportunities, using concessions or other contracts with a variety of government entities, and requiring permits, authorizations, and regulation.
[b] World Bank (2013).
[c] On the specific case of maintenance and transparency of whole-of-life costs, the PPP Reference Guide (2017) argues how a PPP requires an up-front commitment by the private operator to the whole-of-life cost of providing adequate maintenance for the asset over its lifetime. This commitment strengthens budgetary predictability over the life of the infrastructure, and reduces the risks of needing funds for maintenance after the project is constructed.
[d] Risks transferred to foreign investors may reduce overall risks, but those retained by governments in owning and operating infrastructure may carry substantial costs; therefore, transferring some risks to private investors can reduce the risks to the taxpayer (see PPP Reference Guide, 2017). See Ketterer and Powell (2018) for a proposed typology of risks associated with infrastructure projects and how such risks might be best addressed.
[e] Typically, the financing is not counted as public debt, let alone contingent liabilities. Frequently, project support requires multi-year commitments and thereby has an impact on future budgets and debt trajectories. If all the above were strictly accounted for in public accounts, governments may find such projects less attractive. Some countries do estimate PPP impacts (both direct and contingent) on public accounts. See Engel, Fischer, and Galetovic (2013, 2014) for general discussion and Reyes-Tagle (2018) for analysis of the fiscal implications of PPPs in Latin America and the Caribbean.

[f] In a related theoretical model, Cordella (2018) outlines when private investment might be superior to public in a model incorporating the possibility of reforms.
[g] See Neto, Cruz, and Sarmento (2017); Guasch (2004); and Guasch, Laffont, and Straub (2008).
[h] Campos et al. (2019) consider all projects undertaken by the Brazilian conglomerate Odebrecht in eight countries over a ten-year period, and find that the value of the average renegotiation was 71 percent of the initial investment where bribes were paid, compared to 6 percent where there were no bribes with no substantial differences between PPPs and public provision.
[i] See Suárez-Alemán, Astesiano and Ponce de León (2020a) on airports; Suárez-Alemán, Astesiano, and Ponce de León (2020b) on ports; and Pérez, Pereyra, and Sanroman (2020) on roads.
[j] See EIU (2019) and Cavallo and Powell (2019), online Appendix F, for a review of countries' PPP frameworks, http://idbdocs.iadb.org/wsdocs/getdocument.aspx?docnum=EZSHARE-182252029-57.
[k] See Cavallo and Powell (2019), online Appendix F, https://flagships.iadb.org/en/MacroReport2019/Building-Opportunities-to-Grow-in-a-Challenging-World.

Considering those countries that have attracted nongovernment financing in most years since 2010, it is interesting to note that while public financing has been declining since 2013, nongovernment financing had been on the rise and in 2015 accounted for about 2 percent of GDP. However, more recent data show nongovernment investment falling and totaling less than 1 percent of GDP in 2018 (Figure 3.4).

The data illustrated in Figure 3.4 include government investment (meaning infrastructure financed through fiscal accounts as recorded in Infralatam) and nongovernment finance, which includes financing from

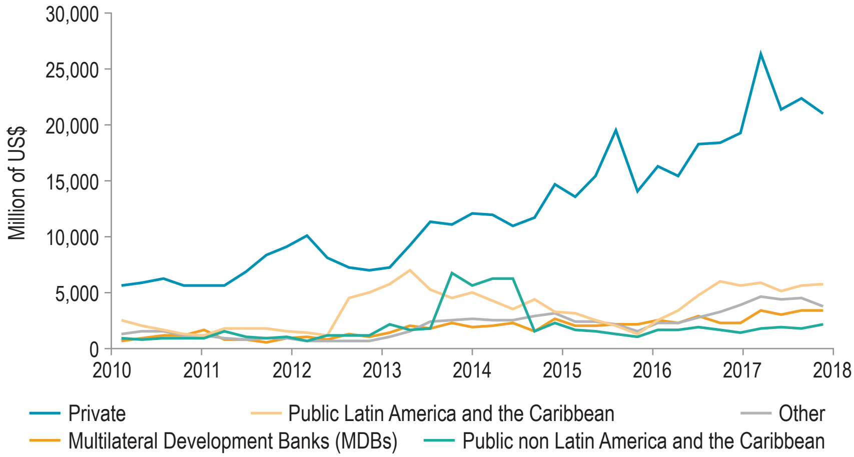
Figure 3.4
Government and Nongovernment Infrastructure Financing



Source: Infralatam, IJ Global, and the World Bank's PPI Database.
Note: Government investment is sourced from Infralatam. Nongovernment investment is sourced principally from the Infrastructure Journal's IJ Global database, supplemented by the World Bank's PPI database, thereby ensuring no double counting. Investment is agreed financing at financial close. Refinancings are excluded but infrastructure used solely for commercial purposes is included. Eleven countries are included to produce this figure, namely those countries that have positive government and nongovernment investment for most years over the period of analysis.

private entities (such as private banks, firms, and funds). They also include financing from multilateral development banks (that does not go through the fiscal accounts), state entities from outside Latin America and the Caribbean (such as public banks, export credit agencies, and the like), and some state entities from within Latin America and the Caribbean (mainly public banks). The total of this nongovernment financing reached around US$38 billion in 2018. This novel dataset was constructed principally from the Infrastructure Journal's IJ Global detailed project data, applying various filters to ensure it represents new investment (and not for example, refinancing or privatizations of existing assets); it was supplemented with the World Bank's PPI dataset, taking care to preclude double-counting projects.[12] Breaking down infrastructure financing by these nongovernment categories reveals that, truly, private financing has grown strongly in U.S. dollars and as a percentage of total nongovernment financing (Figure 3.5).[13]

Figure 3.5
Nongovernment Infrastructure Financing in Latin America and the Caribbean



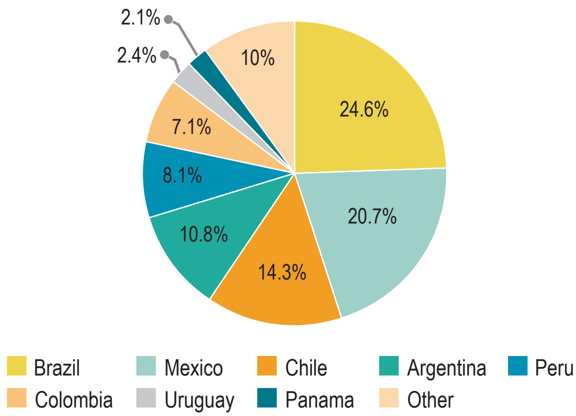
Source: IJ Global.
Note: The "Other" category refers to projects that were not categorized and, therefore, could be in the previous groups.

12 The figures are higher than the World Bank's PPI dataset in some years as the data here include large commercial infrastructure projects such as commercial ports and canals.

13 Note that the figures for nongovernment financing differ from those in Chapter 2, which relied on the World Bank's PPI database. The database created for this chapter includes commercial infrastructure, which is excluded from PPI.

Nongovernment infrastructure financing is concentrated in certain countries. Brazil captures about 25 percent of all such financing followed by Mexico which accounts for about 21 percent. The financing in just six countries (Argentina, Brazil, Chile, Colombia, Mexico, and Peru) accounts for over 85 percent of the total (Figure 3.6).

Figure 3.6
Share of Nongovernment Infrastructure Financing across Countries

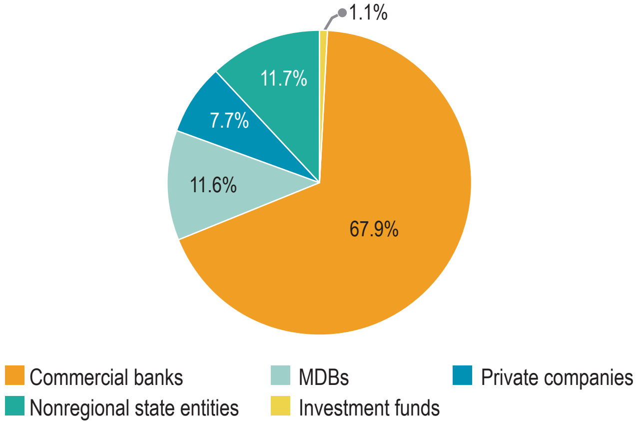


Source: IJ Global.
Note: Figures refer to 2014–18 totals. "Other" refers to other countries where there are data for projects that are not financed through the fiscal budget or regional state entities.

It is notable how important commercial banks are as financiers. If projects financed by regional state entities are excluded, commercial banks accounted for some 68 percent of the remaining nongovernmental financing over the last 5 years (Figure 3.7). In this figure, a private company refers principally to what is frequently referred to as the sponsor of a project. This could be a construction company, a utility company, or an industrial or mining corporation. Notably, little infrastructure is financed by investment funds (this includes pension funds, mutual funds, or other funds) in Latin America and the Caribbean.

Almost all the financing supplied by commercial banks is in the form of debt (around 99.5 percent) and only 0.5 percent of their financing is in the form of equity. Banks lend using several different instruments, but the main ones are term loans and bonds. Term loans have long average maturities. The average maturity of such loans in 2013 was 15 years with some loans well in excess of 20 years. But tenors have been coming down; in 2016, the average maturity was 12 years and in 2018 about 8.5 years. In recent years, longer-term loans have been provided in particular from

Figure 3.7
Share of Total Infrastructure Financing, by Financier



Source: IJ Global.
Note: Figures refer to 2014–18 totals. This figure focuses on the financing of infrastructure in the region by sources other than the fiscal budget and regional state entities.

Spanish, Japanese, and regional (particularly Brazilian) banks. Note that in addition, regional public development banks and nonregional state entities (particularly Chinese official banks) and MDBs may also provide term lending. These long-maturity loans may be part of a syndicated structure.

Indeed, syndicated lending for infrastructure is an important element of the syndicated loan market. Around 32 percent of all cross-border syndicated loans extended to the private sector in Latin America and the Caribbean were to finance infrastructure projects. Box 3.4 discusses the role of syndicated lending for infrastructure finance. The excellent data on syndicated loans make it possible to analyze other interesting questions. For example, and as reviewed in the Box, MDBs can play an important stimulating role in terms of attracting greater financing from commercial banks.

Interestingly, commercial bank lending instruments have switched from term lending to bond financing. While this change has been led in particular by U.S. and U.K. banks, it is evident in the statistics for aggregate commercial bank lending to infrastructure projects (Figure 3.8). In the case of bond financing, an infrastructure project SPV may issue a bond that is then bought by the relevant bank. A caveat with infrastructure project finance datasets is that the role of different financiers is not tracked through the life of the project. Banks may sell part of their participation; they may reduce their participation in a syndicated

Box 3.4

Syndicated Bank Lending, Infrastructure, and the Mobilization Impact of MDBs

In 2015, a total of 193 countries adopted the 2030 Sustainable Development Agenda, which set ambitious targets for poverty reduction and inclusive development. The United Nations estimates that total investment in economic infrastructure (power, transport, telecommunications, water, and sanitation) in developing countries is under US$1 trillion per year but will need to reach between US$1.6 and US$2.5 trillion a year over the period 2015–30. This opens up a key role for the private sector (UNCTAD, 2014).

An important question—for both policy and research—is how the international community can mobilize private financing. In this respect, multilateral development banks (MDBs), as international institutions that provide financial assistance to developing countries to promote their economic and social development, can play a fundamental role, providing financial assistance directly to developing countries, but also mobilizing additional private sector resources. The first role, direct financial support to member countries, is part of the mandate of MDBs, which are expected to step in when private financing is scarce (Humphrey and Michaelowa, 2013), possibly mitigating the pro-cyclicality of private capital inflows (Galindo and Panizza, 2018). But direct financing is constrained because countries' demand outstrips the potential supply from MDBs (United Nations, 2015a; Perraudin, Powell, and Yang, 2016; Settimo, 2017). As a response, MDBs reaffirmed their pledge to catalyze more investment from private investors (World Bank, 2018).

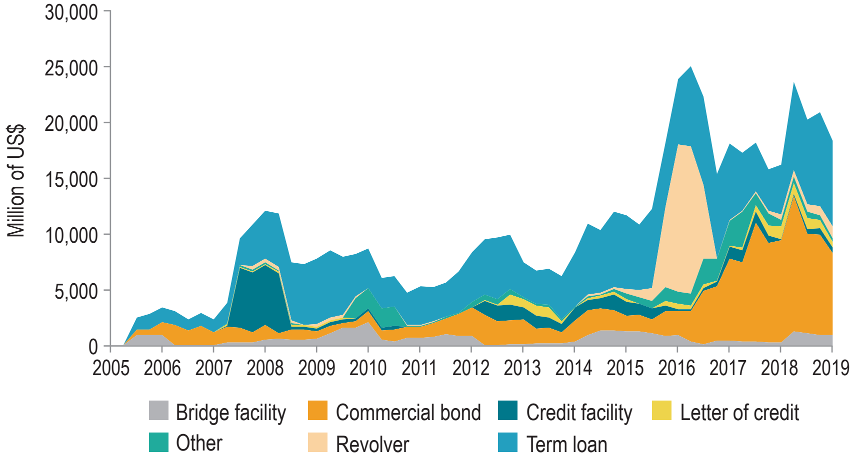
Infrastructure can provide relatively high total returns with low correlations to traditional asset classes (e.g., equities, real estate) but several different types of risks must be considered. Ketterer and Powell (2018) argue that MDBs may have a comparative advantage in bearing risks that relate to public sector contract performance, regulatory risks, or expropriation risks.[a]

Broccolini et al. (2020) find that MDBs crowd in private investors. Specifically, the analysis finds that the number of loans, the size of private capital flows, the number of creditors per loan, and the average loan maturity all increase in the years following the presence of syndicated loans with MDB participation. When focusing on infrastructure, they find that when MDBs participate in syndicated loans, the average maturity of loans in the country-sector increases by 0.8 years in the short term and over a three-year period, it rises to 2.6 years.

[a] See also JPMorgan (2017) and Blended Finance Taskforce (2018).

structure or perhaps more easily, they may sell bonds backed by project returns to a third party. Indeed, moving to bond finance suggests a greater degree of interest in such sales as bonds are likely transferable at lower cost.

Figure 3.8
Commercial Bank Infrastructure Financing, by Instrument



Source: IJ Global.

A number of interesting trends in global financial markets may be important for the future of financing greenfield infrastructure in emerging markets.

First, as a result of the global financial crisis, a set of large global banks reduced their cross-border lending. While bank balance sheets have since recovered markedly, global bank cross-border lending volumes have not recovered to pre-crisis levels (see Beck and Rojas-Suárez, 2019).

Second, the revised Basel III Accord, which includes recommendations for minimum levels of bank capital and new recommended liquidity ratios for banks, may have a significant effect on bank lending practices. As these reforms are still being implemented across the world, impacts may be only partial to date.[14]

Third, while the global syndicated lending market network remains relatively highly centralized (comparatively few large banks are connected to many smaller banks through the syndication), the network is less centralized now than before the global financial crisis. This may have been driven by the retreat of global banks and the entrance and growth of new cross-border players, particularly a set of Chinese banks but also banks from other emerging economies.[15]

14 See Financial Stability Board (2018); Beck and Rojas-Suárez (2019).

15 See Lotti, Powell, and Conesa (2020).

Fourth, while there have been mixed trends in cross-border loan financing, international bond financing has continued to grow. Issuance was just shy of US$7 trillion in 2019 with US$1.1 trillion of that being in structured finance.[16]

Considering all these trends, it seems likely that it may become more difficult for advanced economy banks to provide long-term loans to finance infrastructure and to maintain those loans on their balance sheets. To some degree, their lending may be replaced by that of emerging economy banks including Chinese entities or other state players, but it seems likely that internationally recommended capital and liquidity regulations may eventually be applied to these players as well. This suggests the shift to bond financing of infrastructure may continue.

Improving Service Quality: The Financing Dimension

As infrastructure assets are financed in different ways and services are provided by different actors, the above analysis suggests a multipronged strategy to improve the quality of services delivered by infrastructure. Four mutually supporting avenues are suggested here.

First, boosting public spending on infrastructure in the region, given current fiscal pressures, will require significant reforms to gain greater efficiency in spending as well as tax reforms in some countries. In those countries where public infrastructure spending remains significant, there is ample space to improve the quality of services that stem from that investment.

Second, the quality of services provided by SOEs and private regulated companies needs to be improved. While some SOEs are well run and provide excellent services, others suffer from political interference, are burdened by many competing objectives, and have not adequately addressed problems of accountability. Many SOEs are also inadequately funded and have built up high levels of debt. These wider issues of governance also impinge on the quality of infrastructure services. There are several approaches to reform, assuming the political willingness exists to confront the vested interests involved. Some countries have established holding companies for SOEs that monitor various aspects of their

[16] See Robert Triffin International (2019) for a general analysis of the trends in international financing and Standard and Poor's "Credit Trends: Global Financing Conditions: Bond Issuance Is Expected to Grow 3.8% in 2020," January 30, 2020. Available here: https://www.spglobal.com/ratings/en/research/articles/200130-credit-trends-global-financing-conditions-bond-issuance-is-expected-to-grow-3-8-in-2020-11327333.

performance. Others have created offices that serve a similar purpose but without the holding company structure. These types of reforms could be coupled with instruments to monitor and make more transparent the quality of any infrastructure services provided. Regarding private regulated companies, both costs and margins are relatively high. As discussed in more detail in Chapter 13, ample room remains to improve regulation in the region.

One route to improve firm governance and other firm responsibilities is to tie financing to performance indicators. Interest is growing among investors to know more about firms' corporate responsibility policies, including how they may help communities where they are located (or at least safeguards to protect communities from pollution or other negative externalities), their environmental footprints, sustainability, and policies, and the quality of their governance. Box 3.5 discusses how environmental, social, and governance (ESG) indicators may be used by investors to provide incentives to improve corporate responsibility. Given the links between good governance and environmental and community responsibility, such measures would likely improve the quality of infrastructure services provided by firms.

Box 3.5

Financing and the Future: The Rise of ESG Investing

Investors increasingly seek investments that couple good financial returns with the promise of a better future. The desire to consider societal benefits in investment strategies has driven a huge increase in the demand for investments that consider sustainability factors. For example, by 2018 one of every four dollars of all professionally managed assets in the United States were invested as part of strategies that considered environmental, social, and governance factors (Connaker and Madsbjerg, 2019).

For infrastructure investing, integrating sustainability considerations has particular importance given the long life span of infrastructure assets, infrastructure's role in achieving development goals, and the numerous ways in which infrastructure and the environment interact. For example, infrastructure will play an important role in achieving climate change mitigation goals. In a 2018 survey conducted by the Callan Institute, 72 percent of the largest infrastructure portfolios reported incorporating environmental, social, or governance factors (Bennon and Sharma, 2018).

Given that infrastructure investors increasingly incorporate sustainability elements in their investment strategies, countries need to better integrate these considerations in the planning, design, and procurement of infrastructure projects and communicate sustainability achievements to investors in a standardized and transparent way. Multilateral development banks are assisting countries with these objectives.

Toward this end, Mexico has adopted the IDB's Sustainable Infrastructure Framework. The IDB group is working with the government of Mexico to embed the IDB sustainable infrastructure taxonomy in the planning, design, procurement, and financing of infrastructure projects. As part of Mexico's initiative to match infrastructure projects with foreign investors, the "Proyectos Mexico" platform has developed sustainability "index cards" to classify the country´s project portfolio based on its sustainability performance. To date, 20 pilot projects have been developed. The goal is to communicate key sustainability information about each project to potential investors (Cárdenas and García Rojas, 2019). In addition to utilizing the Sustainable Infrastructure Framework to attract private-sector investment, IDB is working with the Investment Unit at the Ministry of Finance to incorporate these sustainability attributes into the cost-benefit calculations used to allocate federal funds to infrastructure projects. Hopefully, these practices will trickle down to state and local investments, increasing the share of sustainable infrastructure projects at every level of government.

Further, the idea is spreading. Brazil is slated to follow in Mexico's footsteps, utilizing the Sustainable Infrastructure Framework to secure private investment in infrastructure projects by creating a Sustainable Infrastructure Observatory.

Finally, a fourth avenue is to boost the private financing of infrastructure in ways that would enhance service quality. Banks are currently the main private financiers, but regulatory pressures may limit their financing in the future. At the same time, the amount of financing from pension funds, sovereign wealth funds, and other types of professional institutional investors in the region is low. And yet trillions of dollars are available in such funds worldwide as well as in local pension funds.[17] It seems an obvious proposition to increase the small percentage of such institutional money currently invested in infrastructure.

However, this is not as easy as it sounds. Large infrastructure projects are complex and risks during the construction phase can be daunting, often quite specific to the project and hard to monitor. Most infrastructure financed through project finance includes equity investment by the sponsor (the firm actually building the asset) and debt (and sometimes equity) put up by commercial banks. The sponsor knows the risks and putting

17 Arezki et al. (2016) estimate as much as US$100 trillion in institutional funds.

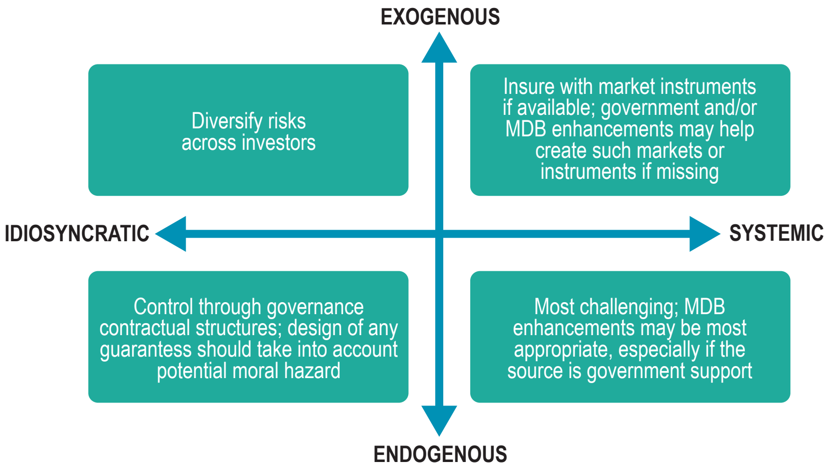
down financing means it has skin in the game and the incentives to build the asset to the quality required. As sponsors typically provide equity finance, these incentives are sharpened since they will get a return on that investment only once more senior debt holders are paid. Many commercial banks have built up project finance expertise, meaning they have skills monitoring such projects and likely have relationships with the sponsor; they may finance several projects with the same firm and as a result have built up a level of trust and cooperation. Other financiers have become important. State-owned banks or other public corporations and international actors such as export credit rating agencies and official banks from other regions (including China) may also put up debt finance and sometimes equity. These actors frequently have varying incentives, not only maximizing their returns or minimizing risk. For example, they may have to use firms or inputs from the donor country concerned. Such conditions may not always be in line with improving governance and the quality of the services delivered by the infrastructure project.

Why is it so difficult for large pension funds and sovereign wealth funds to finance infrastructure projects? Typically, such institutions control large amounts of investible funds with few people and seek assets that are liquid and trade on financial markets. Liquidity provides comfort that assets are valued fairly and allows for greater diversification of risks. It would be particularly valuable to diversify infrastructure construction risks among many investors employing liquid assets. The problem, however, is that the firm building the actual infrastructure asset may have little incentive to ensure high quality or timely construction. That firm would have less skin in the game. For large institutional funds to invest might require dedicated units and significant monitoring capacities, essentially mirroring the project finance skills of commercial banks. Still, innovations are underway. In Europe, more specialized traded funds that then invest in infrastructure projects are growing. Such investors tend to seek projects that are fully funded and have fewer political or environmental risks and where underlying regulatory frameworks inspire confidence. Renewable energy projects have been particularly popular.

Once construction risks pass, the cash flows from more complex infrastructure projects may become less risky and those risks may be more exogenous in nature—in particular related to demand-side and macroeconomic risks. If so, this may open the possibility for arm's-length investors to invest and commercial banks might then be able to reduce their exposure. Infrastructure bonds to refinance infrastructure projects are becoming more popular for this purpose and may lie behind the trend by some banks to switch from loans to bonds as the preferred financing instrument.[18] However, other risks may persist through the life of projects and may still limit the participation of large institutional funds. Political and regulatory risks and the performance risk associated with contracts with other entities (such as public sector actors that might be at a local or state level or with an SOE) tend to be present through the life of infrastructure projects. Moreover, for liabilities in dollars, exchange rate risks may also be a significant concern.

This discussion suggests a typology and a set of principles for how to best manage these different types of risks. One possible categorization is illustrated in Figure 3.9 and distinguishes between individual versus systemic, and endogenous versus exogenous risks.[19] An example of an individual, endogenous risk is that associated with the construction of a project. While some construction risks may be exogenous, the risk associated with the performance of the firm contracted to build the asset is normally considered critical. Such risks are best dealt with by an appropriate contract that ensures the firm has the right incentives to use the right materials, employ workers with the right skills, and sufficient time to work on the project. This normally means ensuring that the firm has significant skin in the game, perhaps by owning an equity stake in the project. It is

Figure 3.9
A Typology of Risks in Infrastructure Projects



Source: Ketterer and Powell (2018).

[18] See Ehlers, Packer, and Remolona (2014) on the experience of infrastructure bonds in Asia.
[19] This figure and the discussion below are taken from Ketterer and Powell (2018).

important to note that offering a guarantee against such risks may well be counter-productive, as it may create incentives for precisely the kind of behavior the guarantor wants to avoid—normally known as moral hazard.[20]

An individual but exogenous risk might relate to weather or the demand for the specific infrastructure services to be provided. In principle, such risks need not be managed or mitigated. Such risks can be diversified across many investors assuming that the right financial instruments exist for that purpose.

Thinking about projects across a single country, a systemic exogenous risk might relate to more general economy-wide factors such as growth, which then affects demand for all such projects, or exchange rate risks, assuming a floating exchange rate regime. Such risks can be diversified if an investor holds a portfolio of investments in projects across countries, if the correlation between growth rates or exchange rate movements are not high. Also, in some countries financial markets allow investors to buy insurance against these risks. If they are indeed exogenous, in theory such markets can be developed. If not, guarantees can be considered. However, if the government offers a guarantee against such risk, this guarantee is likely to be called in bad times, when growth is low or exchange rates depreciate sharply. Such policies may then have very poor risk-sharing characteristics. A better solution might be a proactive policy to create financial instruments that then allow private investors to hedge these risks. There have also been some interesting innovative developments to allow investors to hedge such risks. The Current Exchange Fund (TCX) was a creation of the Dutch government and a set of multinational actors to allow investors to hedge currency risk in frontier markets.[21] However, given its current scale, it is designed more for smaller projects than large infrastructure projects.

Finally, there may be exogenous and systemic risks. Perhaps the most salient are political or regulatory risks that are described more generally as a change in the rules of the game. As they may depend on a national government, they might be systemic across projects in a country. In this case, a guarantee by the government is a useful mitigation technique. A limitation, however, is whether investors attach much value to a guarantee offered by the same government that is tempted to change the rules. Arguably, MDBs may play a particularly important role in this area. Given a close relationship between MDBs and borrowing governments, and the incentive to maintain a good relationship to receive fresh funds in the

20 See Ehlers (2014) on this point.
21 See www.tcxfund.com for further information.

future, MDBs have some persuasive power over countries to ensure the rules of the game are respected. They also give a seal of approval on such rules and thus reduce the likelihood of changes for purely political reasons.

The typology developed above may also be harnessed to consider the technological and climatic risks discussed later in this book. This is related to the general problem of stranded assets, or the risk that a large infrastructure project may be initiated but then given rapid technological change or a sharp shift in policy (perhaps due to climate concerns), the project is rendered obsolete or at least its present value is strongly impacted. Both risks are fundamentally exogenous. Some technological risks may be idiosyncratic as they may be sector- or even project-specific. But climate and some technological risks may be systemic in nature, making it hard to seek diversification across investors. For example, it may become more and more difficult to manage risks in fossil-fuel-based energy projects as investors anticipate future policy decisions toward a zero-carbon emission world, even if policymakers today are not moving decisively in that direction. Good project selection will become increasingly critical and may imply selecting a particular scenario for how a sector will develop.

The typology and the associated discussion make the point that infrastructure projects present many different types of risks and such risks should be managed in different ways. This suggests developing a financing structure in which risks can be separated and managed in different ways. As risks change over the life cycle of a project, the appropriate management of risks may also change. Infrastructure projects normally consist of a construction phase (that may last several years) and then an operation phase that may continue for well over a decade. After construction risks have passed, the main risks facing projects tend to be related to demand or exchange rate risks and to the relationship with the government in question—such as contract risks with government entities and regulatory risks.

It may be a challenge for a large diversified institutional investor to dedicate sufficient person-hours to understand specific project risks in emerging economies; hence, the role of commercial banks with project finance expertise is likely to continue to be important in the foreseeable future, especially during the construction phase. Such investors may find a bond backed by project returns after the construction phase to be a more attractive instrument, especially if regulatory risks are contained through, say, an MDB guarantee. Such instruments gain liquidity which also aids in pricing and liquidity. The fact that some banks are now using bonds rather than term loans as the instrument of choice is telling in this regard. Commercial banks may also find the use of this instrument attractive to be able to offload investments when convenient, especially when banking regulations penalize long-term holdings on the balance sheet.

This is not to say that an attempt to make projects more transparent from the outset is misguided. Better information and a standardized way to analyze projects would be extremely valuable. Moreover, some fund managers will find it profitable to set up specific infrastructure units and may well start to invest in equity type instruments. However, to date this requires considerable investment and such units then resemble inside investors that have developed project finance expertise. Moreover, given the current state of information availability, and the risks involved, individual project equity instruments are less likely to become highly liquid. The market, however, is developing, particularly in Europe, but to date is more through the vehicle of traded funds (which may then gain a reputation themselves) rather that equities linked to single projects. To be sure, standardized information and instruments may well eventually allow arm's-length investment in some type of equity product, but given the urgent need to boost private infrastructure investment, infrastructure bonds initially on commercial bank balance sheets to be sold after the construction phase may be a more convenient strategy for emerging economies.

The potential for such instruments is significant. Given an estimated US$30 trillion in investible funds (just one-third of that claimed by Arezki et al., 2016), suppose 5 percent can be attracted to infrastructure in emerging economies. The share of Latin America and the Caribbean in the GDP of all emerging economies is about 15 percent. If investment follows GDP shares, this would amount to some US$225 billion.[22] If this were built up over a 10-year period, then this could add US$22.5 billion of investment per year over the period, almost doubling the current level of nongovernmental investment in the region.

[22] Here the focus is on additional investment that might be garnered from external institutional investors. This would then not crowd out financing from domestic sources. Serebrisky et al. (2015) focus on domestic institutional investors and estimate that up to 0.4 percent of GDP might be raised from those sources.

4

The Good, the Bad, and the Ugly of Services

In Latin America and the Caribbean, the story of the basic services delivered by a country's infrastructure—energy, water and sanitation, and transportation—is anything but straightforward. When considering the three pillars for evaluating services—access, quality, and affordability—the region's experience runs the gamut from impressive to dismal. This chapter reviews the good, the bad, and the ugly of services in Latin America and the Caribbean and highlights successes in each area that could help rewrite the story.

The region has made great strides in expanding access to infrastructure to ever larger populations. Countries tend to perform well according to basic measures of access. Beyond the basics, however, performance is lacking and is decidedly poor in some jurisdictions, especially rural areas. Quality gaps, meanwhile, can be severe. A majority of people suffer from irregular service, particularly in water supply. Transportation services do a poor job of connecting people to their homes, schools, and jobs. And the price of infrastructure services can represent a heavy financial burden for low- and middle-income households, thereby accentuating the inequality characteristic of the region.[1]

Unfortunately, the future of services is uncertain, at best. Climate change, population growth, and urbanization are bound to increase pressure on services and underscore their deficiencies. On the plus side, the often-neglected social dimension of infrastructure—that is, its importance for personal well-being as well as economic development and firm

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[1] Analyzing services in Latin America and the Caribbean is complicated by limited data, which is a key barrier to setting consistent, transparent, and efficient policy. The data that do exist is spread across institutions, with no central institution charged with gathering, housing, and analyzing such data. This paucity of solid data weakens regulators' capacity to set, monitor, and enforce quality standards.

competitiveness—is being addressed by the global commitment to achieving the United Nations' Sustainable Development Goals (SDGs), which have the social importance of services at their core.

To Be or Not to Be (Connected): The Challenge for Access

Access to infrastructure services can be measured using a variety of criteria. For example, access to public transit within three blocks of home may be considered "good," as may access to an improved source of water (piped, protected well, or spring) that involves no more than a 30-minute round-trip journey. More stringent measures, meanwhile, might look at access to a public transportation route that allows users to reach jobs, education, and health facilities within a specific time frame, or to piped water inside the home. The region fares well according to basic measures of access, but the picture changes rapidly as the measures become more demanding. Despite the considered measure, one general trend is clear: access rates are significantly better in urban areas and among higher-income households across all standards of electricity, water and sanitation, and urban transport services.

Let There Be Light: Expanding Access to Electricity

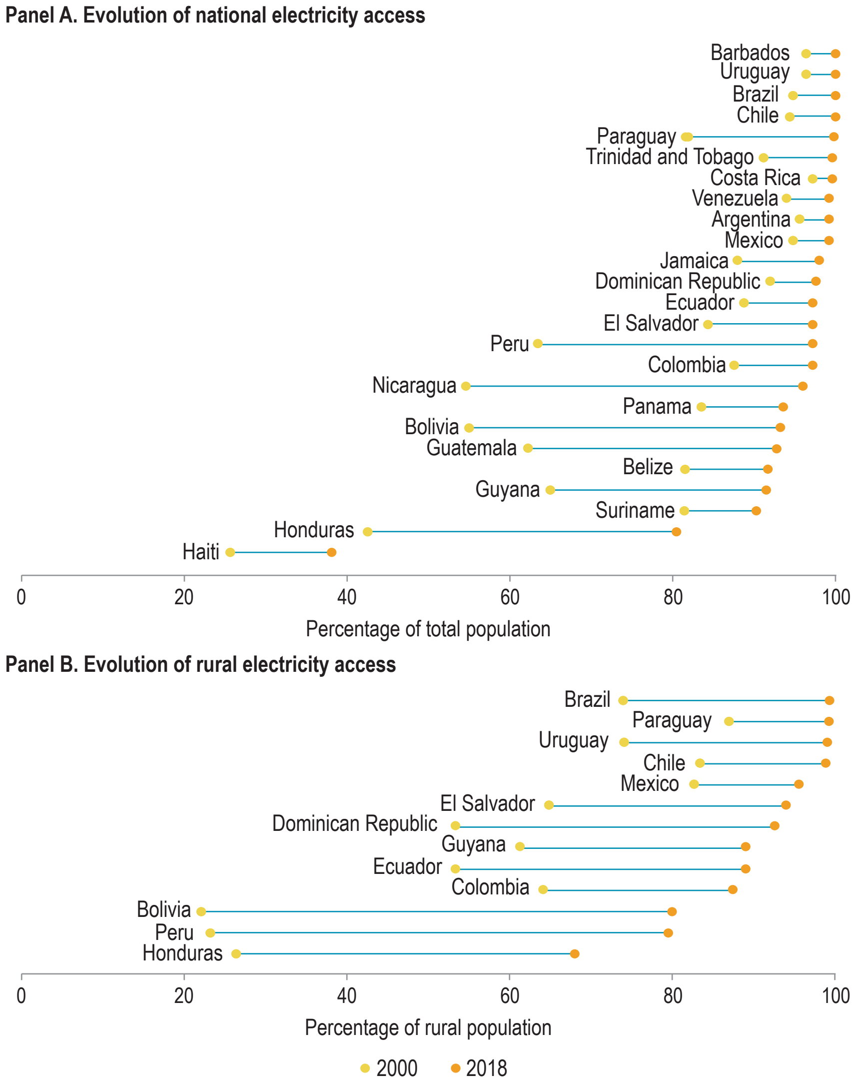
Most countries in the region have reached all but 3 percent of their population with electricity services[2]. Access to electricity in Latin America and the Caribbean is above the world average, higher than in the Middle East and North Africa, but below North America, Europe, and Central Asia. But averages hide important disparities across countries and between rural and urban areas (Castillo et al., 2018). Whereas most countries have achieved rates of electricity access higher than 90 percent, countries such as Haiti and Honduras still have significant gaps, with access rates at 39 percent and 81 percent, respectively, in 2018 (Figure 4.1, Panel A).

Countries in the region have made important strides in rural electrification, although huge disparities persist: while Brazil, Chile, Paraguay, and Uruguay have achieved almost universal access in rural areas, only 68 percent of the rural households in Honduras have electricity. Yet those countries with the lowest rural access rates have made remarkable progress in the past two decades. Coverage in Honduras jumped from 26 percent to 68 percent, in Bolivia from 22 percent to 80 percent, and in Peru from 23 percent

2 This measure takes into account households that declare having at least basic access to electricity services, independent of the quality and continuity of the received services.

to 80 percent (Sanin, 2019; Figure 4.1, Panel B). As rates approach universal coverage, the "last mile" becomes increasingly challenging to cover. Closing the final gap means providing services to remote and dispersed areas where conventional solutions are often inadequate. A significant investment of time and effort is required to tailor services to local conditions.

Figure 4.1
Access to Electricity, National vs. Rural, 2000 and 2018



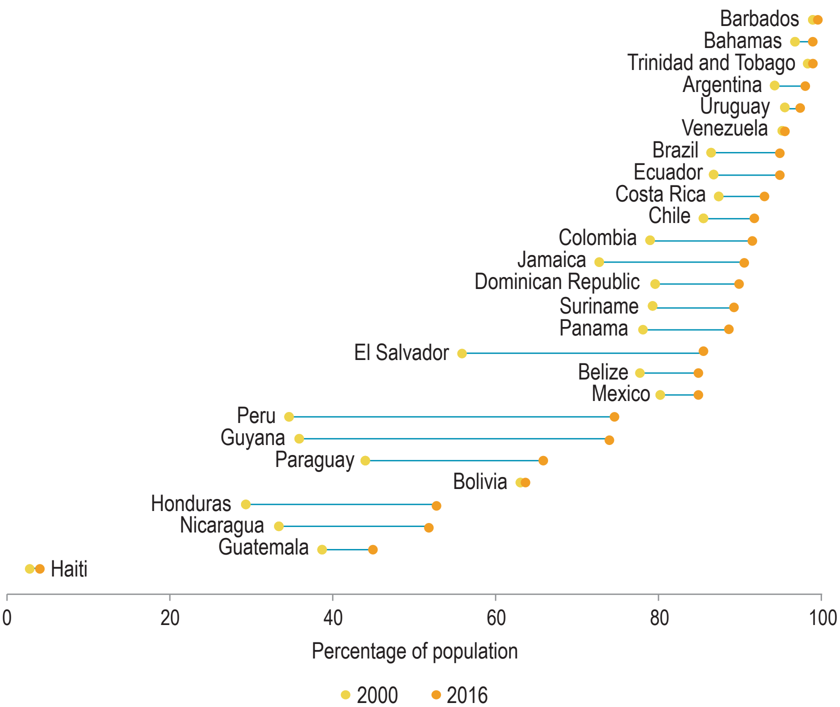
Source: Sanin (2019).

In addition to the disparities between geographical areas, differences in access by household income are significant. Most people without access are poor. In Panama, for example, 47 percent of households in the poorest income quintile have no access to electricity. In Guatemala and Honduras, this figure is over 30 percent, and in Bolivia and Peru, over 20 percent (Iorio and Sanin, 2019).

Cleaner Cooking: Another Side of Energy

Energy infrastructure services are not limited to electricity. One important SDG is to increase reliance on clean cooking fuels like natural gas, liquid petroleum gas, and on electric cookstoves. Cleaner alternatives can relieve the significant health, environmental, and economic burdens of traditional, polluting fuels such as coal, kerosene, and wood. Access to these cleaner fuels is much lower than access to electricity and has progressed at a slower pace (Figure 4.2). In 2016, more than 80 million people in the region still

Figure 4.2
Access to Clean Cooking, 2000 and 2016



Source: Sanin (2019).

relied on traditional fuels. Using 2019 figures, the World Bank's SE4ALL database reveals that, of this population, 23 percent were in Mexico, 13 percent in Haiti, 12 percent in Brazil, and 11 percent in Guatemala. Transitioning to clean cooking is not easy. Where electricity is not available, lack of proper infrastructure to supply modern fuels poses challenges to their adoption. But even where electricity is available, it is often difficult to change the customs and tastes of people and convince them to abandon traditional ways of preparing food (Jeuland et al., 2020).

Moving the Goal Posts: The Impact on Access to Water and Sanitation

As with electricity, the state of access to water services in the region may be measured using either basic or more demanding indicators. To evaluate the progress made toward the Millennium Development Goals (MDGs) of 2015, all households with piped water or using water from a protected source (e.g., covered cistern, protected well, or spring) were considered to have access to "improved" water.

According to AmericasBarometer 2018–19 survey data by LAPOP, the percentage of urban households in this category recently reached 96.7 percent in the region. But in 2015, the SDGs raised the bar substantially. The new gold standard is to achieve access to "safely managed" water, which means improved water that is located on premises, available when needed, and free from contamination. Achieving universal access to safely managed water by 2030 is an ambitious effort requiring substantial financial resources, but the data needed to evaluate existing access gaps, devise solutions, and track progress are largely unavailable (Bain et al., 2018).[3]

Intermediate access metrics can provide a glimpse of the work that lies ahead. Moving the threshold from, for example, piped water anywhere to piped water on household premises implies a significant drop in access rates (Figure 4.3, Panel A). The situation in rural areas is significantly worse than in urban areas, across access definitions. Important differences also exist between poorer and more affluent households, particularly in Argentina, Bolivia, Brazil, Costa Rica, El Salvador, and Mexico (Gómez-Vidal, Machado, and Datshkovsky, 2020).

[3] Although the number of countries without information on water quality is not disclosed by the Joint Monitoring Program of the World Health Organization and United Nations Children's Fund (the program that estimates progress toward the SDGs for water and sanitation), it acknowledges that fewer countries collect data on quality than basic access. Moreover, in those few countries with information, most of it is available only for piped supply, which is only one of several service types. Rural areas, which are most in need of improvement, lack the most data.

Sanitation solutions vary across locations. Urban areas are in general more suitable to sewer networks connected to a treatment facility. More remote areas, in contrast, require smaller-scale or individual solutions, such as septic tanks or composting toilets, because houses are few and far between. These differences are stark when comparing access between urban and rural areas (Figure 4.3, Panel B).

Similar to water, the standards for access to sanitation were raised between the MDGs and SDGs. The MDGs instituted the concept of improved sanitation, which includes solutions that prevent human contact with excreta, and facilities that are not shared between households. The SDGs raised the standards to what is known as safely managed sanitation, which required human excreta to be safely disposed of and/or treated.

AmericasBarometer 2018–19 data reveal that access to sanitation services, however their quality is defined, is lower than access to water across the region. An important challenge is how to extend services to informal settlements in urban and peri-urban areas. Disorderly sprawl, rudimentary housing construction, and lack of home ownership hinder the adoption of conventional solutions.

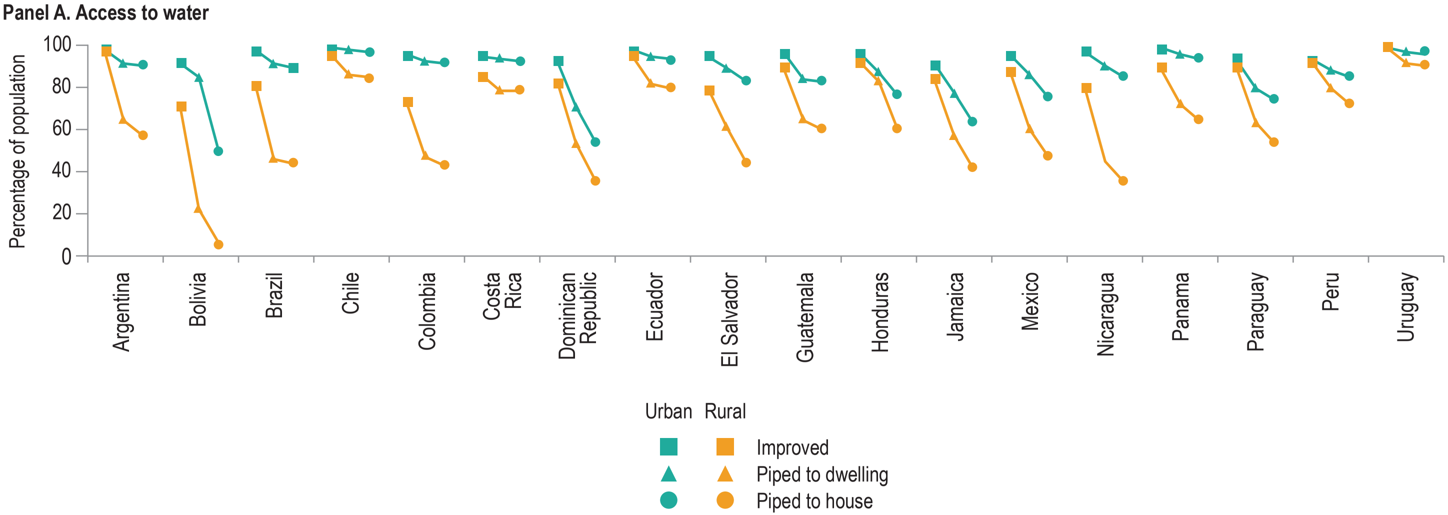
If connection rates are low, the amount of sewage collected and actually treated is even lower. Only about 30–40 percent of the wastewater collected is treated in the region (World Bank, 2019). A few exceptions are in Chile, where access rates rose from 21 percent in 2000 to 100 percent in 2012 (see Box 4.1), and Mexico, where they rose from 23 percent in 2000 to around 63 percent in 2017 (OECD, 2017a).

The Longest Mile: Achieving Access to Urban Transportation

Transportation is the service in which the region has progressed the least in recent years. According to a 2015 survey conducted by Development Bank of Latin America (CAF) across 10 cities in the region, access to a public transit stop within three blocks of home is almost universal (from 87 percent in Bogotá and 90 percent in Panama City and Quito to 98 percent in Buenos Aires and Montevideo). Such conventional measures of access, however, paint only a partial picture of the sector. A person's ability to reach destinations in a timely manner involves a multitude of interdependent considerations. Urban planning determines the distances between residential areas and common destinations such as offices, schools, health-care facilities, or shopping areas. Road density, together with economic activity levels, motorization rates, population density, and choice of mode of transportation, all affect congestion levels and travel times. The density and length of public transit lines are thus central, but far from the only factor determining mobility.

Figure 4.3

Access to Water and Sanitation in Latin America and the Caribbean



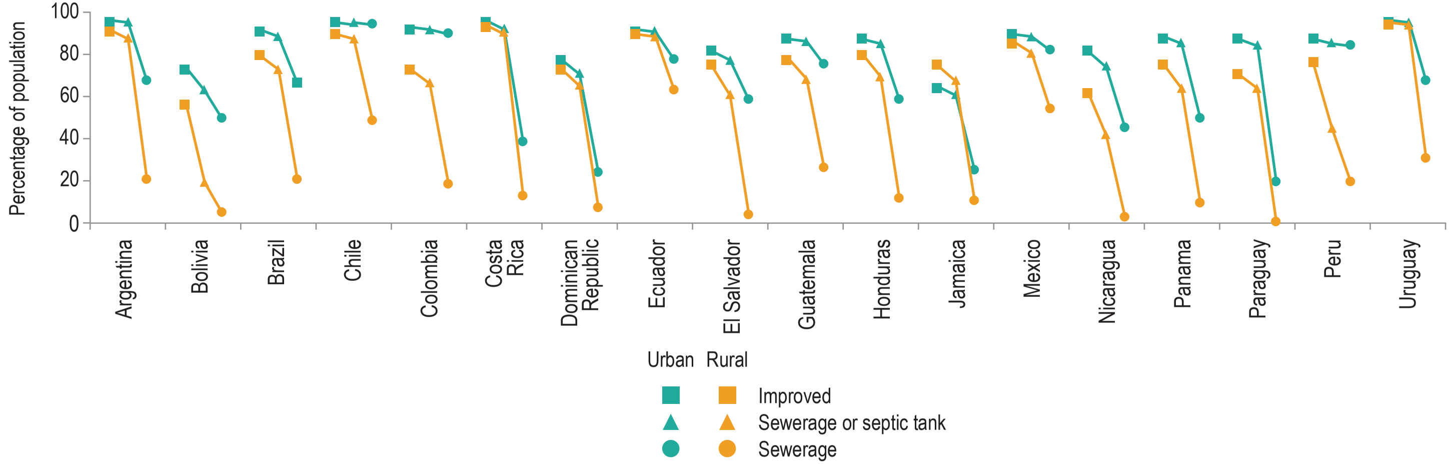
Source: LAPOP AmericasBarometer survey, 2018–19.
Note: Improved water comes from pipes, protected wells, rainwater, or protected springs. "Piped to dwelling" means either into the yard or inside the house. Piped to house means inside the house itself.

(continued on next page)

THE WIDENING GAP FROM RAISING THE STANDARDS OF ACCESS TO WATER AND SANITATION IS A SLIPPERY SLOPE.

Figure 4.3
Access to Water and Sanitation in Latin America and the Caribbean *(continued)*

Panel B. Access to Sanitation



Source: LAPOP AmericasBarometer survey, 2018–19.
Note: Improved sanitation involves either a flush toilet or latrine that separates excreta from human contact and is used by only one household. “Sewerage and septic tank” refers to a sanitation system in which the excreta is either connected to sewage pipes or a septic system. “Sewerage” refers to a sanitation system in which the household is connected to sewage pipes.

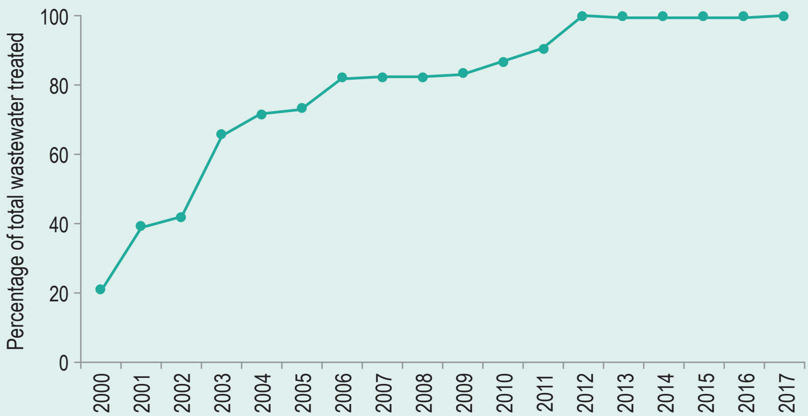
Box 4.1

Wastewater Treatment in Chile: Saving the Planet (and the Economy)

Chile's wastewater treatment rates were average at best in the 1990s, in sharp contrast with the notable advances in access to water and sanitation services that have made the country a regional leader. The government's plan to improve wastewater treatment rates included reforms that allowed the private sector to help finance an estimated US$2 billion backlog in investment in wastewater treatment plants (Peña, Luraschi, and Valenzuela, 2004; Jouravlev, 2004; OECD, 2017). The success of the wastewater treatment plan rested on several measures: new emissions standards to regulate pollutants associated with the discharge of liquid industrial waste by sewerage (Chilean Ministry of Public Works, 1998a) and liquid waste into the ocean and inland waterways (Office of the President of Chile, 2000); stronger supervisory powers of the Superintendency of Sanitary Services (SISS) in 1998 (Peña, Luraschi, and Valenzuela, 2004); and a new regulatory framework allowing private capital in the companies of the sector (Chilean Ministry of Public Works, 1998b; SEP, 2006).

The government's efforts have resulted in benefits not only in terms of public health, quality of life, and protection of the environment, but also in terms of the economy. In particular, the decline in wastewater irrigation has increased the potential of the tourism industry and increased the export potential of agricultural goods (Jouravlev, 2004). During 2000–17, private companies alone invested US$2,300 million in wastewater treatment (Andess, 2018) and allowed Chile to reach levels of treatment comparable to those of the leading countries in the world (Figure 4.1.1).

Figure 4.1.1
Evolution of Wastewater Treatment in Chile, 2000–17



Source: OECD Waste Water Treatment Indicator, 2019.

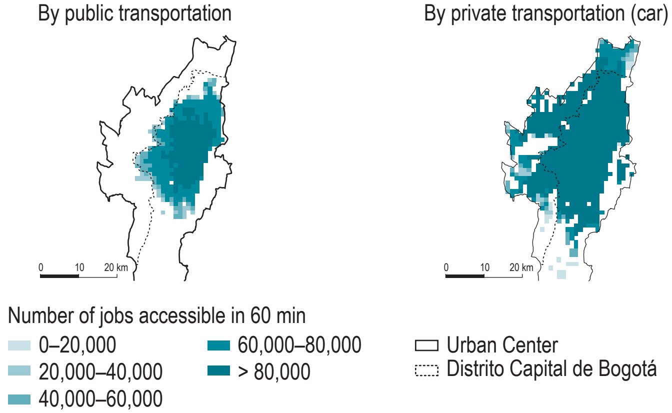
But given climate change, properly treating wastewater is only the first step in developing a sustainable approach to transforming wastewater into an economic resource. Although Chile currently treats almost 100 percent of the total wastewater produced, it does not use it productively. In fact, most of the treated wastewater ends up in the ocean. The environmental and economic potential of changing this situation is huge: the total volume of unused wastewater would meet close to 10 percent of the country's total hydrological deficit, unlocking important agricultural opportunities. A recent study estimated that the total volume of treated wastewater currently being discharged into the ocean (2.6 cubic meters per second) in the region of Valparaiso alone would be enough to irrigate 27,300 hectares of vineyards or 10,250 hectares of avocados, representing potential exports of US$1,146 million and US$885 million, respectively (Fundación Chile, 2016). Clearly, the potential for resource recovery and reuse is enormous (see Chapter 11).

Disorderly urban sprawl has contributed to the decay of transportation networks. As cities grow outwards to accommodate an increasing population, the density of roads in most urban centers is declining. This expansion seriously limits access and mobility. Fewer areas are within walking distance of major arteries, connectivity between peripheral and metropolitan areas is limited, and walking in peri-urban areas is more difficult due to longer distances and lack of walkable infrastructure (Rivas, Suárez-Alemán, and Serebrisky, 2019a).[4]

Despite relatively high rates of access to public transit close to home, people's mobility needs are significantly limited by the quality of services, including their frequency, safety, and reliability. Moreover, problems tend to disproportionately afflict low-income groups, who tend to live in remote areas where they can afford housing. Such peripheral areas often have poor road infrastructure and are difficult and expensive to serve via formal public transit systems. In addition, they offer limited local job opportunities. According to a study of three large cities in the region (Mexico City, Bogotá, and Santiago de Chile), accessibility to jobs in a 60-minute commute is significantly higher when private rather than public transportation is used (see Figure 4.4 for the case of Bogotá) (ITF, 2020), even considering factors such as peak-hour congestion and time spent searching for parking. Deficiencies in public transportation are often filled by informal

[4] Even as developed countries increasingly seek to encourage less polluting and healthier means of transportation, such as biking and walking, cities in Latin America and the Caribbean are not conducive to their adoption. Bike sharing is still low in the region, at an average of 2.2 percent (exceptions include Bogotá at 5 percent and Rosario at 5.3 percent) (Rivas, Suárez-Alemán, and Serebrisky, 2019b). In Europe, this figure is 8 percent (TNS Opinion and Social, 2014).

Figure 4.4
Jobs Accessible within 60 Minutes in Bogotá



Source: ITF (2020).
Note: blank areas correspond to cells with no population record or cells that lack suitable for driving roads.
Urban center refers to high density urban cluster (1,500 inhabitants per km^2).

transportation modes, such as vans and minibuses. In Bogotá and Mexico City, these alternative vehicles make another 40 percent of jobs accessible (ITF, 2020).

The Big Picture of Access

The portrait painted above shows a range of access gaps in the region that vary according to the standards adopted by each country. Even using basic measures, however, the region has significant catching up to do, in particular in sanitation, the use of clean cooking fuels, and adequate public transport services. Governments also need to contend with the significant discrepancies in coverage that exist across localities and income groups. In urban areas, disorderly growth poses severe challenges to service extension, in particular where infrastructure relies on large and disruptive construction, such as for water and sanitation networks, roads, and public transport systems. In rural and peri-urban areas, time and resources need to be invested in tailored solutions.

Closing the gaps will require more than just new physical infrastructure. Often, behavioral and cultural norms keep people from using physical infrastructure or from adopting practices that make access meaningful. Access to water, for example, only brings health benefits if paired with good hygiene practices, such as hand washing. Reluctance to connect to existing sewer networks is common in the region. Not only do the benefits not accrue to the population, but the service provider fails to receive a return on its investment. Learning what works to overcome these obstacles requires rigorous evidence and policy experimentation (see Box 4.2).

Box 4.2

Innovative Solutions that Promote Access

Latin America and the Caribbean has made tremendous advances in furthering access to services, but extending water and sanitation, energy, and transport networks over the "last mile" becomes harder and more costly. Moreover, the approaches that worked well in the past may not be suitable to the areas that remain out of reach. Applying new technologies and creative solutions is the key to success. Cable cars in La Paz-El Alto in Bolivia and photovoltaic systems in Peru are examples of how innovative solutions in the region can help improve access, especially for low-income groups.

Designing and developing a modern transportation network in La Paz–El Alto was an urban planning nightmare. Despite being contiguous cities with a high level of economic interaction, the commute between them had long been complicated by geographical barriers. Many sections of road were unpaved and featured steep slopes and poor drainage, creating high congestion rates. Traditional solutions such as bus rapid transit (BRT) or subways were technically unfeasible or prohibitively costly. Inspired by a pioneer project in Medellin, in 2011 the Bolivian government decided to try a new approach and construct an extensive urban cable car network called "Mi Teleférico" that has now become

Figure 4.2.1
Savings from Mi Teleferico in Bolivia

Source: Based on Suárez-Alemán and Serebrisky (2017).

CABLE CAR USERS OF MI TELEFÉRICO IN BOLIVIA SAVE 22 PERCENT ON TRAVEL TIME, A NET BENEFIT OF US$0.54 PER TRIP

the biggest of its kind in the world. The scale of the project is huge: in the first five years after its inauguration in May 2014, the system had transported more than 200 million passengers, 70 percent of whom were low-income people (Mi Teleférico, 2019).

Mi Teleférico is a success story. It is estimated that after the implementation of the first three lines, Mi Teleférico reduced travel times by an average of 22 percent compared with other transportation services (Suárez-Alemán and Serebrisky, 2017). The time savings translated into a net benefit of US$0.54 per trip for users, encouraging them to switch from private to public transport (Figure 4.2.1). Moreover, Martínez, Sánchez, and Yañez-Pagans (2018) found that the time saved was reallocated primarily to educational and recreational activities, improving quality of life and human capital formation. Users have also augmented self-employment activities and income, potentially because of their improved access to labor markets. Last but not least, the principal beneficiaries are the residents of El Alto, which has a higher proportion of low-income and indigenous households.

Peru has made the most progress in expanding access to electricity services. Between 2000 and 2018, access rates rose from 64 percent to 97 percent (Sanin, 2019). Peru's success can be traced to a number of key factors. The state i) assumed a leading role in investing in extending energy access to the poor; ii) applied targeted subsidies to promote access among the most isolated and lowest-income populations, and; iii) involved beneficiaries in installing and operating off-grid energy solutions. These off-grid solutions included specific programs to increase the use of decentralized renewable energy in rural areas.

Table 4.2.1
Photovoltaic Policies in Peru

Program details	Results in terms of electrification
Photovoltaic program for areas not connected to the network, Social Inclusion Energy Fund (FISE), 2012-present	
• It enabled affordable access by subsidizing renewable energy.	• By 2017, the program had set up photovoltaic panels in 26,544 homes in rural areas, connecting a total of 106,000 inhabitants.
ACCIONA Microenergía Perú (AMP), 2009-present	
• ONG, created by the Spanish group ACCIONA and led by the Energy and Water Foundation, rents individual photovoltaic systems for a monthly rate of US$3 for 20 years, which constitutes the life span of the panel.	• As of 2018, the program had reached 4,000 households, 17 community centers, and 12 Centros Luz en Casa (i.e., small businesses) in the isolated areas of Cajamarca department. • The program involves communities in the installation and operation of panels.

Source: Based on Sanin (2019).

Service Quality: A Widening Gap

The actual benefits that result from access to infrastructure services hinge greatly on the quality of the services delivered. A sizeable proportion of the population in Latin America and the Caribbean suffers from discontinuities in regular service and unplanned interruptions. These service deficiencies generate significant costs to society. At the household level, users waste time waiting for services or procuring alternative sources. At a broader level, interruptions in electricity and water service can disrupt the functioning of critical facilities like schools and hospitals. Inadequate public transportation services increase reliance on private vehicle usage, which impacts negatively on traffic, commuting times, and the environment.

A growing population, rising incomes, and climate change will place services under severe stress. Vehicle ownership is increasing, and cities are becoming more congested. Extreme weather events can disrupt service and further deteriorate existing infrastructure. The longer governments wait to act, the costlier it will be to bring about solutions.

On-and-Off Quality of Electricity Services

Frequent and prolonged interruptions in electricity supply can take their toll in financial losses and well-being. Frequent interruptions can damage appliances while lengthy interruptions can lead to spoiled food, exposure to extreme temperatures, or the inability to perform needed activities such as housecleaning and studying. Lengthy interruptions hurt industries, disrupt traffic—especially at intersections with traffic lights and at airports—and negatively affect critical services such as hospitals.

The System Average Interruption Frequency Index (SAIFI) and the System Average Interruption Duration Index (SAIDI) are commonly used to evaluate the quality of electrical supply. The SAIFI measures the frequency of interruptions and the SAIDI measures the average total duration of an interruption over the course of a year for each customer served. Countries in the region had 16 nonprogrammed interruptions in 2018 with a duration of 33 minutes on average. The mean is very high compared with developed countries but varies widely among countries (Figure 4.5).

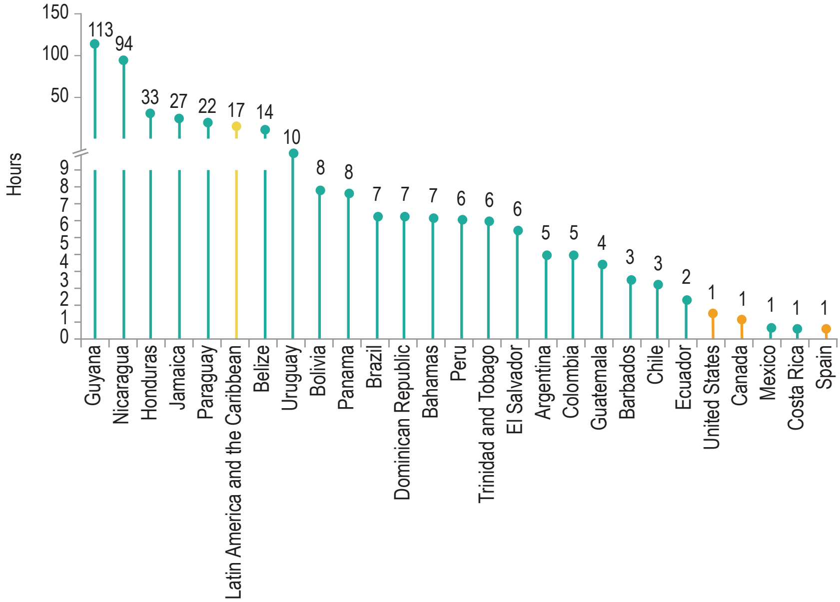
Water Quality: More than a Bad Taste

Lack of water service on a daily basis makes it difficult to achieve the required minimum deemed necessary to meet basic needs. According to 2019 World Development Indicators data, unsafe water, unsafe sanitation, and lack of hygiene are responsible for 1.67 deaths per 100,000 population in the region.[5] By 2020, more than 9,000 lives per year would be saved if the region could raise the quality of its water services to European levels. Lack of continuous access to water also means users are likely to store it in tanks,

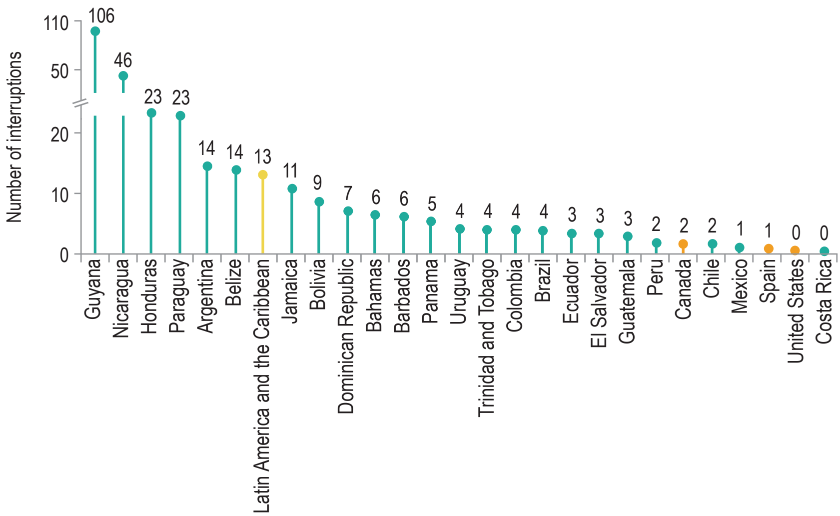
[5] In the European Union, this figure is 0.26. The estimate only takes into account "diarrheal diseases, intestinal nematode infections, and protein-energy malnutrition."

Figure 4.5
Average Annual Duration and Frequency of Interruptions in Power Supply, 2019

Panel A. Average annual duration of power interruptions (SAIDI)



Panel B. Average annual frequency of power interruptions (SAIFI)

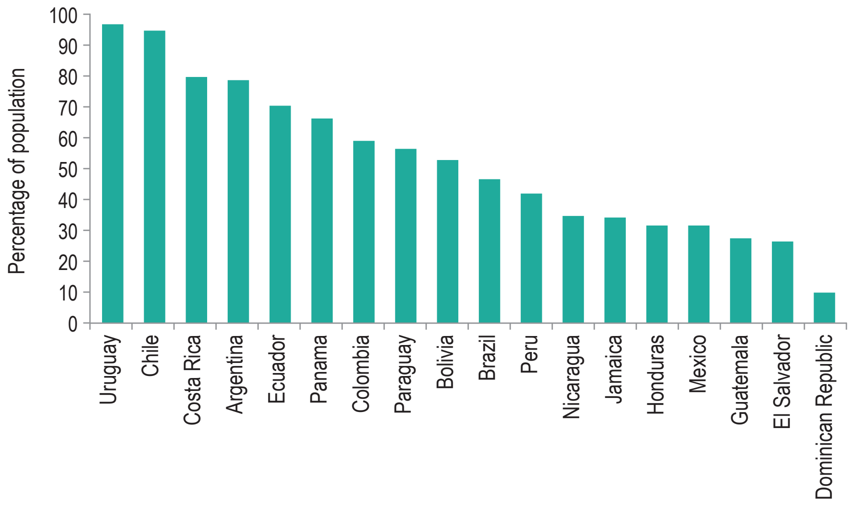


Source: Based on 2019 data from World Bank's Doing Business database.
Note: SAIDI measures the hours per interruption. SAIFI measures the number of interruptions per year.

so it is available as needed. However, tanks are often not washed enough or do not offer sufficient protection to prevent contamination before use.

Based on interviews with a representative sample, the Latin American Public Opinion Project (LAPOP) finds that people with access to piped water report high rates of intermittent supply and unscheduled interruptions. In some countries, including the Dominican Republic, El Salvador, Guatemala, Honduras, and Mexico, AmericasBarometer 2018–19 data show that more than 20 percent of the population do not receive adequate water services two or more days per week, and on average, service can be as short as half a day. The percentage of people without access to water services 24/7 is quite high in many countries, led by the Dominican Republic (at 90.1 percent) (Figure 4.6). Most people in several countries suffer from both intermittent supply and

Figure 4.6
People with Access to Water Service 24/7



Source: LAPOP AmericasBarometer survey, 2018–19.

unscheduled interruptions, which tend to disproportionately afflict poorer households (Gómez-Vidal, Machado, and Datshkovsky, 2020).

A key quality indicator relates to the properties of the water being provided. The most important aspect is safety, that is, whether the water is clean and free from contaminants. Consumption of bottled water, which is high in the region, is an indicator of the poor quality of piped water. According to AmericasBarometer 2018–19 data, for example, 81 percent of respondents in Mexico reported access to piped water, while 77 percent reported drinking bottled water. In many places, a lengthy process between initial extraction and final consumption exposes water to several risks. Low rates of wastewater treatment, inadequate disposal of solid waste, heavy metals, and pesticides that run off into rivers from agriculture and mining, and extreme weather events, all contribute to the deterioration of water sources and the subsequent ineffectiveness of their treatment. Even if the initial treatment is successful in removing contaminants and producing high-quality water, run-down distribution systems with old, broken pipes and irregular water pressure, expose water to contamination and impurities. At the household level, poor water storage and water-handling practices have been shown to pose significant risks to users (Jeuland et al., 2020). Moreover, contamination can come from unexpected sources, such as the expansion of sewage infrastructure; a recent study using district-level panel data in Peru found that districts in which multiple sewerage expansion projects had been undertaken suffered a 6 percent increase in the under-five mortality rate compared to districts with fewer or no such projects, mainly due to the higher risk posed during the construction stage (Bancalari, 2019).

Box 4.3

Using Performance-based Contracts to Increase Service Efficiency

Performance-based contracts and regulations have been successfully used to increase the efficiency of service provision and boost the revenues of service providers while improving the quality of service. Two examples stand out: Ecuador's regulations to lower electricity losses, and the Bahamas' performance-based contracts for reducing nonrevenue water (NRW).[a]

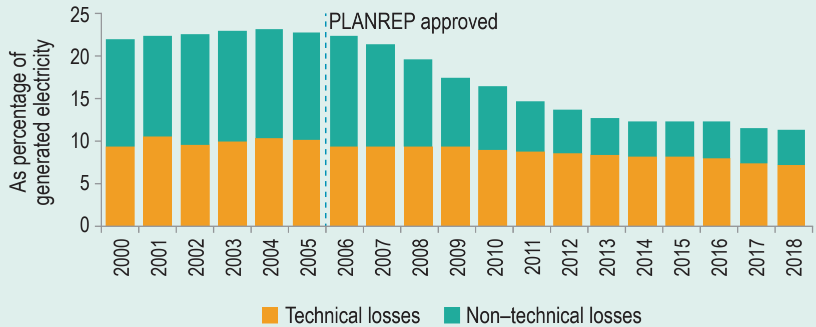
In Ecuador, several steps were taken to achieve policy goals. First, in 1999 a "quality of technical service" regulation made distribution companies responsible for compiling data on the frequency and duration of interruptions. In the case of noncompliance with regulatory limits, the distribution company was fined by the regulatory agency. Later, in 2006, an electrical losses reduction plan (Plan de Reducción de Pérdidas, PLANREP) was approved with the specific purpose of reducing nontechnical losses, meaning electricity used but not paid for. During the first years of its implementation, meters were systematically changed to improve control of theft and remote metering. In 2011, penalties for electricity theft and abolition of land squatting were implemented, and meters were placed outside homes to facilitate more frequent and accurate inspections. The regulation also

[a] Nonrevenue water (NRW) is water that is produced but lost due to physical losses from leaking and broken pipes, or commercial losses caused by the under-registration of customer meters, illegal connections, and theft.

gave companies responsibility for surveying customers about service quality. This comprehensive plan had results along several dimensions: nontechnical losses decreased from almost 13 percent in 2006 to only 5 percent in six years (Figure 4.3.1); between 2011 and 2015, the duration of interruptions fell by 67.6 percent; and the frequency of interruptions dropped 59 percent from an average of 26 to 11 per year.

Another success story was the use of performance-based contracts (PBCs) in The Bahamas. New Providence Island had endemic problems with water quality, low pressure, and occasional rationing, as well as ever-increasing NRW quantities. In 2008–09, the utility (Bahamas Water and Sewerage Corporation) developed a comprehensive plan for NRW reduction and control including technical interventions under a PBC. The PBC reduced NRW through i) a baseline study and target/plan adjustment period; ii) definition of a minimum scope, combined with flexibility for the contractor to adjust plans to the evolving situation, to both exceed targets and receive additional performance-based remuneration; iii) rapid NRW reduction, with its technical, financial, and political benefits; iv) reduced project risks for the utility; v) a lengthy maintenance phase to promote sustainability of the NRW reductions; and vi) overall improvement of technical and financial performance at a competitive price. The results were sound: between 2013 and 2019, the utility reduced NRW from 54 percent to only 23 percent, a value that is in line with the best-performing utilities in the region (Figure 4.3.2).

Figure 4.3.1
Electricity Losses in Ecuador Following the Implementation of PLANREP

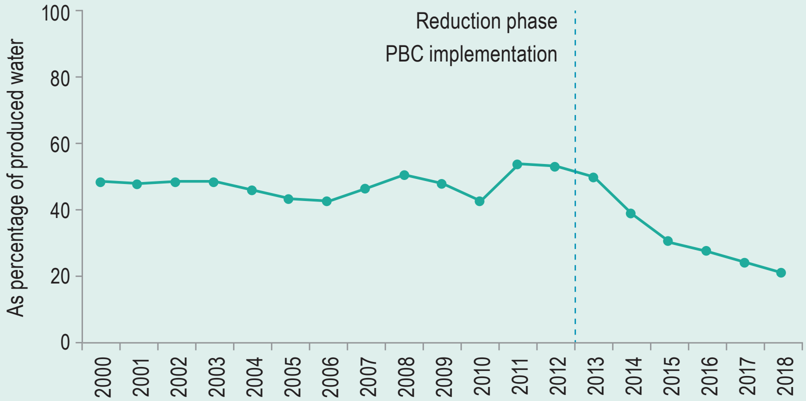


Source: Sanin (2019).

Urban Transport Quality: A Long Way to Go

The quality of urban transportation services in the region is poor. People in the region take longer to travel shorter distances than people in advanced economies (Figure 4.7). The average work commute in the region's cities is

Figure 4.3.2
Nonrevenue Water in the Bahamas before and after Implementation of a PBC



Source: Based on data from The Bahamas Water and Sewerage Corporation.

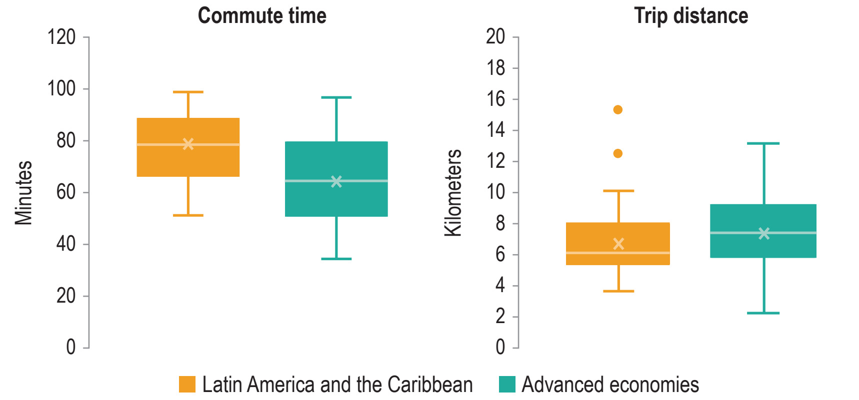
77 minutes. In many cities in the region, from more populated ones such as Bogotá, Colombia, to less populated ones such as Manaus, Brazil, and from established megacities such as São Paulo, Brazil, to rapidly expanding urban areas such as Lima, Peru,[6] the average daily commute can take longer than 90 minutes; according to 2019 data from the Moovit Public Transit Index, 30 percent or more of users report travel times that exceed two hours.

Although most people in the region's cities use public transportation, the share of public relative to private transport is decreasing. In most countries, motorization rates have grown at an average annual rate of 4.7 percent in the past 10 years. In 2015, the average motorization rate reached 201 vehicles per 1,000 inhabitants. Although this figure remains below the averages for Europe (471 vehicles per 1,000 inhabitants) or the United States and Canada (805 vehicles per 1,000 inhabitants), its growth rate is one of the highest in the world (together with Asian and Middle Eastern countries) (Rivas, Suárez-Alemán, and Serebrisky, 2019a).

In European cities, the trend is toward fewer car trips and greater use of public transportation and walking. The opposite is occurring in Latin America and the Caribbean (Figure 4.8). In some cities, the share of public transportation use has been cut in half. Increasing motorization and a

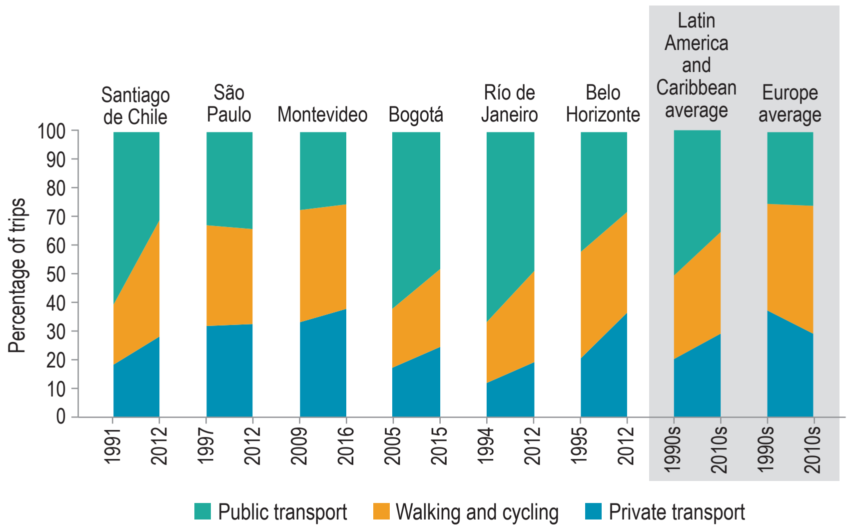
6 Other cities in the database where travel times often exceed 90 minutes include Brasília, Goiânia, Recife, Rio de Janeiro, Salvador, and São Luis (all in Brazil).

Figure 4.7
Commute Times and Trip Distances Using Public Transport: Latin America and the Caribbean vs. Advanced Economies



Source: Rivas, Suárez-Alemán, and Serebrisky (2019a).
Note: Data based on a weekday. Simple average of 52 Latin American and Caribbean cities and 67 advanced economies' cities reported by Moovit in 2019. Box and whisker chart: The length of the box represents the interquartile range (difference between quartiles 3 and 1); the mean is shown as a cross, and the median is shown as the middle line of the box. The lines extended vertically represent the "whiskers," indicating variability outside upper and lower quartiles. Any point outside the whiskers is considered an outlier and is represented by dots.

Figure 4.8
Mode of Transport Shares in Selected Cities



Source: Rivas, Suárez-Alemán, and Serebrisky (2019a).
Note: Comparisons among cities are limited by differences in methodologies and timing of surveys. Private transport includes cars and motorcycles. Cities included in the European average are Amsterdam, Berlin, Copenhagen, Hamburg, London, Munich, Paris, Stockholm, Vienna, and Zurich.

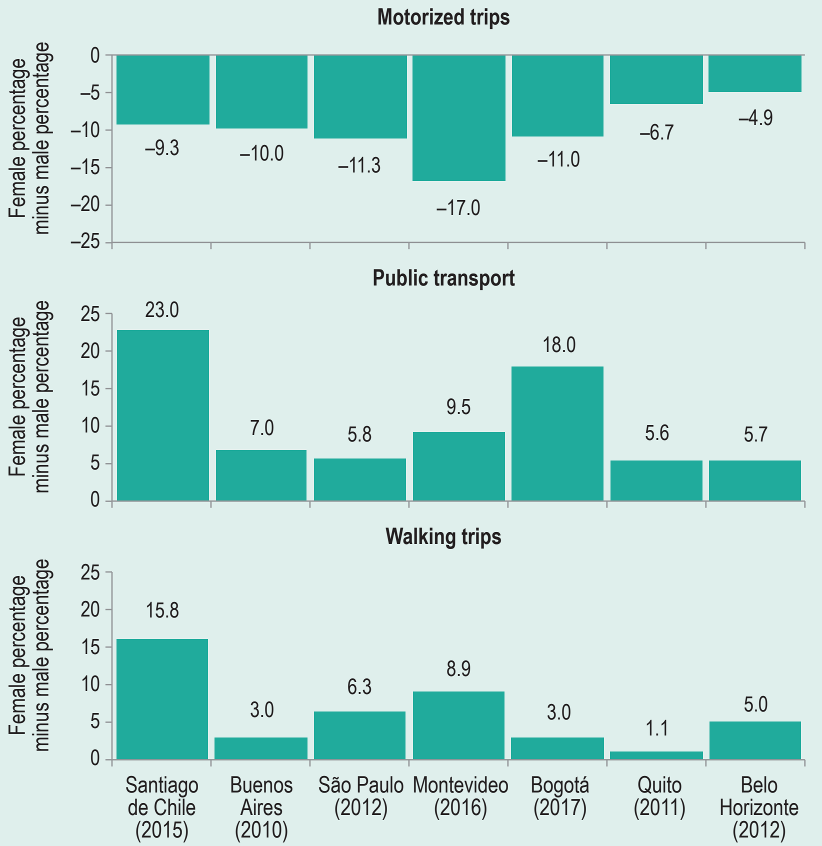
public transit system of poor quality (in terms of travel time, comfort, and safety) generates a vicious circle whereby users shift from public to private transportation as soon as they can afford to purchase a vehicle. It takes a combination of swift policy action and investment in mass public transport systems to break this vicious circle (see Box 4.4, and also Chapter 10).

Box 4.4

Neglecting Gender in Transport

Transportation services are not gender neutral. Women and men have different mobility patterns: women usually make more trips, at more dispersed times throughout the day. Women use significantly more public transportation and

Figure 4.4.1
Gender Differences in Mobility Patterns in Selected Cities



Source: Rivas, Suárez-Alemán, and Serebrisky (2019a).

walk more, whereas men are more likely to drive (Figure 4.4.1). This pattern reflects economic and cultural factors, among others, and can be observed, for example, in the distribution of driver's licenses by gender: female driver's licenses represent a mere 30 percent of the region's total (Rivas, Suárez-Alemán, and Serebrisky, 2019a).

Although more than 50 percent of the users of regional public transport systems are women (52 percent in Buenos Aires, 51 percent in Mexico City, 53 percent in Quito, and 52 percent in Santiago de Chile) (Granada et al., 2016), the characteristics of their mobility and their travel needs have not been systematically considered. Often, public transport services do not meet the standards of quality, safety, and comfort required by women. Since women often travel with small children, strollers, shopping bags, or elderly relatives, they are particularly inconvenienced by overcrowded and nonaccessible transport systems. As a result of multiple transfers or little to no integration of transport systems, women end up paying more and travelling longer distances, and finding that their physical and occupational mobility is more limited than men's (Granada et al., 2016).

Safety is another important concern; sexual harassment disproportionately affects women. Six out of ten women in the region's cities have suffered some form of sexual violence, whether physical or verbal aggression, on public transport. In Santiago de Chile, 59 percent of women surveyed had suffered physical or verbal violence on public transport. Rates in other cities around the region are even higher: Bogotá (64 percent); Mexico City (65 percent); Quito (67 percent); and Buenos Aires (80 percent) (IDB, 2018).

In response to the decline of urban transport, countries in the region have adopted a diverse set of policies to improve public transport networks, of which bus rapid transit (BRT) systems are the most striking example (see Box 4.5).

Box 4.5

Reducing Travel Times with Bus Rapid Transit Systems

Latin America has pioneered the implementation of bus rapid transit (BRT) systems. The first BRT was implemented in the region in the 1970s in Curitiba, Brazil. Since then, the TransMilenio in Bogotá revolutionized the industry by moving 45,000 passengers per hour per direction (Gómez-Lobo and Barrientos, 2019). According to 2019 Global BRT data, Latin America and the Caribbean now leads the world with approximately 1,900 kilometers of BRT networks in 55 cities and 10 countries—Argentina, Brazil, Chile, Colombia, Ecuador, Guatemala, Mexico, Panama, Peru, and Venezuela. Overall, the systems have positively impacted travel time, transport costs, the environment, and accidents (Hidalgo and Carrigan, 2010).

BRT systems have improved the quality of service of public transport in the region, especially by reducing travel time. An IDB evaluation of Cali's and Lima's BRT systems reveals significant savings in travel time (Table 4.5.1). The Metropolitano BRT system in Lima has cut the previous average travel time of three to four hours down to two hours for some individuals, while the Masivo Integrado de Occidente (MIO) BRT system of Cali offers time savings of up to 35 minutes for people in the lowest- and highest-income populations, and up to 25 minutes for individuals in middle-income groups (Scholl et al., 2016). Although both systems reported significant savings in travel time overall, limited use among poor households living in feeder areas remains a challenge.

The region's first BRT systems were designed as closed systems that operated exclusively in segregated infrastructure (buses never mixed with other vehicles). In recent years, however, open BRT systems have been introduced to provide more flexibility by allowing BRT buses to serve stops located in non-segregated infrastructure.

Gómez-Lobo and Barrientos (2019) advocate for open BRT systems in transport reforms because of their flexibility. Open BRT systems do not increase transfers, are easy to implement, shorten riders' travel time, and reduce the operating costs of service providers (owing to higher speeds). They argue that this alternative is especially important to consider in small cities. Examples of open BRT systems in the region include Metrobus in Buenos Aires and segregated central-lane BRT and segregated corridors in Gran Concepcion (Chile), which were implemented without changing how buses operated before the BRT system was built (Gómez-Lobo and Barrientos, 2019). In Buenos Aires, Metrobus has reduced travel times by 20–50 percent (Rivas, Suárez-Alemán, and Serebrisky, 2019b).

Table 4.5.1
Impact of BRT Systems on Travel Times in Cali and Lima

Metropolitano, Lima	MIO, Cali
Time savings: • Overall: Average network time savings of around 7 minutes for all income groups • Extremely low-income group (Stratum E): up to 28 minutes in some zones • Low-income group (Stratum D): up to 32 minutes in some zones • Lower-middle-income group (Stratum C): up to 34 minutes in some zones	Time savings: • Overall: time savings of at least 11 minutes for 90 percent of the poorest population • Low-income group (Stratum 1): up to 35 minutes in some zones • Middle-income group (Strata 2 to 5): up to 25 minutes in some zones • Highest-income group (Stratum 6): up to 35 minutes in some zones

Source: Scholl et al. (2016).
Note: Lima is divided in five socioeconomic strata where E=lowest and A=highest. Cali is divided in six socioeconomic strata where 1=lowest and 6=highest.

Affordability: The Blind Spot of Services

In a region where a sizeable share of the population is poor, being unable to pay for needed services is a day-to-day struggle for many people. Lack of access and low-quality services, too, can pose a considerable burden on the finances and well-being of users. They need to find alternative ways to meet their needs, ways that might be less safe and more expensive. The weight of these burdens, however, depends on the context. The data and insights provided below refer to the affordability of formal services provided continuously over time, in pursuit of the goal of universalizing access to quality services. The extent and the determinants of the affordability problem vary considerably by city and sector, and call for tailored solutions. Of the three sectors analyzed, transportation represents the heaviest burden for consumers in the region.

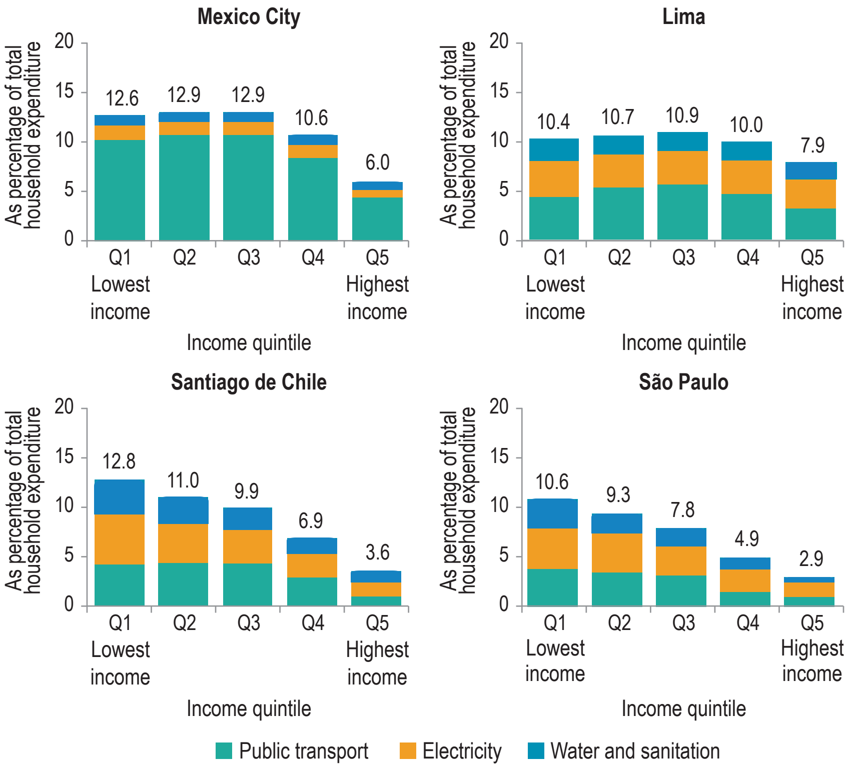
While the capacity to pay for connections and services is a key aspect of affordability, it is not the only one. Another relevant issue is the quantity of services poor households require relative to their richer counterparts. Financial constraints may actually mean that poor households need to spend more on services than do wealthier households. Living in a peripheral urban area, where housing is more affordable, means longer and more costly commutes. The inability to buy new energy-efficient appliances means low-income households need more energy to run older models. Poorer households may, in fact, require larger quantities of services to enjoy benefits comparable to more affluent households. All of these issues contribute to the affordability problem in the region.

Measuring Affordability: Basic Metrics and their Limitations

The most basic measure of affordability is the share of household income allocated to a particular service. As shown in Chapter 1, this measure reveals that households in Latin America and the Caribbean devote a larger share of their income to infrastructure services than their peers in other developed and developing regions of the world, and that this difference is more acute, the poorer the household is. Moreover, the regional average hides variations across countries, not only in the total amount that citizens spend on services, but also on the composition of that expenditure (Figure 4.9).

There is no consensus on how big expenditure on those services should be for the average household since many factors influence such an estimate: the quality of the service, the efficiency of the providers, and policy decisions on how much of the service costs should be recovered through consumer fees, among others. Despite this limitation, each sector uses some benchmarks as general guidance in signaling affordability problems. In the transport sector, the threshold is generally 15–20 percent of household income in developing economies (Estache, Bagnoli,

Figure 4.9
Expenditure on Infrastructure Services, in Megacities of Latin America and the Caribbean



Source: IDB staff elaboration based on Household Expenditure Surveys (2017 for Santiago de Chile, 2018 for Lima and Mexico City, 2019 for São Paulo).

and Bertomeu-Sánchez, 2018).[7] In the energy sector, spending levels above 10 percent of household income are flagged as a problem (Boardman, 1991). In water and sanitation, the threshold is between 3 percent and 5 percent (OHCHR/UN-Habitat/WHO, 2010; Fankhauser and Tepic, 2007). Affordability thresholds are usually set independently of one another: even if none of a sector's expenditures exceed the established

[7] There are some important caveats to the estimation of expenditure thresholds in transportation. Most methodologies include spending on cars, for example, which reflects taste more than need. Moreover, given that transportation costs go up with distance, it can be misleading to look at transportation thresholds without taking housing expenditures into account, as affordable transportation may involve expensive housing, and vice versa.

benchmarks, allocating almost one-third of a household's income to just three services may prove impracticable for many low-income families.

Based on the analysis of household expenditure surveys[8] in the region, on average, the percentage of household's expenditure on infrastructure services is below the established thresholds in each sector. However, this statistic likely underestimates the problem for several reasons. First, actual expenditure does not include forgone consumption to keep the bill manageable.[9] Second, it ignores fare and bill evasion, either in the form of payment defaults or illegal use of services. Additionally, service prices may be lower than the cost recovery level; despite an alarming lack of evidence on the cost of service provision, the scant evidence on subsidies indicates that average prices of services are below their cost (see Chapter 1). These are not small problems in the region.

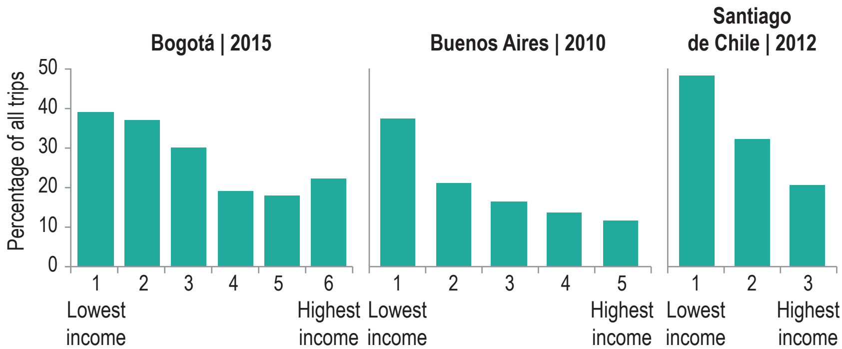
The proportion of poor people who walk, rather than use public transportation, is one example of forgone consumption. An analysis of modes of transportation by income quintile in a sample of cities in the region finds that about 40 to 45 percent of all trips taken by low-income people are on foot (Figure 4.10). The figure for higher-income groups is between 10 and 20 percent. Thus, people may sacrifice motorized trips because of affordability, becoming "captive" walkers over relatively long distances (Venter and Behrens, 2005; Falavigna and Hernández, 2016). Considering that most economic activities and job opportunities tend to be concentrated in the urban center, low-income residents may be limited to informal or lower-paid jobs closer to their place of residence in the outskirts.

Fare and bill evasion can be significant in services. In 2016, bus fare evasion was estimated at 27.6 percent in Santiago de Chile, 15 percent in Bogotá, 12 percent in Buenos Aires, and 10 percent in Lima (Troncoso and de Grange, 2017). Guarda et al. (2016) find that fare evasion in Santiago de Chile is higher at bus stops located in low-income areas, suggesting a link between fare evasion and the inability to pay for bus fares. Electricity losses in the region are double the worldwide average, and only a few countries have shown improvement between 2004 and 2014. In general,

8 The variation in the share of household expenditure allocated to services between countries is partially explained by methodological issues. Estimates of actual expenditures on services are often inaccurate, as they rely on household surveys and, therefore, on respondents' accurate recollection of the amounts of their bills.

9 In energy, for example, according to the Latinobarometro, 63 percent of the region's population reports having trouble sleeping at night due to extreme temperatures, which in many cases is because they cannot afford climate control equipment and the associated electricity needed to run it (Corporación Latinobarómetro, 2018). Moreover, many survey respondents reported having difficulty paying their electricity bill.

Figure 4.10
Share of Walking Trips in Transport, by Income Level



Source: Rivas, Serebrisky, and Suárez-Alemán (2018).
Note: Figures show trips in which walking was the main transportation mode, except in Buenos Aires, where figures include people who walked just part of the trip. The number of income levels varies among the cities shown depending on the socioeconomic stratification of each city.

a significant portion of those losses is nontechnical, meaning electricity used but not paid for. In 2006 in Ecuador, for example, more than half of the losses were nontechnical (Sanin, 2019).

Illegal connections to water systems, also common, pose two aggravating problems. Because they are not professionally built, they tend to leak more than regular connections and expose water to higher risks of contamination. Leaks at connection points contribute significantly to the problem of nonrevenue water (NRW), which is serious in the region. The percentage of water that is extracted and treated by utilities but not paid for is estimated at 40 percent in the region (GRTB, 2017). Variation across and within countries is immense. Just within Brazil in 2017, NRW estimates ranged from 26 percent to 75 percent across states, whereas internationally accepted levels are around 10 to 15 percent (SNIS, 2019).

Households that cannot afford connection rates often turn to low-quality solutions that, in some cases, may end up costing more than conventional ones. It is not uncommon for those without access to water to rely on private suppliers that charge more than water utilities and offer no quality control (Huberts, 2019). Furthermore, poor households with access usually cannot afford water-saving devices, such as dual-flush toilets or washing machines, and suffer a higher incidence of leaks. All lead to higher consumption. But even for those with fewer resources, this is not a hopeless situation: low-cost efforts can reduce overconsumption with positive consequences for affordability (see Box 4.6).

Box 4.6

Behavioral Interventions to Reduce Water Consumption

In Belén, Costa Rica, a study found that despite broad consensus on the importance of water conservation in general, few residents believed that they needed to use less water (Datta et al., 2015). Belén sought to reduce household water consumption by randomly communicating in one of three ways with households. Households received a message telling them that they were either i) conserving more or less water than the average of the households in their neighborhood, or ii) more or less water than the rest of the households in the city. The third method of communication was a postcard along with their July 2014 bill. The postcard featured a worksheet that prompted them to enter their water consumption and compare it with that of the average Belén household in the same month.

The study found that households that received the messages featuring a neighborhood comparison and plan-making reduced their water consumption by statistically significant levels, while the city comparison had no significant effect. The neighborhood comparison reduced average monthly water consumption between August and September 2014, by 0.98 and 1.47 cubic meters per household or between 3.7 percent and 5.6 percent of water consumption relative to the control group. Instead, the plan-making intervention reduced con-

Figure 4.6.1
Notification of a Household's Water Consumption Relative to Its Neighborhood

Source: Datta et al. (2015).

sumption by 0.90 and 1.49 cubic meters, or 3.4 percent and 5.6 percent, relative to the control group. It was found that the plan-making intervention was most effective among low-consumption households, and the neighborhood comparison was most effective among high-consumption households. If all households in Belén received the treatment, 6,720 cubic meters of water could be preserved in a single month. This figure is equivalent to 94,080 washing machine loads, 188,000 showers, or 222,000 dishwasher loads.

Tackling Affordability to Meet Basic Needs: Measurement and Policy Options

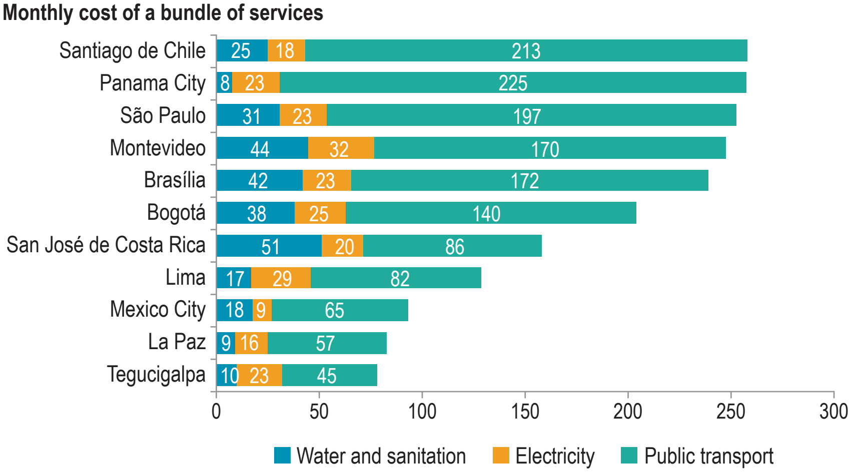
An alternative way to understand the extent of the affordability problem is to simulate spending on infrastructure services. The simulations consist of determining how much it would cost a family of four to procure a “basket” of services considered necessary to meet basic needs, an exercise similar to that of national bureaus of statistics to track the evolution of inflation of a consumption basket. The monthly quantities (basket) considered for this exercise are 18 m^3 of water, 150 kilowatt-hours (kWh) of electricity, and 180 transport trips (45 trips per person per month in a household of four[10]).

Once the basic basket of services is determined, the second task is to collect the corresponding prices. In the case of electricity, prices are relatively uniform at the national level. In the case of transportation and water, however, the variation across municipalities is remarkable. Therefore, prices are collected for a sample of cities in the region. The results of this exercise are shown in Figure 4.11. Both simulated total expenditure and sectors vary widely across the region. Total expenditures range from US$78 for Tegucigalpa to US$256 for Santiago de Chile, with transport representing the largest category across cities. But spending also varies significantly across cities in each sector: paying 18 m^3 of water in San José, Costa Rica, costs 6 times more than in Panama City, and making the same number of trips on public transportation in Santiago de Chile costs 4 times more than in Tegucigalpa.

This approach to quantifying affordability bypasses some of the measurement issues raised earlier. First, since it looks at a fixed basket of basic

10 These bundles correspond to what a family of four, composed of two adults and two children, would need to spend in order to satisfy its basic infrastructure needs. This basket is only one of many possible, but the general results presented in this section are robust using other reasonable definitions of basic infrastructure services.

Figure 4.11
Simulated Monthly Cost of Infrastructure Services, 2018 (US$)



Source: IDB staff elaboration based on information from utilities and city governments.
Note: Cost of 180 bus trips, 18 m³ of water, and 150 kilowatt-hours (kWh) of electricity in one month in US$. These bundles correspond to what a family of four would need to spend in order to satisfy its basic infrastructure needs.

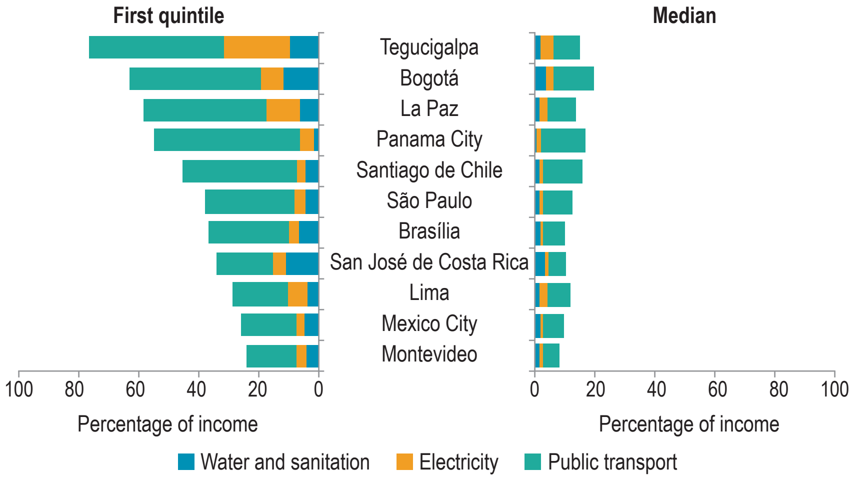
services, this approach avoids the problems related to bill evasion and forgone consumption due to lack of income. Second, as service prices are collected from the actual prices for each service, it avoids the biases introduced by self-reporting typical of household surveys. Third, since the same consumption basket is assumed for each country and city, the results are more comparable.

Unfortunately, this effort to enhance comparability falls short for two reasons: the role of supply-side subsidies and the huge disparities in service standards. Most service subsidies in Latin America and the Caribbean are given directly to providers and are, thus, impossible to separate from the calculations. Brichetti and Rivas (2019a) highlight that direct subsidies to services are, on average, 0.6 percent of GDP in the region. That is, the prices set for services are usually lower than the level required for cost recovery. And given the wide variation by country and service in the level of subsidies and the profit margins allowed service providers, the comparison of prices may be distorted.

Another factor that affects comparability is the variation in quality standards under which services are provided. For example, paying a water and sanitation bill in Mexico or Chile includes paying for the cost of properly treating a large proportion of wastewater; in most other countries in the region, the service does not cover this feature and is, therefore, not included in the bill. In that sense, paying a certain share of income could be cheap or expensive depending more on the quality than the quantity of services received.

Finally, the extent and severity of poverty in the region's cities also vary tremendously. Coupled with variations in prices, the magnitude of the affordability problem and its potential solutions will also vary significantly across cities. Figure 4.12 displays how much of the average income of the

Figure 4.12
Monthly Expenditure on a Simulated Bundle of Services in Selected Cities, 2018



Source: IDB staff elaboration based on income information from National Household Surveys; and service tariffs and fees from utilities and transport service operators.
Note: Tariff levels include supply-side but not demand-side subsidies. Calculations are based on a family of four consuming 150 Kwh of electricity per month and 18 cubic meters of water (150 liters of water per person per day), and making 180 public transit trips (45 trips per person per month).

poorest and of the median households in each city is spent on the minimum bundle of infrastructure services. Water and sanitation, electricity, and transportation services can eat up anywhere from 25 percent to 75 percent of a four-member, poor household's income if it does not receive demand subsidies[11]. Cities like Tegucigalpa, where poverty is high, face serious affordability

[11] Some cities in the region provide demand subsidies based on geographical zones, personal characteristics (such as age and education status), consumption, or income. This type of subsidies may improve infrastructure services affordability of those users receiving the benefits. However, the impact of demand subsidies in the region is limited considering that they represent a small share of total subsidies and they are not well targeted to reach the poor.

problems despite low prices. It is important to understand these results correctly: if the simulations indicate that in Tegucigalpa a household in the lowest quintile needs to use more than 75 percent of its income for a minimum bundle of services, then the simulation is indicating that these households cannot actually pay for those services. From an inequality perspective, not being able to pay is the same as lack of access for the poor.

The bottom line of this analysis is clear: the region faces serious affordability challenges, even though governments are allocating abundant resources to subsidize services. That many countries in the region still have much to do to improve service quality exacerbates the situation. Solving the puzzle of how to provide better (and likely more costly) services without compromising affordability for the poor will require increasing the efficiency not only of service provision, but also of the use of public funds. Better-targeted demand subsidies must be part of the solution (see Box 4.7). Inherent problems of comparability and lack of political willingness to report information on prices and costs of services may help explain the impressive lack of affordability benchmarking studies in Latin America and the Caribbean. Better information is needed for policymaking to adequately address the service problems that feed inequality and exclusion in the region.

Box 4.7

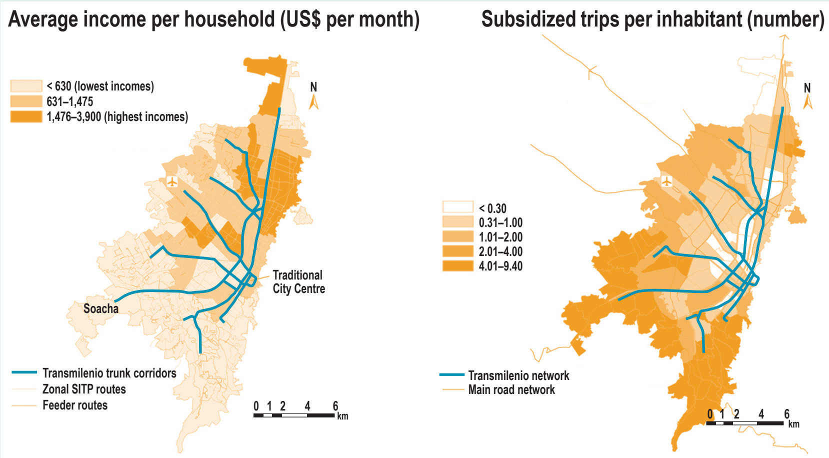
Expanding the Policymaker's Toolkit: Demand-Side Subsidies to Tackle Affordability

Making services affordable is a multidimensional problem. It depends on local geographical characteristics as well as general considerations such as the kind of service being provided. It requires efficient service providers, but also demands public funds. Subsidies can and should play a role in making services affordable, especially for the poor. The key question is, which type of subsidies most effectively fulfill their purpose? In this regard, demand-side subsidies are underexploited as a tool in Latin America and the Caribbean.

Demand-side subsidies are recommended over supply-side subsidies chiefly because they target beneficiaries (Serebrisky et al., 2009). In the past, supply-side subsidies were preferred and justified on the basis that implementing demand-focused transfers was difficult; most schemes focused on simple, observable criteria. But things have changed: the development of smart technologies has helped improve operating efficiency, pricing flexibility, and the targeting of subsidies (Gwilliam, 2017).

Colombia provides a good example of how demand-side subsidies can be applied (Figure 4.7.1). In 2014, a pro-poor public transport subsidy was implemented in Bogotá through a national social policy targeting mechanism, SISBEN, which

Figure 4.7.1
Targeting Subsidies in Bogotá: Average Income per Household and Subsidized Trips per Inhabitant Are Mirror Images



Source: Guzmán and Oviedo (2018).
Note: SITP stands for the Spanish initials of the Integrated Public Transportation System.

enables planners to classify beneficiaries and allocate subsidies. The system considers several socioeconomic characteristics of individuals and households to build a score, which is a proxy of poverty (Guzmán and Oviedo, 2018). Based on this targeting mechanism, the current structure of subsidies and alternative scenarios for increasing their coverage show that both are progressive and positively impact accessibility and equity for beneficiaries (Guzmán and Oviedo, 2018). Furthermore, the policy helped increase monthly trips by 56 percent among subsidy beneficiaries (Rodríguez Hernández and Peralta-Quiros, 2016).

Argentina has also made efforts to target its energy subsidies by establishing a federal social tariff for residential users in 2016. By 2015, Argentina was making transfers to gas and electricity companies of 2.9 percentage points of GDP with few conditions. This scheme had detrimental effects on sectoral sustainability and efficiency. The discretional management of energy prices sent distorted signals that led to overconsumption and underinvestment in the sector (Barril and Navajas, 2015). The challenge was to reestablish market price signals and reduce the fiscal burden, both of which required rapid tariff hikes without compromising affordability for poor and lower-middle-income households. In this context, in 2016, the federal government introduced a demand subsidy ("social tariff") that included some income thresholds (two minimum wages), among other conditionalities, as requirements to benefit from the policy. This policy endowed a pro-poor profile to the subsidy scheme (particularly in gas, where the poorest 20 percent received 36 percent of the total subsidies) and reduced the total amount of subsidies by 1.6 percent of GDP by 2018 (Giuliano et al., 2018).

The Irony: Mediocre Services, But Political Apathy

While some access gaps remain, the real challenges for the region are quality and affordability. Meeting some of these might involve a complex set of incentives, such as pricing schemes that encourage transportation choices that help lower traffic and emissions. Some options call for significant investments, such as the rehabilitation of water and sanitation systems. The location of households most affected by gaps in quality and affordability also matters.

Making the necessary changes and investments takes political will. The perceptions and political attitudes of end users are critical to holding politicians accountable. Inherent in any representative form of government is the problem of multidimensional preferences. Individuals have preferences over an array of policies and areas, but are usually constrained to a few votes when choosing their political representatives. Achieving representation across all these dimensions is thus impossible. Therefore, the weight of particular issues in political choices will depend on their relative, rather than absolute, importance to voters. The issues voters rank at the top are the most likely to guide their decisions and, therefore, to become the yardstick for accountability.

In this race for attention, infrastructure suffers. Consistently, over more than a decade, when asked about major problems facing their country, individuals in the region mention first and foremost issues related to the economy, violence, and corruption (LAPOP surveys). In a voting experiment using a representative sample of the Mexican and Brazilian populations, candidates running on an infrastructure or environmental platform, all else being equal, gathered 15 percent and 20 percent fewer votes, respectively, compared with platforms emphasizing employment or education (Machado, Huberts, and Kearney, 2019). These rankings highlight the difficulty of encouraging political action to improve services.

Not only does infrastructure rank low among people's priorities, but levels of satisfaction with the current state of affairs are surprisingly high, despite shortcomings in quality. This means that electoral returns from improvements are limited, in particular from the many low-visibility investments required.

Interviews with Mexicans and Brazilians in 2016 unveiled high rates of satisfaction with water services, at 75 percent and 70 percent, respectively (Huberts, Machado, and Kearney, 2017). A study of Bolivia, Brazil, Chile, Ecuador, Panama, and Uruguay in 2018–19 reveals similar levels of satisfaction with specific attributes of piped water. An average of 75 percent approved its taste, 80 percent its cleanliness, and 82 percent its pressure. When it comes to electricity services, an astounding 96 percent reported satisfaction with the reliability of services, and 92 percent were satisfied with customer service in case of interruption (Gómez-Vidal, Machado, and Datshkovsky, 2020).

The sector viewed more negatively is transportation. Overall, only 37 percent of surveyed people in cities rated their satisfaction with the urban bus system as good or very good, with significant differences across city sizes (Juan et al., 2016). In mid-sized cities, 50.6 percent of those surveyed indicated that they were satisfied with the bus system, while in megacities, the figure dropped to 34.6 percent. The situation is worse for transport users with long commutes. In Mexico City, São Paulo, Buenos Aires, Bogotá, and Lima, transport is the second-highest urban priority, below public safety, for users travelling more than one and a half hours per day (Serebrisky, 2014). It seems the sector has reached a relatively low threshold that has tipped the balance toward greater dissatisfaction and criticism.

Infrastructure services' low political salience and people's complacency regarding their quality are not unique to the region. Historically, the largest interventions establishing urban sanitation systems were prompted by serious public health crises, such as cholera outbreaks in New York and London (Ashraf, Glaeser, and Ponzetto, 2016). One explanation is that a lack of experience with higher-quality services leaves people without a meaningful reference point. Similarly, it is often an abrupt drop in access or quality of service that prompts more critical evaluations and a change in infrastructure's political importance. Over 10 years of public opinion polling in the region, conducted by the LAPOP, infrastructure was among the top priorities only in Haiti after the devastating earthquake in 2010.

In such a scenario, reliance on political accountability mechanisms to promote the necessary changes may prove insufficient. A question that arises is whether population and urbanization growth, rising incomes, and climate change are likely to contribute to lowering satisfaction levels and increasing the political salience of these issues. Population growth automatically places current systems under higher strain by the sheer increase in the number of users. According to 2018 UN data, these challenges are likely to amplify in the near future with urbanization rates predicted to reach almost 84 percent by 2030, and 88 percent by 2050. But waiting for matters to get worse to take action may be too little too late.

Climate change can have mixed repercussions on the political salience of infrastructure services. On the one hand, by exposing existing systems to extreme conditions it can cause breakdowns and deteriorate assets. The resulting impact on service quality can be significant and fuel criticism and pressure from users for improvements. On the other hand, problems that stem from climate change tend to blur and complicate accountability. Floods and droughts leading to water service interruptions are caused by a mix of environmental factors (climate change and degradation) and poor service management. The relative contribution of each factor is difficult to estimate for a long-time researcher, let alone for the average user. In the opinion of people in the region, according to the LAPOP data, floods and droughts resulting in service interruptions are believed to result from climate change or human action, while blackouts are mostly blamed on providers.

From the perspective of decision makers, earning political support in such a context may require actions that are clearly visible or whose benefits are directly and easily perceived by citizens. In such cases, the incentive is to prioritize short-term wins, rather than long-term investments that take time to yield benefits. They may also favor new construction over spending on the maintenance of hidden pipes and roads or on protection of the environment. Moreover, given the prevalence of pocketbook voting—that is, voting for the candidate that provides the highest financial benefit—political decisions over pricing risk being skewed toward low levels that can threaten cost recovery and the rational use of the resource. The social protests in the region blamed on increases in public transportation prices (e.g., Chile in 2019) or on the removal of fuel subsidies (e.g., Ecuador in 2019) are testaments to the political weight that infrastructure prices carry. It is difficult to strike the right balance between the financial sustainability and quality of the services rendered, and the price that users must pay for them.

In the absence of bottom-up incentives, the necessary changes must come from the top. Governments need to take the lead in ensuring coverage and quality of services. In some cases, for example in extending access to rural populations, a centralized approach may be viable. The variety of solutions required to solve the last-mile problem may prove too heavy a burden for local governments, while offering the possibility of scale gains from centralized planning.

5

Rapid Technological Change: Past and Future

In 1873, Jules Verne set his novel *Around the World in 80 Days* in a world full of marvels.[1] But the fantastic world Verne described was not fictional; it was none other than the world Verne was living in as he wrote his literary classic. Just a few years before its publication, the first high-speed communication between North America and Europe took place thanks to the transatlantic telegraph cable (1858); the first transcontinental railroad in America was completed (1869); India's railways linked the subcontinent (1870); and the Suez Canal provided a shortcut to the Northern Atlantic by joining the Mediterranean with the Red Sea (1869). Because all these events had made the world smaller, the remarkable voyage of Phileas Fogg and Passepartout was not science fiction at the time Verne wrote his novel. A few years later, journalist Nellie Bly actually made Fogg's trip in just 72 days—visiting Verne along the way (Bly, 1890). To most people, of course, these new developments may have *seemed* like science fiction. The transport and communication services that allowed Fogg to win his wager had been unknown a generation before. A combination of novel technologies (such as steam machines mounted on wheels or boats) and large infrastructure investments (including channels, railways, and bridges) had radically changed how communication and transport services were provided.

Jules Verne knew that technology and infrastructure are closely linked. And since then many more have confirmed his observation. Infrastructure can determine the direction and intensity of technological progress across productive sectors. For instance, the availability of roads and railroads stimulated the adoption of productivity-enhancing technologies in

[1] Much of the text of this chapter comes from Murphy (2020) and Puig Gabarró (2019), both background notes commissioned for the preparation of this DIA.

agriculture since it gave farmers access to new markets. And infrastructure often ends up adapting to the needs of technological innovations. For instance, the development of jet airplanes led to the demand for paved runways.

The links between technology and infrastructure will be paramount in coming years, as our world undergoes a transformation as disruptive as the one that shaped Jules Verne's time, especially in transport and energy. Many headlines focus on innovations related to transportation such as autonomous, connected, electric, and shared (Chapter 10). Similarly, profound changes are also expected in the energy sector thanks to the growing efficiency of renewable energy sources (such as solar and wind power) and the greater capabilities and lower cost of storage devices. The governance of these sectors is also likely to evolve. Traditional electric utilities that have been monopoly providers and managed centralized distribution networks could see their size and business models change radically as a result of intense competition from "prosumers" (households and firms generating and trading electricity) (Chapter 9). And the infrastructure subsectors will be increasingly interconnected. Communication technologies will be a key input and enabler of innovations in transport, energy, and water services. Without adequate communications infrastructure, countries will be unable to take advantage of the positive effects that technological change can have on the accessibility, quality, and cost of infrastructure services. In some ways, digital technologies are expected to "uberize" infrastructure services.

Because these changes are at least as sweeping as those that inspired Jules Verne, they are bound to generate anxiety, especially in markets like Latin America and the Caribbean that have hardly changed in decades. While most of the changes will produce positive payoffs, like new jobs in the digital industry, more efficient and environmentally friendly transportation networks, and more resilient energy services, some may also produce negative effects, such as lower public revenues from gasoline taxation, job losses in the auto industry supply chain, and a higher incidence of cyber-crimes and thefts of personal data. In many ways, these negative effects should be viewed as transitional costs, but government action will be needed to ease these costs.

Subsequent chapters argue that, sooner rather than later, the positive changes generated by technology could more than compensate for these transitional negative impacts. But these payoffs depend on a strong commitment to support the changes—something that is largely missing in the region. Most Latin American and Caribbean countries are behind in adopting new technologies (most notably broadband) that can help unleash productivity gains as well as higher and better shared growth prospects (see Chapter 12). An outdated communication infrastructure in most countries of the region is holding back the technological changes needed to improve infrastructure services. The opportunity to improve the global competitiveness of the region and the local well-being of its population depends on a willingness to make the most of technological change in communication infrastructure as other regions have done.

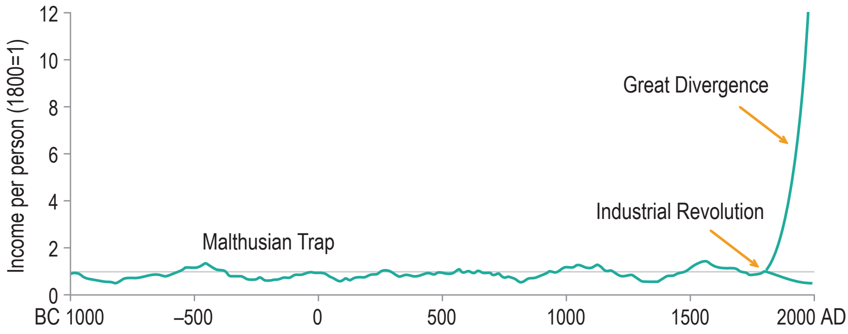
Every country must craft its own approach to adopting disruptive technologies. This chapter explores the challenges the region must address to prevent its communications infrastructure from holding back the technological changes needed to improve infrastructure services. History shows how high the return to massive technological change in infrastructure can be if managed properly. It also highlights how easy it is to miss opportunities as a result of inertia and business-as-usual approaches. Finally, history teaches how relatively small changes in mindsets can lead governments to make the most of these opportunities. Change is not easy, but it is possible. More importantly, it is surprisingly sensitive to the political willingness to make it—or simply let it—happen. The political economy of change, along with details on the management of change in the infrastructure sector, may be one of the main historical lessons presented in this chapter.

Infrastructure, Technology, and Growth

For most of human history, little changed in how people lived. Until about two hundred years ago, standards of living varied somewhat from one society or period to another, but there was no general long-run trend. Some people lived better in the Late Middle Ages than did their peers in ancient Rome, but the average person was no better off, still living at subsistence level. However, sometime around 1800 this changed; an era of unprecedented growth and prosperity began.

The hockey-stick pattern of long-run stagnation (the shaft of the stick) with a recent, sudden outburst of growth (the blade) is commonly associated with the income-per-person graph of Clark (2007), reproduced here in Figure 5.1, but it can be replicated using other proxies for the standard of living such as real wages, population growth, and urbanization, or anthropometric measures (e.g., human height or life expectancy). The main message is that income per capita remained largely at subsistence level for a long time, with only marginal or temporary improvements in the standard of living during the period known as the Malthusian Trap. Then—barely two centuries ago—this ceased to be the case. An era of sustained growth began in some regions of the world in the wake of the

Figure 5.1
Income per Person, 1000 BC to AD 2000



Source: Clark (2007).

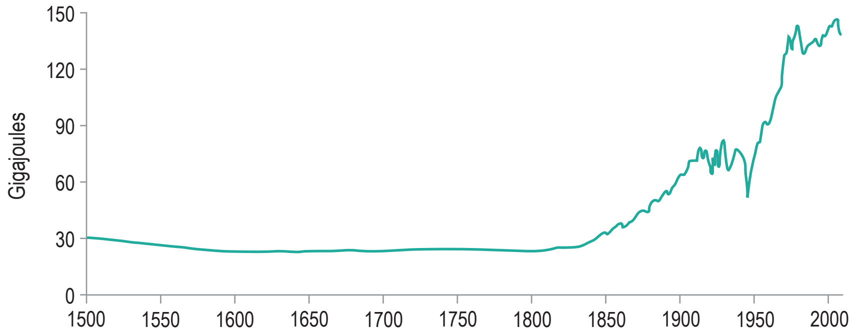
Industrial Revolution, creating a great divergence in global incomes. It is generally agreed that economic growth during the so-called Great Divergence was driven largely by the constant technological change and rapid innovation characteristic of the Industrial Revolution.

Although no other single event has been more studied in economic history, the Industrial Revolution still generates heated debate. Was there an actual "revolution?" How widespread was it? Why then? Why England? None of these questions is entirely answered in the literature, but the discussion has generated countless insights. For one, if ever there was a "disruption," this was it. And most of the technological disruptions and innovations related to providing infrastructure services.

Technological change had a disruptive impact on how energy was harnessed. The incredible economic progress of the last two hundred years could not have been achieved without greater access to energy, which in pre-industrial times imposed a serious limit on growth. The new technologies opened up the use of energy carriers (e.g., coal, oil, or natural gas) that had previously been used only marginally, as well as entirely new sources, notably electricity (Kander, Malanima, and Warde, 2013). As Figure 5.2 shows, the consumption of energy exploded as it became increasingly cheap.

The method of harnessing energy that kicked off the Industrial Revolution was the steam engine. Steam revolutionized many industries, but arguably its effect on transport was of the greatest consequence for the economy at large. Infrastructure investment in the form of river channels and turnpikes helped expand markets in pre-industrial times, but steam engines in boats and locomotives took expansion to another level. Steamships came

Figure 5.2
Energy Consumption per Capita in Europe, 1500–2000



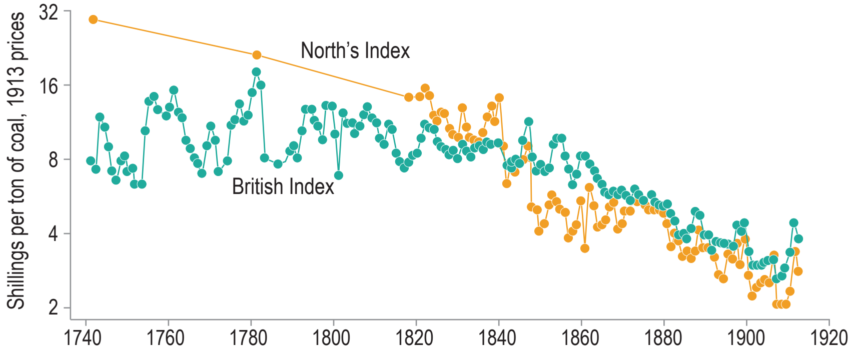
Source: Kander, Malanima, and Warde (2013).

first. The first commercial ships appeared in rivers in the early 1800s, and the first steamship crossing of the Atlantic took place in 1838. Latin America and the Caribbean was not immune to this technological change, although it came late to the party. Steam-powered navigation of the Magdalena River (1824) allowed Barranquilla to become a major hub for Colombia's tobacco and coffee exports during the nineteenth century, enabling inland producers to access international markets (Posada-Carbó, 1996).

Railroads took longer to get started because they required additional infrastructure. The first intercity train service, between Manchester and Liverpool, began only in 1830. But soon thereafter rail mileage expanded rapidly in Britain to 6,600 miles in 1850, 15,500 in 1870, and 20,000 in 1890. Expansion was even faster in the United States (9,000, 52,900, and 116,700 miles, respectively) (O'Rourke and Williamson, 1999). Again, with a delay and on a much smaller scale, Latin America and the Caribbean built the infrastructure to take advantage of steam-driven locomotion. Argentina was an early adopter in the region, inaugurating its first railway in 1857 and expanding the network to 10,000 miles by the end of the nineteenth century (Lobato and Suriano, 2000).

Subsequent innovations, like the introduction of refrigeration systems, expanded the variety of goods that could be carried by trains and steamships. These improvements were accompanied by large infrastructure projects, such as the opening of the Suez Canal in November 1869, which cut the trip from London to Mumbai from 12,300 miles to 7,200 miles. The impact on transport costs was substantial, as Figure 5.3 shows. Freight prices plummeted from the early 1800s, fostering an era of ever-decreasing transport costs that continues today.

Figure 5.3
Evolution of Freight Costs, 1741–1913



Source: Harley (1988).
Note: North's Index was constructed to estimate shipping contributions to the U.S. balance of payments, so the costs assumed are weighted in proportion to U.S. exports. British Index uses data from the most important British shipping routes for the late eighteenth and nineteenth centuries. The weighting in the index approximately reflects the employment of British shipping in the early nineteenth century. Indices were deflated by the U.K. gross national product deflator and are shown in a ratio scale.

The Impact of Technological Change: Mostly Good, But Not for All

Without a doubt, technological change in infrastructure has brought enormous benefits to society. William D. Nordhaus, Nobel Laureate in Economics, has documented the remarkable increases in productivity associated with technological improvement. In his famous exploration of lighting (Nordhaus, 1996), he compares quantities of light in lumens (a measure of the total quantity of visible light emitted by a source) with the corresponding amounts of heat, measured in British thermal units.[2] For most of human history, artificial light came from burning wood, which is a highly inefficient source of light: An open fire gives off just 0.69 lumen-hours per thousand BTUs, whereas a mid-nineteenth-century kerosene lamp yielded 46.6. The first lamps produced by Edison in 1883 yielded 762 lumen-hours per thousand BTUs; a compact fluorescent bulb in 1992 produced 20,011 (Nordhaus, 1996). That is, using the same amount of energy, a fluorescent bulb produced nearly 30,000 times more light than burning wood.

But if technology is so good, why does it generate cultural anxiety? There are two main reasons (Mokyr, Vickers, and Ziebarth, 2015). First, innovations that are now ubiquitous were initially opposed on moral grounds or out of fear of change. Cars caused a certain amount of terror

[2] A BTU is the amount of heat required to raise the temperature of 1 pound of water by 1 degree Fahrenheit.

when they first appeared. A generation before, in 1881, a writer complained in the *New York Times* that "the bicycle [is] the most dangerous thing to life and property ever invented. The gentlest of horses are afraid of it.[3]" And there is a tendency to identify new technology as a privilege for the rich. When news of the first telephone conversation between Europe and America appeared in 1914, the *Gettysburg Times* reported on July 10 that the "wireless telephone will be too expensive to become a public service, but it will be a boon to privileged persons.[4]"

The second group of anxieties relates to whether the new technology will substitute machines for human labor. Does it? As vividly described by Schumpeter (1942), technology is the driving force behind creative destruction. The old is replaced by the new. One of Schumpeter's most famous examples pertains to the Illinois Central Railroad replacing mail coach (Andersen, 2002). As railroads expanded, so did many activities around them, beginning with the actual manufacture of trains and the railways on which they traveled. Then there were the products to be transported, and the networks that connected producers and customers to the railroad. All of these activities added up to regional development. At the same time, however, many types of farming and agricultural systems in the U.S. Midwest were destroyed. As new and more efficient means of transport were created, an entire way of life disappeared. The mail coach was just one direct victim. Farmers moved from subsistence farming, growing crops that they needed, to more commercial farming, growing crops for the market that could be transported by rail.

The types of employment that are actually destroyed are not always clear. Acemoglu (2002) argued that the nature of this process changed radically from the nineteenth to the twentieth century. Between the first Industrial Revolution and the second (1870–1914), the process was largely one in which machines replaced skilled labor. The greatest concern about employment effects currently centers on automation, in particular on low-skilled and middle-skilled workers whose tasks are prone to being replaced by sensors, robots, and algorithms. The effects of automation on infrastructure services are expected to be widespread, ranging from automated water sensors that will replace the measuring formerly done by humans to artificial intelligence that can respond to the claims of unsatisfied energy users; the effects of automation on transport services are expected to be among the strongest. While automation will reduce the costs of mobility and logistics and, consequently, boost disposable income and competitiveness, it will

3 "A Test Bicycle Case.; Shall the Machine Be Allowed in Central Park?" *New York Times*, July 15, 1881.

4 "Wireless Telephone for Wealthy Only," *Gettysburg Times*, July 10, 1914.

certainly reduce employment (e.g., as drivers become redundant). Chapter 10 explores the potential extent of job losses in the automotive industry and in urban transport and freight. New jobs will certainly be created in services associated with the new technology, but many workers stand to lose their present employment. Training programs and safety nets will have to be deployed to mitigate and compensate for the loss of employment.

The Infrastructure-Technology Link

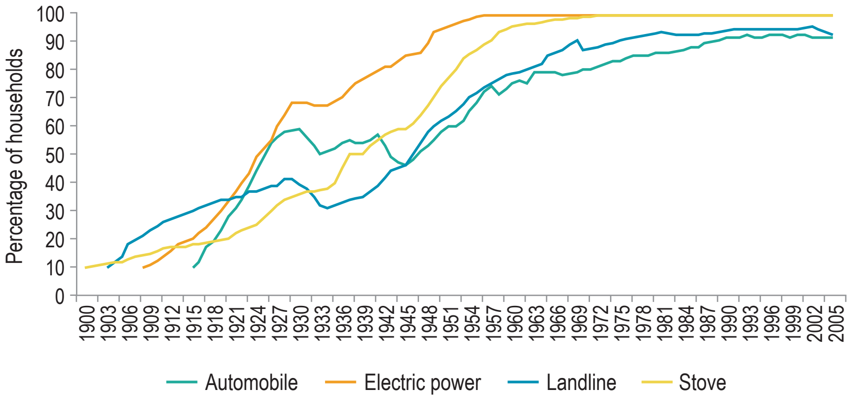
The previous discussion focused on the role of technology and infrastructure as sources of growth, stressing their symbiotic relationship. Indeed, technology, infrastructure, and infrastructure-based services are intimately linked in many ways. For one thing, technological improvement, paired with infrastructure, invariably leads to the creation of a new service:

> Nineteenth-century Europe saw a massive expansion of railway track, telegraph lines, electricity stations and cables, gas and water works and mains, followed at the turn of the century by tramways and telephone lines. Apart from water supply, these infrastructure industries were offering new services based on technological innovations. (Millward, 2005)

Although the most common assumption about the relationship between infrastructure and services is that infrastructure leads to new services, the relationship between them is rather fluid, with services promoting infrastructure and vice versa. The telegraph (technology) did not need the communication grid (infrastructure) to be invented, but the grid was needed to provide large-scale communication (service). Likewise, roads or airports were not necessary for the invention of cars or airplanes, yet they were absolutely necessary for consumers to adopt the new inventions.

Both the quantity and the quality of infrastructure affect the rate of technology adoption. For society to profit the most from a new technology, the infrastructure must be right, as illustrated by the rapid adoption of electrical gadgets once the electrical grid was set up and the proliferation of cars once road networks were in place. Figure 5.4 presents the evolution of technology adoption for several items in American households over the twentieth century. The patterns are somewhat similar, but some items required more infrastructure than others. Stoves, for example, do not need infrastructure, and their rate of adoption was largely determined by the alternative sources of heating available. At the other end of the spectrum, electricity and telephones require a grid, and the speed

Figure 5.4
Technology Adoption by Households in the United States, 1900–2005



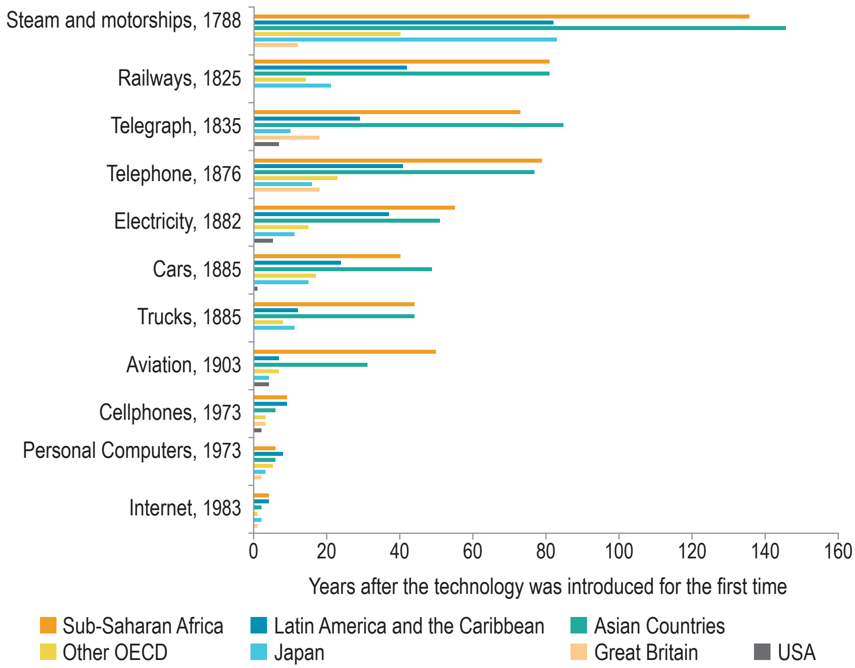
Source: Authors' elaboration based upon information in https://www.visualcapitalist.com/rising-speed-technological-adoption/.

with which that grid was built determined the rate of adoption. In the case of the telephone, adoption was particularly slow. The telephone was invented in 1876, but 75 years later, more than half of households still had no telephone. Telephones need a massive infrastructure as their usefulness depends on network effects: others need a phone for you to call them. Electricity also required massive infrastructure but did not face the same network problem, which probably explains why adoption was faster. Automobiles present an interesting case because part of the infrastructure was already in place—albeit for horses and carriages—so early adoption was relatively easy. After the initial adoption, road improvements and automobile technology had to co-evolve to make additional adoption worthwhile.

The process of co-evolution of technology, infrastructure, and services is far from uniform, and in many cases, technologies are never adopted due to delays in infrastructure development. In other cases, infrastructure becomes redundant because technology did not develop as initially expected. The *idroscalo* of Milan, Italy, is an example of how technology does not always develop according to plans. Located near one of Milan's current airports (Linate), the *idroscalo* is an artificial lake that opened in 1930 as a seaplane airport, at the peak of the seaplane rage. But seaplanes for passengers never really took off, and the lake became a recreational and sport facility. More recently, during the 1990s many Latin American countries adopted public policies to provide (subsidized) rural public fixed telephony. Although initially successful in providing access to telecommunication services to isolated rural populations, fixed telephony technology was quickly superseded by the more convenient personal mobile telecommunications, which made the previous investments obsolete. Both examples highlight the importance of carefully considering the risks of committing public resources to a particular infrastructure in the context of evolving and fast-moving technological environments.

Two dimensions of technology adoption are relevant here. The first relates to when the technology becomes available and is used for the first time; the second relates to how fast it spreads among its potential users. Understanding how Latin America and the Caribbean has performed historically in diffusing newly invented technologies is crucial to assessing the impact of future innovations on productivity and the quality of life. The historical record is important, since past delays are good predictors of future gaps in the adoption of technological advances.[5] Figure 5.5 presents the time intervals between discovery and the first introduction of several infrastructure-related technologies in various regions of the world.

Figure 5.5
Delays in the Diffusion of Infrastructure-Related Technology, by Region



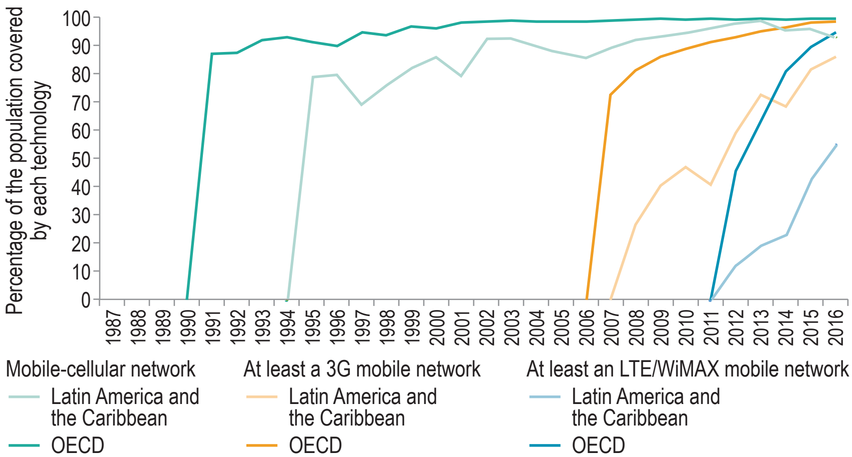
Source: CEPE/AC&A (2019), based on information from Comin and Hobijn (2010).

5 Comin, Easterly, and Gong (2010) present evidence of the importance of past technology adoption to determine current uses of technology.

The average lag in technology diffusion has decreased over time all over the world, but somehow the reduction has been smaller in Latin America and the Caribbean than in other regions, such as East Asia. The adoption of communications technology provides a good example. It took Latin American and Caribbean countries 41 years on average to adopt telephones after their first commercial use in the United States in 1878, while it took some of the most dynamic Asian economies (Hong Kong, Korea, and Singapore) 74 years to reach the same milestone. A century later, the adoption time gap for cellular phones was 6 years for the same Asian economies, but 10 years for Latin America and the Caribbean.

The infrastructure of digital connectivity will play the role that the electrical grid played a century ago, acting as a material constraint on the adoption of new devices and technologies that will transform productivity and the quality of life. Without access to connectivity and to the broadband services it enables, Latin America and the Caribbean will be at a disadvantage, as infrastructure services will be of lower quality and more expensive. The time lag in deploying the most recent standards for mobile telecommunication in Latin America and the Caribbean has almost disappeared; however, the speed of diffusion and the intensity of use remain a problem, as many people in the region are slow to adopt or are totally left out (Figure 5.6).

Figure 5.6
Delays in Deploying Mobile Telecommunications Technologies, Latin America and the Caribbean vs OECD, 1987–2016



Source: ICT Indicators (WTI); International Telecommunications Union (ITU), https://www.itu.int/en/ITU-D/Statistics/Pages/publications/wtid.aspx.

The links between technology and infrastructure will be much in evidence in coming years, as the world experiences disruptive transformations in energy and transportation. To take full advantage of disruptions, digital connectivity is essential. Without adequate communications infrastructure, countries cannot take advantage of the positive effects that technological change can have on the accessibility, quality, and cost of infrastructure services.

Digital Connectivity and Broadband: Getting Wired for the Future

Trying to guess the technological disruptions and innovations that will shape the provision of infrastructure services is an exercise in science fiction. But there is no doubt that access to digital connectivity will be indispensable. Autonomous vehicles, digital twin utilities, and trading of electricity generated by households and firms, just to name a few of the emerging technologies, will all require advanced, extensive, and reliable digital connectivity.

Information is most efficiently transmitted as digital data sent as electrical, optical, or radioelectric signals over a transmission medium (e.g., copper wire, fiber optic cable, or radioelectric spectrum). The infrastructure supporting the transmission media through which digital data flow, along with their transmitters and receivers, constitute the infrastructure of digital connectivity; that infrastructure provides digital connectivity services.

Digital connectivity infrastructure encompasses a wide range of technologies that make it possible to transmit data virtually anywhere. Since the early days of analog connectivity, deploying the infrastructure faced numerous challenges, most of them geographic, yet by the mid-nineteenth century, telegraph cables had been laid across oceans.[6] Today, the globe is interconnected by hundreds of submarine fiber optic cables,[7] thousands of satellites,[8] and countless microwave links (on hills), fiber optic cables (on electricity transmission towers and distribution poles), copper cables (in ducts), and mobile antennas (on rooftops). Thus, the availability of complementary technologies has made digital connectivity technically feasible almost everywhere.

6 In 1850, a submarine telegraph cable was laid between Britain and France; by the end of the nineteenth century, 15 transatlantic telegraph cables had been laid, https://www.itu.int/itunews/manager/display.asp?lang=en&year=2007&issue=02&ipage=pioneers&ext=html.

7 More than 400 active submarine cables are currently active, https://www.submarinecablemap.com/.

8 More than 100 new satellites are launched every year, http://www.eenewseurope.com/design-center/emerging-trends-satellite-communications-high-throughput-satellites-leo-meo-and-geo.

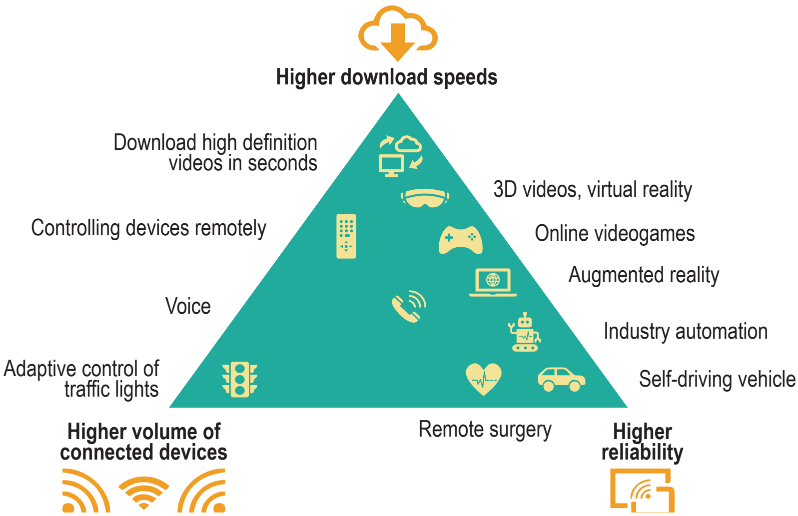
Traditional telecommunications services—including fixed and mobile telephony, SMS (messaging), fax, and TV and radio broadcasting—have converged into broadband services, which are becoming the new common platform for traditional telecommunications services. At the same time, digital services based on the Internet Protocol (IP) are becoming (quasi-)substitutable services: voice-over IP, messaging apps, email, online streaming of television and radio, and audiovisual content on demand. Thus, most new digital technology and applications requiring digital connectivity (such as the Internet of things) are being developed using the IP so as to run over broadband services.

Innovation across sectors is increasingly driven by digital technologies that require connectivity infrastructure. The growing capacity, speed, and affordability of digital data processing and transmission have triggered recent developments in digital technology, including augmented reality, virtual reality, real-time language translation, chatbots, robotics, artificial intelligence, machine learning, cloud computing, and autonomous vehicles. Two innovations that will be particularly important for infrastructure services are the Internet of things (IoT) and autonomous vehicles.

IoT application consists of numerous electronic devices (often sensors) exchanging information among them and with computing nodes. IoT devices can be installed in very different environments, such as large outdoor areas (water-level measuring sensors along a river), indoors (sensors to meter the power consumption of appliances), underground (water pipes), and on conveyances (ships and airplanes). Autonomous (self-driving) vehicles drive their autonomy from a built-in set of complex and constantly interacting sensing, communicating, and computing systems that enable precise automatic decision-making in real time. As more vehicles and roads become ready for autonomous operation, all these elements will interact to increase traffic efficiency and safety. Vehicles will continuously exchange data with neighboring vehicles to coordinate movements to avoid collisions, and vehicles will automatically read and act upon traffic signs and directions. For a massive rollout, both IoT and autonomous vehicles will require a high level of digital connectivity infrastructure and related services, including satellites serving large outdoor areas, wi-fi for buildings, and 5G for reaching underground devices and moving assets.

Innovations in digital connectivity technologies embedded in future infrastructure will enable a wide variety of new uses. For instance, 5G mobile broadband is the most promising cutting-edge digital connectivity technology because it has significantly improved (by orders of magnitude) the previous technology (4G) on several key performance dimensions such as download speeds, increased reliability, and the ability to manage a greater number of connected devices. These technology evolutions make 5G suitable for autonomous vehicles to interact in real time with other vehicles and traffic elements thanks to 5G ultra-reliable communications. It is also needed for countless IoT sensors and computing nodes to constantly exchange data, which is required for the development of energy markets with active trading by houses, firms and utilities. Hence, even what is commonly conceived of as a single technology actually offers a rich set of features that makes it a key enabler for a diverse portfolio of uses (Figure 5.7).

Figure 5.7
Digital Technologies Unleashed by the Adoption of 5G

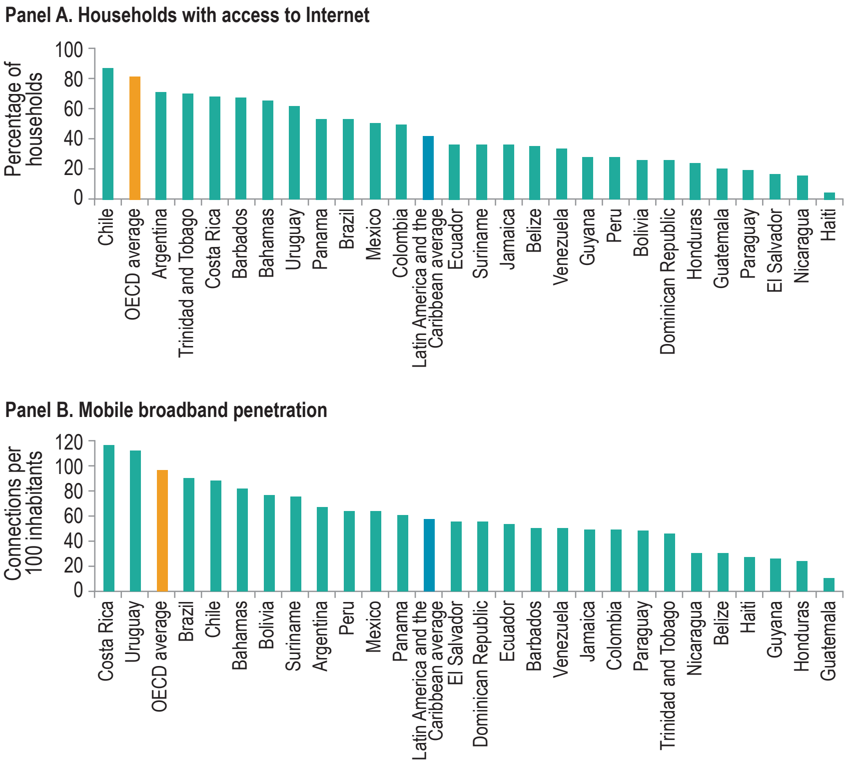


Source: Authors' elaboration based on ITU (2015).

To profit from future technological developments in infrastructure services, Latin America and the Caribbean will need to develop the necessary digital connectivity infrastructure. But availability of infrastructure will not be enough: users need the means to access the infrastructure and receive reliable and affordable connectivity services. An analysis of access indicators, however, shows that Latin America and the Caribbean trails OECD countries. Figure 5.8 illustrates the access gap: in Latin America and the Caribbean, only two-fifths of households have internet access and only two-thirds of the population have access to mobile broadband.

Access to digital infrastructure in Latin America and the Caribbean varies widely across countries and shares the same urban-rural access gap as other infrastructure services (see Chapters 1 and 4). Since investments in digital

Figure 5.8
Access to Fixed and Mobile Communication Technologies, Latin America and the Caribbean vs. OECD, 2018



Source: ITU World Telecommunication/ICT Indicators (WTI) database 2018.

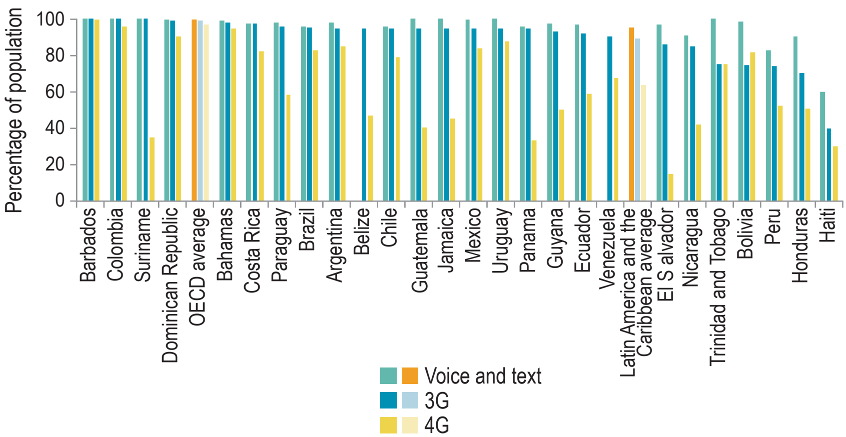
connectivity infrastructure tend to be recovered through user subscription fees, investors prioritize densely populated communities: deployment tends to start in urban areas (where it is close to 100 percent in most of the region), expanding from there to suburban areas, before eventually reaching rural areas. The result of this investment dynamic is that while the access gap in mature technologies such as mobile-cellular is almost closed (by 2017, about 89 percent of the rural population was covered by mobile-cellular networks compared with 93 percent in the OECD), it remains wide open in terms of the latest technologies (in the region, only 76 percent of the rural population was covered by a 3G network compared with 87 percent in the OECD).[9]

9 Authors' elaboration based on ITU World Telecommunication/ICT Indicators (WTI) database 2018.

Getting the most from digital technologies requires not only access to connectivity services but also proper quality standards. Available information reveals that Latin America and the Caribbean also has a quality gap to close with the OECD; in 2018, population coverage of 4G was 97 percent in the OECD and 62 percent in Latin America and the Caribbean (Figure 5.9, Panel A). But even for those with access to 4G, download speeds available in Latin America and the Caribbean are ten times slower than in OECD countries (Figure 5.9, Panel B), thereby limiting the services and digital solutions that can be provided and, therefore, their impact on productivity and quality of life.

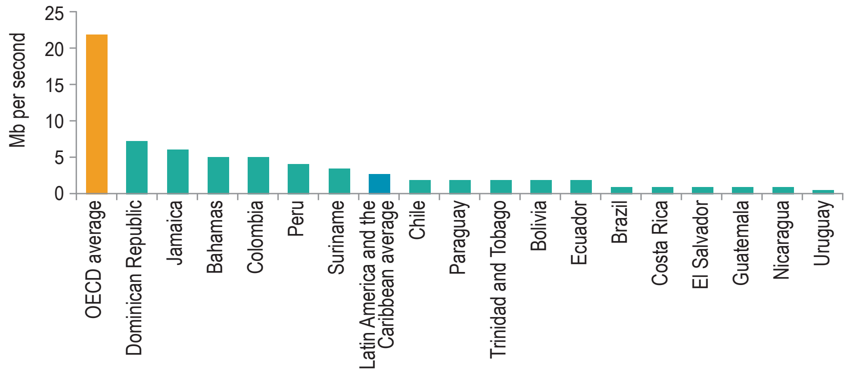
Figure 5.9
Quality Gaps in Digital Connectivity, 2018

Panel A. Population covered by different mobile connectivity technologies



Source: ITU World Telecommunication/ICT Indicators (WTI) database 2018.

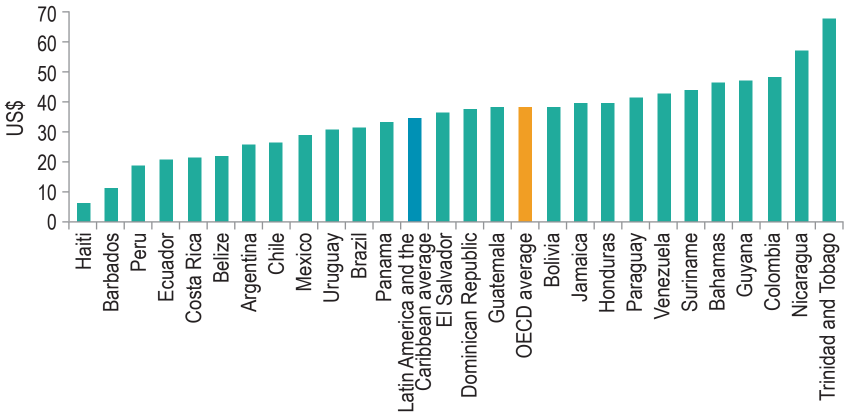
Panel B. Minimum advertised mobile broadband downloading speed



Source: IDB's digiLAC database 2018.

Even more important than gaps in coverage and quality, it is pointless to offer access to digital connectivity services if users are unable to pay for them. Considering the world's most popular digital connectivity service as of 2018, 4G mobile broadband, the monthly subscription price in Latin America and the Caribbean is US$32.62 (measured in PPP), which is only slightly lower than in the OECD (US$39.13) (Figure 5.10). In relative terms, this means that while the poorest 40 percent of the OECD population has to spend 3 percent of its monthly income to obtain a basic 1Gb mobile broadband

Figure 5.10
Retail Price of a Mobile Broadband Subscription



Source: ITU World Telecommunication/ICT Indicators (WTI) database 2018.
Note: A subscription includes local calls plus 1G of data.

THE PRICE OF A MOBILE BROADBAND SUBSCRIPTION IN LATIN AMERICA AND THE CARIBBEAN IS LOWER THAN IN THE OECD IN ABSOLUTE TERMS, BUT GIVEN INCOME LEVELS, IT IS OUT OF REACH FOR THE POOR.

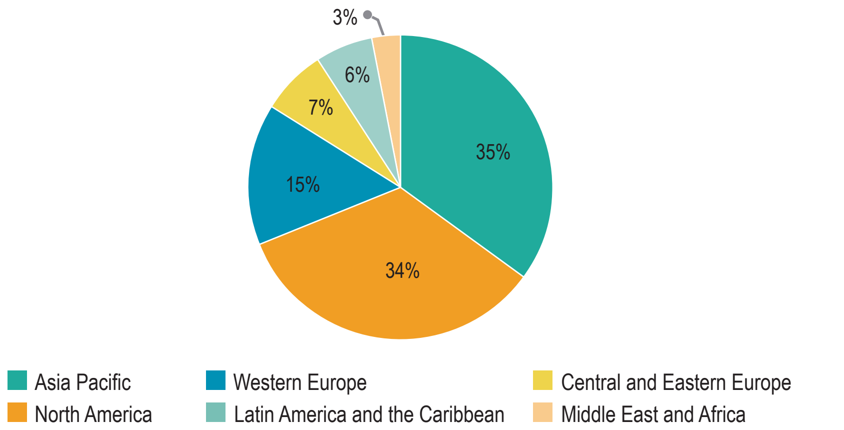
plan (in line with the target of a monthly cost of 2 percent of the gross national income per capita set by the UN Broadband Commission for the year 2025),[10] in Latin America and the Caribbean the same income group must spend 10 percent of their monthly income for the same service.[11] In practice, these costs put the service out of reach for a large share of the population, exacerbating inequality of access and service.

Not surprisingly, the lack of access to digital connectivity, the low quality of the services

[10] See Broadband Commission for Sustainable Development (2018).
[11] See IDB's digiLAC database, 2018 data.

provided, and the relatively high price-to-income ratio translates into low adoption and use of digital technologies. Many indicators suggest there is room to increase the use of digital connectivity: Latin America and the Caribbean has 2.1 digital devices[12] per capita, far below North America (8.0) and Western Europe (5.4), and slightly below the global average (2.4) (Cisco, 2020). In 2017, Latin America and the Caribbean accounted for 5.7 percent of total digital traffic data worldwide, lower than its share in the world economy (6.5 percent) or population (8 percent)[13] (Figure 5.11).

Figure 5.11
Share of Total Digital Data Traffic Worldwide by Region (percentage)



Source: Cisco (2020).

No studies exist to explain the gap in access and use of digital connectivity between Latin America and the Caribbean and the OECD. Most likely, the combination of inadequate regulatory systems and supply and demand constraints drive the underperformance of the region. Normative frameworks in Latin America and the Caribbean are outdated and may provide part of the answer (Prats Cabrera and Puig Gabarró, 2017). Just one-third of countries in the region enacted or updated laws that regulate the communications sector after 2010 while half of the countries have laws that

12 Including smartphones, televisions, personal computers, connected machines, tablets, and non-smart phones.

13 Estimates of the weight of the region on world economy and population are based on information from the World Development Indicators of the World Bank for the year 2018.

were enacted in the twentieth century and have been only partially updated since.[14]

Enhancing competition *in* and *for* the market is a prominent avenue to reduce service costs. The current state of competition in the provision of connectivity services also shows a gap with the OECD. The Herfindahl Hirschman Index, which measures concentration and provides information on the intensity of competition in the market, reveals that the mobile broadband market was 30 percent less concentrated in the OECD than in Latin America and the Caribbean in 2018.[15]

Peru provides a recent example of a policy action to increase competition in the market. In 2014, the market price for a wholesale broadband transport link exceeded US$200 per Mbps.[16] The price was high partly because the main national telecommunications operators were vertically integrated—meaning wholesale service was not their main business line. Moreover, the main operator held 83 percent of the fixed broadband market, 59 percent of the pay TV market, and 54 percent of the mobile telephony and broadband market.[17] In this context, Peru decided to prioritize the affordability of broadband services in the design of its public tender to develop the national wholesale backbone network. The tender was to be awarded to the bid that required the smallest subsidy to deploy a 13,500 km country-wide fiber optic network and provided service for a fixed price of US$27 per Mbps. The awardee earned the exclusive right to build and operate a state-owned national fiber optic network for 20 years.[18] Just three years after the entry of the new competitor, the wholesale price for broadband services fell to US$30, which is close to the intended price set in the tender (OSIPTEL, 2017).

Chile provides another example of how public intervention can help increase competition. Currently, the region of Magallanes in the extreme southern part of the country has limited broadband services using private fiber optic cables passing through neighboring Argentina. This limitation reduces service accessibility and affordability. To address the problem of limited connectivity and in the context of a national plan with the goal of using fiber cables to reach all urban areas with more than 5,000 inhabitants,

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14 See Prats Cabrera and Puig Gabarró (2017).

15 See IDB's digiLAC database, 2018 data. The Herfindahl Hirschman Index measures market concentration, taking into account a market's size and the size and number of its stakeholders.

16 See Mellado (2014).

17 TeleSemana, https://www.telesemana.com/panorama-de-mercado/peru/.

18 https://andina.pe/agencia/noticia-consorcio-tv-azteca-tendai-mexico-ejecutara-proyecto-red-dorsal-fibra-optica-487834.aspx.

the government deployed 2,800 kilometers of marine fiber optic cable (named *Fibra Óptica Austral*), managed by private concessionaires. The auctions to assign those concessions included a US$100 million subsidy to guarantee open access to infrastructure, which is expected to allow entry of new providers to the market and to decrease service prices.

Technology could be the most effective tool to increase competition in the infrastructure connectivity market. If the promising technological developments of recent years (e.g., balloons, drones, constellations of small satellites, automated dynamic spectrum sharing) achieve enough technical maturity and business viability to be mainstreamed, they could disrupt the deployment of traditional digital connectivity infrastructure and enable new, better-quality, more-affordable connectivity services. These developments would make it possible to reach unserved and underserved communities faster while also developing new uses, thanks to new services of better quality (mainly 5G). As in the case of Google's balloons, change sometimes comes from firms in other sectors that see the market for digital connectivity infrastructure as a limitation to their business and are willing to barge in, increase competition, and introduce new business models. Already, strong players in the markets for online digital content and advertising (e.g., Facebook, Google) have entered the global markets for digital connectivity (e.g., Facebook Messenger, Google Voice) and for the infrastructure underpinning it. They have deployed both terrestrial fiber optic cables (Facebook has invested in terrestrial fiber optic cable in Uganda,[19] Google in Ghana, Liberia, and Uganda)[20] and international submarine fiber optic cables (Facebook has invested in a submarine cable connecting Argentina and Brazil[21] while Google has installed a submarine cable connecting Brazil and Uruguay).[22]

19 Facebook, jointly with Airtel Uganda and Bandwidth and Cloud Services Group, has invested in a shared 770-kilometer terrestrial fiber optic cable network in Uganda reaching more than 3 million people and enabling future cross-border connectivity, https://code.fb.com/connectivity/airtel-and-bcs-with-support-from-facebook-to-build-shared-fiber-backhaul-connectivity-in-uganda/.

20 Google has partnered with other investors to create CSquared to deploy terrestrial fiber optic cable in Ghana (1,000 km in Accra, Tema, and Kumasi), Liberia (200 km), and Uganda (Kampala), http://www.csquared.com/.

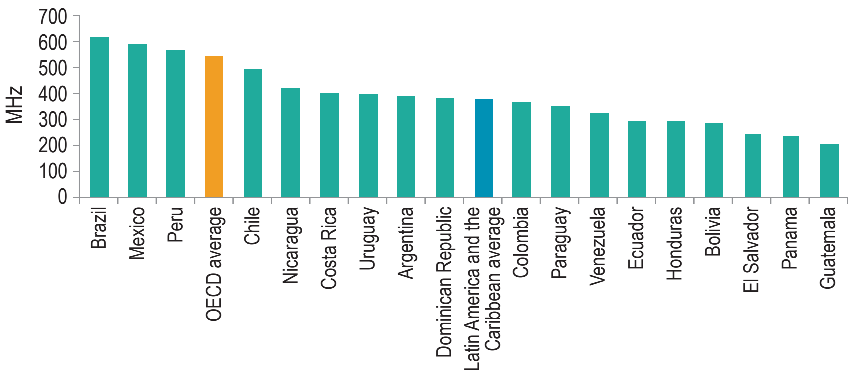
21 The Malbec submarine cable, owned by Facebook and GlobeNet, will connect Argentina (Las Toninas) and Brazil (Praia Grande, Rio de Janeiro), https://www.submarinecablemap.com/#/submarine-cable/malbec.

22 The Tannat submarine cable, owned by Google and Antel Uruguay, connects Brazil (Santos) and Uruguay (Maldonado), https://www.submarinecablemap.com/#/submarine-cable/tannat.

In addition to technological developments and disruptive business models, other policy actions can foster competition *for* and *in* the market. A concrete policy is to improve the allocation and management of the radioelectric spectrum. The radioelectric spectrum is a scarce resource in any given place or time, meaning that only a finite amount of spectrum can be used, and it cannot be stored. Its inefficient management can lead to insufficient wireless telecommunications infrastructure and investment, inadequate coverage for the population of wireless telecommunication networks, low quality, and high prices.[23] Countries looking to foster competition should design tenders to allocate free space of the radioelectric spectrum to new competitors in the telecommunications market and allow them to lease, transfer, and donate unused and underutilized spectrum in a secondary market to enable more efficient use.[24] Figure 5.12 shows that Latin American and Caribbean countries

Figure 5.12

Radioelectric Spectrum Space Allocated to Mobile Communications, Latin America and the Caribbean vs. OECD



Source: 5G Americas (2019).

on average only devote 380 MHz of radioelectric spectrum to mobile communications, 30 percent less than the OECD average. The region presents huge heterogeneity: while the share of radioelectric spectrum

[23] See OECD/IDB (2016).

[24] Costa Rica (2008), Colombia (2009), Argentina (2014), Mexico (2014), and Brazil (2016) have recently enacted legislation that allows for leasing, transferring, or donating allocated spectrum with the authorization of the competent authority.

devoted to mobile telecommunications in countries such as Brazil, Mexico, and Peru is similar to that of the OECD, El Salvador, Panama, and Guatemala could allocate far more.

Another policy action that could foster competition in the provision of connectivity services is to encourage the participation of mobile virtual network operators (MVNOs). MVNOs are operators that offer retail connectivity services relying on communication infrastructure that they do not own. In order to give MVNOs the opportunity to succeed, regulatory frameworks have to set effective open access rules to the available connectivity infrastructure. MVNOs are still an emerging player in Latin America and the Caribbean but in other countries they managed to seize a share of the market. Such is the case in the United Kingdom, where MVNOs have a market share of 16 percent of total mobile subscriptions, Spain (11 percent), and Italy (7 percent); Colombia stands out in the region with an MVNO market share of 8 percent.[25] Beyond specific policies to manage the radioelectric spectrum and foster the introduction of MVNOs, competition in the sector would grow if competition authorities were more proactive in guaranteeing a level playing field for incumbents and new market players and ensuring strong competition for and in the market in the telecommunications industry.

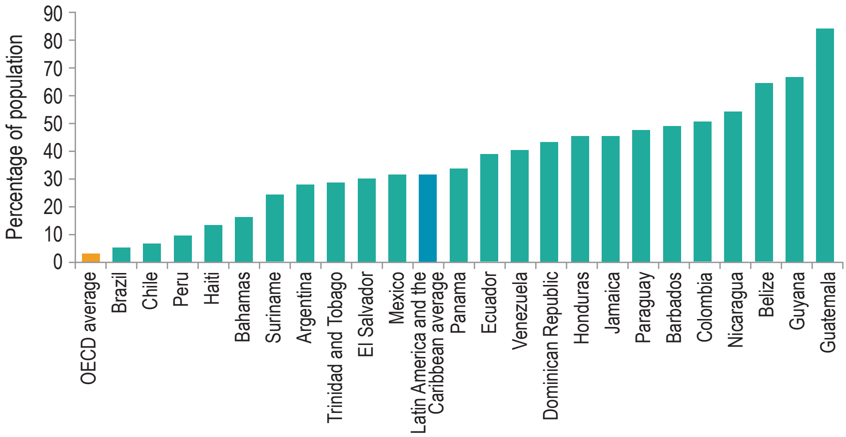
Lack of competition, slow roll-out of technological innovations, and a market that offers a restricted menu of price-quality service options constitute supply-side limitations to developing the connectivity services market. However, focusing only on supply-side limitations ignores the role of demand as a key determinant of market performance. Two demand characteristics in the region—low disposable income to pay for services and lack of skills (commonly referred to as digital literacy) to understand and get the most out of them—are also key to explain the current state of connectivity services.

The combination of relatively high prices and low capacity to pay for and use digital communication services curb their adoption, especially for the poor. In many countries, the market is not reaching its full demand potential (Figure 5.13). In 2018, one-third of the population that lived in areas covered by 3G networks in Latin America and the Caribbean was not subscribed to mobile services compared with only 3 percent in OECD countries.

Several developed nations include in their national broadband strategies the need to provide a direct subsidy in order to guarantee access to broadband services. In the United States, since 2016 the Federal

[25] See IFT (2019).

Figure 5.13
Nonsubscribers to 3G Services



Source: IDB's digiLAC database 2018 and ITU World Telecommunication/ICT Indicators (WTI) database 2018.
Note: This figure represents the percentage of the population that is not subscribed to 3G communication services despite being in a geographical area where 3G services are available. The actual percentage may be underestimated since the information available refers to subscriptions and not to individual subscribers; therefore, individuals with more than one subscription to 3G services may be double counted.

COVERAGE IS NOT ENOUGH: IN MANY LATIN AMERICAN AND CARIBBEAN COUNTRIES A LARGE SHARE OF THE POPULATION DOES NOT SUBSCRIBE TO COMMUNICATION SERVICES.

Communications Commission has implemented a program, Lifeline Support for Affordable Communications, targeted to low-income subscribers. The program consists of a monthly subsidy of US$9.25 per month to support payments for wireline or wireless broadband services.[26] The Norwegian government went even further by recently proposing to include broadband with download speeds of either 10Mbps or 20Mbps and 2Mbps upload speed into the country's universal service obligation.[27]

Unfortunately, focalized direct subsidies to end users for telecommunications services are not a common policy in the region. However, some countries have adopted an indirect approach to subsidies by

[26] https://www.fcc.gov/consumers/guides/lifeline-support-affordable-communications.
[27] https://ovum.informa.com/resources/product-content/norwegian-government-consults-on-extending-uso-to-include-basic-broadband-glb005-000186.

bundling together in tenders the right to service profitable areas with the obligation to provide access to remote and high-cost areas, cross subsidizing *de facto* the service in the more distant areas. An example of this type of policy is what Mexico's federal government did in the national wholesale Shared Network project. The public tender for a block of high-value radioelectric spectrum and for the buildout and operation of the national wholesale shared network was awarded to the bidder that offered to cover the highest percentage of the population with the 4G mobile broadband infrastructure. The awardee committed to providing a 4G mobile broadband signal to 92 percent of the population by 2024 in exchange for an exclusive 20-year concession to provide mobile broadband services. This policy is an example of a public policy-led cross-subsidy to promote the deployment of digital connectivity infrastructure in geographic areas that are not financially attractive for a private investor but have social returns that exceed direct financial returns.

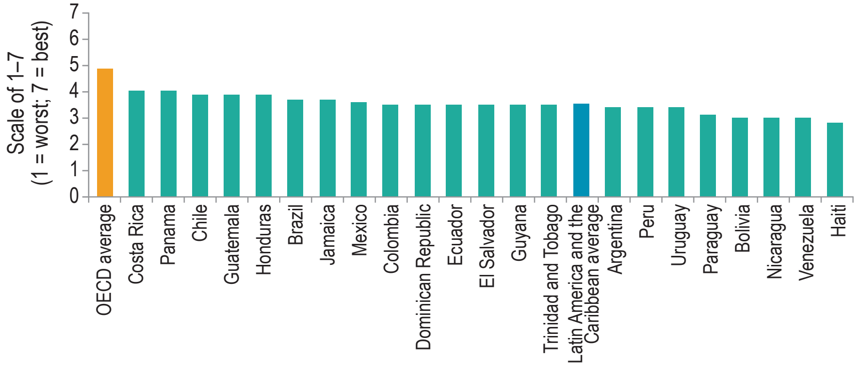
The decision to subscribe to services depends not only on consumers' ability to pay but also on their perception of what can be gained from using the services. And ability and capacity to use depends largely on information and digital skills. Assessing what skills are required is a difficult task since the range of possible uses of the technology is broad. DigiLAC, an IDB initiative for improving the availability of data on broadband services and their impact on development, produces two synthetic indices to assess the use and impact of digital services on business and for educational purposes in schools. The information is based on surveys and data collection on access and usage of digital technologies.[28] In terms of both metrics, Latin American and Caribbean countries perform well below their OECD benchmarks (with the notable exception of Uruguay on Internet use at school, after several years of consistent digital initiatives for education). These results show that the use of connectivity services is far below its full potential (Figure 5.14).

Several countries in the region have taken steps to narrow the skills gap. Peru (Perú Educa) and Mexico (@prende 2.0) implement national programs focused on improving digital skills in schools, both for students and professors. Training includes fixing hardware, utilizing and solving problems of different types of software, and even learning basic principles of online security to ensure data privacy. The efforts were wide-reaching: for example, the Peruvian program educated 25,000 professors at the national level, offering them 107 different online courses; @prende 2.0 set a

[28] https://digilac.iadb.org/en.

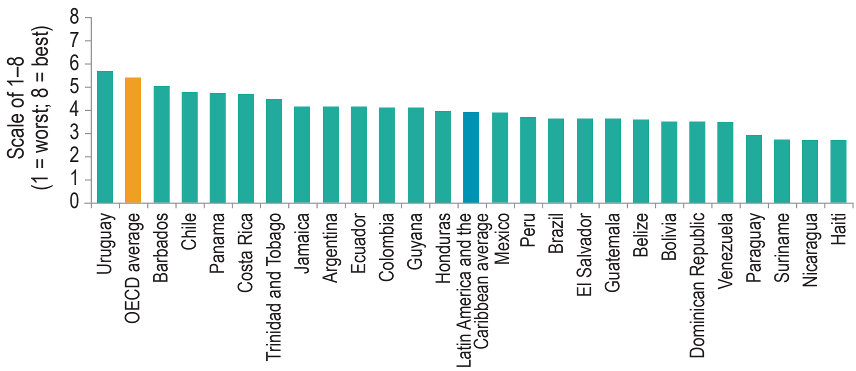
Figure 5.14
Internet Usage at Work and School

Panel A. Business Internet Usage Index



Source: IDB's digiLAC database 2018 and WEF's Networked Readiness Index 2018.
Note: The business internet usage index measures the extent of business internet use as well as the efforts of firms in an economy to integrate information and communications technology into an internal technology-savvy, innovation-conducive environment that generates productivity gains. Consequently, it measures the firm's technology absorption capacity as well as its overall capacity to innovate, the production of technology novelties measured by the number of patent applications under the Patent Cooperation Treaty, or the number of staff trained, so that management and employees are better capable of identifying and developing business innovations. This index ranges from 1 (worst) to 7 (best).

Panel B. Internet Use at School Index



Source: IDB's digiLAC database 2018 and WEF's Networked Readiness Index 2018.
Note: Internet Use at School Index is a survey-based assessment of the readiness to use internet resources at school, and their effectiveness. This index ranges from 1 (worst) to 8 (best).

goal of upgrading 3,000 schools in the country with fully equipped digital classrooms. Other countries have focused more on improving the skills of vulnerable populations. Costa Rica, for example, developed the Programa Institucional para la Persona Adulta y Adulta Mayor with the objective of reducing the intergenerational digital skills gap by educating adults over

60 years old in digital technologies. Taking a different approach, Trinidad and Tobago institutionalized a National Training Agency to help re-train the unemployed by focusing on digital skills as a tool to find new employment opportunities. Despite these valuable efforts, the region still has room for improvement. Reducing the skills gap is crucial to make the opportunities that digital technology offers available to all, especially vulnerable populations such as the poor, youth, and the elderly.

Finally, another demand driver that can increase value for users of broadband services is the implementation of e-government practices. E-government allows citizens and firms to remotely access information, obtain certificates, or pay taxes, as well as other interactions. Establishing a successful e-government strategy has the potential not only to boost demand for broadband services but also do it in an inclusive manner, increasing geographical equality, transparency, and citizen engagement in the governmental process.

The Way Forward: Policies to Enhance Digital Connectivity

Technological progress has shaped the demand for infrastructure and created new services. The demand and supply of future transport, energy, and water and sanitation services will depend on the availability and quality of communication infrastructure and the digital services it provides. It is, therefore, imperative that Latin American and Caribbean countries adopt today strategic policies and regulations that help develop communication infrastructure to reach universal coverage while fostering a vibrant market for digital services.

Countries in the region will need to create and implement digital agendas and new national broadband plans to achieve efficient coordination between all the economic sectors impacted by digital technologies. Those agendas should identify key performance indicators to improve accountability and be implemented by strong public institutions that continuously consult with the private sector to keep track of a dynamic sector, prone to constant technological shocks. The salient features of the changes in the regulatory framework to be adopted are presented in Box 5.1.

Strengthening digital connectivity regulatory frameworks will need to be complemented with inclusive policies to foster technology adoption. Implementing national programs focused on reducing the skills gap for the poor, the young, and the elderly is vitally important for the digital connectivity market to reach its full potential. ICT infrastructure may often remain underutilized not only because it is unaffordable, but because potential users lack education and literacy in digital skills to make productive use of ICTs and Internet. Policy should be based on the premise that no one can be left out of the emerging digital technologies. Targeted education, training, and skills-building programs, and an e-government strategy must be important components of the new digital agendas and broadband plans.

Box 5.1

Regulatory Guidelines for Catalyzing Digital Connectivity Benefits

The telecommunications market is rapidly evolving, following the pace of continuous technology innovation. The increase of data traffic, the decrease of average revenue per user, and the need to keep high levels of investment in infrastructure to satisfy the ever increasing demand of customers for better services are trends that are challenging the current business models and making regulatory frameworks outdated. However, technology innovation also provides new opportunities to increase the quality of the services, while making them more accessible and affordable. In order to mainstream digitalization's most promising benefits and tackling their most worrisome challenges, setting an adequate regulatory framework is essential. Even though there is no one-size-fits-all strategy, some regulatory guidelines and instruments can be suggested for reforming current frameworks:

Promoting open access to digital infrastructure. Many markets in Latin America and the Caribbean do not have the minimum scale that would be needed to ensure competition among networks. That is, building more than one network for digitial infrastructure will not provide sufficient financial returns to recover investment costs. In these cases, infrastructure sharing regulations in the form of an open regime that sets prices and use rights, is instrumental for avoiding inefficient investment and for making the most of the existing capacity. As importantly, open access regulation when appropriate can foster competition among digital connectivity services provided over shared infrastructure (i.e., MVNOs).

Foster competition whenever possible. The private sector has led the provision of infrastructure connectivity and services in Latin America and the Caribbean and all over the world. Competition and innovation have led to new business models and expanded geographic coverage. Lowering barriers to entry should be a policy priority. A concrete example is the allocation of the radio spectrum. Adopting agile and flexible radiofrequency spectrum management frameworks, as well as allocating spectrum blocks that have not been licensed yet, are key actions that could help lower barriers of entry, enable innovative business models, maximize use of this valuable and scarce resource, and, as a result, increase competition in service provision. The ultimate goal of fostering competition must be to improve affordability and quality of services, hence making them more attractive and likely to be adopted by users.

Implement a well-targeted subsidy policy to reach universal access and foster the use of communication services for those who cannot afford them. Public subsidies to digital connectivity services in Latin America and the Caribbean have been aimed at lowering infrastructure deployment capital needs to extend geographical coverage and contribute to universal access. In pursuit of this goal, governments often include incentives in public tenders such as public funds contributions or access to concessional financing. Means-targeted demand subsidies have not been common in the menu of policy options in the region. Thus, in Latin America and the Caribbean, public subsidies are more often designed to make digital connectivity services accessible to targeted areas (e.g., rural areas) rather than to targeted populations (e.g., low-income households). These policies can achieve the goal of reaching universal coverage but can have high errors of inclusion (i.e., can benefit those with the means to pay the cost of connection). Latin American and Caribbean countries should explore setting up means-targeted subsidies that include items such as demand incentives to purchase smartphones, home fixed broadband installation cost subsidies, and mobile broadband use subsidies.

Part 2 Seeking Sustainability

6

Resilient Infrastructure for an Uncertain Future

On September 1, 2019, Hurricane Dorian struck the Bahamas with devastating force. Media attention focused on the US$7 billion in losses to residential, commercial, and industrial property (KCC, 2019). But property damage was far from the only lasting consequence. Grand Bahamas International Airport was under water.[1] Roads were flooded, stymieing rescue efforts.[2] Well water became contaminated.[3] The island of New Providence suffered a total blackout.[4] And on Abaco and Grand Bahama, life ground to a halt as residents were left with "no electricity, no running water, no banks, no grocery stores, or gas stations."[5]

Although Hurricane Dorian was an outlier historically, it may not be an outlier looking forward as the effects of climate change proliferate and intensify. Importantly, the effects of climate change on infrastructure services go well beyond natural disasters; changing temperature and

1 *The Tribune*. Sunday's Live Updates: Dorian over Grand Bahama after Devastating Abaco. September 2, 2019, http://www.tribune242.com/news/2019/sep/01/dorian-predicted-make-landfall-early-sunday-mornin/.

2 Semple, Knowles, and Robles. *The New York Times.* Bahamas Relief Efforts Frustrated as Dorian Pulls Away. September 3, 2019, https://www.nytimes.com/2019/09/03/world/americas/bahamas-hurricane-dorian.html.

3 *International Federation of Red Cross*. Bahamas: Shelter and Clean Water Priorities in Wake of "Catastrophic" Hurricane. September 2, 2019, https://media.ifrc.org/ifrc/press-release/bahamas-shelter-clean-water-priorities-wake-catastrophic-hurricane/.

4 Weissenstein, Michael and Coto, Dánica. *AP News*. Dorian Triggers Massive Flooding in Bahamas; At Least 5 Dead. September 2, 2019, https://www.apnews.com/02c093eb6ce24d24a959e6d87088590a.

5 Beaubien, Jason. *NPR News*. Little Miracles, Huge Problems: The Bahamas a Month After Dorain. October 15, 2019, https://www.npr.org/sections/goatsandsoda/2019/10/15/770107636/after-dorians-wrath-little-miracles-amid-a-painful-recovery.

precipitation, for example, can have a dramatic impact on the provision of energy, water, and transportation services. Governments must heed warnings of this "new normal;" they must acknowledge the uncertainty they face due to future climatic trends and events and their increasing exposure to natural disasters by planning resilient infrastructure services. By establishing constructive regulatory and policy regimes and incorporating principles of decision-making under uncertainty, governments across the region are beginning to make important investments in infrastructure that will be resilient to natural disasters and the uncertainty of climate in the future. These investments pay off in lower maintenance costs and fewer service interruptions, thereby minimizing economic losses for businesses and individuals and reducing disruptions to the daily lives of citizens.

Nature's Toll on Infrastructure

Supply Interruptions

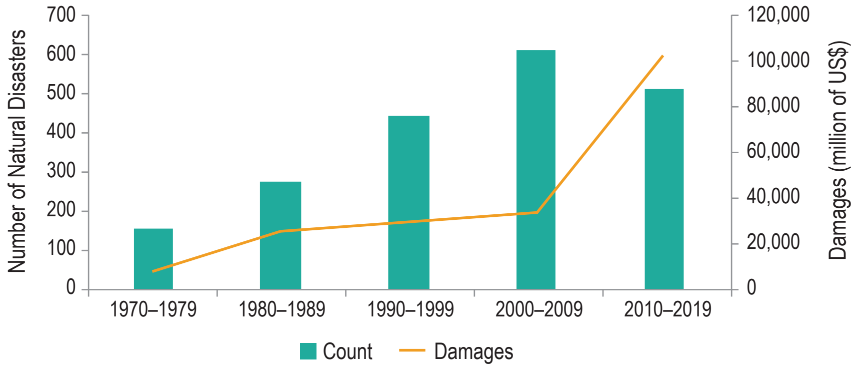
Natural disasters and climate change disrupt the supply of infrastructure services. Over the past 50 years, the number of natural disasters in Latin America and the Caribbean has tripled, and damages to roads, buildings, machinery, equipment, and crops have exploded from US$7.4 billion to US$102.7 billion (Figure 6.1). Climate change will increase the frequency and magnitude of some types of natural disasters in Latin America and the Caribbean, such as hurricanes, droughts, and floods (World Bank, 2014b; ECLAC/CCAD-SICA/DFID, 2010; Dai, 2013; Prudhomme et al., 2014; Nobre and Young, 2011; Marengo, Valverde, and Obregón, 2013; Field et al., 2012).

Over the past five decades, the number of natural disasters and the magnitude of damages reported by EM-DAT have surged in the region. The number of natural disasters in 2010–19 was three times greater than in 1970–79 and the total damage from natural disasters in 2010–19 was nearly 14 times the total damage in 1970–79. The infrastructure sector bears a large share of the asset destruction. Assets in the power, water, transport, and telecommunications sectors are often located in areas exposed to natural hazards, which places them in the line of fire when natural disasters occur (Hallegatte, Rentschler, and Rozenberg, 2019). For instance, damage to infrastructure accounted for 52 percent of the physical assets damaged by Hurricane Irma (2017) in the Bahamas (Ibarra-Bravo, 2018).

In addition to destroying infrastructure assets, natural disasters disrupt infrastructure services. Infrastructure service interruptions spill over from one sector to another and extend broadly across time and space (Box 6.1). As a result, the loss of infrastructure services can have a wider, larger,

Figure 6.1

Frequency and Cost of Natural Disasters in Latin America and the Caribbean, 1970–2019



Source: Authors' elaboration based on EM-DAT database accessed July 22, 2019. EM-DAT: The Emergency Events Database-Université catholique de Louvain-CRED, D. Gruha-Sapir. www.emdat.be, Brussels, Belgium.

Note: Data sample is 1970-2019. The Latin American and Caribbean region includes Argentina, Bahamas, Barbados, Belize, Brazil, Bolivia, Chile, Colombia, Costa Rica, the Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

IN LATIN AMERICA AND THE CARIBBEAN, NATURAL DISASTERS ARE BECOMING MORE FREQUENT AND DESTRUCTIVE.

and longer-lasting effect on households and businesses than the direct effect of asset destruction (Gordon, Richardson, and Davis, 1998; Okuyama and Rose, 2019; McCarty and Smith, 2005; Rose and Wei, 2013).

Infrastructure systems are interdependent and the loss of infrastructure services in one sector can affect the ability of other sectors to provide services. For instance, electricity is important to households and businesses to power lighting, electronics, and machines, but is also crucial for transportation and water and sanitation services. Electricity powers traffic lights, street lights, computer systems, and electrified rails that roads, rails, and airports need to provide transport services. Similarly, electricity powers pumps and water treatment plants that provide water and sanitation services.

The loss of infrastructure services imposes long-lasting costs on businesses and households. These costs continue to accumulate until reconstruction is complete, which can take years for large disasters. After the 1995 Kobe earthquake in Japan, power and telecommunications were fully restored within a few days, but transportation services were hobbled for almost two years (Chang and Nojima, 2001). Countries that are unable to finance rapid reconstruction may incur disproportionate costs, which

Box 6.1

Natural Disasters and Infrastructure: The Case of Hurricane Mitch in Honduras

The case of Hurricane Mitch (1998) illustrates both that infrastructure bears a large share of the damage to physical assets and that disruptions in infrastructure services play an important role in economic losses from natural disasters. The total cost in Honduras was estimated at US$3.8 billion (14 percent of GDP), approximately equally split between damages to physical assets and economic losses that extended over a period of four years.[a]

The damage to physical infrastructure assets was concentrated in the transportation, water and sanitation, communications, and energy sectors. Transport infrastructure assets—mainly roads and bridges, but also airports and ports—sustained US$241 million of damages. Water and sanitation infrastructure experienced US$58 million in damages to storage reservoirs, water mains, and pipelines. The communications sector took a US$42 million hit, primarily to telephone infrastructure; and damages in the energy sector, mainly to electricity generation works, transmission, and distribution networks, reached US$9.9 million.

Economic losses were primarily driven by the disruption of transportation services caused by widespread damage to transportation assets. Transport costs reached an estimated US$262 million due to an increase in passenger and freight transport costs, longer transportation times, and higher vehicle operating costs. Declines in production and sales cost firms an additional US$500 million. Production cuts were largely the result of interruptions of the water, electricity, and transport services as well as high absenteeism for several weeks following the disaster, likely because workers lacked transportation to work. This case study clearly illustrates the ripple effect of natural disasters and the value of designing resilient infrastructure assets.

Source: ECLAC (1999).

[a] Total nominal GDP of Honduras for 1998–2001 was US$27.5 billion; Rozenberg and Fay (2019).

increase exponentially when the disruption to infrastructure services drags on (Colon, Hallegatte, and Rozenberg, 2019).

Geographically, the loss of infrastructure services has widespread impacts. First, the networks that provide infrastructure services often serve large populations. In 2012, Superstorm Sandy hit the eastern coast of the United States, leaving over 8 million people without power in an area stretching as far inland as Michigan.[6] Second, damage to a single asset can

6 Gibbens, Sara. Hurricane Sandy, Explained. *National Geographic*. February 11, 2019, https://www.nationalgeographic.com/environment/natural-disasters/reference/hurricane-sandy/.

imply the loss of services for a large geographic area. The loss of one bridge can strand an entire island. Third, disruptions in infrastructure services can affect households and businesses that did not suffer a loss of infrastructure services themselves, resulting in lost revenue for firms, lower income for employees, and lower tax revenue for governments. These effects can propagate across the country or around the world through supply chains and changes in the availability of goods (Cavallo, Cavallo, and Rigobón, 2014). Disruptions to parts producers in northeastern Japan caused by the 2011 Great East Japan triple disaster impacted automobile production in the United States and Europe (Chang, 2016).

Climate change also implies changes in weather patterns that affect the supply of infrastructure services. In addition to the potential impact of weather on the life span of infrastructure assets, weather directly impacts the supply of infrastructure services in the energy, water, and transportation sectors.

Weather affects the generation of energy from nuclear and thermal power plants as well as from wind, solar, and hydropower. For example, droughts decrease hydropower generation (Gleick, 2016) and high temperatures reduce power output due to the lower efficiency of solar photovoltaic, nuclear, and thermal generation (Dubey, Sarvaiya, and Seshadri, 2013; Mideksa and Kallbekken, 2010). Precipitation increases congestion on roads and the number of traffic accidents (Koetse and Rietveld, 2009). Extreme precipitation can contaminate drinking water and increase the incidence of waterborne diseases (Chen et al., 2012). The Panama Canal offers a good example. Longer and more frequent droughts combined with a growing population and its commensurate demand for drinking water threatens the functionality of the canal. As the water level drops in the Lake Gatun segment of the canal, the Panama Canal Authority must restrict the cargo of container ships. Despite numerous measures to conserve water and reduce the impact of the drought, the Panama Canal Authority had to impose restrictions on vessels in 2019.[7,8] These restrictions disrupt global shipping operations and reduce government revenues, one-eighth of which are derived from the Panama Canal Authority.[9]

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7 Vice Presidency for Transit Business, "Advisory to Shipping No. A-01-2019," January 4, 2019.

8 Vice Presidency for Transit Business, "Advisory to Shipping No. A-03-2019," January 22, 2019.

9 *The Economist.* Climate Change Threatens the Panama Canal. September 21, 2019, https://www.economist.com/the-americas/2019/09/21/climate-change-threatens-the-panama-canal.

Demand Effects of Disasters

Natural disasters and climate likewise affect the demand for infrastructure services in the energy, water, and transportation sectors. Climate change will alter the relative attractiveness of different locations leading to a different spatial distribution of the population and, therefore, the demand for infrastructure services.

Climate change and its associated impacts on weather will also affect the quantity of infrastructure services demanded. In warm regions, electricity demand increases with temperature and this relationship is expected to get stronger as more households install air conditioners (Davis and Gertler, 2015). Precipitation affects the demand for water used for irrigation (Wisser et al., 2008). Evidence from other contexts suggests that weather impacts the demand for transport services. For example, rainfall increases the demand for taxis in New York City and higher temperature boosts the demand for public transit in Chicago (Kamga, Yazici, and Singhal, 2013; Guo, Wilson, and Rahbee, 2007).

Extreme weather events such as heat waves and drought substantially increase the demand for electricity and water, respectively, and can strain infrastructure systems. For example, a heat wave in January 2014 in Rio de Janeiro prompted record-breaking electricity demand and blackouts in some parts of the city.[10] In countries dependent on hydropower, droughts can cause cascading problems as water demanded for agriculture increases at a time when river flows and reservoir levels are low, meaning less water is available for hydroelectric generation (Dias et al., 2018).

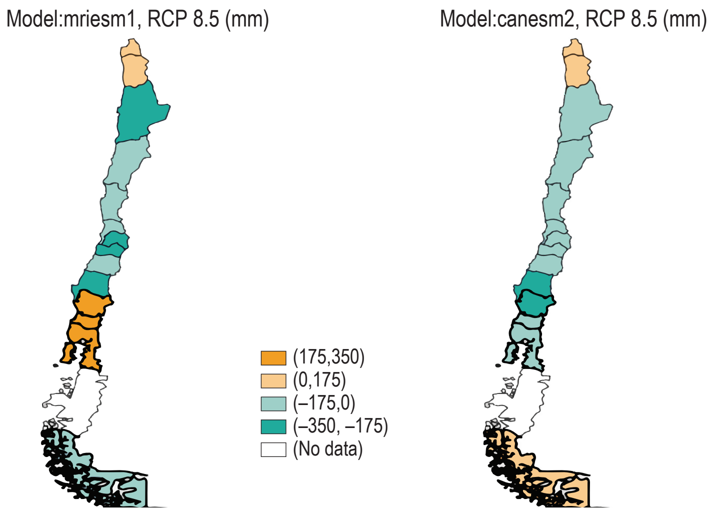
The Infrastructure Design Problem

Due to the long life span of infrastructure assets, infrastructure built today should be designed to provide infrastructure services under future climatic conditions. Although some of the changes in climate can be accurately predicted, many impacts are largely unknown. The probability of experiencing specific events, the value of different strategies, or the model that relates variables and parameters are often unknown or the subject of disagreement (Kalra et al., 2014). While scientists agree that climate change will lead to sea level rise, an increase in global temperature, and a greater frequency of some types of natural disasters, the frequency and

[10] Rinaldi, Alfred. *The Rio Times*. Heatwave Brings Record Breaking Energy Demand. January 14, 2014, https://riotimesonline.com/brazil-news/rio-business/heatwave-brings-record-breaking-energy-demand/.

magnitude of extreme events and future weather patterns that a specific infrastructure asset will be exposed to over its lifetime are uncertain. For example, the amount of precipitation that some regions of Chile will receive by 2050 is deeply uncertain: one model predicts more precipitation, and another predicts less (Figure 6.2).

Figure 6.2
Change in Annual Precipitation in Chile by 2050



Source: Author's elaboration based on data from Climate Data Factory.
Note: Change in annual precipitation by 2050, in one GHG emission scenario, according to two different climate models. Relative to the current climate, in four regions of Chile (shown with bold borders) the direction of the predicted change in annual precipitation by 2050 depends on the climate model used. The Lagos, Rios, and Araucania regions of Chile are predicted to receive more precipitation by the MRIESM1 model (left), but less precipitation by the CANESM2 model (right) and the Magallanes y de la Antartica Chilena region of Chile is predicted to receive more precipitation by the CANESM2 model (right), but less by the MRIESM1 model (left).

CLIMATE MODELS DO NOT AGREE WHETHER PRECIPITATION WILL INCREASE OR DECREASE IN THE SOUTHERN REGIONS OF CHILE.

Not only is the future climate uncertain, but the effects of climate change on the supply of and demand for infrastructure services are also uncertain. The available evidence on the effect of weather on the supply of and demand for infrastructure services is drawn primarily from studies of short-run weather variations, and these short-run effects may differ from the long-run effects of a new climate. The solution is to invest in infrastructure that is resilient to natural disasters and the future climate.

The Solution: Resilient Infrastructure

In response to natural disasters and climate change, governments can design resilient infrastructure. Investments in resilience made before disaster strikes reduce damages to infrastructure assets and minimize disruptions to infrastructure services, preventing widespread economic losses to people and firms. Many engineering options can increase the resilience of infrastructure: using earthquake resistant building materials, elevating roads or rails, or increasing redundancy in transmission networks. To remain resilient, infrastructure assets must also be properly maintained. Inadequate maintenance can decrease resilience and substantially increase the costs of natural disasters. The 2007 earthquake in Peru caused 77.3 million soles (US$24.7 million) in direct damages to drinking water and sanitation infrastructure. Two-fifths of these direct damages could have been avoided if proper maintenance had been performed (Andrade, 2011). Better decision-making strategies and planning can also boost resilience. Risk assessments should be conducted from the outset and uncertainty should be factored into the design of infrastructure assets. Finally, because infrastructure assets are part of co-dependent systems, a comprehensive regulatory environment is needed to ensure that all of these steps to increase resilience are taken for every infrastructure project.

Investments in resilience are smart investments in a future that will be shaped by climate change and more frequent natural hazards. When smart investment decisions are made, resilient infrastructure can deliver substantial benefits at reasonable up-front cost. The World Bank estimates that the additional cost of making power and transport infrastructure resilient in low- and middle-income countries is between US$11 billion and US$65 billion a year, or only 3 percent of the investment needed to achieve infrastructure-related sustainable development goals. In Latin America and the Caribbean, the cost is estimated between US$2.5 billion and US$13 billion per year, which implies making an additional investment equivalent to 5 percent of what the region invested between 2008 and 2018 (Rozenberg and Fay, 2019; Hallegatte, Rentschler, and Rozenberg, 2019).

The evidence shows that the additional up-front expense of resilient infrastructure pays off. The higher up-front costs of building more resilient infrastructure are usually more than outweighed by lower maintenance and repair costs for infrastructure assets and benefits to users from fewer interruptions in infrastructure services. In the United States, each dollar spent by the Federal Emergency Management Agency on hazard mitigation provides US$4 in benefits (MMC, 2005). Analyzing over 3,000 future scenarios, the World Bank finds that the net benefit of building more resilient infrastructure in developing countries is positive in 96 percent of the scenarios considered (Hallegatte et al., 2019). This net benefit of resilience is largely driven by expected impacts of climate change.

The Road to Resilient Infrastructure Services

Regulatory and Policy Environment

Government regulations and policy must elevate the importance of resilience in investment decisions at every stage of the infrastructure project cycle, from design to operation and maintenance (Bhattacharya et al., 2019; Fisher and Gamper, 2017; Hallegatte et al., 2017; Lacambra and Guerrero, 2017). This ensures that infrastructure investments achieve their maximum impact.

Regulations for infrastructure design should require a thorough risk analysis early in the design and planning stage of all new projects to ensure that decisions with long-term consequences are made while all options to increase resilience are feasible. Addressing resilience from the outset is significantly more time and cost effective than attempting to do so later by modifying the design, or worse, retrofitting after construction, when many features, such as location, are fixed (Georgoulias, Arrasate, and Georgoulias, 2016).

The regulatory framework should establish building codes to enforce minimum technical standards that are location and sector specific. Building codes should be adapted to account for specific locations' hazard patterns and risk level, and these standards should be updated regularly as technology advances, experience is gained, and the climate changes. Chile regularly updates its anti-seismic building codes, which have been instrumental in reducing casualties and damage from earthquakes. In response to the 8.8 magnitude earthquake that struck Chile in 2010 and caused severe tsunamis, the government revised building codes to increase the required distance between coastal structures and the ocean.[11] Certain infrastructure assets—such as public health infrastructure, electricity generation, and water supply—are critical to the delivery of crucial infrastructure services. Regulations should define critical infrastructure and the minimum technical standards for these structures should be more stringent than for other types of infrastructure.

[11] Wyss, Jim. *Miami Herald*. Engineers vs. God: Chile's Building Codes Take Edge Off Massive Earthquake. September 17, 2015, https://www.miamiherald.com/news/nation-world/world/americas/article35576640.html.

Even with the best efforts, not all risk can be avoided. Therefore, governments should manage residual risk by regulating financial instruments to share risk and finance rebuilding and contingency plans for rapid recovery after disasters. Mexico has such a comprehensive strategy for disaster risk transfer and financing (World Bank, 2012). The Fund for Natural Disasters (FONDEN) was established in the 1990s as a budget item for rehabilitation and reconstruction of infrastructure, low-income housing, and the natural environment in the wake of a natural disaster (World Bank, 2012). Since then, FONDEN has evolved and now follows a layered risk financing strategy in which financing for reconstruction after low-cost, high-probability events is drawn from reserve funds while contingent financing and risk transfer instruments finance recovery from high-cost, low-probability events (Hallegatte, Rentschler, and Rozenberg, 2019). For example, in 2006, FONDEN issued the first government catastrophe (cat) bond, and in 2009, Mexico issued a cat bond that provided coverage for hurricanes and earthquakes in different regions of the country through the World Bank MultiCat program (World Bank, 2012).

Financial and contingency planning is essential before a disaster strikes because any delays in securing financing for recovery prolongs the period over which economic losses accumulate. This can persuade governments to divert money from long-term growth and development goals to disaster recovery, which could have long-lasting consequences. However, many governments have concluded that the cost of issuing cat bonds is simply too high or that the parameters that govern payout don't necessarily correspond to the disasters with the greatest impact (Borensztein, Cavallo, and Jeanne, 2017).[12]

In the region, countries have room to improve their disaster risk management governance frameworks (Box 6.2). Approximately two-thirds of countries in Latin America and the Caribbean have formal regulations that require a pre-investment disaster risk analysis, earthquake-resistant standards or similar, a definition of critical infrastructure, and standardized technical requirements for critical infrastructure. Less than one-third of countries in the region have formal regulations mandating risk transfer mechanisms, insurance for public construction, or continuity plans for water and sanitation services.

As with any regulations, their impact on the resilience of infrastructure depends on enforcement. Agencies that oversee enforcement need to be properly funded. Enforcement isn't free, but small investments in

[12] Blackman, J., Maidenberg, M., and Varnham O'Regan, S. *Los Angeles Times*. Mexico's Disaster Bonds Were Meant to Provide Quick Cash after Hurricanes and Earthquakes. But It Often Hasn't Worked out That Way. April 8, 2018, https://www.latimes.com/world/mexico-americas/la-na-mexico-catastrophe-bonds-20180405-htmlstory.html.

enforcement can lead to large savings by significantly reducing losses in the event of a natural disaster. Building codes should be enforced through monitoring at construction sites, inspections, and procurement rules. Pre-investment risk analysis, the use of risk-sharing instruments, and the development of contingency plans can be enforced as part of countries' National Systems of Public Investment (SNIPs).

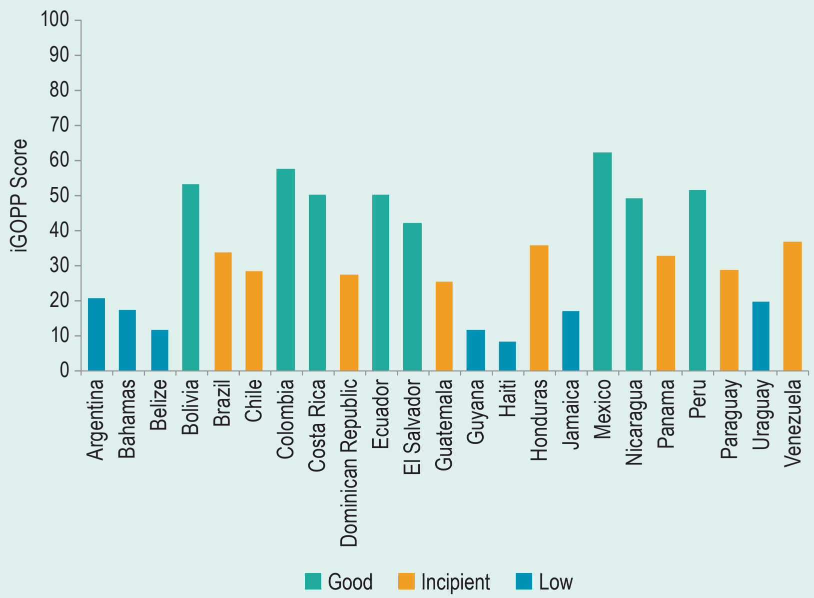
Box 6.2

Measuring Disaster Risk Management: The IDB's iGOPP

The IDB's Index of Governance and Public Policy for Disaster Risk Management (iGOPP) represents an effort to create a uniform measure of governance conditions at the national level (Lacambra et al., 2015).[a] The iGOPP measures the existence of formal legal, institutional, or budgetary conditions that are crucial to effective disaster risk management. Although, iGOPP scores vary across countries in the region, all countries have room for improvement (Figure 6.2.1).

Historically, most countries in Latin America and the Caribbean have focused on emergency response. For example, almost all the countries surveyed have

Figure 6.2.1
Disaster Risk Management Scores



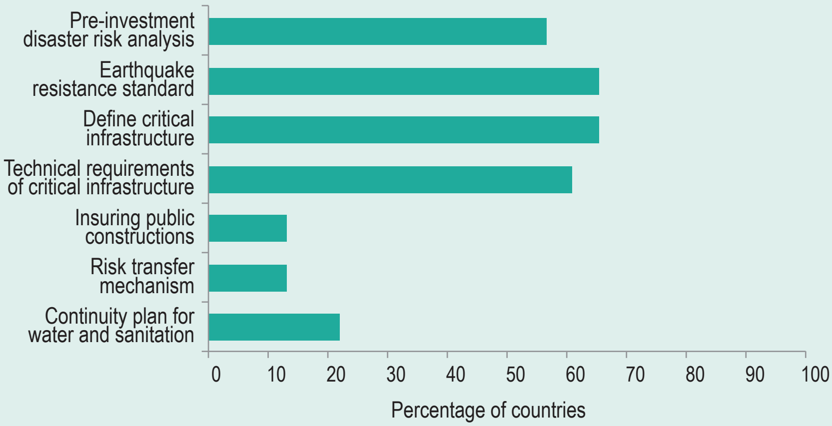
Source: Lacambra et al. (2015).
Note: The iGOPP score measures a country's formal disaster risk management governance and public policy conditions. The score ranges from outstanding (91–100); to very good (71–90); good (41–70); incipient (21–40) and low (0–20).

regulations that allow adoption of extraordinary emergency measures in case of disasters to facilitate a prompt response (Figure 6.2.2).

In contrast, other areas of the regulatory framework need to be strengthened. Over a third of the countries do not have regulations that mandate disaster risk analysis during the pre-investment phase of the project cycle, national safety standards for earthquake-resistant (or similar) design of public or private buildings, a definition of critical infrastructure, and standardized technical aspects of construction for critical infrastructure.

Formal requirements related to business continuity and recovery plans and financial instruments for reconstruction are even rarer. Fewer than one-quarter of countries in the region have regulations that require at least one risk transfer mechanism to collectively cover the portfolio of fiscal assets of one sector, standards approved by the Ministry of Treasury (or other related entity) for insuring public constructions in the event of disaster, and business operations continuity plans for public providers of water and sanitation services in the event of disaster.

Figure 6.2.2
Countries with Disaster Risk Management Regulations



Source: Authors' elaboration based on Lacambra et al. (2015).
Note: Percentages are for the 23 countries for which the iGOPP has been applied. Indicators represent the presence of formal regulations. The iGOPP scores for each country were created between 2013 and 2017 and have not been updated to reflect changes to the legal, institutional, or budgetary framework since the initial creation.

COUNTRIES IN LATIN AMERICA AND THE CARIBBEAN NEED TO STRENGTHEN DISASTER RISK MANAGEMENT REGULATIONS.

[a] The iGOPP scores for each country was created between 2013 and 2017 and have not been updated to reflect changes to the legal, institutional or budgetary framework since the initial creation.

Implementing complementary policies is also important to make infrastructure more resilient. Research and development funding and institutions that foster innovation can pay off in technological advances that lower the costs of upgrading infrastructure to be resilient to natural disasters and climate change. Smaller improvements in resilience can also come from economic instruments and behavioral nudges (Allcott, 2011). Subsidies for energy efficient appliances, real-time pricing, and demand response programs can alter patterns of demand and supply of infrastructure services by changing the prices for suppliers and users (Allcott, 2011; York, Relf, and Waters, 2019). Behavioral nudges, such as social comparison messaging, can modify demand patterns to lower resilience requirements. For example, the primary reservoir that supplies drinking water to São Paulo fell to 3 percent of its capacity during the drought of 2014–15. Sabesp, the water utility, implemented financial incentives to reduce water use, and nearly 80 percent of customers received a financial reward. The financial incentives, combined with other measures such as improved pumping capacity, helped Sabesp to narrowly avoid a catastrophe.[13]

Planning Projects: Decision-Making Under Deep Uncertainty

Given a constructive regulatory and policy environment, governments still need tools to plan resilient infrastructure projects. Not all infrastructure assets have equal exposure to natural hazards or climate change impacts, and the consequences of one asset failing may be far more dire than those of another. Accordingly, key questions for planners to consider in investment decisions include: (i) current and possible future exposure of the asset; (ii) consequences of failure; (iii) the level of risk acceptable to users, and; (iv) cost savings on maintenance over the lifetime of the asset, compared to the incremental up-front cost. In some cases, comprehensive analysis reveals that the increased up-front investment costs to achieve a given level of resilience are not justified by benefits. The key to achieving resilient infrastructure at an affordable cost is to invest selectively, guided by a comprehensive analysis of alternatives, and to design contingency plans for those cases when the up-front cost is not justified (Barandiarán et al., 2019).

One emerging practice to design resilient infrastructure assets is to use decision-making *under deep uncertainty* principles (Marchau et al., 2019).

[13] Ritter, Kayla. São Paulo Heading to Another Dry Spell. *Circle of Blue*, March 7, 2018, https://www.circleofblue.org/2018/water-climate/drought/sao-paulo-heading-to-another-dry-spell/.

Methods of decision-making under deep uncertainty attempt to identify infrastructure investment strategies that perform well under a broad range of future scenarios and metrics for success (such as access, affordability, and reliability indicators), developed collaboratively with stakeholders. The evaluation is performed across thousands of future scenarios formed by combinations of assumptions on relevant future conditions, such as climate change, natural hazards exposure, demographic trends, economic growth, energy prices, and the impact of disruptive technologies. This contrasts with traditional decision-making processes that first predict a single most likely future scenario and then identify the optimal strategy by maximizing one metric for success, often net present value.

Comprehensive analysis across many alternative scenarios can improve infrastructure investment plans, particularly when conducted early in the infrastructure design process. First, it can uncover "no-regrets" investments that are expected to pay off according to a decision-maker's metrics of success under any future scenario. For instance, the net present value of flood proofing the Carretera Central in Peru is positive under all scenarios for climate change, flood duration, traffic reduction, and cost of interventions (Briceño-Garmendia, Moroz, and Rozenberg, 2015). Second, it can identify strategies that avoid disastrous or high-cost outcomes. The Inland Empire Utilities Agency in the American West developed an adaptation strategy that eliminates 72 percent of the high-cost scenarios for providing water supply (Lempert and Groves, 2010). Third, it can identify unnecessary investments. The Lima water utility identified US$600 million worth of unnecessary investments (Box 6.3).

Decision-making under deep uncertainty techniques have become more widespread in recent years with the greater availability of computing power and environmental data. Globally, the water sector has led the way in formally incorporating uncertainty into infrastructure investment plans, and the practice is becoming standard in the sector (Marchau et al., 2019). In the transportation sector, these techniques are spreading with the use of so-called Blue Spot Analysis and transportation asset management tools (Abkowitz et al., 2017; Axelsen and Larsen, 2014; Cordeiro et al., 2017; Espinet et al., 2018). These methods focus on identifying critical links in transportation networks and their exposure to possible extreme weather events and evaluating options to reinforce the links or build redundancy in the network.

In the region, the practice is not yet standard, but policymakers have recently started to embrace decision-making under deep uncertainty techniques to design large-scale infrastructure projects. As in planning, the use of decision-making under deep uncertainty methods in the design

Box 6.3

Using Decision-Making under Deep Uncertainty in Peru

SEDAPAL, the Peruvian water utility that serves 93 percent of the residents of Lima and the province of Callao, used decision-making under deep uncertainty principles to develop an investment plan that ensures water reliability across a wide range of future scenarios (SEDAPAL, 2018). The investment plan takes an adaptive approach that implements no-regrets reservoirs in the short term with the flexibility to develop additional, feasible reservoirs in the medium and long terms as needed to meet demand.

The plan was developed through a participatory and iterative process that involved multiple stakeholders to define the metrics of success (the 90th percentile of monthly demand met as a percent of total demand, and cost of the investment plan), identify key drivers of uncertainty and vulnerability (future water demand, future stream flow, project feasibility), and identify investment options available to policymakers under different budget scenarios. The analysis primarily evaluated portfolios of investments drawn from SEDAPAL's Master Plan. Simulating 300 future scenarios using SEDAPAL's own water-accounting model, the project identified US$600 million (25 percent) of planned investments that SEDAPAL could forgo because these investments would not have contributed to improving the resilience of the system.

Source: Kalra et al. (2015).

of infrastructure is well established in the water sector and growing in the transport sector.

In addition to the case study of water reliability in Lima described in Box 6.3, examples abound in the water sector throughout Latin America and the Caribbean. The Pontifical Catholic University of Chile collaborated with policymakers and stakeholders from over 30 organizations to develop the Maipo Adaptation Plan for sustainable water supply (Ocampo-Melgar et al., 2016). The plan considers the important water uses in the Maipo River basin and analyzes uncertainties across 15 future climate scenarios and 5 land use scenarios. The plan develops performance indicators, such as water quantity, water quality, sustainability, and reduction of risks, to evaluate adaptation strategies that could minimize the impacts of climate change and variability. Aguas de Manizales in Colombia and Empresa Publica Metropolitana de Alcantarillado y Agua Potable de Quito in Ecuador have also recognized the importance of resilience to extreme events and conducted a comprehensive risk analysis (Balcázar, 2012). In Mendoza, Argentina, the IDB is piloting the use of decision-making under uncertainty techniques to evaluate the exposure of irrigation and residential water supply to changing precipitation patterns and assessing how different investments can increase water supply resilience.

Despite this progress, the formal incorporation of uncertainty in infrastructure plans remains elusive in local infrastructure projects. Even in developed countries, decision-making under deep uncertainty techniques have yet to take hold in the planning phase for smaller-scale infrastructure projects. In the United States, 75 percent of the local adaptation plans reviewed in a study identify uncertainty as a concern, but none use formal strategies for decision-making under uncertainty (Stults and Larsen, 2018).

The effects of climate change are already being felt by people, firms, and governments. Resilient infrastructure can minimize the impacts of climate change and natural disasters on the delivery of infrastructure services that people and firms rely on for a functioning economy and daily life. However, resiliency is only half the answer. To comprehensively address the risks of climate change, governments also need infrastructure plans that are compatible with a low-carbon future (see Chapter 7). With resilient, low-carbon infrastructure, the region—and the world—can better face the challenges of nature in the future.

7

Services in a Net-Zero-Carbon World: Good for the Environment, the Economy, and the People

Latin America and the Caribbean made a commitment to the environment—and to the future of the planet. All countries in the region ratified the 2015 Paris Agreement on Climate Change, which aims to limit the increase in the average global temperature to between 1.5° and 2°C (United Nations, 2015b). Fortunately, with the right policies and incentives, governments can both combat climate change and support their economies at the same time.

Both temperature goals outlined in the Paris Agreement are ambitious targets: they require reaching net-zero emissions of CO_2 by 2050 or 2070, respectively, and drastically reducing emissions of other greenhouse gases (GHG) before the end of the century (IPCC, 2015). CO_2 has a special role to play because it is the main greenhouse gas and because it has a very long lifetime: once emitted, it stays in the atmosphere for centuries. Reaching net-zero CO_2 emissions means reducing the sources of CO_2 emissions, such as the combustion of fossil fuels, and, simultaneously, increasing carbon sinks, such as forests, where trees capture carbon from the atmosphere as they grow.

The Paris Agreement explicitly recognizes the need to achieve carbon neutrality to stabilize climate change and, as of 2019, 66 parties to the agreement, including 21 countries in the region, had developed or were developing plans to reach net-zero emissions by 2050 (Government of Chile, 2019).

In the region, as in the rest of the world, transportation and energy services are the leading sources of CO_2 emissions. The good news is that providing energy and transport services in a carbon-neutral fashion by

2050 is technically achievable and offers economic opportunities (IDB/DDPLAC, 2019). The cost of renewable electricity and electric mobility, two solutions key to net-zero emissions, is dropping fast. At three cents per kilowatt-hour, solar and wind energy are already the cheapest ways to generate electricity in many countries. Done right, the transition to a net-zero-carbon economy will create jobs and generate benefits worth several percentage points of GDP.

Yet challenges need to be overcome to make the transition possible. The prevailing market organization in the power and public transport sectors is often linked to incumbent technologies and business models, making it difficult for renewable energy and electric buses to compete. In addition, prices send the wrong signal. The region has subsidized fossil fuels to the tune of more than 1 percent of GDP per year since 2010, keeping prices artificially low and reducing incentives to adopt energy efficient technologies and use electricity for cooking or mobility.

The transition can also create winners and losers; negative social effects need to be carefully managed. For example, thousands of jobs could be lost in fossil-fuel power plants and extractive activities, making the political economy of decarbonization strategies difficult to manage. Phasing out fossil-fuels could also damage public finances in countries that tax gasoline for revenue or rely on fossil-fuel royalties to fund a large share of government expenditures.

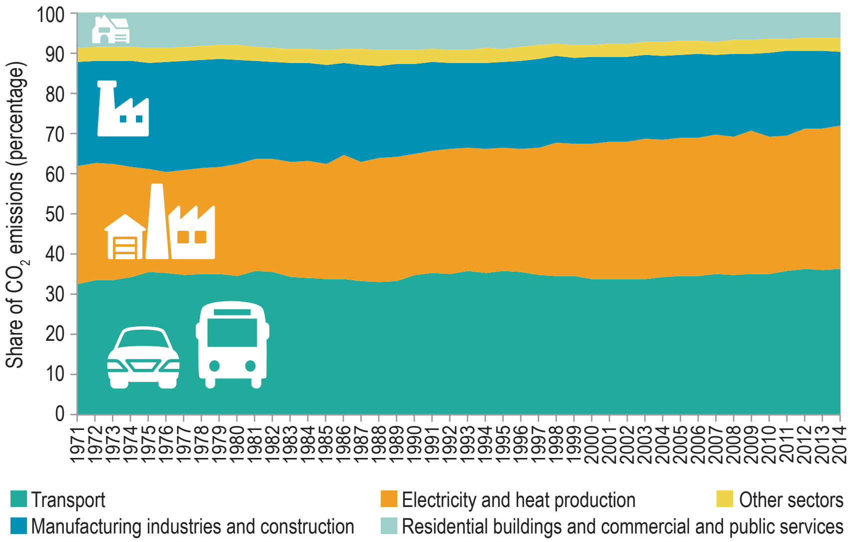
Finally, for the transition to a net-zero-carbon economy to become effective, government planning must change. Since signing the Paris Agreement, governments have designed a first set of plans to reduce emissions by 2030, known as the Nationally Determined Contributions (NDC). The NDCs are generally aligned with infrastructure expansion plans in the region, but, in the region's power sector, those plans rely heavily on natural gas. Implementing them would result in emission levels in the sector that are twice as great as those needed to meet the global temperature targets. In short, in the context of the Paris Agreement, natural gas is not the best solution to reduce emissions. The NDCs will have to be revised to focus on delivering zero-carbon solutions as soon as possible. More broadly, the countries of the region will have to develop a clear view of what type of infrastructure services they require in a carbon-neutral future.

This chapter shows how governments can use long-term decarbonization strategies for four purposes: (i) to guide the revision of their NDCs; (ii) to align plans for infrastructure assets and services with goals for decarbonization and economic development; (iii) to anticipate and minimize costs in the transition to net-zero emissions; and (iv) to plot a roadmap of infrastructure investments and regulatory reforms.

The Transition to Net-Zero Emissions: Four Pillars of Change

As a region, Latin America and the Caribbean accounts for 9 percent of the world's population but generates 12 percent of CO_2 emissions. Both globally and in the region, the two leading causes of GHG emissions are (i) energy services, because the fossil fuels used to generate electricity and heat and to fuel vehicles emit CO_2 when burned; and (ii) food production, because livestock and rice crops emit methane, synthetic fertilizers

Figure 7.1
Emissions of CO_2 in Latin America and the Caribbean by Source, 1970–2014



Source: World Resource Institute's CAIT Climate Data Explorer 2018.
Note: Excludes emissions from land use and land use change.

POWER GENERATION AND TRANSPORTATION ARE THE LEADING SOURCES OF CARBON DIOXIDE IN LATIN AMERICA AND THE CARIBBEAN, AND THE PROBLEM IS GETTING WORSE.

emit nitrous oxide, and deforestation and the transformation of ecosystems into cropland result in CO_2 emissions. Fossil-fuel combustion for transport and energy represent close to 70 percent of total CO_2 emissions both globally and in the region (Figure 7.1). Between 1990 and 2014, CO_2 emissions from fuel combustion in the region grew by 87 percent.

Can this picture change? Would it be possible to provide adequate and reliable infrastructure services in a zero-carbon economy? The answer is yes, but achieving the goal would require action on the four pillars of decarbonization (IDB/DDPLAC, 2019):

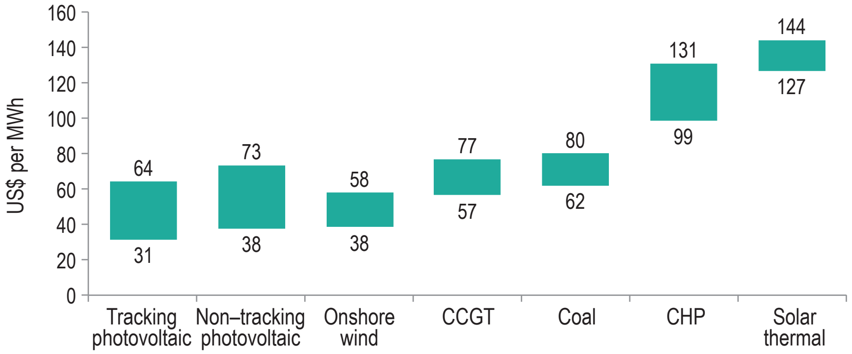
- Zero-carbon electricity generated from renewable and other low-carbon sources
- Massive electrification of economic activities through the use of electric vehicles and electric boilers and heat systems for industrial and residential users, and, where this is not possible, replacing fossil fuels with carbon-free fuels, such as hydrogen and sustainably produced biofuels
- Greater use of public and nonmotorized transportation and lower demand for transportation through development aligned with mass transit
- Using reforestation and restoration of other high-carbon ecosystems to capture carbon from the atmosphere

To decarbonize on schedule, countries will need to move simultaneously on the four pillars of decarbonization, starting as soon as possible. For instance, it makes sense to promote electromobility, even in countries where coal is used to provide the last mega-watt hour (MWh) of electricity, as long as the country is simultaneously advancing to decarbonize power generation. The deciding factor should be long-term progress toward zero net carbon, rather than immediate, isolated effects on emissions (Audoly et al., 2018).

The Economic Case for Decarbonization

Decarbonizing offers many opportunities to improve the region's economy and the lives of its citizens. The cost of renewable power has fallen steadily and increasingly outcompetes fossil-fuel power. Between 2010 and 2017, the global average cost of generating a MWh of electricity with new plants has dropped from US$360 to US$100 for solar photovoltaic and from US$80 to US$60 for onshore wind. As of 2019, auctions in the region awarded contracts at about US$30 per MWh for solar in Mexico, Peru, and Chile, and for wind in Mexico. Those were record-low costs globally (IEA, 2019d). In many countries such as Chile, the levelized cost of electricity from renewables like wind and solar is lower than the cost of fossil fuels (Figure 7.2). Costs are expected to continue to fall. By 2025, new renewable power in the region is projected to be cheaper than existing fossil-fueled power by a margin of US$10–30 per MWh (Vergara, Fenhann, and Schletz, 2015). If the cost

Figure 7.2
Ranges of the Levelized Cost of Generating Electricity in Chile, 2019



Source: BNEF 1H 2019 LCOE Data Viewer Index.
Note: The bars show the full range of costs measured in Chile. Tracking photovoltaic refers to panels that change position to maximize irradiation received while non-tracking photovoltaic refers to fixed panels. Combined-cycle gas turbines (CCGT) and combined heat and power (CHP) are power generation technologies based on natural gas.

RENEWABLE ELECTRICITY IS OFTEN THE CHEAPEST OPTION; CHILE IS AN EXAMPLE.

trend continues and accelerates, it will soon be technically and economically feasible to scale up renewable power in Latin America and the Caribbean using batteries, hydropower, and regional integration of the grid to absorb and compensate for the intermittency of variable renewable energy. Chapter 12 reports that in many countries of the region, sharp increases in the share of renewables in the electricity matrix have positive effects on economic growth and on income distribution.

Electric-powered and public transportation will yield economic benefits for the region. In Costa Rica, the cost of accidents, pollution, and time lost in traffic has been estimated at 3.8 percent of GDP (Programa Estado de la Nación, 2018). Costa Rica's numbers are representative of global estimates, which put time and fuel wasted in urban congestion at between 2 and 5 percent of 2015 GDP (Lefevre et al., 2016). These data highlight the socioeconomic potential of reducing the dependence of the transportation system on private cars. In addition, the cost of switching to electric public transportation is decreasing rapidly. Lithium-ion battery prices dropped by a factor of seven between 2010 and 2019 and are expected to become even cheaper, making electric vehicles more affordable than internal combustion vehicles sometime by 2023.[1] Some

1 See BNEF's 2019 Battery Price Survey.

cities are already seizing the opportunity: Bogotá and Santiago de Chile, for example, put large fleets of electric public buses into service in 2019; many other cities are following their lead.

Energy efficiency investments can also spur economic development by lowering electricity bills for businesses and households. The International Energy Agency reports that large-scale energy efficiency policies have a positive impact on annual GDP in a range of 0.25 to 1.1 percent (IEA, 2014). Implementation of Colombia's climate mitigation commitments would add 0.15 percent to yearly GDP growth until 2040, as a result of avoided energy costs (Álvarez-Espinosa et al., 2017).

In addition to cost savings, the transition to net-zero emissions can also be a net job creator in manufacturing, renewable energy, and copper mining, creating one million jobs in Latin America and the Caribbean by 2030 (ILO, 2018b). The transition will mean job losses in carbon-intensive sectors, however, which can generate political opposition to decarbonization strategies. Ways to manage that problem are discussed below.

Eliminating or reducing the energy subsidies that are pervasive in the region constitutes another opportunity to increase economic efficiency and improve environmental and health outcomes, while also making progress toward decarbonization. The International Monetary Fund estimates that energy subsidies and the absence of environmental taxes (to compensate for the effects of energy consumption on pollution, time wasted in congestion, accidents, and road damage) cost governments around the world nearly 5 percent of annual GDP in forgone fiscal revenue, and about 3 percent in Latin America and the Caribbean (Coady et al., 2019). Removing subsidies and enacting environmental taxes worldwide would result in a 21 percent drop in global CO_2 emissions and increase fiscal revenues by 3 percent of 2017 GDP. In Latin America and the Caribbean, the change in fiscal accounts would be in the range of 1–1.5 percent of GDP (Coady et al., 2017).

Considering the benefits, the costs of decarbonizing are affordable. In 2014, the Intergovernmental Panel on Climate Change (IPCC) estimated that the cost of curbing emissions in order to reach the 2°C target would grow gradually, reaching 2 percent of GDP in 2030 and about 4.5 percent in 2100, with the numbers for the region aligned with global averages. These costs, measured in forgone consumption, represent an annualized reduction in the growth of consumption of 0.04 to 0.14 percentage points (median: 0.06) relative to annualized consumption growth in the baseline, which is between 1.6 and 3 percent per year (IPCC, 2015).

Barriers to Change

While a zero-net emission economy is achievable in the region at reasonable cost with a net benefit, many barriers stand in the way. International experience and analysis provide evidence on the economic, financial, and regulatory barriers that impede decarbonization and show how policy reforms can begin to remove them.

Business Models in the Transportation Sector

In the transportation sector, for example, the prevailing market organization can be an obstacle to the adoption of electric buses. Electric buses are cost-effective over their lifetime, as they have lower operating costs than diesel-powered conveyances. But the high cost of batteries, which can represent more than half the cost of an electric bus, means higher up-front investments and longer amortization periods for bus owners. Operators also face uncertainties about the long-term performance of batteries and the resale value of their investments. Traditional small and medium enterprises, many of them consisting of a single owner-driver operating on a single line, lack technical expertise on batteries. They may be unwilling to assume the financial risk of batteries failing or may not have access to the financing required to make the higher up-front investment required to buy an electric bus.

In Santiago de Chile, the solution was to reform bus concessions, separating fleet ownership from operation. Electric utilities were offered a contract for fleet ownership, which the utilities can manage at low cost, given their large financial capacity, in-house expertise with battery technologies, and the salvage value of used batteries, which can be used to provide ancillary grid services. Utilities then lease out electric buses to transportation companies, which benefit from greater certainty on costs. As a result of the reforms, 200 electric buses were introduced in 2019, with 500 more to follow in 2020; up to 80 percent of the fleet should be electrified by 2022.

Market Design and Pricing in the Power Sector: A Hot Topic

In the power sector, prevailing market designs often reserve a share of the market for thermal generation (often based on natural gas) to ensure the ability to respond to variations in demand. Increasing the share of renewables in the electricity mix in order to achieve net-zero emissions will challenge the traditional approach to regulating electricity prices. Most electricity pricing regimes in the region are based on rates that increase with the quantity consumed (Chapter 9). But as nonconventional renewables like solar photovoltaic lower costs, the prevailing rate structure will provide growing incentives to disconnect from the electricity grid. To avoid this—and be able to expand and maintain the grid as a public good—the structure of electricity prices will have to shift to a scheme in which fixed charges play a greater role. Successful modification of pricing structures depends on detailed data and accurate modelling of the electricity sector so as to allow utilities to obtain an adequate return on invested capital while making electricity services affordable to low-income and vulnerable households. Regulatory capacity to adopt these changes is weak in many countries. This regulatory deficiency, combined with a bias for the status quo, constitute a barrier to the rapid adoption of nonconventional renewables.

Energy Prices and Their Impact on Inequality

Failure to align energy prices with social costs can hinder the adoption of carbon-free technologies. Economists have long emphasized that a carbon price should be the preferred instrument to incentivize reductions of GHG emissions at the lowest social cost. But instead, many governments subsidize energy.

Environmental taxes and energy subsidy reforms have proved difficult to implement, in part because of their adverse impacts on the cost of food, utilities, and public transportation. These effects conspire against the goal of providing affordable and inclusive infrastructure services and increase resistance to decarbonization strategies. Anticipating the impact of price hikes on consumers and compensating negatively affected households would improve the political economy of reforms and make it possible to align environmentally motivated price reforms with broader development goals. Communication and the engagement of stakeholders in the design of price reforms and compensation packages are also critical for political acceptability.

Conditional cash transfer programs may be one option for compensating affected consumers. Cash transfers are one of the most efficient ways to deliver social assistance, and several countries in the region already have conditional cash transfer programs. The Inter-American Development Bank estimates that allocating 30 percent of carbon tax revenues to an expanded program of cash transfers would be enough in most cases to compensate poor and vulnerable households, leaving 70 percent of carbon tax receipts to fund other development priorities (Vogt-Schilb et al., 2019).

In-kind transfers are another option. Most of the impact on households of carbon taxes and lower energy subsidies comes in the form of higher prices for food, public transportation, electricity, and the fuels used for heating and cooking. To shield vulnerable households, governments can focus on providing those items directly to them at affordable prices, for example, through targeted public transport subsidies, food vouchers, and electricity lifelines (Schaffitzel et al., 2020).

Price reforms can reduce the competitiveness of firms built around the previous set of prices, raising the prospect of stranded assets should those firms go bankrupt. For instance, a substantial economy-wide carbon price in Chile could make coal power plants unprofitable overnight, resulting in the immediate firing of thousands of employees. In many countries, sudden removal of diesel subsidies could bankrupt bus owners or sharply increase the price of public transportation. Though these outcomes might be deemed cost-efficient, they would be politically unpalatable. Climate policies may benefit the society at large, but if their costs fall on small groups, those groups will organize quickly to oppose the measures. And concentrated opponents organize more easily than diffuse proponents, making the political economy of climate policies difficult to sustain.

One limitation of price instruments is that their impact on fossil energy prices could be offset by lower international oil prices, eroding the incentives for firms and consumers to decarbonize; this is the so-called green paradox. Policies to decarbonize services will have to combine pricing (e.g., carbon taxes) with other instruments, such as mandatory quotas for nonconventional renewables in the electricity mix.

Banning Polluting Technologies and Mandating Clean Ones

Policies that promote investments in clean infrastructure without penalizing the use of existing polluting infrastructure can be effective in advancing decarbonization with greater social and political acceptability. Many countries, including Argentina and Mexico, have used mandatory quotas for clean sources in the electricity mix. If investments in clean energy can supply any and all new growth in demand, they will gradually replace existing services as facilities become obsolete. To this end, governments can ban the deployment of new carbon-intensive assets. Chile, for example, has banned the building of new coal power plants. Norway, France, and the United Kingdom have pledged to ban the sale of gasoline and diesel cars by 2025, 2040, and 2050, respectively, and Bolivia has banned sales of new incandescent light bulbs, mandating the use of efficient LEDs or fluorescent bulbs.

Planning for Net-Zero Emissions: On the Wrong Track

Just as misguided infrastructure planning can pose a barrier to decarbonization, sound planning can and must align short-term infrastructure investment decisions with long-term goals. Unfortunately, most present planning in Latin America and the Caribbean is not yet well aligned with decarbonization.

Avoiding Carbon Lock-in and Stranded Assets

Because infrastructure or equipment that produces emissions often has a lengthy life span, long-term decarbonization targets are dependent on today's investment decisions. Cars, for example, can be used for more than 15 years, and power plants for more than 40 years, while transportation systems and human settlements can last even longer. Deploying carbon-intensive infrastructure or equipment today may lock in emissions for 2030, 2050, and beyond.

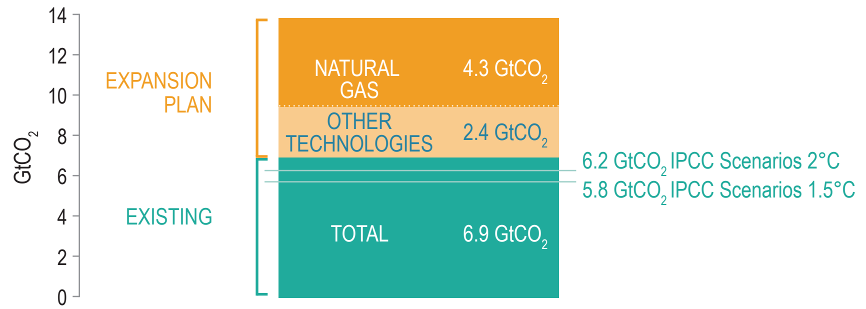
Globally, existing fossil-fuel energy infrastructure is already at odds with the 1.5°C target. If operated as originally planned, existing fossil-fuel infrastructure, including power plants, industrial plants, and transport equipment, will cumulatively emit more than 650 $GtCO_2$ (gigatonnes of CO_2) over its lifetime. These so-called committed emissions are already greater than the 420 to 580 $GtCO_2$ that the IPCC estimates can be emitted globally to stay below 1.5°C. To meet the global temperature targets, some existing infrastructure will need to be retired early or be retrofitted with expensive carbon capture and storage technology, which has yet to become commercially viable. In other words, fossil-fuel-production infrastructure is at risk of becoming stranded. For the global climate goals to be met, most existing fossil-fuel reserves will need to stay in the ground, including up to 80 percent of oil reserves in Latin America and the Caribbean (Solano-Rodríguez et al., 2019). Policymakers should not plan on sustained oil demand to fund their government programs with royalties, and plan instead to diversify their fiscal and export strategy before it is too late.

Building all planned or announced fossil-fuel power plants in Latin America and the Caribbean would bring committed emissions to 14 $GtCO_2$, far greater than the 6 $GtCO_2$ of emissions from the region's power sector that the IPCC estimates is consistent with the 1.5—2°C temperature targets (Figure 7.3).

Many technology choices that marginally reduce emissions, such as using natural gas to replace coal in power generation, or promoting efficient

Figure 7.3

Committed Emissions from the Region's Power Sector vs Average Emissions Consistent with Temperature Targets in IPCC Scenarios



Source: González-Mahecha et al. (2019).
Note: IPCC Scenarios up to 2050.

EMISSIONS FROM EXISTING AND PLANNED POWER PLANTS IN LATIN AMERICA AND THE CARIBBEAN ARE INCONSISTENT WITH THE TEMPERATURE GOALS OF THE PARIS AGREEMENT.

gasoline cars to replace inefficient ones, would still lead to substantial committed emissions. To avoid carbon lock-in, governments will have to act early on emissions reductions, and focus on options that are consistent with a rapid transition to net-zero emissions, such as electric vehicles in conjunction with zero-carbon electricity.

Beyond technology choices, urban planning, which drives demand for transportation services, can take centuries to change. Many of the fastest-growing cities in Latin America and the Caribbean are characterized by low density and heavy reliance on individual vehicles. If policymakers fail to take steps now toward decarbonized transportation and greater density in cities, they may find themselves facing an impossible task by the 2030s.

A Lukewarm Start for NDCs

Inadequate planning can also block decarbonization. The current round of emissions reduction pledges outlined in the NDCs, which are the planning instrument agreed upon by the international community to guide actions toward decarbonization, are insufficient, as they would collectively fail to put economies on track toward limiting global warming to below 2°C. Worldwide, current NDCs will allow emissions of 52–58 $GtCO_{2eq}$ (carbon dioxide equivalent) in 2030, instead of the 15–30 $GtCO_{2eq}$ needed to reach the 1.5°C target (UNEP, 2018). Ironically, policies, laws, and investments designed to support the implementation of existing NDCs could erect technical and economic obstacles to achieving the temperature targets of the Paris Agreement.

To achieve emissions targets consistent with the 1.5°C and 2°C targets, Latin America and the Caribbean must derive 83 and 90 percent, respectively, of its electricity from zero-carbon sources by 2050, up from 53 percent in 2015 (Binsted et al., 2019). But under the NDCs submitted by the countries of the region, the share of zero-carbon sources will remain stable at 53 percent by 2030, and half of the growth in electricity demand over the next decade will be met by natural gas power plants. These fossil-fuel power plants would then have to be decommissioned by 2050, before the end of their lifetime. This result confirms that there is little space for natural gas to play the role of a "bridge fuel" in the transition to a net-zero power system.

The good news is that the Paris agreement anticipated this situation. Under the agreement, governments are expected to increase the ambition of their NDCs every five years. If the temperature targets of the Paris Agreement are to be met, the next round of NDCs should reflect the necessity of long-term carbon neutrality. They should include short-term actions to minimize the risk of stranded assets and provide for substantial transformation by 2030.

The Need for Long-Term Strategies

To operationalize a strategy that minimizes stranded assets in the transition to net-zero emissions, governments can use what has been called "decarbonization plans or long-term strategies" (IDB/DDPLAC, 2019). A long-term strategy has three objectives: (i) to build a shared vision of where the country wants to be in 2050 in terms of decarbonization, prosperity, and development (with an emphasis on the infrastructure services needed to support these); (ii) to anticipate and mitigate potential costs and trade-offs in the transition so as to ensure a fair transition; and (iii) to align sector planning with the long-term decarbonization goal and to lay out a roadmap of investments and policy reforms to accomplish the transition.

Costa Rica has the most advanced and ambitious strategy in the region. Its national decarbonization plan, published in 2019, aims at reaching net-zero emissions by 2050. It sets mid- and near-term targets to monitor the progress of all emitting sectors of its economy. One of its long-term goals is to have 85 percent of buses and 95 percent of cars running on electricity by 2050. Recognizing that transforming fleets requires time, the plan sets a midterm target of electrifying 30 percent of buses and cars by 2035 (Government of Costa Rica, 2019). The plan includes similar targets for electricity generation, agriculture, forestry, livestock, and waste management. Such midterm targets should be used to update NDCs and align them with the long-term decarbonization goal.

The Paris Agreement invites countries to design and communicate their long-term decarbonization strategies by 2020. As of early 2020, Costa Rica and Mexico are the only countries in the region that have formally conveyed their strategy to the United Nations. Mexico's "mid-century strategy" starts from a goal of halving GHG emissions by 2050 over 2000 levels, sustained by targets for the penetration of renewable electricity (up to 50 percent in 2050), for improving the energy efficiency of road vehicles (up to 100 percent improvement by 2030 and 500 percent by 2050 over 2015 levels), and explores scenarios to contain deforestation (SEMARNAT/INECC, 2016). In 2019, 21 countries in the region announced that they are working on plans to achieve net-zero emissions by 2050 (Government of Chile, 2019).

Good practices in the design of a long-term decarbonization strategy emerge from international experience (IDB/DDPLAC, 2019). Chief among them are (i) establishment of a clear long-term vision and mandate at the political level (such as Mexico's climate change law and a mandate from the head of state in Costa Rica); (ii) utilization of models to inform sectoral pathways to reach these goals; (iii) consultations with stakeholders to refine and validate targets and increase buy-in from the sectors that will be responsible for implementing them; and (iv) recognition that decarbonizing an economy can work only as part of a broader long-term development agenda that yields broad benefits and minimizes transition costs.

Clear sectoral targets for transitioning to net-zero emissions allow governments to identify barriers to decarbonizing, thereby improving the design of policy reform roadmaps. Costa Rica's national decarbonization plan provides a comprehensive example. It contains a list of regulatory updates and policy reforms required to remove obstacles to decarbonization, including:

- Updating business models for bus companies to enable electrification of the fleet
- Analyzing possible reforms of electricity pricing to incentivize electrification of energy uses
- Introducing energy efficiency standards for residential and industrial appliances
- Improving payment for the ecosystem services scheme to foster reforestation and restoration of high-carbon ecosystems

The plan also identifies infrastructure investment needs, such as designating lanes for exclusive bus use to raise the value of public transportation.

Long-term strategies can also help governments plan a fair and inclusive transition for households and communities. The government of Chile has set the objective of phasing out coal power generation by 2040. This would create between two and eight thousand additional jobs in the renewable energy industry by 2030, but it would also eliminate four thousand jobs in coal power plants (Vogt-Schilb and Feng, 2019). While these numbers are negligible as shares of the Chilean job market, they can be sizeable at the local level. In the most affected communities, up to 7 percent of inhabitants work in a coal power plant (Viteri Andrade, 2019).

A long-term vision gives governments time to anticipate the impact of decarbonization on affected communities and workers, and to make plans to help them adjust. Options include: (i) offering access to general-purpose social protection and workforce benefits; (ii) planning phase-outs to coincide with the natural retirement of workers and smooth the impact on local job markets; (iii) siting renewable power plants and industries that supply them in the same communities where coal is being phased out; and (iv) retraining workers to fill new jobs in the renewable energy supply chain. All of these are critical to align decarbonization objectives with social development goals.

Finally, a long-term vision gives government time to plan for the fiscal impacts of decarbonization. The political feasibility of any reform depends ultimately on its effect on the public treasury. Yet, absent adjustments to current transport-related taxation schemes, the uptake of electric vehicles has the potential to reduce revenues from gasoline and diesel taxes. Among solutions suggested by the International Energy Agency to compensate for an eroding base, ministries of finance can gradually increase taxes on fossil fuels, progressively adjust taxes on electricity, vehicle ownership, and, if possible, use distance-based charges that capture the effects of driving on congestion, accidents, and road damage (IEA, 2019a).

In sum, long-term strategies can help governments plan for net-zero emissions, guide the revision of NDCs, align infrastructure plans with development and decarbonization goals, ensure a smooth transition that avoids stranded assets, and design the policy and investment roadmaps needed to make the transition politically feasible. Because long-term strategies set priorities for infrastructure investments and policy reforms needed to redirect development, they can facilitate dialogue with international donors and development agencies. Several countries in the region have already issued their strategies and are now in the early stages of implementation. Everywhere, a long-term decarbonization strategy to align infrastructure services with climate goals should be a top priority.

8

Back to Nature: Alternatives to Concrete and Steel

Not all infrastructure is man-made. Natural and quasi-natural ecosystems can deliver many of the same services as conventional "gray" infrastructure. For example, in coastal areas, naturally occurring coral reefs and mangroves can provide the same type of protection against storm surges and flooding as sea walls, breakwaters, and bulkheads. In cities, quasi-natural green roofs and green spaces can stem stormwater runoff, significantly lightening the load on sewerage. And in both rural and urban areas, natural forests and constructed wetlands can perform the same water purification functions as wastewater treatment plants.

In recent years, awareness of, enthusiasm for, and investment in such green infrastructure (GI), also known as natural infrastructure, have grown exponentially both in industrialized and developing countries. For example, in 2013, the European Union adopted a formal strategy to promote GI (EU, 2013). In the past five years, multi-million dollar GI projects have been used to help preserve drinking water quality in New York City and to reduce stormwater runoff in Washington, DC (Bloomberg and Halloway, 2018; EPA, 2015). In 2019, the World Bank released a flagship report on GI that catalogued 81 World Bank projects with GI components in the environment, urban, water, and agricultural sectors (Browder et al., 2019). And in 2019, the Asian Development Bank and the Association of Southeast Asian Nations launched a US$1 billion financing facility for GI (ADB, 2019).

What role can such GI play in helping to fill Latin America and the Caribbean's infrastructure gap? A growing body of evidence suggests that policymakers would do well to carefully consider both opportunities for using GI, and the special requirements for making GI work in any given situation. As for opportunities, considerable evidence shows that under certain conditions, GI can provide services as effectively, and in some cases as cost-effectively, as conventional gray infrastructure. What's more, GI provides valuable services that conventional gray infrastructure does not. For example, coral reefs, seagrasses, and mangroves not only help control flooding, they also cycle nutrients, filter water, provide habitat for flora and fauna, and spur recreation and ecotourism. Latin America and the Caribbean would seem to be well positioned to take advantage of GI. Often referred to as a biodiversity superpower, the region contains half the world's remaining tropical forests, one-quarter of its mangroves, nearly one-fifth of its coastal habitats, and its second largest coral reef (Blackman et al., 2014; Bovarnick, Alpizar, and Schnell, 2010).

But using GI also requires policymakers to build specialized knowledge, capacity, and oftentimes funding streams. A variety of site-specific factors determine GI's benefits and its costs. Therefore, to determine whether and how to invest in GI, policymakers need to understand these factors and how they come into play in a specific project site. For example, in general, the efficacy of a coral reef in stemming storm surges depends on its position relative to the coastline, size, submergence, and structural characteristics. And in general, the costs of conserving and restoring coral reefs will depend on the ecological health of the reef, the agents and institutions that use and manage it, and whether the main threats are pollution, fishing, or other factors. Policymakers need to understand how all of these factors come into play in a proposed project site. Given these opportunities and special requirements, successful application of GI requires careful planning.

Green Infrastructure, in Broad Brushstrokes

This chapter focuses on six types of GI that have received considerable attention in the literature: coral reefs, mangroves, forests, constructed wetlands, green roofs, and green spaces.[1] These types span four geophysical settings: marine, coastal, terrestrial, and urban (Table 8.1).

As noted above, GI provides a variety of services. The 2005 Millennium Ecosystem Assessment, a seminal analysis, groups ecosystem services into four categories (Table 8.2): provisioning services, which entail the supply of products like food and fuelwood that are directly consumed by humans; regulating services like flood control and water purification, which have to do with the regulation of ecological processes; cultural services, which refer to nonmaterial benefits like spiritual well-being and recreation; and supporting services, which are basic ecological processes

[1] GI types omitted include oyster reefs, seagrasses, sand dunes, salt marshes, living walls, green facades, urban forests, urban wetlands, and rainwater harvesting.

Table 8.1
Green Infrastructure Types Analyzed in This Chapter

Geophysical setting	Green infrastructure type
Marine	Coral reefs
Coastal	Mangroves
Terrestrial	Forests
	Constructed wetlands
Urban	Green roofs
	Green spaces

Source: Authors' elaboration.

Table 8.2
Ecosystem Services Categories

Provisioning	Regulating	Cultural
Products obtained from ecosystems	Benefits obtained from regulation of ecosystem processes	Nonmaterial benefits obtained from ecosystems
• Food • Freshwater • Fuelwood • Fibre • Biochemicals • Genetic resources	• Flood control • Climate regulation • Disease regulation • Water regulation • Water purification • Pollination	• Spiritual and religious • Recreation and ecotourism • Aesthetic • Inspirational • Educational • Sense of place • Cultural heritage
Supporting services		
Services necessary for the production of all others ecosystem services		
	• Soil formation • Nutrient cycling • Primary production	

Source: MEA (2005).

like soil formation and nutrient cycling that maintain ecosystems without necessarily benefiting people directly (MEA, 2005).

Using the Millennium Ecosystem Assessment categories, Table 8.3 lists the ecosystem services provided by each of the six GI types on which this chapter focuses. Although each GI type provides multiple ecosystem services, these GI types are typically planned and/or managed to provide a single or small number of regulating ecosystem services. Because this chapter is broadly interested in the potential of GI to substitute for or complement conventional gray infrastructure, it focuses on those regulating ecosystem services that can substitute for services provided by gray infrastructure. These ecosystem services are highlighted in bold type.

Table 8.3
Ecosystem Services Associated with Green Infrastructure, by Type

	Green Infrastructure	Regulating	Provisioning	Cultural	Supporting	Sources
Marine	**Coral reefs**	• **Coastal flood regulation** • Coastal erosion regulation • Sediment trapping • Beach/island formation • Climate regulation	• Fisheries • Aquaculture • Biota for aquarium trade • Pharmaceutical prospecting • Building materials • Decorative materials	• Tourism and recreation • Education and research • Scientific value • Aesthetic appreciation • Spiritual sacred sites	• Nutrient cycling • Habitat provision	UNEP-WCMC (2006)
Coastal	**Mangroves**	• **Coastal flood regulation** • Coastal erosion regulation • Sediment trapping • Water filtration/ purification • Climate regulation	• Fisheries • Aquaculture • Fuelwood • Medicinal plant collection	• Tourism and recreation • Education and research • Scientific value • Aesthetic appreciation • Spiritual sacred sites	• Nutrient cycling • Habitat provision	UNEP-WCMC (2006) Lawrence, Baker, and Lovelock (2012)
Terrestrial	**Forests**	• **Water quality regulation** • Flood regulation • Soil erosion control • Bioregulation (disease) • Climate regulation	• Water supply • Food cultivation/ collection • Shelter • Fuelwood • Medicinal plant collection	• Tourism and recreation • Education • Scientific value • Aesthetic appreciation • Spiritual sacred sites	• Soil formation • Biotic production • Nutrient cycling • Habitat provision	Maass et al. (2005) Campbell et al. (2007) Lawrence, Baker, and Lovelock (2012) Brandon (2014) Elias and May-Tobin (2011)

(continued on next page)

Table 8.3
Ecosystem Services Associated with Green Infrastructure, by Type *(continued)*

	Green Infrastructure	Regulating	Provisioning	Cultural	Supporting	Sources
	Constructed wetlands	• **Wastewater treatment** • Flood regulation • Climate regulation	• Water supply • Decorative materials	• Tourism and recreation • Aesthetic appreciation	• Nutrient cycling • Biotic production • Habitat provision	DiMuro et al. (2014) Nahlik and Fennessy (2016) Sandoval-Herazo et al. (2018) Konnerup, Trang, and Brix (2011)
Urban	**Green roofs**	• **Stormwater runoff regulation** • Water treatment • Climate regulation	• Decorative materials	• Aesthetic appreciation	• Nutrient cycling • Biotic production • Habitat provision	UNEP-DHI (2014) Fioretti et al. (2010) Santamouris et al. (2005)
	Green spaces (bioswales and rain gardens)	• **Stormwater runoff regulation** • Water treatment • Climate regulation	• Decorative materials	• Recreation and community cohesion • Aesthetic appreciation	• Nutrient cycling • Biotic production • Habitat provision	UNEP-DHI (2014) Mehring et al. (2016)

Source: Authors' elaboration.
Note: Ecosystem services in bold type are those focused on in the following section. Biotic production refers to plant growth. Climate regulation refers to local, regional, continental, and global regulation of the flows of energy (radiation, heat) and materials (e.g. water, carbon, nitrogen) between the atmosphere, oceans, and terrestrial systems (Brandon, 2014). Water quality regulation refers to reductions in water pollutants such as fertilizers and other nutrients, suspended solids, and micro-organisms.

Filling in the Picture

The weight of evidence suggests that given appropriate local conditions, GI can provide infrastructure services as effectively and sometimes as cost-effectively as conventional approaches.

Coral Reefs for Coastal Flood Control

Efficacy. Coral reefs regulate coastal flooding by attenuating wave energy.[2] They reduce wave energy by an average of 97 percent and wave height by an average of 84 percent (Ferrario et al., 2014). Compared to other types of costal GI (seagrasses, salt marshes, and mangroves), they have the greatest potential for coastal protection because they are highly effective at reducing wave heights and tend to be located in areas exposed to more powerful waves (Narayan et al., 2016). However, their effectiveness in attenuating wave energy depends on site-specific factors such as reef submergence and smoothness—more submerged, smoother reefs are less effective (Beck et al., 2018).

Cost-effectiveness. From a policy perspective, two broad strategies for enhancing or maintaining ecosystem services that GI provides are to conserve it and to restore it. To conserve existing coral reefs, the main policy option is to establish marine protected areas, which help conserve all types of marine GI including mangroves. The costs of establishing and operating marine protected areas vary widely, from less than US$100 per km^2 to more than US$1 million, depending on, among other factors, size and vintage—not surprisingly, large and longer lived marine protected areas are less costly because fixed set-up costs are spread over a larger area and more years (McCrea-Strub et al., 2011; Balmford et al., 2004).

Coral reefs can be restored by transplanting coral grown in laboratories, in-situ nurseries and, as discussed in Box 8.3, deploying artificial reef structures. The costs are high relative to those for other types of GI, ranging from an average of US$4,479,769 per ha. in developed countries to US$48,308 per ha.[3] in developing countries (Bayraktarov et al., 2016).

[2] Wave energy—the transport and capture of energy by ocean surface waves—is a function of wave height, length, and speed. Wave attenuation results in lower wave heights (Wright, Colling, and Park, 1999).

[3] Restoration costs of both coral reefs and mangroves are calculated using 2010 US$.

Despite this high price tag, restoration can be cost effective compared to gray infrastructure. For example, Caribbean Catastrophe Risk Insurance Facility (2010), which examined 20 approaches to coastal risk reduction including both GI and gray solutions, finds that reef restoration is one of the most cost-effective approaches for seven of eight nations involved.

Mangroves for Coastal Flood Control

Efficacy. Mangroves, which are intertidal forests dominated by trees and shrubs adapted to coastal habitats, reduce wind-driven wave heights by an average of 31 percent and cyclone driven wave heights by an average of 60 percent (Narayan et al., 2016). They are resilient to storms and, therefore, provide reliable protection in successive events (Dahdouh-Guebas et al., 2005). Their capacity to attenuate wave energy depends on site-specific factors including the features of the mangroves forest like species composition and age, characteristics of the ecosystem including water depth, slope, and presence of adjacent vegetation, and the characteristics of the wave event such as wave height and speed (Alongi, 2008; Hashim, Catherine, and Takaijudin, 2013; McIvor et al., 2012). Although mangroves are effective at attenuating wave energy, they are often found in sheltered areas and as a result, are not well positioned to attenuate the largest and most powerful waves (Narayan et al., 2016).

Cost-effectiveness. Marine protected areas are the principal means of conserving marine GI, including mangroves, and their set-up and operating costs vary widely. Mangrove restoration typically entails planting seeds, seedlings, and propagules, clearing invasive plants, and dredging and re-contouring the site (Bayraktarov et al., 2016). Compared to other types of marine GI, mangroves have the lowest restoration costs per hectare—averaging US$42,801 per ha. in developed countries and US$1,413 per ha. in developing countries—partly because mangrove restoration projects typically cover large areas (Bayraktarov et al., 2016).

Forests for Water Quality Regulation

Efficacy. Forests can effectively prevent sediments and other impurities in runoff from contaminating surface water (Hewlett, 1982; Bruijnzeel, 2004; Hurley and Mazumder, 2013). However, these water purification properties are neither simple nor linear; they depend on a variety of site-specific characteristics including the proximity of forests to surface water (Curtis and Morgenroth, 2014; Hurley and Mazumder, 2013).

Cost-effectiveness. Considerable econometric evidence indicates that at the watershed-level, forest cover is negatively correlated with water treatment costs (Abildtrup, García, and Stenger, 2013; Fiquepron, García, and Stenger, 2013; Warziniack et al., 2017; Singh and Mishra, 2014; Ernst et al., 2004; Freeman et al., 2008; McDonald et al., 2016; Vincent et al., 2016). Among the most compelling studies is Vincent et al. (2016), an econometric analysis that uses plant-level panel data on surrounding forest cover and treatment costs in Malaysia. The authors find that protecting both virgin and managed forests from conversion to cleared land uses reduces water treatment costs; protecting virgin forests reduces costs more.

Constructed Wetlands for Water Quality Regulation

Efficacy. Although not widely used in Latin America and the Caribbean, constructed wetlands—engineered systems that use natural functions to treat wastewater—are a viable, low-cost alternative to conventional wastewater treatment plants (Noyola et al., 2012). They can remove a range of pollutants from wastewater including organic compounds, pathogens, suspended soils, metals, and nutrients and have been successfully deployed in a variety of economic sectors (Zhang et al., 2015; Vymazal, 2014; Kivaisi, 2001). Their efficacy varies widely because they entail complex biological, chemical, and physical processes that, in turn, depend on design parameters (Wang et al., 2017; Trang et al., 2010).[4] They tend to perform better in tropical and subtropical climates where year-round high temperatures and direct sunlight promote microbial biodegradation (Zhang et al., 2015; Kaseva, 2004).

Cost-effectiveness. The business case for constructed wetlands is strong across many different wastewater applications (Cohen and Orlofsky, 2018). Long-term operation and management (costs (associated with personnel, harvesting vegetation, insect and pest control, and energy costs for pumps) are generally significantly lower than for conventional treatment plants, although fixed set-up costs are not (Arias and Brown, 2009; Zhang et al., 2015). Constructed wetlands are designed to be self-sustained systems that grow and improve over time with limited human intervention.

4 Key design options include hydrology (open water-surface flow versus subsurface flow), water flow path (horizontal versus vertical), and vegetation type (floating-leaved, free-floating, submerged, or emergent), which may be combined to create a hybrid approach (Vymazal, 2014).

Green Roofs for Storm Water Regulation

A green roof is one that is partially or completely covered with vegetation planted in soil or some other growing medium placed on top of a waterproof membrane. The two principal types are extensive green roofs, which rely on lightweight plants, and intensive green roofs, which use deeply planted vegetation (Stovin, 2010). Green roofs may be incorporated into new buildings or added to existing ones (retrofitted).

Efficacy. Green roofs are effective at attenuating stormwater runoff. For example, retrofitted green roofs cut stormwater runoff by 50–80 percent (Shafique, Kim, and Kyung-Ho, 2018). A range of factors moderate this effect including climate and weather conditions, seasonality, roof designs, roof slope, depth, and desired life span, and the type of substrate and vegetation (Shafique, Kim, and Kyung-Ho, 2018). For example, the amount of water that a roof can retain for a given rain event depends on how saturated the roof is before the event (Stovin, 2010).

Cost-effectiveness. The private benefits to building owners of installing green roofs—including lower energy demand and a longer roof life-span—typically exceed the costs (Enzi et al., 2017). Public benefits from green roofs are significant as well. For example, installing extensive green roofs on all suitable buildings in Toronto, Canada, would save an estimated CAD$37 million (US$20 million) annually thanks to reduced stormwater runoff (38 percent) and combined sewerage overflow (15 percent) as well as lower energy costs (22 percent) and urban heat island (25 percent) (Banting et al., 2005).

Green Spaces for Storm Water Regulation

Green spaces are vegetated areas designed to filter and reduce the quantity of stormwater runoff (WHO, 2017). Two key types are bioswales, which are strips of vegetated land, and rain gardens, which are gardens that use plants, soils, and configurations effective in retaining rainwater (UNEP-DHI, 2014; Shuster et al., 2017).

Efficacy. Green spaces are effective at attenuating stormwater runoff. For example, experimental bioswales in California reduced runoff by 89–99 percent and a rain-garden network in Ohio retained around half of the water volume flowing into the system over a four-year study period (Xiao and McPherson, 2009; Xiao et al., 2017).

Cost-effectiveness. A comparative cost-benefit analysis of various types of green spaces in Michigan found that conserved natural areas offered the highest net-present value per volume of water reduced, followed by street trees, and finally bioswales (Nordman et al., 2018).

Location, Location, Location: The Key to Analyzing GI Investments

In certain settings, GI can effectively provide targeted infrastructure services like coastal flood regulation and can sometimes do that at lower cost than gray infrastructure. Moreover, GI can supply a host of co-benefits such as providing biodiversity habitat (Table 8.3). But GI is not the best choice in every setting. Both its benefits and costs depend critically on site-specific factors having to do not only with its effectiveness in providing infrastructure services, but also how quickly those services are needed, the value stakeholders place on GI co-benefits, and the magnitude and timing of the costs of conserving or restoring GI. An additional consideration is the availability of private and public financing for GI. Information on these factors is likely to be less readily available than for gray infrastructure, which has a longer track record, entails less outcome variability, and is in general better understood (Browder et al., 2019). Therefore, it is important that policymakers carefully collect and consider this site-specific information before deciding whether and how to invest in any particular GI project.

Measuring Benefits

A variety of site-specific factors determine the efficacy of each type of GI in providing targeted infrastructure service. Collecting and analyzing information on such factors often requires specialized expertise. The same is true of the co-benefits that GI provides. For example, the extent to which forests provide biodiversity habitat, recreational opportunities, and cultural services depends on characteristics of local ecosystems and communities. To further complicate matters, the monetary value of co-benefits like biodiversity habitat and cultural services can be difficult to estimate because they are often not traded or priced in markets (Barbier, 2007; World Bank, 2016). Here too, specialized expertise may be needed to fill knowledge gaps.

Aside from the variability and value of benefits provided by GI, policymakers also need to consider the timing of these benefits. While conventional gray infrastructure typically provides the intended service soon after construction, some GI types take years to do that (Ozment, DiFrancesco, and Gartner, 2015). For example, coral reef growth rates are slow and a newly formed or restored reef may take upwards of a decade to colonize and build up protective defenses (Sutton-Grier, Wowk, and H. Bamford, 2015; Ferrario et al., 2014). Hence, in cases where infrastructure services are urgently needed, GI may not be the best approach.

Weighing the Costs

GI can be more cost-effective than gray infrastructure, but not always. In some applications, either fixed and/or variable costs of GI can be higher. As for fixed costs, some types of GI, including mangroves, salt marshes, and forests, have extensive land requirements, a feature that can be a barrier to uptake where the opportunity cost of land is high. For example, the opportunity costs of land in coastal areas is typically relatively high and can pose barriers to mangrove and salt marsh conservation and restoration (Dinesh, Chinchu, and Geeji, 2018; Bayraktarov et al., 2016). And constructed wetlands generally require more land than conventional water treatment plants (Brissaud, 2007; Kivaisi, 2001). However, GI policies can be adapted to address these concerns. For example, development of some GI, such as green spaces, can take place on underutilized lands or by regenerating brownfields (van der Waals, 2000).

While some GI types, including constructed wetlands, have relatively low operation and management costs, others do not, particularly in the initial years of construction and restoration. For example, green roofs require watering, pest-control, and specialized labor with a variety of expertise ranging from horticulture to architecture, particularly during the first two years after installation (Dvorak and Volder, 2010). By contrast, conventional roofs have minimal operations and maintainenance costs (Enzi et al., 2017). Likewise, marine GI require long-term maintenance and highly skilled personnel including marine biologists.

Finding Financing

Many of the ecosystem services GI provides are public goods enjoyed by society at large, rather than by the service providers, i.e., the owners and managers of GI. That creates the usual free rider problem that dampens both beneficiaries' willingness to pay for GI, and the private sector's willingness to invest in it. This is less of a problem for GI types like green roofs and constructed wetlands that provide ecosystem services that providers can more easily appropriate. But for other GI types, alternative sources of financing are often needed (Toxopeus and Polzin, 2017). Potential sources include (i) public finance, including grants, in recognition that GIs contribute co-benefits from the regulation of ecosystem services, (ii) private finance from individuals and companies interested in green investments, and (iii) development finance aligned with sustainability mandates (Browder et al., 2019). Examples of the first source of financing are the fuel tax revenues and oil royalties that Costa Rica and the Brazilian state of Espirito Santo contribute to support payments for ecosystem services programs (Kissinger, 2014; Blackman and Woodward, 2010).

"No Two Leaves Are Alike:"[5] Case Studies in Green Infrastructure

Three case studies from Latin America illustrate the importance of collecting and considering site-specific information on the benefits and costs of GI investments. FONAPA is a WaterFund project in Southern Ecuador that aims to lower the costs of treating potable water provided to two cities by conserving upland forests (Box 8.1). Although the project has been successful in preventing these forests from being cleared, it has been less successful in lowering water treatment costs. The main reason is that the project has not identified and targeted the right forests, i.e., those that would have the biggest effect on the quality of the water used by treatment plants.

Box 8.1

Using Forests to Improve Water Quality in Ecuador

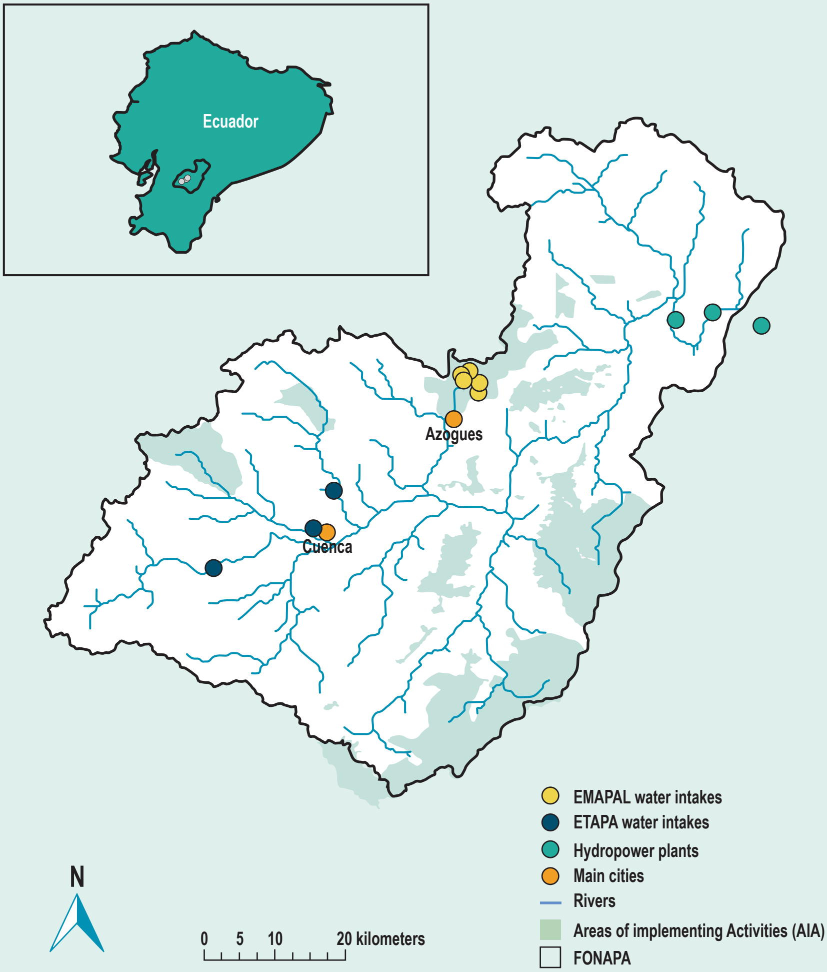
Founded in 2008 and affiliated with the Latin American Water Funds Partnership, Fondo del Agua para la Conservación del Río Paute (FONAPA) is a multi-stakeholder initiative in southern Ecuador aimed at improving surface water quality by conserving upland forests. FONAPA works in Ecuador's Paute river watershed where the upland forest and páramo help improve the quality of surface water used to supply potable water to Cuenca (population 500,000) and Azogues (population 40,000) (Figure 8.1.1).

Within the Paute watershed, FONAPA has designated 43 Areas of Implementing Activities (AIAs) for conservation and restoration, which collectively comprise about 95,000 hectares. Inside AIAs, FONAPA imposes land use and land use change restrictions, discourages cattle ranching and agricultural burning, and provides fencing, technical extension, environmental education, and research.

A quantitative evaluation was undertaken to assess whether FONAPA has been successful in improving the quality of surface water used by residents of Cuenca and Azogues (Blackman and Villalobos, 2019). The evaluation had two parts. The first

5 "In a forest of a hundred thousand trees, no two leaves are alike. And no two journeys along the same path are alike" (Coelho, 2010).

Figure 8.1.1
Fondo del Agua para la Conservación del Río Paute (FONAPA): Río Paute Watershed and Areas of Implementing Activities



Source: Authors' elaboration.

used fine-scale satellite data on forest loss along with statistical methods that control for confounding factors to measure FONAPA's effect on deforestation inside its 43 AIAs. The second used a hydrological model to generate back-of-the-envelope estimates of the effect of any avoided forest loss on water treatment costs for ETAPA and EMAPAL, the water treatment utilities for Cuenca and Azogues.

The results indicate that between 2008 and 2014, FONAPA reduced deforestation inside its 43 AIAs by 60 percent or by about 9 percent per year. But hydrological modeling indicates that this avoided deforestation had only small effects on water treatment costs. It reduced costs for the ETAPA by less than 1 percent and for EMAPAL by less than 3 percent. On an annual basis, these avoided water treatment costs amount to about a quarter of FONAPA's operating budget. In other words, the value of the benefits FONAPA generates by lowering water treatment costs are lower than its costs.

An important reason FONAPA has not had a more substantial effect on water treatment costs has to do with the location of FONAPA's forest conservation interventions. The AIAs in the southwestern part of the watershed are 10 km or more from ETAPA water intakes. This siting greatly dampens the potential water quality benefits of forest conservation and restoration. The choice to locate these AIAs at a distance from ETAPA water intakes may reflect the fact that conserving and restoring forest lands closer to Cuenca proved challenging because the opportunity costs were relatively high and/or because these lands had already been cleared.

A key challenge in using GI is overcoming information gaps, including data on the value of ecosystem services provided by GI and links between site-specific characteristics and GI efficacy and costs. Fortunately, new methods for collecting and analyzing data on coastal and marine GI can help policymakers fill those gaps. A master plan created to guide both economic development and conservation in a resource-rich Bahamian island illustrates these opportunities (Box 8.2). For example, project planners modeled the link between GI and tourism by relying on photo geotagging to estimate tourism demand. The effort to fill gaps in data on the likely effects of GI led local planners to select a development strategy that balanced economic development and conservation of GI rather than simply prioritizing the first goal.

Box 8.2

Filling Data Gaps in The Bahamas

Andros is the largest, least developed, and arguably the richest in natural resources of Bahamas' islands. It is increasingly being targeted for economic development. Recently, the Government of The Bahamas, in collaboration with Stanford University and the University of The Bahamas, developed a Master Plan for Andros that featured investments in GI for coastal resilience (GOB/IDB, 2017; Lemay et al., 2017). The study team used a participatory stakeholder process to draft a Master Plan. First, it developed four alternative scenarios titled, Business as Usual, Conservation, Sustainable Prosperity, and Intensive Development, each corresponding to different levels of GI, mining, cruise ship development, and timber exploitation. For each scenario, the study team estimated the level and value of three different ecosystem services provided by GI: fisheries, tourism, and coastal protection (Sharp et al., 2018).

Estimating those values, in turn, required application of innovative data collection and analysis methods. For example, geotagged photos from social media data (Wood et al., 2013) and survey information from The Bahamas Ministry of Tourism were used to map the numbers of visitors and tourism expenditures as a function of human activities and ecosystem health. And for storm protection, results from a coastal hazard index, incorporating information on storm surge, waves, wind, elevation, shoreline type, sea-level rise, and ecosystems were combined with census data to estimate the number of people at risk from coastal hazards, and the role of seagrass, mangroves, and corals in reducing risk (Arkema et al., 2017). Application of these and other new data technologies made clear that implementation of the Intensive Development scenario would result in significant decreases in tourism, fisheries, and coastal protection-related benefits, and it put dollar values on these losses.

Having estimated the value of ES associated with each of the four alternative development scenarios, the study team then presented them to key stakeholders. At the end of the day, the Intensive Development scenario was rejected in favor of the Sustainable Prosperity scenario (GOB/IDB, 2017).

The experience of Puerto Morelos, a coastal community on Mexico's Yucatan peninsula plagued by chronic beach erosion and vulnerability to storms, also illustrates the importance of careful planning for GI. Local policymakers partnered with academic experts to develop a plan for addressing this erosion and vulnerability to storms, ultimately opting to rely on hybrid green-gray infrastructure—an artificial reef. The reef has proven successful in restoring national processes that replenish the beach and in protecting against natural disasters.

Box 8.3

Hybrid Green-Gray Infrastructure in Mexico

Beach erosion is an increasingly severe problem in many Latin American and Caribbean countries.[a] Three main factors have been responsible for erosion: sea level rise caused by global warming; destruction of coastal GI due to urbanization; and the proliferation of badly planned gray infrastructure like seawalls. Beach erosion problems are often particularly pressing in coastal centers of tourism because that is where urbanization has been most intense and where beach erosion can trigger the greatest economic damage.

Common approaches to stemming beach erosion are artificial nourishment, which entails moving sand from offshore dunes to the beach, and gray infrastructure such as seawalls, groynes, and breakwaters. However, both approaches have serious drawbacks, including the limited long-term availability of offshore sand that can be used for nourishment, and the tendency of gray infrastructure to simply shift erosion problems from one location to another. Given these limitations, an increasingly common solution is to rely on hybrid green-gray infrastructure—artificial reefs built from concrete and steel and other manmade materials but eventually colonized by coral and other marine flora and fauna.

Puerto Morelos is a seaport and resort town about 35 kilometers south of Cancun on Mexico's Yucatan Peninsula. Unlike other nearby tourist locations, the port is not directly fronted by the Mesoamerican Reef; the nearest section is about 0.5 kilometers away. Beach erosion in Puerto Morelos was a growing problem in the early 2000s, exacerbated by construction of a marina and other structures. The port's susceptibility to storm damage became evident during this period. Both problems came to a head in August, 2007 when waves, storm surge, wind, and current associated with Hurricane Dean deposited tons of sand on the grounds of an important beachside resort.

Local planners determined that a strategy was needed to address both Puerto Morelos' susceptibility to storm damages and its chronic beach erosion. Working with scientists at the coastal engineering laboratory of the National Autonomous University of Mexico (UNAM), they ultimately decided to build an artificial reef, which was expected to dissipate wave energy, help restore natural beach replenishment altered by existing engineered structures, be colonized at low cost by coral from the nearby Mesoamerican reef, and preserve aesthetics valued by tourists.

After testing by UNAM, a Wave Attenuation Device made of PH-neutral reinforced marine-grade concrete was selected for the artificial reef (Burcharth et al., 2014). In 2010, prefabricated sections were placed at a depth of 2.5 meters, which is 0.5 meters below mean low water level, to form a 60-meter reef. Since installation, the Puerto Morelos beach has stabilized, exhibiting natural patterns of growth from May through October and shrinkage from November through April. Moreover, the artificial reef has been colonized by corals and other marine flora and fauna.

[a] This case study is drawn from Silva et al. (2016 and 2017).

Growing a Greener Region

Clearly, GI can cost-effectively provide infrastructure services given the right local conditions. In coastal areas, coral reefs and mangroves can provide substantial protection from flooding and erosion. Forests can significantly improve surface water quality. Constructed wetlands can effectively eliminate a range of pollutants from wastewater. And green roofs and green spaces can appreciably reduce runoff in urban areas. Moreover, GI provides benefits in addition to infrastructure services (Table 8.3). Coral reefs and mangroves harbor fisheries, support tourism, and cycle nutrients. Forests provide timber and non-timber forest products, deliver cultural, aesthetic, and recreational services, and cycle nutrients. And constructed wetlands, green roofs, and green spaces harbor biodiversity and help cycle nutrients.

Fast accumulating evidence of GI's benefits and co-benefits has contributed to the growing momentum for GI in both industrialized and developing countries. However, that same evidence—including the three case studies presented here—also demonstrates that using GI requires policymakers to build specialized knowledge, capacity, and, oftentimes, funding streams. While the benefits and costs of deploying conventional gray infrastructure in any given situation are relatively well understood, that is less often true of GI: both its performance in providing infrastructure services and the costs of those services depend critically on site-specific factors. To decide whether and how to invest in GI in any specific context requires collecting and analyzing data on these linkages. In addition, policymakers have the opportunity to tap into unconventional sources of financing for green investments.

In sum, closing Latin America and the Caribbean's infrastructure gap will require significant investments of human, financial, and physical resources. A welcome broad message from this chapter is that those investments can leverage the region's rich endowment of natural capital. The trick will be gathering and analyzing the data needed to carefully target, plan, and finance those investments.

Part 3 The Future

9

An Enlightened Future for Energy

The energy sector is moving toward a cleaner, digital future. In this transition, questions abound: will electricity generated by renewables power all economic activities in the future? Will electricity be exchanged all over Latin America and the Caribbean through a seamlessly integrated electrical network? Will it be possible to program home appliances to turn on automatically when electricity's daily rate is at its lowest? Will it be possible to sell power from electric vehicles to neighbors or the grid? Although the outcome is difficult to predict, the ongoing transformation stands to benefit everyone—if it is managed correctly.

In the wake of the 2016 United Nations Framework Convention on Climate Change (the Paris Agreement) and the increasing awareness of climate change, the energy sector is undergoing major changes. To achieve the Paris Agreement goals, the world must drastically reduce its emissions (see Chapter 7). To that end, by 2018, some 169 countries had adopted targets to increase the share of renewable energy sources (relying especially on the growth of nonconventional sources like wind and solar) in their electricity production matrices (REN21, 2019).

Technology is helping advance this process. Nonconventional renewable sources are becoming the cheapest sources of power, enabling countries' electricity matrices to become progressively cleaner and making clean electricity the energy source of transport, heating, cooking, and a wide range of industrial production processes.

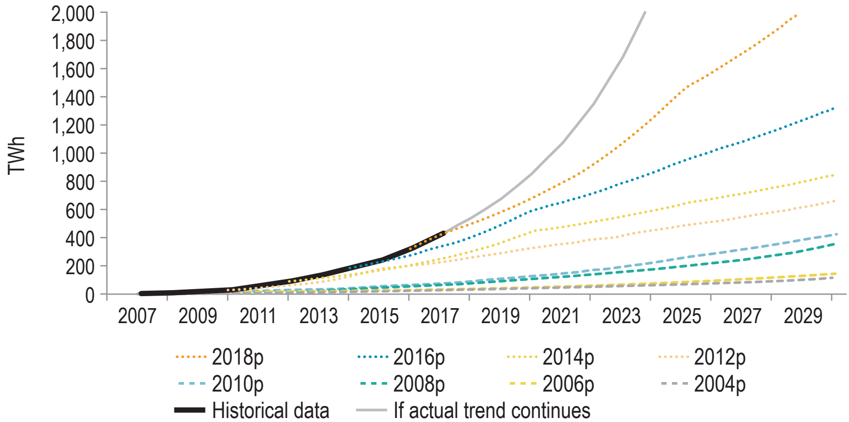
Initially, the adoption of solar photovoltaic and wind generation was fostered by regulatory and pricing support mechanisms such us feed-in-tariffs.[1] At the same time, research and development (R&D) policies

[1] Feed-in tariffs are an example of a pricing policy that has been used to foster the adoption of nonconventional renewable sources. They guarantee the producer a minimum price for the electricity it generates with a specific technology.

spurred innovation. Between 2005 and 2017, worldwide applications for green energy-related patents increased 140 percent, especially in solar energy (Rivera León et al., 2018). Thanks to innovation and industry economies of scale, the costs of clean electricity generation technologies have fallen drastically (Figure 9.2). As the costs of renewables plummeted, the world moved from specific support mechanisms that relied on high levels of direct government subsidies to more competitive tools such as long-term power purchase agreements allocated through auctions. The number of countries that held auctions for renewables increased from 50 in 2018 to more than 100 in 2019 (REN21, 2019).[2]

The pace of adoption of nonconventional renewable electricity has surprised experts and industry alike. Figure 9.1 shows the global growth of photovoltaic adoption, which year after year has exceeded estimates by energy agencies.

Figure 9.1
Prediction and Actual Volume of Solar Electricity Generation, 2004–18



Source: International Energy Agency (IEA) World Energy Outlook.
Note: The letter p after every year refers to predicted. Datapoints for each trend extracted from the IEA World Energy Outlook for each referenced year. Gap between datapoints filled using a geometric progression (constant growth rate). Extrapolation trend follows a constant growth rate as well.

How does Latin America and the Caribbean compare to other regions in this transition to renewables? Historically, the region has had the cleanest electricity matrix of all developing regions, thanks to the high capacity of its hydroelectric generation plants, which are the main source of conventional

2 For examples in Latin America and the Caribbean, see López-Soto et al. (2019).

renewables. In 2018, renewable sources accounted for 58 percent of total electricity generation (OLADE, 2019). However, most of that came from hydroelectric power, which is an energy source constrained by environmental and social concerns, conflicts usually associated with the construction of hydro plants, high capital requirements to build plants, and uncertainty over water availability in certain locations due to climate change (see Chapter 7). Given the constraints to expanding conventional renewables, and the decline in the cost of nonconventional renewables, several countries in Latin America and the Caribbean have been actively developing nonconventional renewables—an electricity source that was almost nonexistent in 2000 but accounted for 6 percent of the electricity generated in 2018 (OLADE, 2019).[3]

Some countries in the region are at the forefront in adopting nonconventional renewables. Uruguay, for example, had the world's second-largest share of nonconventional renewables (after Denmark and before Germany) in the electricity matrix in 2018. It is not uncommon for Uruguay to generate all the electricity it needs exclusively from renewable sources for days and even months. The good news for Latin America and the Caribbean is that its solar and wind potential is more than enough to serve its actual and forecasted electricity needs (Paredes, 2017).[4]

The main incentive governments have used to expand nonconventional renewables in the region has been auctions. They were first used in Brazil in the early 2000s before spreading throughout the region. Prices resulting from the auctions have been among the lowest in the world (Figure 9.2).[5]

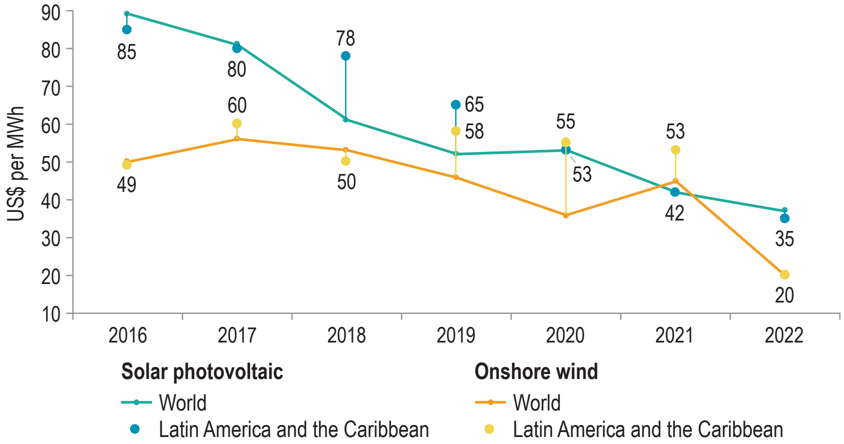
Despite their undisputed environmental and (growing) cost advantages, nonconventional renewables face an important constraint to becoming the predominant electricity source. Unlike fossil-based energy sources, wind and solar are variable sources of electricity; they cannot generate electricity on a constant basis—to wit, the sun does not shine at night. They can, therefore, replace fossil-based electricity sources only if the variability constraints are overcome with cost-effective solutions such

[3] This chapter focuses on the role of solar and wind as the main sources of nonconventional renewable electricity. However, other sources, like nuclear power, are also used as a source of renewable energy. And others, like hydrogen, could eventually play an important role.

[4] According to Paredes (2017), the gross potential of wind and solar energy in Latin America and the Caribbean is about 40,000 gigawatts (GW). Total installed capacity was 398 GW in 2017.

[5] The auction defines the price of the bid for the electricity generated in the next several years (often three to five years). Brazilian auctions made headlines in 2019 with a record low solar average price of US$17.5 per MWh (BloombergNEF, 2019b).

Figure 9.2
Evolution of Wind and Solar Power Costs Globally and in Latin America and the Caribbean



Source: Authors' elaboration based on IEA's average auction prices for photovoltaic and wind, by region and commissioning date.

as storage technologies, demand response mechanisms, and investments in interconnection of transmission networks.

The transformation underway in the electricity sector represents an opportunity for policymakers in the region to tackle longstanding challenges in the sector, including inadequate access, quality, and affordability. The changes the sector is undergoing will require adjustments in the way electricity markets are organized to induce efficiency and welfare gains. Utilities will need to alter their business models because declines in the cost of both solar electricity at small scale (and for some industries, wind) and storage have helped decentralize production and will bring competition to the provision of electricity. Regulatory policies, instruments, and institutions must be adapted to address the emerging challenges. This chapter presents four scenarios that could emerge from technological disruptions and discusses the most important regulatory priorities. Which of those scenarios materializes will depend on two driving forces: the evolution and pace of adoption of digital technologies affecting the demand for electricity, and the decentralization of electricity production.

Digitalization and Decentralization: Shaping the Future of Electricity

In the future, electricity production and consumption will look much different than they do today, thanks to two driving forces: the digitalization of consumption and the decentralization of production. The digitalization of consumption will advance thanks to information and communication technologies (ICT) that allow cost-free, quick, and automated demand responses to changes in electricity prices and other market conditions and shocks, such as blackouts. The decentralization of production will result from the reduction in cost and deployment of small-scale power generation and storage technologies (such as solar photovoltaic and batteries). This transformation will lead to greater diversification, the democratization of electricity sources, and decarbonization, thereby paving the way for new opportunities to move toward efficient and zero-net carbon emission economies.

Digitalization and the Emergence of Prosumers

Digitalization is transforming the role of consumers. Until recently, electricity consumers were either connected to the grid and received service at a regulated price or they did not have electricity; they could not make choices. Coupled with the ability to generate power from nonconventional renewables at very small scale and store it in batteries, digitalization is transforming the role of consumers from passive to fully responsive "prosumers" (actors that both consume and produce).

Digitalization will allow consumers to become active players by choosing and changing their consumption patterns through demand-response mechanisms; utilities will most likely offer menus of different prices and service qualities along the same lines as cell phone and internet service menus. In houses with access to digital infrastructure and services, for example, consumers will be able to program their smart appliances to work during times of the day when demand and electricity prices are low.[6]

Deploying technologies with communications, data, and information features, from smart meters to grid automation tools, will change the way electricity services are provided. Throughout the day, utility companies will collect consumer data—on showering, making coffee, and sending smartphone messages, for example—in order to provide customized services and cut the cost of energy. Aggregating consumption at the city or regional levels will increase the efficiency of the electricity system by allowing them to lower peak loads and reduce the need to expand generation capacity.

[6] To illustrate the magnitude of changes in demand led by digitalization, Hledik et al. (2019) estimate that the potential of demand response capability in the United States for 2030 could approach 200 GW, which represents 20 percent of system peak capacity.

Thanks to better information on electricity use throughout the day, decisions about electricity generation will be better informed and partially automated.

But data availability also brings challenges. Utilities can use data to increase their profits without sharing benefits with consumers, by selling personal data to third parties, or creating price discrimination schemes, for example.

Despite its potential to change the future of services, digitalization of the energy sector in Latin America and the Caribbean has been slow and uneven. While in Uruguay and Mexico, which lead the region in digitalization, the penetration of smart metering technologies is around 10 percent; in Barbados, Bolivia, Colombia, and Peru it is less than 1 percent. Moreover, even the most advanced countries in the region have penetration rates below the global average (14 percent) and much lower than global leaders such as the United Kingdom and the United States, which were already achieving smart metering penetration rates above 50 percent in 2020 (Ernst & Young, 2020; IoT, 2010). The region's lag in digitalization merits in-depth analysis of the drivers of the slow speed of adoption and the policies that could accelerate it.

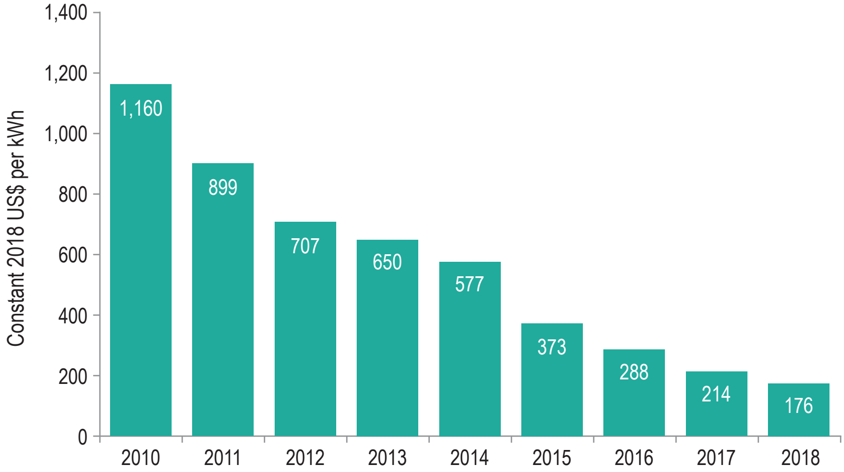
Transforming Network Use through Decentralization

The other key driver shaping the future of energy is decentralization. Historically, as the use of electricity grew, the scale of electricity generation increased in order to take advantage of economies of scale. But the rapidly decreasing costs of smaller generation alternatives and storage devices has the potential to change this historical dynamic by facilitating the decentralization of production and the entry of more players (and consequently more competition) in the electricity sector.

Storage allows electricity to be generated and consumed at different times. The simplest form of storage is a battery. One of the main hurdles for economy-wide adoption (at the utility or household scale) of batteries is their cost, although it is falling rapidly (Figure 9.3). Increased use of batteries is expected to drive their prices down, as battery production moves up the learning curve and benefits from economies of scale. It is estimated that every doubling in production reduces costs by 18 percent (Bloch et al., 2019).

Renewable energy—in particular solar photovoltaic bundled with small storage (such as batteries)—allows electricity to be generated close to or at the point of consumption. These bundles play a significant role in disrupting centralized electricity production. Increasingly, consumers (households and firms) can decide whether to purchase electricity from a utility or generate it themselves. Having that choice become economically feasible for a relevant part of the population is unprecedented.

Figure 9.3
Evolution of the Cost of a Battery Pack, 2010–18



Source: Authors' elaboration based on data extracted from Goldie-Scot (2019).

The transformation of network usage has already started in Latin America and the Caribbean. Distributed generation still represents just a small share of the electricity mix in the region, but the growth rate is exponential in Brazil, Chile, and Mexico (Figure 9.4).

Figure 9.4
Net Metering Capacity and the Number of Solar Photovoltaic Installations in Brazil, Chile, and Mexico

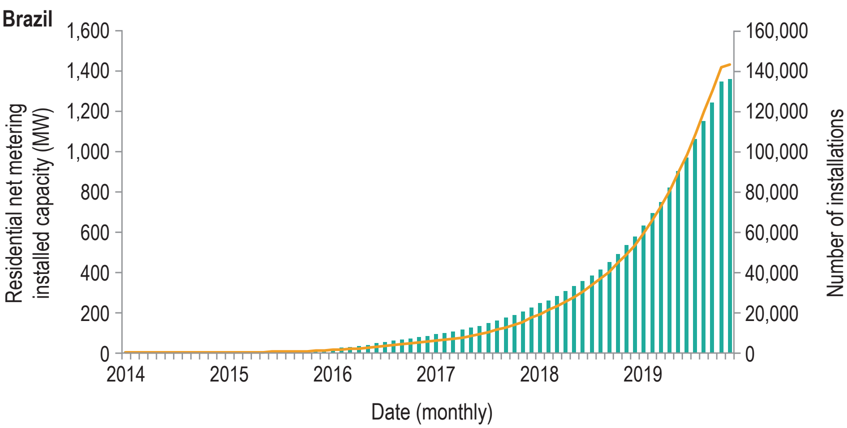


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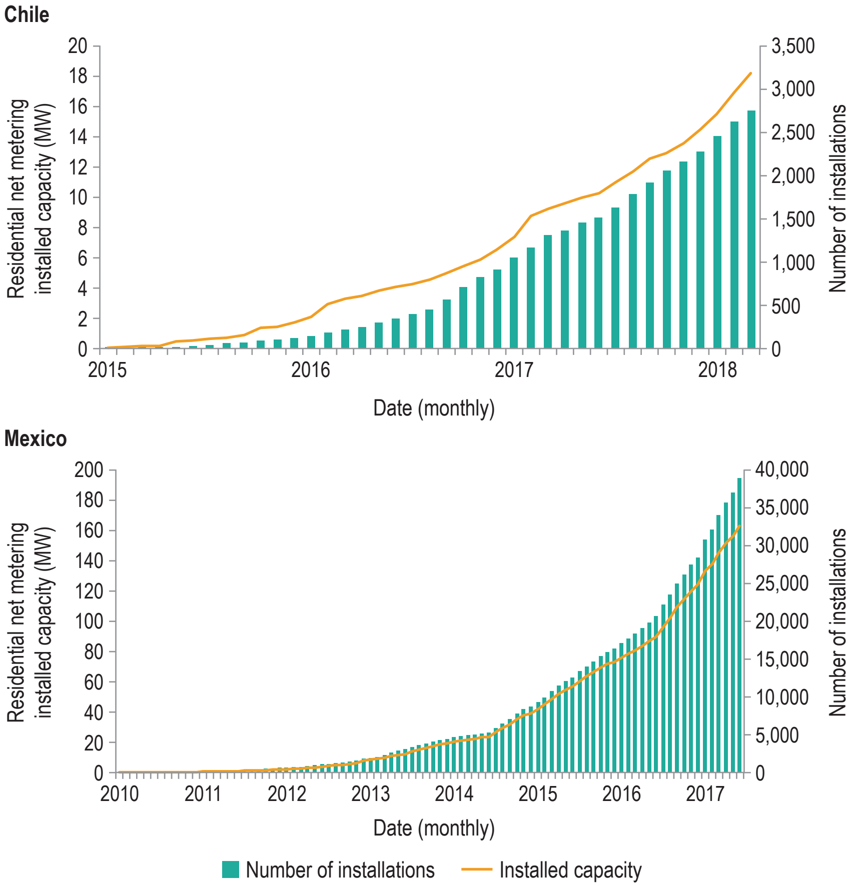
Figure 9.4
Net Metering Capacity and the Number of Solar Photovoltaic Installations in Brazil, Chile, and Mexico *(continued)*



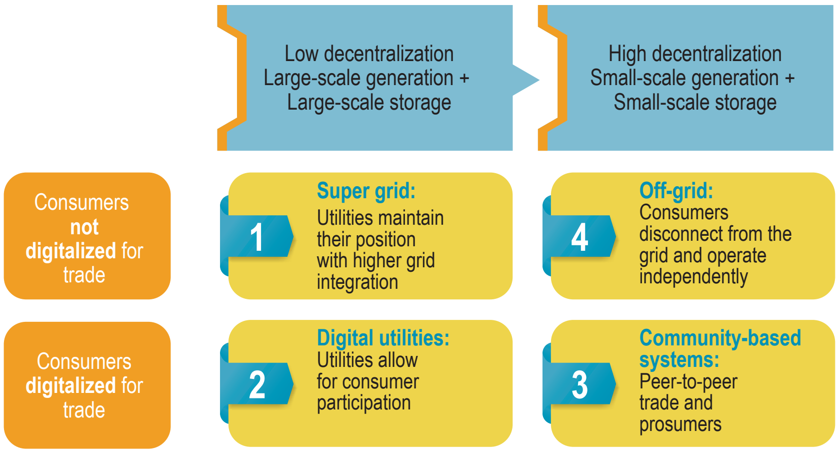
Source: Authors' elaboration based on data provided by energy regulators.

Scenarios for the Future of the Electricity Sector

Predicting with accuracy how the ongoing transformations will change the face of the electricity sector in a few decades' time is impossible. However, given the information available today, four scenarios are possible: a super-grid system, digital utilities, a community-based system, and off-grid power. (Figure 9.5). The scenarios are determined by the two main forces that are shaping the electricity sector: the transformation of consumer behavior made possible by digitalization, and the transformation of electricity generation through decentralization. The four scenarios assume that in accordance with Latin America and the Caribbean's targets of net zero emissions set in the Paris Agreement, renewable sources will supply almost all the electricity demanded by 2050.

The four scenarios presented in this section are extreme forms of market organization and, consequently, should not be understood as mutually exclusive. They will most likely coexist in different countries. The prevailing scenario will depend on the technological evolution and on local characteristics, both physical and regulatory. Some countries may interconnect with each other; utilities in some countries may continue to use power from large hydroelectric plants or draw on large on- and offshore wind farms, while at the same time new prosumers will generate large amounts of distributed power through microgrids and/or off-grid systems (especially in isolated areas). The scenarios can evolve through a smooth or disruptive transition.

Figure 9.5
Four Scenarios for the Future of Electricity



Source: Authors' elaboration.

While the four scenarios are not inevitable, they differ from the current situation of electricity markets in Latin America and the Caribbean (see Chapter 4), which have the following characteristics:

- Specialized firms dominate electricity generation. Some are large and vertically integrated utilities, while others are only active in electricity generation.

- Electricity is transported via transmission lines that are managed by private or state-owned firms.
- Electricity is distributed to consumers by a (monopoly) utility, which operates under the supervision of a regulator.
- Electricity is traded across countries, but lack of physical networks and regulations hinders meaningful regional trade and integration.
- Consumers (households and industrial firms) produce only a negligible amount of electricity; houses and firms are just beginning to install solar panels.
- Households are passive; they do not play a relevant role as active players who change their behavior according to market and/or supply conditions.
- Consumer digitalization is low or inexistent. Programmable appliances are not common, meaning that utilities cannot offer data-based incentives to induce demand changes.

Super Grid: Integrating Systems as the Keystone of the Sector

This scenario relies on large-scale generation and centralized system operation; the prevailing market organization changes very little from today's electricity market organization in Latin America and the Caribbean. Large-scale generation remains the core business of utilities, and the market works via long-term contracts with independent power producers through power purchase agreements or with wholesale electricity markets for generation. The consumer profile does not change substantially; the typical consumer remains fully dependent on the grid supply and has little or no possibility of actively participating in ICT-based demand-response programs.

The main mechanism through which a large quantity of variable renewable electricity meets increasing demand is by integrating countries' national systems. Integration yields benefits thanks to countries' different resources and time zones, which allow supply to complement demand.

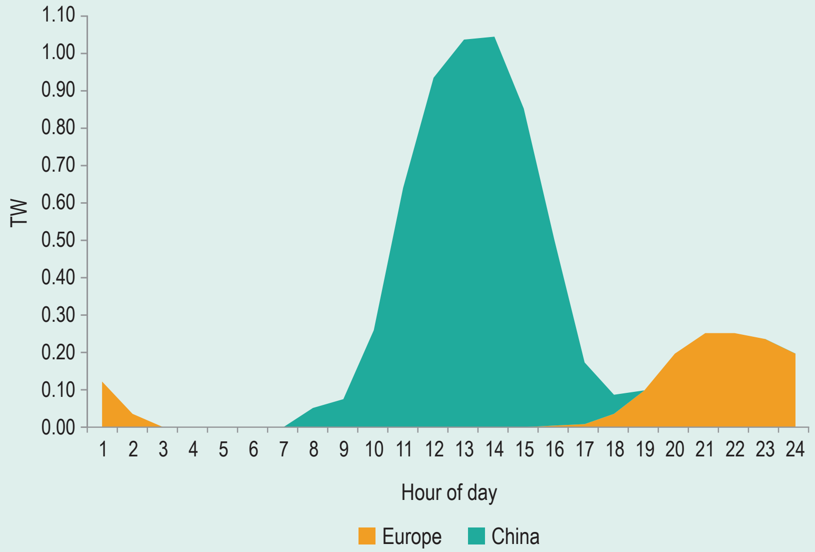
From a supply-side perspective, an integrated electrical system allows countries to pool their energy resources and use their most efficient units more intensively. Integrating the energy systems hedges against the risk of not being able to produce electricity locally, by taking advantage of the complementarities of different solar, wind, and hydrological regimes across regions. An example of this potential is to integrate electrical systems across time zones to allow solar energy generated in a place where the sun is shining to be used in a place where it is already dark (see Box 9.1).

Box 9.1

Time Travel? Integrating Electricity Systems Based on Nonconventional Renewables across Time Zones

As of 2020, the opportunities for taking advantage of supply and demand complementarities across time zones were limited by transmission infrastructure constraints. But in the near future, this may no longer be the case. Europe and China are two of the biggest electricity markets in the world that may benefit from integrating their grids. For instance, time differences can make European solar energy available for Chinese nighttime peak demand (Box Figure 9.1.1).

Figure 9.1.1
Total Solar Energy Output per Hour, Beijing Local Time



Source: IDB/GEIDCO (2019).

To assess this potential, Wu and Zhang (2018) evaluated the economic benefits of interconnecting power grids between Europe and China in a scenario that relied heavily on renewable energy. The study considered not only time zones, but also seasonal wind and hydrological differences, to estimate the yearly profits of building an ultra-high voltage connection line. The results show that integrating Europe and China's electricity markets has the potential to reduce up to 30 percent the combined total cost, compared with estimates without interconnection. For the possibilities and benefits of integrated regional solutions in Latin America and the Caribbean, see Paredes (2017).

Another supply-side benefit from integrating energy systems is that, by making all the different sources of electric generation compete in an integrated market, the most efficient technologies are used most intensively. The grid integration between Argentina, Brazil, and Uruguay is already providing this benefit. In 2018, Uruguay exported 1,195 gigawatt hours (GWh) of electricity (about 10 percent of its demand) to its bordering countries. Most of this exported energy was generated with low-marginal-cost wind power and replaced more expensive fossil-fuel generation in Argentina and Brazil. Without the electrical integration between these countries, Uruguayan ‘’green’’ energy—as well as the opportunity to save money and CO_2 emissions—would have been lost (Di Chiara, Sanin, and Nogales, 2019).

From a demand-side perspective, the main benefit of grid integration is that it helps smooth demand profiles and, therefore, avoids costly investments to serve peak demand. This effect is particularly strong when the integration is between regions in different times zones, because electricity demand profiles change significantly during the day.

Overall, in this scenario, integrating electrical systems makes the use of renewable sources more manageable and efficient. Moreover, integration unlocks the region’s high potential to install large-scale solar and wind power plants by using distant hydropower plants as an effective storage mechanism. The integration of electricity grids among countries in the region could also allow them to smooth the increasing hydrological uncertainty caused by climate change.

These benefits notwithstanding, this scenario faces many challenges related to the costs and risks of cross-border network construction and operations. Coordinating institutional and regulatory frameworks to make physical integration and exchange of electricity effective is challenging. Ensuring smooth system operation through the grids of different countries is key if this scenario is to be feasible. Operating systems across borders raises significant geopolitical sensitivities because security of supply is always a top concern in electricity systems. Advancing and institutionalizing cross-country coordination is necessary to ensure the sustainability of such a complex system.

Digital Utilities: Empowering Users in Traditional Large-scale and Centralized Electricity Sectors

This scenario relies on large-scale generation accompanied by consumer empowerment. Utilities remain at the heart of the electricity system, but they transform their business to offer diverse services to consumers and compete at the distribution level with third-party energy providers.

Economies of scale keep the generation models centralized. They feature large wind and solar farms, including possible offshore systems, coupled with large storage, transmission, and distribution systems. As in the super-grid scenario, generation features higher variation and lower controllability of "firmness" (the amount of capacity available for generation when needed during a defined interval of time) due to the high share of renewables in the electricity matrix.

Demand in this scenario behaves differently from demand in the first scenario. It posits an increase in "responsive" consumption, in which consumers cut or shift their electricity use at certain times of the day directly from their smart devices. The main difference between this scenario and the current situation in Latin America and the Caribbean is that consumers will play a more active role. Houses become smart places that can respond dynamically to price incentives and user preferences. Consumers define when and how they want to use utility services. They set their home temperature from their smart devices or smart phones from anywhere. They decide when to charge their electrical vehicle, when to have a robotic vacuum clean their house, when water should be heated and to what temperature. Instead of just selling power to consumers, utilities offer services. The menu of electricity services and bills in this scenario could be as dynamic and differentiated as in the telecommunications' industry.

Digitalization allows utilities to match client demand to generation supply, minimizing forecasting error. It provides consumers with smart meters and apps that provide utilities with real-time information about consumption load. Consumers still rely on the grid in this scenario, but the low transaction costs enable utilities to offer services such as demand management to consumers.

Capturing all the advantages of this scenario requires a reduction in the cost to obtain, process, and exchange data, in order to allow for continuous and individualized high-precision control of the power load. The availability of large amounts of consumption data lets artificial intelligence produce instantaneous information analysis for utilities. Such factors enable an increase in the efficiency of utilities.

In this scenario, decentralized mechanisms coordinate generation and consumption and provide system flexibility when necessary. Such flexibility could be provided by a combination of large storage infrastructure, such as hydroelectricity reservoirs, hydrogen, and lithium batteries. Flexibility can also be provided by developing technologies in other sectors, such as electric vehicles. For the purpose of electricity markets, electric vehicles are the equivalent of batteries on wheels because they help balance supply and demand as they arbitrage demand in time and location (Box 9.2).

Two types of new digitalization technologies are associated with this scenario:

- Large-scale automation to improve system efficiency;
- Software and ICT associated with consumer participation in the electricity market, including smart metering, trading platforms, virtual power plants, aggregators, utility-scale batteries, battery-electric or fuel-cell vehicles, and demand-side management tools, such as sensors, machine learning, and artificial intelligence.

Some of these technologies have already reached commercial status. Others remain to be piloted and tested.

Box 9.2

Using Electric Vehicles to Smooth Price Fluctuations of Solar and Wind Power in Mexico

One problematic consequence of the higher penetration of wind and solar power as generation sources is that it has the potential to increase electricity price volatility. This is due to the difference between the costs of producing electricity when renewables are available and when they are not: while the marginal costs of solar and wind generation are close to zero, the cost of back-up technologies are relatively high since they need to cover for the fuel used and other variable costs. This increased volatility in electricity prices has been already experienced in California and Germany, where penetration of wind and solar power is high, and regulation allows prices to fluctuate.

The massive entry of electric vehicles (EVs) could further increase price volatility if they are charged when renewable generation capacity is low. Recharging EVs when and where power is cheaper reduces the total costs of the energy system by reducing the mismatch between the renewable supply of electricity and household demand. Encouraging this virtuous behavior in Latin America and the Caribbean will depend crucially on market design, incentives, and tariffs.

Castro (2020) simulated Mexico's electricity market under the expected increase of solar (3.4pp) and wind (8.4pp) generation in the total electricity matrix by 2025. Taking into account the marginal costs of the new electric generation matrix, the authors estimated hourly wholesale prices of electricity needed to satisfy Mexican electricity demand. As is already happening in California and Germany, the results show that the volatility of electricity prices increases due to the greater participation of renewables. Under this scenario, in order to reduce total costs of the system, EV owners should be incentivized to charge at midday, when total solar and wind output is high in Mexico, which would reduce electricity prices to zero. Similarly, EV users should be penalized for charging during the evening, when electricity demand is high, by paying costs up to US$40 per kWh, which exceeds prevailing 2020 electricity prices by over 30 percent.

Community-Based (Peer-to-Peer) Systems: Consumers in the Spotlight

This scenario varies from the current organization of electricity markets in Latin America and the Caribbean and elsewhere. In this scenario, the consumer is the key supplier and provider of services, through decentralized generation, demand management, and trade. Large- and small-scale generators coexist and compete under the same rules and terms. For example, a small business with solar panels on its roof could sell electricity to a neighbor. This peer-to-peer model forces utilities to transform their business model and provide a new set of services, such as off-the-shelf products including LED lights, smart thermostats, energy-efficient water heaters, and electric vehicle-charging stations.

Given that a legacy electricity transmission and distribution network would most likely coexist with smaller micro-grids, a major regulatory challenge is who will act as coordinating dispatcher of electricity across networks and coexistent grids (more specifically, the regulator must ensure the funding of services provided by the grids).

An additional regulatory challenge is how to regulate the new market players and the services they provide. Dynamic pricing allows the entry of aggregators, which are new providers of electricity. Aggregators pool different types of consumers and, understanding how their demand responds to incentives, offer and trade electricity (that is, they “create” electricity by shifting demand patterns, creating virtual power plants). Aggregators rely on service platforms for peer-to-peer trading and the regulator sets incentives to allow the market to develop and function.

Off-Grid Solutions: Small Is Beautiful

In this scenario, off-grid solutions (stand-alone independent grid systems) are widespread, and generation, optimization, and investment decisions are decentralized. In the most extreme version of this scenario, all generation and consumption take place off-grid. This scenario assumes that digitalization takes place at the household level, controlling all inputs and energy withdrawals. Consumers optimize production (probably though solar technologies), storage (with batteries), and the use of multiple services (through smart home appliances and electrical vehicles).

Digitalization is used to optimize and allow the system to operate (as in the super-grid scenario). However, it is not used to aggregate or manage demand; high transaction costs translate into less consumer interaction and, therefore, trading platforms do not develop.

In this scenario, utilities that sell services through the electric grid become obsolete and eventually disappear. Even more than in the community-based scenario, utilities' services must transform. New business models, such as battery-swapping stations, are created.

The off-grid scenario is already happening on a small scale. In Latin America and the Caribbean, where in 2019 about 20 million people still lacked access to reliable electricity, off-grid solutions have already been proven a cost-effective option to solve access to electricity in rural and isolated areas (see Chapter 4).

But the real challenge for utilities is that off-grid solutions are becoming an attractive option for high-income consumers seeking zero net energy homes. Led partially by the decrease in the cost of the technology needed, this trend also responds to the fact that this type of consumer (at least under most of the predominant tariff schemes in the region) pays higher electricity prices to cross-subsidize low-income users. If these consumers could run completely off-grid by generating their own solar power and using highly efficient appliances and high-capacity batteries, the utilities in the region would become underfunded. However, for that to happen on a large scale would require a disruptive drop in the cost of batteries. Implementing tariff schemes that avoid this pervasive effect should be a priority for the future.

Which Scenario Will Prevail?

Any one of the four scenarios could materialize in the future depending on how digitalization and decentralization trends unfold. Digital utilities and community-based systems will most likely be the prevailing scenarios if digitalization trends persist. The degree of decentralization is less certain, and trends may vary even within countries as rural and urban areas may be suitable for different models. However, governments can influence the outcomes. Policies and regulation will determine the costs of the technologies behind the digitalization and decentralization trends.

Scenarios should not be considered static; transitions from one to another will probably be common. For instance, the digital utilities scenario could evolve into the community-based scenario, as digital technologies are increasingly adopted and the cost for small-scale solutions comes down gradually.

Off-grid solutions can become the most efficient mechanism for generating and storing energy, especially in more isolated (rural or peri-urban) areas. But in urban areas where grids already exist, empowering consumers within the energy system may help discourage costly off-grid solutions. Regulatory and policy incentives that neglect consumer participation, or push for too much or too little centralization, could lead the system to lock in an undesirable solution. Avoiding lock-in at this tipping-point moment requires understanding the current state of technology adoption, future trends, and the effects of regulation.

Adapting Regulatory Frameworks to a Changing Sector

The transformation of regulation needs to consider both governance and regulatory substance. Policymakers must prepare institutions and the regulatory system to deal with a much more dynamic and competitive industry. New tools should be developed and applied to open the regulatory decision process to new players (including empowered consumers and players from other industries). The speed of innovation in the sector also makes it critical for regulators to have updated knowledge in order to constantly update policies and instruments in a transparent and credible way. Tools for assessing regulatory impact should also be embraced for continuous learning and adaptation.

All tools allowing adaptability demand strong and resourceful regulatory agencies. Most countries in Latin America and the Caribbean actively regulate the electricity sector, but the lack of well-established legal frameworks and resources has produced institutions with limited power (Rodríguez Pardina and Schiro, 2018). In an environment without disruptive innovation, the regulator could gain credibility and predictability through well-designed and stable regulatory frameworks, for which some of the functions have usually been outsourced to sector experts. The effectiveness of this strategy may be lessened in a context that requires adaptable regulations. In such environment, credibility must come from the regulator, and therefore cannot be outsourced.

As for regulatory substance, innovation calls for urgent action to update regulatory instruments. Digitalization and decentralization are disrupting the grid's business model. Historically, transmission and distribution networks were the most efficient methods of transporting electricity. Electricity flowed in a single direction, starting in generation plants before being transmitted and distributed to consumers as the final stop. For years, the network business was a secure and stable service, impervious to innovation or disruption.

In a prosumer framework, the network exists as an interactive platform into which grid users can inject and withdraw energy; system balancing becomes necessary but achieving it is challenging. The emergence of prosumers and the growing possibility of disconnecting from the grid threaten the sustainability of the network. They will force regulators to redesign tariffs and incentives in order to balance the competing objectives of financial sustainability, efficiency, and social equity.

The emerging transformation of the electricity sector will be reflected in the transformation of the network. New services will be offered using the grid at the same time that its financial sustainability will be under threat, compelling regulators to redefine market failures, reconceive market segments, and determine which instruments can best protect users, foster competition, and safeguard the quality of service. Regulators will have to start working on several new challenges, including network service transformation, pricing restructuring, and network and service integration of other services, mainly electric mobility.

Regulating the Transformation of Network Services

In Latin America and the Caribbean and elsewhere, transmission and distribution were built to deliver electricity in the most efficient way to consumers. Electricity was regulated in order to protect consumers while allowing utilities to recover their investment. Capital cost was recovered through tariffs, and utilities faced no (or very little) market risk.

This straightforward logic no longer holds. In a context of digitalization and decentralization, the power network business is changing in at least three ways:

- *Electricity consumption no longer has a one-to-one relationship with grid usage.* With the emergence of prosumers, storage, and digitalization, the use of the network will change. Consumers will not demand all the electricity required to satisfy their needs from the utility, as some of them will generate their own electricity. Moreover, many consumers will sometimes generate more electricity than needed and will want to use the grid to trade electricity. The grid will play an important role as a back-up service provider for prosumers when their own systems fail to produce electricity, providing a new type of insurance service. Other services, such as security of supply (that is, making sure that electricity keeps flowing to those who need it), may have public good features, in which case regulators need to reconsider how to allocate cost, which can no longer be based on use. Redesigning prices in ways that take into account the economic features of the new services will be a challenge that requires a long learning process. An interesting example of this process is the evolution of regulation in the United Kingdom (see Box 9.3).

- *Turning the electricity network into a smart asset: the challenge of data regulation and management.* The network will generate a huge amount of data, which will facilitate a new level of understanding of consumer behavior. Control and efficiency will be vastly increased, but ownership, usage rights, security, and privacy issues associated with these data will demand a new role for power network regulation that goes beyond the traditional areas of prices, quality, and infrastructure access.
- *Asset choice will become more complex.* Utilities may face new investment choices due to newly available technological possibilities. For instance, they will need to choose between investing in storage or in grid reinforcement. Historically, regulators have closely controlled the type of assets utilities were allowed to invest in (type and quantity of distribution lines, substations, transformers). In an increasingly dynamic environment, regulators should tie incentives much more closely to service performance, by focusing on specifying utilities' performance and outcomes while remaining agnostic (as much as possible) about the means of delivery (see Box 9.3).

Box 9.3

The United Kingdom's Framework for Regulating Changing Network Services

The Office of Gas and Electricity Markets (Ofgem)—a nonministerial government department and independent national regulatory authority governed by the Great Britain Energy Regulatory Agency (GERA)—is known for its continuous innovation. The agency has a long record of successfully using new and existing regulatory tools to provide high-quality services. According to Ofgem (2010), Britain's electricity sector will be facing significant challenges due to disrupting technological changes. Consequently, the agency called for an update to its regulatory approach in order to be ready for the expected transformation and the uncertainties inherent in the transition.

In 2013, Ofgem began transforming the logic of its regulation. The previous model, frequently cited as a textbook example of incentive regulation, was based on a five-year tariff adjustment scheme; tariffs were allowed to increase at a rate equal to the increase in the retail price index (RPI) minus the efficiency savings target (X). The main objective was to increase predictability for utilities, while providing incentives to increase the efficiency of the network and guarantee the transfer of benefits to consumers. In 2010, however, Ofgem concluded that RPI – X price control could not deliver the incentives to invest in innovation required for the energy transition.

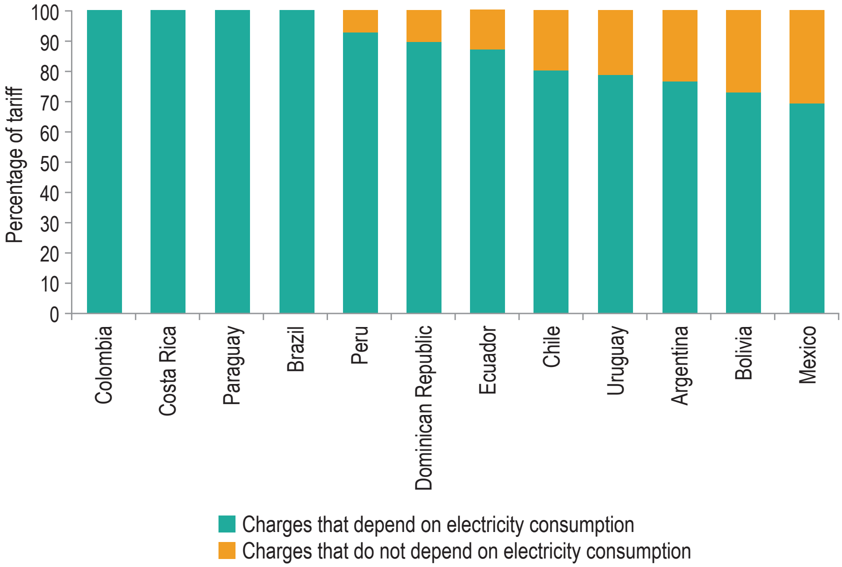
Ofgem replaced the RPI-X model with a new one denominated RIIO (revenue = incentives + innovation + outputs). This performance-based framework sets targets to encourage more innovation (through financial rewards); takes better account of consumers' final services features (targeted incentives that adjust revenues up/down if companies deliver better/worse outputs for consumers); and provides incentives to networks to minimize costs. RIIO extends the price control period from five to eight years with the objective of providing more incentives to adopt innovations that both reduce costs and improve services to users.

Evaluation of the results of RIIO has been mixed, although the consensus is that it spurred utilities to improve their business plans. Analysis by external experts noted increased stakeholder engagement, greater performance risk borne by utilities, and higher efficiency incentives due to a longer regulatory period. The benefits of innovation incentives established through RIIO remain unclear, however. As part of the ongoing RIIO revision, suggestions and improvements are being made that should be implemented by 2021 (CEPA, 2018). Despite unclear conclusions on its effectiveness, RIIO is a benchmark that regulators in Latin America and the Caribbean should consider as they ponder modifying regulatory systems sooner rather than later to be ready for upcoming technological changes.

Flipping the Switch on Pricing

Historically, electricity prices were designed to comply with two simultaneous objectives: cost recovery and affordability. The regulator chose a set of prices that would allow total revenues to cover the cost of service provision. The price structure of choice in Latin America and the Caribbean has been an energy charge—that is, the electricity bill depends on the quantity of electricity demanded (Figure 9.6). A few countries also include a

Figure 9.6
Composition of Electricity Tariffs, 2017



Source: CIER (2017).

fixed component that is independent of consumption; when included, this accounts for a small share of the bill.[7]

In a context in which all consumers are connected to the grid, the prevailing price structure allows for cross-subsidies among consumers (urban vs rural, industrial vs residential, high- vs low-income areas) without compromising the objective of financial sustainability of the utility while promoting fairness and equity. Cross-subsidies in Latin America and the Caribbean are ubiquitous (Foster and Rana, 2019).

Technological innovations will render the prevailing pricing structure unsustainable. Those consumers that currently pay more using the grid than they do generating their own electricity will find it attractive to disconnect from the network. Thus, the ability of the pricing structure to deliver on the two objectives of cost recovery and affordability will be jeopardized.

To avoid developing unsustainable electricity markets, tariffs will have to change. The uncompromising principle for tariffs of the future is to be

7 This section focuses on the pricing structure of residential consumers and does not include an analysis of possible changes in the pricing structure of industrial and commercial consumers.

cost reflective. Table 9.1 compares the prevailing electricity price structure in Latin America and the Caribbean with the one needed to face the challenges of the future.

Current electricity price structures that mostly rely on charges depending on electricity consumption incorporate two costly distortions. First, every time consumers decide to use an extra unit of electricity, they face prices that are higher than the incremental cost of producing it as they also need to cover fixed costs. This disincentivizes electricity consumption and hampers the transition to electrified infrastructure services, from home appliances to electric vehicles. Second, as consumers can avoid paying their share of fixed costs by decreasing their electricity consumption, they are over-incentivized to produce their own electricity even if it is not

Table 9.1
Electricity Price Structure Transformation: Elements to Increase Cost Reflectiveness

	Tariffs today	Tariffs for the future
Charges that do not depend on electricity consumption	Account for a small share of the electricity bill. If included in the bill, the charge is not related to cost characteristics of service provision (e.g., load capacity).	Account for a substantial share of the electricity bill. Fixed charge set to reflect the cost structure of electricity provision. Different cost drivers should be set separately and proper information about their level and changes should be transparent (e.g., right to use the network, right to trade using the network, insurance services).
Charges that depend on electricity consumption	Account for most of the total electricity bill. Set to provide enough revenues to the utility to cover long-run variable and fixed costs. Differentiated among users (e.g. rural vs urban, residential vs industrial) with the intention of fulfilling equity and fairness objectives (cross-subsidies).	Account for a small share of the electricity bill. Increased price “granularity”: prices reflect the marginal cost of providing the services at the time and location of use. Prices set exclusively to fulfill efficiency goals. Equity and fairness goals are addressed with other instruments.
Taxes and sectorial charges	Can represent a high share of total bills. Instrument used to attend policy objectives that are usually beyond the electricity sector (e.g., to contribute to fund general tax revenues).	Taxes and sectorial charges should not distort cost reflectivity[a]
Subsidies	Subsidies to achieve equity and fairness objectives are mostly funded using cross-subsidies. Mostly set as discounts to the price of electricity.	Subsidies to achieve equity and fairness objectives are funded from general tax revenues. Mostly set as discounts to the fixed charge of the electricity bill.

Sources: Authors’ elaboration.
[a] Some taxes or charges like carbon taxes, must be included in tariffs because they make prices reflective of the social costs of electricity generation.

efficient systemwide.[8] Solving these distortions requires introducing into the electricity bill charges that do not depend on electricity consumption to remunerate fixed costs.

The fine tuning on which part of the costs should be covered by each type of charge is not univocal, but some general guidelines can be drawn. To design proper tariff structures requires cost drivers to be set separately and transparency of information about their level and charges. For instance, remuneration to network services can be recovered by capacity charges (when the cost is associated with the size/volume of the consumer) or by fixed charges (when it does not actually depend on consumption at all). The network services that depend on network or consumer characteristics, like the ability to use the distribution network to buy and sell electricity, are more appropriately covered by some type of capacity charge. Other network services that are independent of the characteristics of the consumer, such as the right to access the network, some elements of security of supply, and public lighting, should be covered by a fixed charge.

Increasing tariff's cost reflectiveness also means recognizing that time and location matter for the cost of providing services. Adequate tariff design must provide consumers with real-time information on costs, externalities, and opportunities associated with the time and location of electricity generation and consumption.

Better locational price signals are already technically possible, as well as hourly pricing schemes. Dynamic prices are an option to assure that retail electricity prices pass on at least part of the hourly wholesale price variation to consumers. They can take different formats, such as time of use pricing, real time pricing, variable peak pricing, and critical peak pricing,[9] but the intuition behind these schemes is the same: users adapt their consumption habits to match the availability of resources. These demand responses to prices become even more important when the proportion of renewable energy in electricity generation matrices all over the region is increasing rapidly, making resource availability less predictable.

Finally, to ensure that the new electricity price structures are cost reflective, they must remain free of other price distortions such as taxes,

8 In California, where adoption of decentralized energy is high and done mostly by high-income households, the impact on tariffs is already being felt disproportionately by poor households. The revenue shortfall caused by prosumers in California led to an estimated US$65-per-year increase in the electricity bills of consumers that are not prosumers (Davis, 2018).

9 Many countries are adapting their regulation to allow dynamic pricing; these countries include Estonia, Finland, Germany, Norway, the United Kingdom, and the United States (EURELECTRIC, 2017; IRENA, 2019).

sectoral charges, and subsidies. Achieving this objective may be one of the most challenging parts of transitioning to new tariffs. Nowadays, taxes and sectoral charges can represent a significant part of the electricity bill (e.g. in Brazil and Argentina, taxes and sectoral charges represent more than 50 percent of electricity bills) and cross-subsidies are regulators' weapon of choice to deal with fairness and equity concerns. In a new environment in which consumers are free to dispense of the network and produce their own electricity, increasing the electricity bill beyond the cost needed to cover service provides incentives to abandon the grid.

In this context, the government's ability to raise funds through the electricity bill to finance cross-subsidies is severely reduced. As explained in Chapters 1 and 4, regulators will have to work closely with policymakers to define objectives and to design means-targeted subsidies with a predictable and dedicated source of funding (Cont and Navajas, 2019).

Coordinating Regulation across Sectors

As digitalization and decentralization create new interfaces between energy and other infrastructure sectors, coordinated regulation will be required. Planning and regulating the energy, transportation, telecommunication, and water sectors is now done separately. However, as infrastructure services become more dependent and interrelated, the lines defining the reach of sectoral regulation become blurred. For instance, many of the challenges of electric mobility are associated with the electricity pricing system, charger accessibility, and even power quality incentives that are usually under the watch of the energy regulator, but in the near future may become key elements in defining the efficiency of transport choices.

Another rapidly growing intersectoral relation is between energy and water. The growing importance of hydroelectricity dams to accommodate variable renewables will make decisions on how to use water resources more challenging, particularly in the context of an electrified energy sector and increasingly scarce water due to climate change (see Chapter 11). In this regard, integrating regulation between both sectors will become crucial to avoid coordination failures that could compromise firm and household access to water or electricity.

A more synergistic convergence is taking place between information technology (IT) and the energy sector. Some energy equipment manufacturers are looking at IT acquisitions to increase the pace of their digital transition. Meanwhile, well-established IT players are moving aggressively into the energy sector. Electric system optimization and operation will increasingly depend on new technologies to allow for the collection and analysis of big data. The ownership, use, and security of these data will affect the potential of new energy services and competitiveness (see Chapter 13).

Integrating regulation across sectors creates challenges, but first steps to start the integration include the following:

- Acknowledge the existence of cross-sectorial interdependencies and create coordination mechanisms among regulators to pursue joint regulatory impact assessments.
- Coordinate planning across cities, regions, and countries. One example of such coordination is the use of climate goals as a tool to coordinate planning objectives in different sectors. For instance, in the energy sector, many countries in the region have aligned their electric generation expansion plans with the objectives of their Nationally Determined Contributions (NDCs) under the Paris Agreement (see Chapter 7).
- Integrate planning for system resilience and security, taking into account hardware and software interdependencies. For instance, planning telecommunications systems should anticipate the consequences of a cyberattack that could trigger a blackout.

The Future Starts Now

The fast pace at which the electricity sector is changing means countries face unprecedented and technically difficult challenges. Failing to act now will be an expensive mistake, as countries need to make the most of new opportunities presented by the declining costs of new generation and storage technologies, the proliferation of electrification in different energy usages, and digitalization. These advances can be at the heart of a strategy to solve long-standing issues related to affordability, quality of service, and efficiency.

Regulators need to start now by generating more and better information and build a flexible approach into their frameworks that allows them to cope with innovations and uncertainty. Regulatory policies, institutions, and instruments need a richer understanding of what electricity services are and how they are provided. Many times, this implies redefining regulators' competences. In all cases, countries will need a new approach to tariff design and subsidies that does not compromise financial sustainability and efficiency.

10

The Road to Better Transportation

It is a time of unprecedented change for the transportation sector. In coming decades, digital technologies will dramatically shape the future of both mobility (movement of people) and logistics (movement of goods), presenting major opportunities and challenges for economies and societies. Autonomous, connected, electric, and shared transportation promises to disrupt the sector in a way not seen since cars replaced horses in the early 20th century. Cars fundamentally changed the way people lived, allowing them to access jobs, schools, shops, and entertainment in distant places, in a fraction of the time it took using a horse-drawn carriage or walking. However, people are uncertain about how the future will look and what specific benefits and risks it will bring. This uncertainty is not fundamentally different from the early stages of past technology revolutions; in 1885 Karl Benz could not have anticipated the changes that his gasoline-powered car would bring decades later. That is why governments around the world have launched programs to ensure that new technologies help achieve a transportation system that is efficient (providing lower-cost, higher-quality services), inclusive (accessible and affordable to all), and sustainable (fostering a safer, cleaner, and more livable urban environment).

In this context, the challenge facing Latin American and Caribbean countries is to join other governments in planning the technological transition today or face, tomorrow, the consequences of lagging behind. In fact, should current trends remain unchanged, transportation in Latin American and Caribbean cities will not face a promising future. By 2030, motorization rates are expected to increase by almost 40 percent, reaching 276 vehicles per thousand inhabitants. Together with population growth (9 percent higher by 2030) and urban sprawl, congestion will rise rapidly.

These projections are not to be taken lightly when, according to the INRIX 2018 Global Traffic Scorecard database, already four of the ten most congested cities on the planet are in Latin America and the Caribbean: Bogotá (every driver loses 272 hours each year to congestion), Mexico City (218), Rio de Janeiro (199), and São Paulo (154) (compared to 45 hours in La Paz, the least congested capital city in the region). In turn, product demand from a growing urban population (84 percent of the region's people will live in cities by 2030), together with the boom in e-commerce (650 percent growth by 2030) and consumers' preferences for faster and smaller shipments, will trigger more freight traffic on urban roads.

Without structural changes, negative trends in public transportation may worsen (see Chapter 4). As they do, those who can afford it will shift to individual transportation, while those who cannot will be increasingly underserved by a system of limited accessibility, affordability, and quality. Likewise, without the incentive to be more energy-efficient, the transportation sector will continue to be one of the main sources of greenhouse gas (GHG) emissions: CO_2 emissions will rise 25 percent by 2030, limiting the ability of Latin American and Caribbean countries to achieve their Paris Agreement commitments (see Chapter 7). Finally, if current trends in road safety are not reversed, a million lives may be lost to traffic accidents between 2020 and 2030. The toll on public health may be higher, with a spike in cardiovascular diseases and lung cancer resulting from sedentarism and dangerous air quality in cities. With more time spent commuting, mental health may deteriorate as well: longer commutes reduce job satisfaction and productivity, increase commuters' overall levels of stress, and make them less happy (UK Office for National Statistics, 2014). It is no wonder then that, among the factors affecting quality of life, residents of the region's megacities put transportation among the top five priority concerns, together with safety, transparency, inequality, and participation (Serebrisky, 2014).

There is reason for hope, however. New technologies can become an ally to avert this somber scenario. Electric mobility can reduce CO_2 emissions. Connected and shared mobility can optimize vehicle usage, reduce solo rides, and decrease congestion. Autonomous vehicles can expand mobility for non-drivers and the disabled and increase the productivity of public transport. This chapter describes the trends at work in the transportation sector, the opportunities they present, and policy actions to enable Latin American and Caribbean countries to achieve an efficient, inclusive, and sustainable transportation system underpinned by 21st century technologies.

Disruptive Trends in Transportation

Four converging trends—automation, connectivity, electrification, and sharing (ACES)—will radically change the way people and goods move (Voege, 2019).[1]

Automation is at the forefront of these trends. In the transportation field, automation takes a variety of forms, including the driverless or autonomous vehicle (AV). The Society of Automotive Engineers classifies vehicle automation into six levels, from 0 to 5. At level 0, all driving functions require human intervention; at levels 4 and 5, the vehicle can autonomously cope with all driving situations.

Connectivity refers to the use of information and communication technologies to generate and exchange data among vehicles, roads, and other parts of the transportation system. Its forms are vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and vehicle-to-everything (V2X) connectivity.

Electrification involves the use of electric motors to propel vehicles. They receive electricity by plugging into the grid and store it in batteries. They are also charged in part by regenerative braking, which generates electricity from some of the energy normally lost when braking.

Sharing includes both shared use and shared ownership of cars, bicycles, scooters, and trucks. Currently, the most common forms of sharing are: (i) business-to-consumer car sharing, where a company maintains a vehicle fleet that is rented out to customers; (ii) ride-sourcing services (also known as ride-hailing companies), which offer on-demand rides by connecting drivers using their personal vehicles with passengers hailing a ride, typically via smartphone; (iii) bike-sharing programs; and (iv) micro-mobility programs, whereby a company provides urban transportation services with a fleet of small, electric vehicles such as e-bicycles and e-scooters (Shaheen, Totte, and Stocker, 2018).

Assuming a high market penetration, each of these trends is expected to bring significant benefits to the transportation system by increasing its efficiency, inclusiveness, and sustainability (Table 10.1).

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1 For the past few years, the future of transportation has been gaining the attention of specialized and general audiences. Data from digital sources (Twitter, news, blogs, forums, Facebook) show that, between 2016 and 2018, the conversation about electric vehicles in Latin American and Caribbean countries grew by 48 percent. In turn, the conversation on autonomous vehicles grew by 13 percent. Likewise, data from academic search engines show that, for the same period, global research on electric and autonomous vehicles grew by 30 percent and 250 percent, respectively.

Table 10.1
ACES Potential to Make Transportation More Efficient, Inclusive, and Sustainable

	Autonomous	Connected	Electric	Shared
Efficiency	• Improved comfort and productivity for travelers, who will be able to perform other tasks (sleeping, working) while traveling.	• Enhanced infrastructure utilization (e.g., smart traffic lights that send traffic information to vehicles and to public agencies for dynamic traffic management decisions).[a]	• Lower operating costs due to higher energy efficiency and less maintenance than internal combustion engines (ICE).	• Fewer solo rides and higher vehicle utilization, reducing the number of cars on streets.
	• Enhanced traffic management and city planning by using big data generated by AVs.	• Better enforcement of segregated infrastructure (bus lanes, cycle paths, low-emission zones).	• Increased passenger comfort with quieter, smoother operation.	• Improved convenience of public transportation (e.g. by offering first-mile/last-mile services, and tailor-made mobility solutions based on individual needs through mobility as a service or pay-as-you-go programs).
	• Lower mobility and logistical costs owing to lower labor costs and better vehicle routing enabled by big data.	• Vehicles able to travel closer to each other (lower safety distance needed), thus increasing infrastructure capacity.	• Batteries used as additional storage for the national grid (see Chapter 9).	• Better match of the supply and demand for logistics assets (e.g., fewer trucks running empty on city streets).
		• New revenue mechanisms enabled by technology (e.g., dynamic congestion pricing according to congestion levels).		
Inclusiveness	• Increased mobility for senior citizens, non-drivers, and the disabled. In Latin America and the Caribbean, these segments will account for approximately 118 million people by 2030.[b]	• Improved planning of public transit through the use of sensors and big data, enabling on-demand public transit to serve low-density areas.		• Improved convenience of public transportation, as noted above.

(continued on next page)

Table 10.1

ACES Potential to Make Transportation More Efficient, Inclusive, and Sustainable *(continued)*

	Autonomous	Connected	Electric	Shared
Sustainability	• Improved road safety, due to less reliance on human factors that account for 90 percent of accidents.	• Improved road safety through incident warnings that prevent collisions (warnings 3 seconds before impact can prevent up to 70 percent of car crashes).	• Lower local emissions and noise pollution leading to improved urban livability and lower impact on climate change.	• Fewer solo rides and higher vehicle utilization, reducing the number of cars on streets.
	• Greater eco-driving to lower environmental impact and reap fuel savings of up to 20 percent.			• More active mobility with shared bicycles.
	• Less parking required by shared AVs, freeing up urban space for sustainable, citizen-friendly developments.			

Source: Authors' elaboration based on Millard-Ball, Weinberger, and Hampshire (2016); U.S. Energy Information Administration (2018); Olia et al. (2018); IQAir (2019); Manners-Bell (2019); and Voege (2019); and CEPALSTAT database, 2018.

[a] Data for the United States show that smart parking systems that generate information on available spots can reduce cruising by 50 percent (Millard-Ball, Weinberger, and Hampshire, 2016).

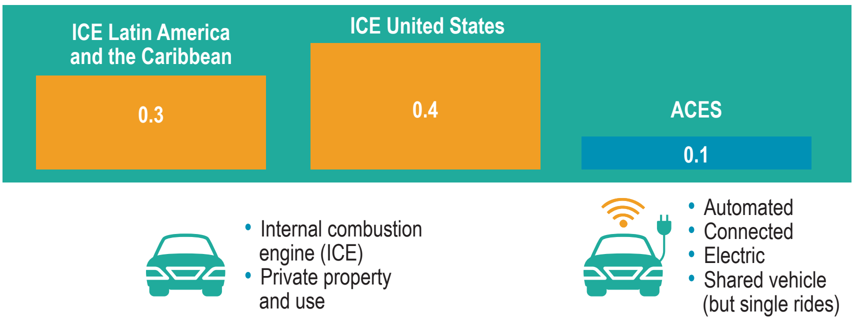
[b] By 2030, Latin America and the Caribbean will have nearly 105 million adolescents (10–19 years), 9 million seniors (over 80), and 4.5 million people with disabilities who might benefit from new mobility services.

Research and business development related to ACES technologies is progressing at a fast pace. From a higher to lower state of adoption, shared mobility is already a reality in many Latin American and Caribbean cities. For example, the online statistics portal Statista shows that, in 2018, Uber was already present in 230 cities in 15 countries, with 30 million users and 1 million drivers, surpassing the figures for North America. Micro-mobility is also becoming available in the region, where the U.S. boom is expected to be replicated. In the United States, micro-mobility trips grew 400 percent in three years, reaching 84 million trips in 2018, equivalent to 15 percent of all first- and last-mile trips taken in New York City (NYC DOT, 2019; NACTO, 2019). Uptake of electric vehicles is growing as well: Europe, the United States, and China are leading the transition toward electromobility, where electric vehicles are expected to account for 50 percent of sales as early as 2030 (BloombergNEF, 2019a). This assumes that the price of electric vehicles continues to fall with battery costs, which in 2018 made up half the car's total costs, achieving price parity with gasoline-powered cars by 2022. In this scenario, by 2030 one in four new cars sold worldwide could be fully electric (BloombergNEF, 2019a). Although Latin American and Caribbean countries lag behind world leaders, significant steps are being taken to initiate a transition to electromobility, with Costa Rica and Chile being the first in the region to formulate specific strategies as early as 2017 (Isla et al., 2019). In addition, the cities of Santiago de Chile and Bogotá have taken the lead in shifting parts of their fleets to electric buses.

Level 3 automation—in which the driver need not monitor the system continuously but must always be in a position to resume control—is already operational in some vehicles. Meanwhile, level 4 tests on public roads are progressing, but no consensus has yet formed on when levels 4 and 5 might be commercially available, depending on a combination of technological progress, operational safety, public policy, infrastructure, and costs. Optimistic projections suggest that AVs will account for 50 percent of vehicle sales by 2030; more conservative calculations suggest that this threshold will be reached only after 2050 (Litman, 2018). Despite the uncertainty, once autonomous vehicles are commercially available, significant cost savings are expected to drive a fast technology uptake (Arbib and Seba, 2017).

Although, to date, the ACES trends have progressed largely independently, the most abrupt disruption in the transportation sector is expected to occur with their eventual convergence—that is, when autonomous, connected, electric, and shared vehicles become the norm on urban streets. Cost savings will be the main factor driving this change. Recent studies suggest that operating an ACES vehicle will eventually cost much less than an internal-combustion or electric vehicle. According to Arbib and Seba (2017), for example, by 2030 using an ACES vehicle will cost just US$0.06 per km for single rides, compared with the US$0.48 and the US$0.38 per km costs of personal gasoline-powered and electric vehicles, respectively. And ACES vehicles, particularly pool services at US$0.02 per km per passenger, will be cheaper than operating an autonomous, non-shared, gasoline-powered or electric car (US$0.24 and US$0.10 per km, respectively). Along these lines, the authors calculated that the cost savings for an average American family using an ACES vehicle will amount to US$5,600 per year, equivalent to a hike of 8 percent in the average household yearly income in 2018, thus incentivizing a fast uptake of ACES technology. In Latin American and Caribbean countries, where using an internal combustion engine (ICE) costs on average US$0.30 per km, these savings will amount to US$3,091 per year, 17 percent of the average household annual income (Rivas, Serebrisky, and Calatayud, 2019) (Figure 10.1).

Figure 10.1
Cost Savings from ACES (US$ per km)



Source: Rivas, Serebrisky, and Calatayud (2019).
Note: Cost estimates correspond to 2018.

Along with these economic benefits, ACES technologies may bring unintended consequences, as did past technologies. For example, although automobiles opened new economic and social opportunities, by the early 1900s traffic density and speed in towns had become dangerous, especially for pedestrians, requiring the installation of traffic lights for both cars and pedestrians. As in the past, obstacles and barriers may in turn emerge to limit the adoption of new technologies, thereby limiting their benefits for the economy and society. For example, despite their ability to save lives, seat belts faced strong resistance; by 1981, a century after their invention, only 11 percent of U.S. drivers were using them. Some of the unintended consequences that ACES technologies may have, and some of the barriers they may face, are detailed in Table 10.2.

Table 10.2
ACES Technologies: Adoption Barriers and Unintended Consequences

Automation	• Increased congestion: vehicles travel more (up to 60 percent more vehicle miles traveled) since occupants can now use their travel time more productively, the cost per mile is lower, and many vehicles travel empty to drop off and pick up passengers.
	• A shift from public transportation and active modes to increasingly affordable private vehicles, thereby raising congestion and sedentarism.
	• Accelerated urban sprawl, as people become less leery of long commutes.
	• New accident scenarios while conventional vehicles coexist with AVs.
	• Increased vulnerability of road users as a result of lack of standards, unsafe AV operations, cyber-attacks, and uncertainties regarding liability.
	• Social conflict: workers displaced by automation may struggle to find alternative employment.
Connectivity	• Cyber-crimes and vulnerability of consumer data.
	• Lack of standards and interoperability, and limited willingness of the private sector to share information.
Electrification	• Range anxiety and lack of a comprehensive vehicle-charging infrastructure (the top two concerns about electric vehicles mentioned by drivers).
	• Nonuniform vehicle-charging technology and standards.
	• Lack of financial resources for fleet replacement.
	• Push-back from car manufacturers concerned about investment in new production facilities.
	• Road safety risks arising from silence of vehicles.
	• Reductions in fuel-tax income, creating a budget gap for infrastructure maintenance and transit services.[a]
Sharing	• Unintentional shift from public transportation and active modes to single-occupancy ride-hailing, thereby raising congestion and sedentarism.[b]
	• Induced traffic.
	• Sector-specific resistance and labor market effects (e.g., among bus and taxi drivers).
	• Push-back from car manufacturers concerned about lower car sales with less private car use.[c]
	• Greater road-safety risks as micro-mobility increases.
	• Resistance to shared mobility services, because of safety and privacy concerns, and cars being seen as symbols of status, independence, and flexibility.

Source: Authors' elaboration based on Graehler, Mucci, and Erhardt (2019); Litman (2018); Soteropoulos, Berger, and Ciari (2019); and Voege (2019).
[a] On average, fuel taxes make up 5 percent of government budgets in Latin America and the Caribbean.
[b] Bus ridership declined 1.7 percent in 22 U.S. cities after the entrance of ride-hailing companies.
[c] The automotive industry in countries such as Mexico, Brazil, and Argentina employs 840,000, 130,000, and 30,000 people, respectively.

Future Transportation Scenarios

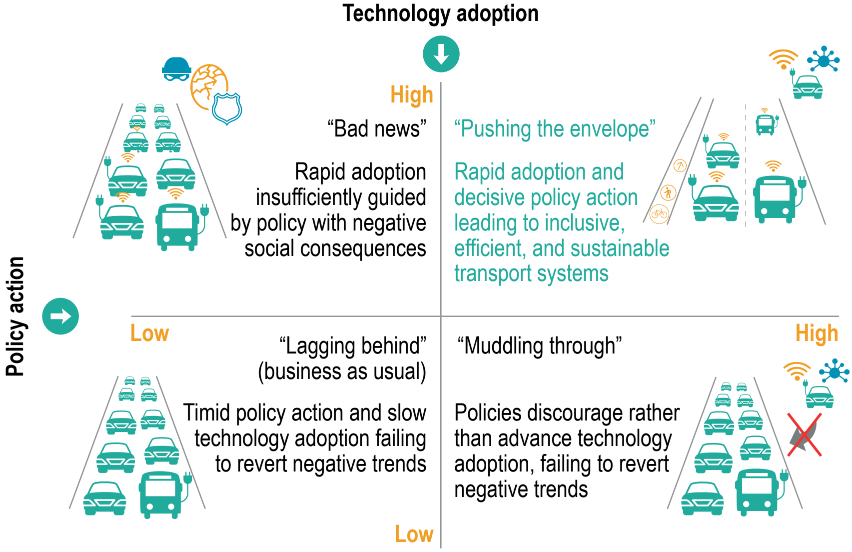
From a transportation planning perspective, the key question in this radically changing context is how to guide the adoption of ACES technologies so that they help achieve an efficient, inclusive, and sustainable transportation system in Latin American and Caribbean cities. Scenario analysis is a useful tool for this purpose, helping policymakers anticipate trends, define desirable outcomes, identify uncertainties, and stimulate critical thinking about how present choices may shape the future. Several agencies around the world—though not yet in Latin America and the Caribbean—have undertaken this approach to long-term planning.[2]

To help policymakers navigate technological changes and design effective policies, this chapter presents four scenarios developed by combining evidence from the literature and insights from international workshops. While acknowledging the heterogeneity of Latin American and Caribbean countries, the scenarios provide an analytical framework to identify plausible futures based on the combination of two driving forces: (i) the degree of technology adoption and the associated benefits and challenges to society, and; (ii) the implementation of public policies that maximize benefits and mitigate risks arising from those technologies. As in the first decades of the 1900s, when cars and airplanes were introduced on a large scale, current innovations will have both positive and negative impacts, thus requiring governments to play various roles. They will have to be catalyzers of new technologies; enablers of innovation ecosystems; providers of monetary incentives; and regulators to ensure benefits and mitigate risks (UK Government Office for Science, 2019). A smooth, successful transition toward an efficient, inclusive, and sustainable transportation system—called "pushing the envelope"—will depend on governments playing all of these roles.

"Pushing the envelope" is the best of the four scenarios. As summarized in Figure 10.2, it involves a high rate of technology adoption shaped and guided by judicious, timely policy action. The other three scenarios suffer from a deficit on one or both dimensions. The discussion that follows focuses on several key variables to describe what the transportation system would look like in each scenario: motorization rate, vehicle miles traveled (VMT), local GHG emissions, infrastructure network utilization, accessibility, affordability, safety, and security.

[2] See New Zealand Ministry of Transport (2014); UK Government Office for Science (2019); Metropolitan Transportation Commission (2009).

Figure 10.2
Future Transportation Scenarios in Latin America and the Caribbean



"Pushing the Envelope:" Rapid Adoption and Decisive Policy Action

This scenario envisions a high level of technology adoption and policies to reap the full benefits of technology and to mitigate its risks. Urban mobility is efficient, sustainable, and inclusive, and cities are designed around people rather than cars (Figure 10.3). The region's governments have followed the example of the world's technology-leading nations, learning from their experience and finding ways to improve mobility without overregulation. In this scenario, the number of vehicles,[3] the distance traveled by them (a.k.a. VMT), local emissions, and congestion have been drastically reduced; transit quality, accessibility, nondriver mobility (particularly in an aging society in which 25 percent of its inhabitants will be over 60 years old by 2050) and road safety[4] have increased; and, overall, cities provide a better quality of life for their inhabitants.

3 Simulations for Lisbon and Austin showed that, when combined with existing transit, shared AV could reduce the number of vehicles by 90 percent (ITF, 2015; Fagnant, Kockelman, and Bansal, 2016).

4 Nine out of ten road fatalities are caused by human factors (Voege, 2019). With autonomous and connected vehicles, over 90 percent of traffic fatalities could be eliminated, saving some 90,000 lives per year in Latin America and the Caribbean.

- Vehicles are autonomous, electric, and shared. Private car ownership and solo riding are rare. An efficient, affordable, collective transportation system provides individuals with accessibility according to their specific needs through online integrated transit platforms. Individuals specify the characteristics and preferences for the trip they want to make (origin, destination, time of departure/arrival, price they are willing to pay, etc.) and are presented with alternatives that maximize individual and social welfare. Those alternatives may include mass transportation (on heavy transit corridors) combined with shared vehicles and micro-mobility (e.g., e-bikes, e-scooters) for the first and last miles; shared vehicles for trips in low traffic areas; and micro-mobility for short trips in heavy traffic areas. Vehicles come in different sizes to accommodate travel demands and eliminate low-occupancy travel. Technology has increased trip traceability, thereby improving passengers' perception of safety in shared rides.
- An efficient, technology-enabled pricing mechanism incentivizes individuals to make the most efficient mobility choice from a social welfare perspective, including higher vehicle occupancy rates and lower VMT. Costs are imputed to the user, and the prices paid for a trip reflect its full costs, including the use of infrastructure and the trip's externalities (e.g., congestion, noise, local emissions). To avoid regressive effects on low-income sectors, some cities have opted to charge the full price of public transportation but provide targeted subsidies to them, while others opt to subsidize public transportation and, in certain cases, even provide free public transportation.
- In megacities, mass transit (metro, light rail, bus rapid transit) is greatly used. Automation and electrification have been successfully deployed in public transportation. Micro-mobility makes mass transit (especially metro) more accessible. Automation has radically improved waiting time, reliability, comfort (passengers are better distributed across vehicles), and user satisfaction. Automation and on-demand public transportation have made nighttime services and services in low-density areas financially feasible.
- The city is no longer designed for cars but for people. The need for parking spaces has decreased by up to 80 percent (ITF, 2015): smaller numbers of shared and autonomous vehicles drop passengers off at their destinations and either drive to the next passengers, find parking in a consolidated location, or return to a home base. Former parking lanes are assigned to active and public transportation, and former parking lots are now used for

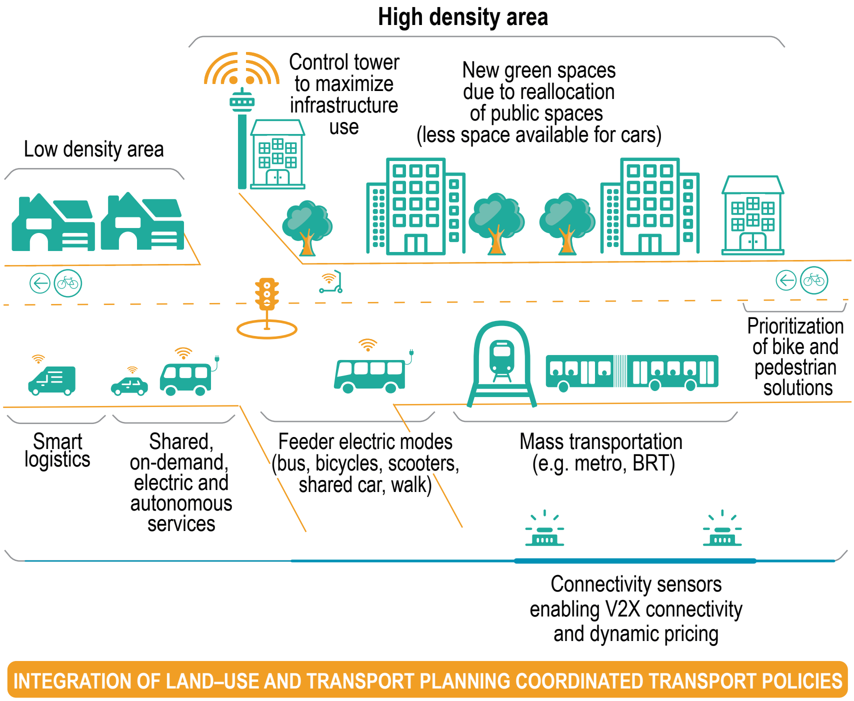
residential, office, and green developments. Higher active transportation promotes and reinforces health improvements.

- V2X connectivity enables efficient real-time traffic management by the public sector, provides incident warnings and routing options to users and traffic managers, improves enforcement of rules on use of segregated infrastructure, and facilitates revenue collection (e.g., dynamic road pricing). Municipal control towers gather big data and use powerful artificial intelligence (AI) software to minimize congestion and maximize infrastructure use. In some cities, the control tower decides the route each vehicle should take to reach its destination on time, or even the time of the day when the trip should start. Heavy traffic is concentrated in some avenues, keeping large areas of the city pedestrian friendly.
- Policies are coordinated to manage transport supply and demand. This includes ensuring the synergies between land-use and transportation planning. Densification is encouraged through land-use policies, yielding revenues that make it possible to provide high-quality public transportation funded, among others, by land value capture strategies. Together, densification, better public transportation, and efficient trip pricing discourage the use of private vehicles.
- Technology has improved efficiency and sustainability in freight transportation, particularly along the last (urban) mile: the widespread adoption of digital platforms and the Internet of Things, together with AI, enable real-time optimization of processes (e.g., truck routing, infrastructure management) and built-in flexibility in logistics for less waste, lower costs, increased traceability and transparency, and higher productivity. ACES in last-mile logistics, combined with integrated management of mobility and logistics by city planners, have led to successfully managing the spike in e-commerce deliveries, balancing customer satisfaction with social goals such as reducing congestion.
- New business models have emerged (e.g., digital platforms for sharing logistics assets), thereby creating new employment opportunities. Countries have put in place effective educational and professional programs to train the population in the skills required by the digital economy, therefore successfully mitigating the risk of higher unemployment rates.

"Lagging Behind:" Business as Usual

This scenario was presented at the beginning of this chapter and can be interpreted as the business as usual or current situation of urban mobility

Figure 10.3
Pushing the Envelope in Latin American and Caribbean Cities



in the region. It portrays a low-technology-adoption, low-policy-action situation in which ACES technologies are not available and policy fails to reverse the negative trends in transportation. In this scenario, motorization, pollution, congestion, and road fatality rates in Latin American and Caribbean cities most likely continue to increase.

"Muddling through:" Policies Discourage Rather than Advance Adoption

In this scenario, policy action is high but instead of promoting technology adoption, policy discourages it. Countries adopt policies that discourage individuals and firms from adopting promising new technologies, thus failing to revert current trends in increasing motorization, pollution, congestion, and road fatality rates. Examples might include:

- Governmental bans on AV deployment owing to concerns about safety and employment.

- High taxes on EVs under pressure from automobile manufacturers and oil companies, or out of fear of losing revenue from gasoline sales taxes.
- No action to achieve a common communication protocol for V2X signals, preventing a common ground for connectivity among all parties.
- Inefficient pricing that continues to subsidize private car use and disincentivizes a more rational and fair use of infrastructure.
- Overprotection of privacy and fear of cyberattacks.

"Bad News:" Rapid Adoption Insufficiently Guided by Policy

In this scenario, technology adoption is extensive but policy action is low; therefore, technology is adopted without due policy guidance and proper policy responses.[5] Governments fail to provide a policy framework to ensure that new technologies contribute to, rather than detract from, major social goals. This scenario may be even worse for urban mobility than business as usual.

- The price of autonomous cars (level 4 and 5 of automation) has significantly decreased, and they are now available for mass consumption. In the absence of regulations to, for instance, make private travelers pay for using infrastructure, the lures of affordability, convenience, and more productive commutes raise car ownership rates and VMT, leading to radical spikes in congestion and sprawling. Megacities now extend for up to a hundred kilometers, and citizens spend twice as much time in their cars. The poor policy response creates uncertainty about liability for accidents involving an autonomous vehicle.
- Ride-hailing companies deploy autonomous cars in their fleets, reducing operating costs (no driver, more efficient transportation) and cutting trip prices. This induces passengers to migrate from mass transit, which comes under severe financial pressure to maintain legacy assets. Capping a chaotic period of resistance by the taxi industry, the last taxis are displaced by more cost-effective, autonomous ride-hailing vehicles. With steep reductions in trip costs and no pricing of infrastructure use, shared mobility has not been encouraged, perpetuating low-occupancy

5 Unregulated markets cannot be trusted to deliver optimal social outcomes due to a variety of market failures (Anderson et al., 2014; Cohen and Cavoli, 2019).

car trips and adding to congestion. People are less inclined to use active modes of transportation, such as walking and biking, contributing to growing obesity rates in the population.[6]

- Sparse deployment of sensor and telecommunications technologies and infrastructure hampers the ability to reap the benefits of V2I and significantly improve traffic flow and infrastructure asset management, which is needed more than ever with higher VMT and motorization rates. The lack of a cybersecurity policy framework exposes critical infrastructure and autonomous vehicles to cyberattacks. Similarly, privacy is compromised by weak policies, allowing users' data to be harvested and sold for marketing or criminal activities.
- Electromobility advances rapidly in some countries. By 2022, electric vehicles are cost competitive with gasoline-powered vehicles. Attracted by savings on fuel and maintenance, and by lower local emissions, individuals, firms, and public agencies are acquiring EVs. But absent incentives from the public sector, charging infrastructure is available only in urban settings, particularly in high-density and high-income areas, where private investors have a secured return. This leads to a twofold problem: range anxiety is not completely allayed, thus limiting the scope of the shift to electromobility, and electromobility is not within everyone's reach, creating an equality problem. Moreover, since no regulation encourages a more efficient use of the electric grid, charging tends to take place mostly at night, creating spikes in demand that the grid is not always able to accommodate. Finally, lower revenues from gasoline taxes limit the government's ability to improve or even to maintain the grid and other key infrastructure.
- In the absence of integrated passenger and freight planning, the e-commerce boom (expected to sextuple in Latin America and the Caribbean by 2030) seriously aggravates congestion in megacities. As deployment of traffic management technology lags, significant opportunities are lost to improve the management of infrastructure assets, resulting in greater congestion at gateways (particularly port cities) and in urban settings. Unregulated use of drones and delivery robots raises concerns about safety, privacy, and data security. Finally, some 6 million people in the region risk losing their livelihood owing to the lack of policies to mitigate the impact of technology on employment in the logistics sector (ILO, 2018a).

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6 Obesity is expected to affect up to 60 percent of Latin America and the Caribbean's population by 2030 (Global Health Intelligence, 2018).

Building Today for a Better Tomorrow

The present challenge for the governments of the region is to identify and implement—*today*—the policies needed to "push the envelope" *tomorrow*. Meeting that challenge can dispel the congestion, pollution, transit flight, and traffic fatalities that will only worsen if the technological revolution is missed. Effective policies are also needed to mitigate the risks posed by technology while encouraging its adoption, thereby avoiding possible "bad news" and "muddling through" scenarios.

To achieve the best results, governments need to act in a coordinated and integrated fashion on many fronts, which are described in the sections that follow and summarized in Table 10.4. Focusing on isolated elements of the transportation system is not enough. Additionally, some solutions will require strong coordination outside the transportation sector (e.g., with land-use planning). Implementing certain policies will not be an easy task for governments. Therefore, the sequencing of policy actions will be key to maximize their effectiveness and soften the impact of transitions on social welfare. Indeed, an integrated, coordinated, and sequenced approach is needed to overcome the challenges—financial, political, institutional—that may emerge while implementing the policies aimed at "pushing the envelope."

A Top Priority: Improving Public Transportation

As already noted, four of the 10 most congested cities in the world are in Latin America and the Caribbean, according to the INRIX 2018 Global Traffic Scorecard database.[7] Increases in population, motorization, VMT, and pollution projected for 2030 require cities that wish to avoid being choked by traffic to enhance mass transportation, marshalling technology for the purpose. Mass transportation is an efficient solution to the movement of people in medium, large, and megacities. A high-capacity corridor can move approximately 40,000 passengers per hour. To achieve the same output by car would require more than 20 parallel road lanes, which is geographically impossible in urban settings.

What is required, then, is high-quality, technologically advanced mass transportation, with good intermodal connectivity from feeder modes

[7] In its traffic index, the TomTom database also places four Latin American and Caribbean cities among the 10 most congested in the world. According to TomTom, congestion increases travel time by 63 percent in Bogotá, 58 percent in Lima, 52 percent in Mexico City, and 49 percent in Recife.

(buses, public bicycles, scooters, pedestrian facilities, and cars), including on-demand transportation systems. The importance of surface transportation for the quality of life in Latin American and Caribbean cities should be reflected in how available space is allocated among pedestrians, bicycles, freight, buses (or trams), and cars. Pushing the mobility envelope will require cities to favor public transportation and its feeder modes over private transportation. In the space allocated to private vehicles, they will need to increase high-occupancy trips through, for example, high-occupancy vehicle (HOV) lanes, monetary penalties for low-occupancy trips, and even banning solo trips in highly congested areas. Technology can help implement, monitor, and enforce these measures.

ACES technologies are particularly important for improving the *quality* of public transportation. Although the region has expanded its stock of transportation assets (see Chapter 4), the challenge ahead is to significantly enhance service performance. Autonomous technology—already in use in automated metro lines in São Paulo and Santiago de Chile—can improve not only safety and cost performance in mass transit, but also user experience through better docking, eco-driving, and smoother rides. Because many buses operate in segregated corridors under predictable conditions, public transportation is a prime candidate for testing autonomous technologies. Transportation authorities should facilitate such tests by implementing regulatory sandboxes[8] and developing testing guidelines.

Connected technologies can significantly improve the performance of public transportation. Real-time information on fleet and infrastructure performance, for example, can help reduce overcrowding, avoid long waiting times, and improve coordination between transportation options to provide a more predictable, demand-responsive transportation system. Digital platforms are another way to connect more people to public transportation, providing access to fares, information, and services that improve the user experience and increase ridership. This requires that governments lay the groundwork for open access to transportation data, integration of fares and modes, standards for enhanced interoperability, and availability of real-time information. Digital technologies also provide an effective way to create on-demand feeder services in suburban and rural areas, replacing more expensive fixed-route services for low-density areas. In small cities, on-demand services could provide an alternative solution to both fixed-route services and private car ownership. Likewise, these services can make night-time transit services more feasible.

8 A regulatory sandbox is a framework set up by the regulator to allow small-scale, live testing of innovations in a controlled environment (operating under a special exemption, allowance, or other limited exception) under the regulator's supervision.

Despite the benefits that ACES may bring to urban mobility, new technologies present challenges to public transportation and active modes. One of the main causes of the declining trend in transit use in the United States is the appearance of ride-hailing services, and the same trend is already emerging in Latin American and Caribbean cities. Available data for Boston indicate that 42 percent of ride-hailing riders would have taken transit if ride-hailing services had not been available (Shaheen, Totte, and Stocker, 2018). In Santiago de Chile and Bogotá, the corresponding figures are 32.5 percent and 33.8 percent, respectively (Granada, Pérez Jaramillo, and Uribe-Castro, 2018; Tirachini and Gómez-Lobo, 2020). Recent studies have also suggested that ride-hailing services are contributing to growing distances travelled by car and congestion: data for San Francisco, Boston, and Washington D.C. suggest that ride-hailing vehicles account for 13 percent, 8 percent, and 7 percent respectively of all VMT in such cities, a third of which are deadheading (Balding et al., 2019).

The potential adverse effects of ride-hailing call for policy action. Under a permissive regulatory framework, the number of kilometers traveled by vehicles and CO_2 emissions in Latin America and the Caribbean may grow by 6 percent and 15 percent, respectively, by 2030 (ITF, 2019). But with an efficient regulation requiring high occupancy rates on ride-hailing trips, shared services could help reduce overall kilometers traveled by 24 percent and CO_2 emissions by 3 percent (ITF, 2019). Some Latin American and Caribbean cities have joined other cities worldwide and started charging ride-hailing companies for road usage. São Paulo charges them an up-front fee based on an estimate of VMT, also referred to as credits, to be used by its fleet of passenger cars in a two-month period, plus a surcharge if credits are exceeded. In Mexico City, a flat 1.5 percent fee per trip is applied to shared mobility services. The effectiveness of these policies is yet to be evaluated.

Beyond these policies, a mix of soft and hard measures is needed to encourage each transportation mode to operate efficiently from a social standpoint. As for economic incentives, several policies are needed: pricing vehicle miles by time of day, pricing parking according to scarcity and availability, and subsidizing mass transportation alternatives.

Get Prices Right

The future of urban transportation in the region's cities depends on getting pricing right. The current practice of subsidizing car use (by not charging for either the use of social assets or negative externalities) is unsustainable and unfair (Gössling et al., 2019). While there is currently no available data for Latin America and the Caribbean, data for the European Union show that the external costs of private cars amount to US$735 billion, equivalent to 3.3 percent of Europe's GDP. This incentivizes—and even subsidizes—solo rides in private cars, creating unfair competition for public and active transportation. The counterproductive effects of this model, together with lower fuel tax revenues with the spread of electromobility, give countries the opportunity to finally get infrastructure pricing right through mechanisms enabled by digital technologies. With massive adoption of EVs looming on the horizon, governments need to replace fuel taxes as a revenue source. Fuel taxes presently account for a significant amount of government budgets: 3 percent in Chile, 4 percent in Argentina and Mexico, 6 percent in Colombia, and 5 percent in Costa Rica.

Road pricing—often implemented as a fee per mile traveled—may be the best tool so far to pay for the externalities introduced by automobile use. It makes the cost of using private cars visible to all users and, at the same time, generates financial resources that could be allocated to maintenance and enhancement of public transportation. Technological progress enables the implementation of these policies, as the location and distance travelled by each vehicle can now be tracked remotely. In the future, ubiquitous technology will allow governments to dynamically adjust the charge according to the actual volume of traffic on the road, thus facilitating traffic management in real time and encouraging a more efficient use of infrastructure. Congestion charges are also gaining ground to influence travel behavior while generating additional fiscal resources. Although often resisted and controversial at the outset, once these charges are implemented, they are favorably evaluated by citizens.[9] Successful implementations in Singapore (15 percent fewer cars enter the cordon area after policy implementation), London (–33 percent), and Stockholm (–28 percent) lead the way (Lehe, 2019). Recently, New York announced a congestion charging scheme for the busiest areas of Manhattan. If successful, it could provide guidance to Latin American and Caribbean cities. By implementing congestion pricing, cities in the region could reduce congestion by 24 to 28 percent (Bocarejo, López Ghio, and Blanco, 2018).

Pricing should also reflect the higher curbside demand now imposed by ride-hailing services, micro-mobility, and delivery vehicles, and soon to be imposed by shared AVs. Ideally, the curb should be assigned in real time to reflect changing demand during the day, giving priority to shared mobility during peak hours and encouraging delivery vehicles to use the curb at night.

[9] For example, congestion charges were introduced in Stockholm in 2006 as a seven-month trial, followed by a referendum in which a majority (53 percent) voted in favor of keeping the charges.

Parking fees are an additional source of funds that have been shown to effectively discourage the use of private cars while raising revenue. Shifting from free to priced parking typically reduces solo travel between 10 percent and 30 percent (ITF, 2019).

Pricing for road use, congestion, curb space, and parking is based on the idea of infrastructure as a service to be paid for through fees that cover the costs of providing it and reflect its value to users. Chiefly, new technologies facilitate applying this concept because they allow for precise pricing responsive to traffic dynamics and adjustable in real time to traffic conditions. Since enhancing the quality of transit systems requires investments that may not always be covered by service earnings, revenues from pricing could be allocated to upgrade transit systems, improving the fairness in resource allocation: subsidies to higher-income private car users are eliminated and the resources are used to improve the quality of pro-poor public transportation. For example, with a congestion charge of US$0.33 per km, Bogotá could raise funding to cover up to 15 percent of the daily costs of the system (Bocarejo, López Ghio, and Blanco, 2018; TransMilenio, 2019).

Measures outside the transportation sector can also help in the effort to get prices right. An obvious example is eliminating the subsidies to purchase cars contained in some industrial policies in the region, subsidies that not only incentivize motorization but also generate unfair competition for public and active transportation.

Setting the correct prices for mobility decisions is no easy task though. Many externalities are involved, and the discussion may trigger social unrest, as seen in Paris (sparked by an increase in the tax on diesel fuel), São Paulo (an increase in transit fares) in 2018, Ecuador (an increase in fuel price), and Santiago de Chile (an increase in metro fare) in 2019. In isolation, high prices can penalize low-income citizens or those who lack other mobility options. That is why sequencing policy actions is important: the quality, accessibility, and flexibility of the collective transportation system (encompassing all mass transit, buses, on-demand services, and micro-mobility) should be enhanced first to provide an efficient, reliable, and responsive service capable of accommodating a diverse set of citizens' demands. It is usually necessary to combine repricing with other measures, such as subsidized public transportation for low-income citizens, for whom traveling represents an important fraction of their monthly income. Technology can also play a role in targeting subsidies. Piloting pricing policies before large-scale implementation can help increase citizens' awareness of the expected benefits and help policymakers make necessary adjustments.

Decarbonize Transportation

Electric cars, invented in the 1820s (U.S. Energy Information Administration, 2018), are finally becoming a relevant actor in urban mobility, offering a timely opportunity to reverse the transportation sector's contribution to climate change (see Chapter 7). In Latin America and the Caribbean, transportation accounts for 37 percent of total emissions, while its carbon footprint is up to 30 percent higher than in OECD countries (Isla et al., 2019). The decline in battery costs will enable electric cars to compete in price with gasoline-powered cars by 2022. At the same time, the lower operating cost of electric vehicles will speed their adoption.

But ambitious policies will be needed to halt the growth of the transportation sector's CO_2 emissions and so enable the countries of the region to achieve their targets under the Sustainable Development Goals. Latin American and Caribbean governments can actively encourage electric vehicle (EV) adoption—thereby reaping the benefits of the region's cleaner energy power matrix—by implementing international best practices such as (i) shifting public transportation to fully electric fleets; (ii) creating low-emission zones and exempting electric vehicles from certain restrictions (HOV lanes and dedicated parking areas); (iii) incentivizing or investing directly in charging infrastructure;[10] (iv) introducing incentives to smooth energy consumption and avoid the spikes caused by simultaneous vehicle charging; (v) eliminating fossil-fuel subsidies; (vii) stimulating fleet renewal in the private sector (both in freight and passenger transportation); and (vii) phasing out the use of fossil-fuel vehicles by 2040 and banning their sale by 2030.[11]

While a big push is needed to promote the uptake of electromobility in a region where 1 out of 2 people still say they are not willing to use an electric vehicle,[12] a number of Latin American and Caribbean countries have made progress in this regard (Table 10.3). Costa Rica stands out in this area with a decarbonization plan that states that 25 percent of the light vehicle fleet should be electric by 2035. When promoting electromobility, governments must take care though not to encourage greater motorization or discourage a modal shift against collective transportation.

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[10] The level of installed charging infrastructure in a given territory is positively and significantly associated with the rate of EV registrations (Morton et al., 2018).

[11] This is in line with policy measures undertaken in other regions (e.g., Europe and some U.S. cities) and is also intended to avoid a tsunami of low-cost new and used gasoline-powered cars that will not be allowed to circulate in those regions. China has introduced rules that basically ban investment in new fossil-fuel-only car factories starting in 2019.

[12] See Latinobarómetro's 2017 Latin American Public Opinion Survey (database).

Table 10.3
Policies to Promote Electric Vehicles

	Argentina	Uruguay	Brazil	Paraguay	Chile	Ecuador	Colombia	Costa Rica	Mexico
EV purchase tax discount/ exemption	X	X	X	X	X	X	X	X	X
EV purchase VAT discount/ exemption	X	X	X	X	X	X	X	X	X
Discount/ exemption from other duties		X				X	X	X	X
Discount/ exemption from registration, ownership, or other fees		X	X			X	X	X	X
Preferential energy rates or free energy	X	X		X	X			X	X
Priority lanes / discount/ exemption from road use charges						X	X	X	
Preferential parking					X	X	X	X	
E-taxi programs		X	X		X	X	X	X	X
E-charging network (approximate number of stations)	4	47	200	10	55	15	40	50	900

Source: Isla et al. (2019).

Last-mile Logistics

With urban population and e-commerce growing in the next decade, efficient and sustainable last-mile delivery will be one of the main quests for urban planners. Rarely do land-use plans integrate freight movements into the management of individual and bus traffic in Latin American and Caribbean cities, resulting in logistical sprawl, increased freight movements, congestion, lower road safety, infrastructure damage, and noise and air pollution. Moving ahead, land-use plans will have to accommodate the growing influx of freight flows created by faster, consumer-driven supply chains.

Zoning should be reassessed in most cities, as the space available for distribution facilities has shrunk in the face of growing demand for residential real estate. This has already produced logistical sprawl,[13] raising VMT, emissions, and congestion. To reverse this trend, governments should set an appropriate policy framework (zoning, tax incentives) to encourage the private sector to deploy multi-tier distribution systems that combine logistical space and vehicle technologies to reduce VMT and increase the rate of vehicle utilization. These systems include urban consolidation/transfer centers, micro-fulfilment centers, delivery bays, and automatic parcel terminals. Recent experiences from European cities such as Madrid and London have shown that when space is made available for micro-fulfilment centers in urban areas, inventory can be stored closer to the end user, and deliveries can be made using more efficient, even shared, vehicles. While decarbonizing delivery, such changes can also help fill in the growing number of empty retail units in downtown areas and shopping malls, as more consumers switch to online shopping.

Zoning can also encourage the transition of last-mile delivery to clean energy. Setting low-emission zones should prepare cities for bold actions such as those taken by Paris, Mexico City, and Athens, which propose banning diesel trucks and cars from their roads by 2025. Latin American and Caribbean cities should consider similar policies, pairing them with the development of charging networks to encourage trucking companies to adopt EVs, and with the reinforcement of electrical grids to support greater demands.

Governments should also take more effective steps to integrate freight with mobility, and to alleviate congestion through a more efficient use of available urban space, now aided by the deployment of new technologies. Actions include:

- *Establish time windows for delivery, incentivizing* off-peak *deliveries.* For example, New York City's off-hour delivery program has achieved important economic benefits: carriers reduced operating costs and parking fines by 45 percent; businesses reduced inventory levels thanks to more reliable deliveries; truck drivers reduced their stress and work hours because of easier driving and parking; and emissions were lowered by 55–67 percent compared to regular-hour deliveries (Holguín-Veras et al., 2018). Likewise,

[13] For example, between 1995 and 2015, the distance from the location of logistics facilities to the city center of Belo Horizonte increased by 2 km (de Oliveira et al., 2018).

pilot programs implemented in Bogotá indicated average savings of 32 percent in trip costs, 42 percent in CO_2 emissions (due to less cruising to find parking space and faster routing during off-peak times), and 50 percent in unloading time (ANDI, 2016).

- *Create (and enforce) special areas for loading and unloading*. Pilots conducted in Queretaro, Mexico, showed that the transit and parking time of delivery vehicles could be reduced by 30 percent with better use of loading/unloading areas (Fransoo, 2019). Through digitization, video-detection and AI, enforcement can occur at a large scale, in real-time, and with fewer traffic officers.
- *Use smart curb management through appointment systems and dynamic pricing*. For example, Amsterdam, Barcelona, and Helsinki have booking systems that offer real-time information about parking spaces. Drivers use the systems to make reservations. Parking spaces are equipped with cameras, sensors, or other tracking devices to share information with drivers and city planners.
- *Dedicate space for parcel lockers in residential zones and mass transit stations, and implement policies aimed at raising utilization rates of delivery vehicles, thereby decreasing their number*. The average load factor presently averages just 30–40 percent, with more than 20 percent of vehicle-kilometers driven empty (Letnik et al., 2018). From the fiscal perspective, some policies currently being implemented include carbon taxes, congestion charges for roads and bays, differentiated parking charges, vehicle taxes, and package taxes.
- *Set vehicle weight, size, and type to traffic and road characteristics.* Smaller, clean-energy vehicles should be the norm for deliveries in low-traffic zones. In line with evidence from around the world, pilots in Rio de Janeiro using electric vehicles for last-mile delivery showed a 28 percent cost reduction per delivery route, in addition to the expected reductions in GHG (Bandeira et al., 2019). The deployment of low-emission zones should be accompanied by other measures to incentivize transport decarbonization and fleet renewal, like the ones included above.
- *Use big data, AI, and digital payments to enable dynamic congestion charges.* Thanks to these technologies, Singapore has improved the effectiveness of its congestion charging system by dynamically adjusting fees according to real-time traffic data rather than fixed hours (Lehe, 2019). The resources collected by charging congestion, curb usage, and parking could be allocated to improve freight and passenger transport systems at the city level.

Because several levels of government often converge in cities, and because multiple entities (planning, transportation, public works, police, industry) have mandates touching on urban logistics, interagency coordination is essential for effective policy implementation. Above all, sound, long-term public-private collaboration is needed to improve last-mile delivery.

Planning: Fuel for Success

Though no one can predict with certainty what transportation will look like in the future, clearly governments should already be taking steps to maximize the benefits and reduce the risks that digital transformation has already introduced into the sector. For governments, the major challenge is how to create, modify, and enforce policy frameworks in a rapidly evolving technological environment, and to use the opportunities that technology offers to develop efficient, sustainable, and inclusive transportation.

- *New planning methods are needed*. Traditional forecasting has become more difficult in the present context, with rapid, radical changes triggered by digital technologies and climate change (see Chapters 1, 7, and 13). The best response to this uncertainty are strategies that are well-hedged against a variety of different futures and capable of evolving over time as new information becomes available. Scenario modelling—as presently used by the British government and the San Francisco Bay Area Planning Agency to guide transport policy—should become a key tool for policymakers.[14] Effective policies are flexible enough to adapt to the challenges presented by the different scenarios.[15]
- *Governments should support regulatory sandboxes as a mechanism for developing regulation that keeps up with the fast pace of innovation*. Areas of interest include autonomous vehicles, micro-mobility, platooning, drones, and robots for last-mile delivery. Moreover, regulators should move away from the "regulate and forget" model, shifting to a more dynamic and adaptive approach

[14] The British government considers four scenarios for the future of mobility: one in which progress continues incrementally; one in which technology is allowed to dominate; one in which environmental and social issues take precedence; and a fourth in which less data sharing predominates. Policies are suggested for each scenario, with the aim to deliver positive outcomes for transport users.

[15] See Chapter 7 for empirical evidence on the effectiveness of scenario planning.

that allows for experimentation and iterative change (ITF, 2019). This is the approach being taken by the British and American aviation authorities as they integrate drones into the airspace. Whenever necessary or opportune, either because of expected gains from technology or for reasons of public safety or security, governments should collaborate with industry to test new technologies and put themselves in the best possible position to regulate. Several U.S. states have joined the automotive industries in AV pilots. The trials help policymakers assess the state of technology progress and inform policy design for AV deployment.

- *It is critical to build regulatory capacity.* Recent data on AV adoption suggests that Latin American and Caribbean countries are lagging behind in this regard. According to the KPMG AV Readiness Index covering 20 countries, Mexico and Brazil (the only two Latin American countries included in the index) rank 19 and 20, respectively, in the policy and legislation component. Public servants should be prepared to ask the right questions of highly specialized technology developers and providers. Policymakers involved in creating new regulations need to consider how best to address the mismatch in skills between government and industry. Some of the world's leading agencies are attracting former employees of technology companies to better understand current trends and shape them toward the public interest. Governments will need to assess whether technological disruptions, which are blurring the frontiers between transportation, land-use planning, energy, and security, require new institutional arrangements to better cope with coming challenges. Among them are data availability and management: who will be in charge of transportation data, what use will that agency make of them, and which data will the private sector be required to share are issues that governments needs to face without further delay.
- *The ICT capabilities of public agencies must be strengthened.* Technological advances enable governments to make more informed and data-driven decisions. For this to happen, public agencies should radically improve their IT capabilities. The world's leading agencies (e.g., Transportation for London, Hamburg Port) have done so by creating positions for chief innovation and information officers, with dedicated budgets and staff, to work on digital transformation plans for both the agency and the sector it regulates. While the challenge of funding for these investments needs to be addressed, by 2030, governments should be widely implementing

real-time infrastructure and traffic management techniques to raise utilization rates and reduce congestion. They should be relying on paperless procedures and AI to reduce costs, speed transactions, and provide prompt replies to individuals and firms; and they should provide real-time, high-quality, and interoperable data from consolidated portals that transportation stakeholders can use in their decision-making processes.

- *New technologies cannot work properly without adequate telecommunications infrastructure and interoperability standards.* Although the private sector should take the lead in both areas, governments have an important role in ensuring that the business environment is conducive to private investment; that networks cover the territory adequately; and that systems from different manufacturers are compatible (see Chapter 5). Several questions currently on the table require government attention: how will investments be provided? Will investors have a natural monopoly? What will be the specific requirements for them? Moreover, governments have a critical role in minimizing the privacy and safety risks that new technologies may generate, including cyberattacks and cybercrime. If not efficiently addressed by both the private and public sectors, these challenges could undermine consumer confidence, thereby limiting adoption. To face them, Latin American and Caribbean governments must update or create legislation on consumer protection, privacy, and national security, and to secure regulatory compliance. Since many of these areas are outside the transportation sector, governments need to enhance interagency collaboration to ensure a consistent and predictable regulatory environment.
- *Transportation and land-use planning must be coordinated.* Policies to promote densification and optimal land-use mixes are critical to prevent sprawl and associated increases in VMT. For example, planners should require that development in a given location achieve a minimum density and contain specific facilities to ensure sustainable transportation, as well as promote transit-oriented development. They should also put in place mechanisms to capture increases in real estate value traceable to transportation improvements. For all this to occur, cities need strong planning departments with appropriate enforcement powers.
- *Interagency coordination is also needed to mitigate the employment effects of automation and retail market disruption, and simultaneously address the shortage of human capital in the areas of science and technology, engineering, and supply chain*

management. Governments need to identify the skills their workforce needs; examine how these demands translate into curriculum reform, teacher training, and professional development; and leverage technologies to improve access to high-quality education

Table 10.4
Policy Actions to Realize the "Pushing the Envelope" Scenario

	Short term 2020	Medium term	Long term 2030
Improve public transportation	🟡 ACES sandboxes 🔵 Investment in high-quality mass transportation 🔵 Space reallocation from vehicles to public and active modes 🔵 Complementarity of ride-hailing services 🔵 Increased funding for higher quality of mass transport and its feeders	🔵 Digital gateways for transport services	
Get prices right	🔵 Increased funding for higher quality of mass transport and its feeders	🔵 Road, congestion, curb and parking pricing	
Decarbonize transportation	🟡 Availability of EV charging stations 🟡 Preferential lanes/zones for EV	🟢 No subsidies to fossil fuel	🟢 Electric public transport fleets 🟢 ICE vehicle sales banned
Address the last-mile logistic conundrum	🔵 Integrated plans for mobility and logistics	🔵 Updated zoning regulations 🔵 Time windows for deliveries 🔵 Smart management of loading/unloading areas	
Plan with perspective	🟢 Enhanced telecommunications infrastructure 🟡 Scenario planning/ Strengthen regulatory and institutional capacity 🟡 Enhanced inter-agency and public-private coordination 🟡 Regulatory sandboxes	🟡 Digital government	

🟢 National level 🟡 Both levels 🔵 City level and training (e.g., through online courses, new learning tools at school) (Bosch, Pagés, and Ripani, 2018).

As with many technological breakthroughs in the past, ACES technologies could become available and widely adopted sooner than expected. The transportation field is not a stranger to such breakthroughs. Two decades after the president of the British Royal Society suggested that heavier-than-air flying machines were impossible (1887), the first commercial airline was carrying passengers. Three decades after investors were told that the automobile was only a fad, the United States had surpassed the motorization rate Latin American and Caribbean countries have today (216 cars per 1,000 inhabitants). Therefore, with the new technological revolution in transportation speeding ahead, countries should use the available transition time for experimentation, learning, and shaping technologies toward reaching an efficient, sustainable, and inclusive transportation system. Making the right policy choices for the future of transportation starts today.

11

A New Paradigm in Water Management

Latin America and the Caribbean has around one-third of the world's water resources and only about 8.5 percent of the world's population. Still, the region's geography and economic structure complicate the management of this apparent abundance. Large agricultural and mineral production, numerous large metropolitan areas (many distant from water resources), and the most urbanized population in the world present many challenges for water and sanitation services. Perhaps due to the ample availability of water in the past, traditional management of the sector has been highly inefficient. Centralized systems have focused on service provision, but institutions have been weak and little attention has been paid to economic and resource sustainability. Moreover, a set of new challenges have emerged. Demand continues to grow, and more and more areas are likely to become water scarce. Natural supplies are becoming increasingly contaminated and unfit for many uses. Climate change is making some areas drier (Uhlenbrook et al., 2018), while other areas may face more extreme events such as floods and droughts. A new paradigm is required. Water resources need to be managed in an integrated fashion. Human, agricultural, and industrial needs must be balanced with environmental concerns in a holistic approach. New technologies will offer greater flexibility and decentralization and a move away from the traditional centralized model.[1]

Riding the Wave in a Changing World

The world that gave rise to conventional systems of delivering water and sanitation service is going through profound changes. Among the most

[1] This new paradigm, albeit harnessing data and innovative methods, reflects the philosophy of water resources in a distant past, and will allow the region to address persistent problems of recent years as well as face the challenges of the future.

consequential are the growing threat of water scarcity and the increasing frequency of extreme events, such as natural and man-made disasters. The threat of water scarcity has many causes. Higher population and increased economic activity are placing ever greater pressure on limited water resources, especially in urban centers. Climate change is altering the hydrological cycle, causing some areas of the globe to lose water resources and others to gain, which can sometimes be too much to handle. Floods, and the resulting sedimentation, can render water unfit for many uses. Other areas have been experiencing episodes of both excess and lack of water over the course of a year due to increased seasonal variability. The old model of service provision is ill-suited to cope with these new conditions.

Old System, New World

The development of the current system of water and sanitation services has gone through various stages (Daigger, 2019). The first consisted of local water distribution systems. Prompted by the spread of waterborne diseases through local water bodies contaminated by wastewater, these systems expanded to bring in cleaner water from more distant sources. But this only increased the volume of contaminated local water. This led to a third stage in which a wastewater system was created to transport sewage away from urban centers, provoking environmental problems and further contamination. Water treatment was the response; water was treated before distribution to make it potable for consumption, and as part of sewage systems to avoid further contamination of water bodies. The centralized, large-scale systems that developed through these stages represented large investments, were designed with long-term horizons, and were energy intensive as both drinking water and wastewater had to be transported long distances. In most urban areas with wastewater treatment, transporting the water accounts for an estimated 70 percent to 80 percent of total costs (Otterpohl, Braun, and Oldenburg, 2003).

Most countries have large, centralized systems with a linear approach to water use. They were designed to abstract water from natural sources, distribute it for use, collect the wastewater to remove contaminants, and then discard it. Even though these conventional systems are known as centralized systems, given their scale and scope, the different components of the service chain are usually managed independently (Mejía-Betancourt, 2015). While centralized across countries or regions, they are often separate in the sense that frequently they have separate supply chains for extracting and treating water for distribution, drainage, stormwater management, and for sewage.

While these centralized systems gain from scale, they are ill-suited to dealing with rapidly expanding cities, changing natural water supply patterns, and extreme events. Conventional centralized systems are costly and cumbersome to expand in urban and peri-urban areas. Many of these systems are now old, expensive to maintain, and overdue for large-scale rehabilitation (Johnson Foundation at Wingspread, 2014). The centralized nature of their components makes them vulnerable to natural disasters and extreme events. Once affected, they are very costly to recover in terms of both time and resources (Sherpa et al., 2014; Vázquez-Rowe, Kahhat, and Lorenzo-Toja, 2017).

The linear approach to water use also tends to create dependence on new withdrawals from natural water sources, normally surface- or ground-water. This is risky in the face of climate change and extreme weather events, when those sources can dry up or be rendered unusable due to sedimentation from floods. It also hinders resource sustainability, given that higher quantities of water must be extracted to meet increasing demand. When local sources are insufficient, water must be brought from further away, requiring costly infrastructure and leading to higher operational costs, in particular, energy use to transport the water (McDonald et al., 2016). Massive transfers of water also disrupt the hydrological cycle and jeopardize future water availability.

The sewage system component of conventional systems suffers from similar difficulties. By centralizing the treatment of wastewater from multiple sources, the process becomes complex and costly. Sources of wastewater contain different compounds (oils, nutrients) and types of contaminants (pathogens, pharmaceuticals) that require different methods and technologies to be removed. In many cases, treating them separately is more efficient. Graywater coming out of sinks, washing machines, and showers, for example, represents the bulk of used water (about two-thirds) and is relatively uncontaminated. It could be directly reused to wash streets or to water gardens instead of being sent to treatment plants. Even wastewater from toilet flushing is not all alike. Urine alone is very rich in nutrients that can be extracted for resale, while water that comes into contact with fecal matter contains harmful bacteria and pathogens that are more safely removed through traditional treatment. Conventional systems not only mix all wastewater from different sources into one stream, they often end up with rainwater runoff in the mix as well. This common problem of sewage overflow, due to the sharing of pipes between drainage and sewage systems, causes some untreated wastewater to leak into rivers while diluted wastewater reaches the treatment plant. Because treatment plants are tailored to the specific composition of wastewater, dilution can compromise its efficiency (rate of contaminant removal) and may exacerbate pollution.

The third problem of linear systems is their lack of "circularity." The conventional centralized approach misses the potential for resource recovery and reuse. It discards treated water and everything that was removed from it during the treatment process, thereby contributing to natural resource depletion. Rather than reselling some of the removed nutrients as fertilizers, for example, these nutrients are discarded while new resources are harvested to produce more fertilizers. Large quantities of freshwater that could be reincorporated into the system are also discarded, meaning new water withdrawals from nature are needed to meet demand. The lack of integration across the different components of the service chain prevents the system from taking advantage of synergies that could prove useful to face water shortages, such as the integration of wastewater systems as an alternative source of water supply.

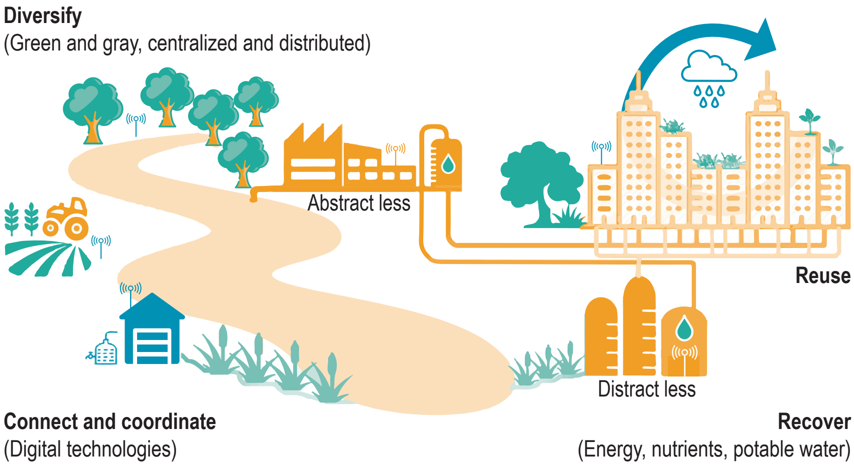
Finally, these systems were designed to run independently from other sectors that also rely on water as a critical input. Water and sanitation services are just one of the many competing uses of water. Agriculture,[2] mining, energy production, and ecosystems all require water in sufficient quantities and quality to function. The quantities used by any one sector and the resulting quality of the water resources affects the ability of other sectors to carry on with their own activities. Independent decisions can easily lead to resource depletion, when combined withdrawals surpass availability, and to the deterioration of water quality, when upstream users fail to take the quality requirements of downstream uses into account. All users need to take responsibility for the health and wealth of the resource and make coordinated decisions about abstractions and pollution discharge.

An Integrated Approach to Water and Sanitation Service

In contrast to the conventional centralized system, the new approach to water and sanitation services should unite the entire water cycle under one system. This means integrating all sector service components and water resource management across sectors (water and sanitation, agriculture, mining, energy) and with ecosystems (Figure 11.1). To accomplish this level of integration, distributed systems need to be combined with, or in some cases, substituted for conventional centralized systems. Distributed systems are smaller-scale facilities situated near or at the point of use that cover one or more components of the service chain. They can be decentralized systems

[2] The agricultural sector is responsible for about 70 percent of total water abstractions as shown later in this chapter.

Figure 11.1
Water and Sanitation Services of the Future



Source: Author's elaboration.

to collect and supply water, such as rainwater harvesting systems. They can be local reuse systems, like a pipe network within a building that redirects graywater to nonpotable uses such as toilet flushing and landscape irrigation. And they can also be small treatment systems, such as constructed wetlands, which use gravity, plants, and soil to filter wastewater.

Digital technologies are key enablers of the integration of centralized and distributed systems and the multiple users of water resources. These new technologies can revamp the operation of conventional centralized systems through a network of sensors and gauges coupled with analytical tools for data processing. These digital "ecosystems" are known as Smart Water Infrastructure Technologies (SWIT). Second, they can connect centralized and distributed systems through shared platforms containing service information. Third, they can integrate this new holistic service system with the broader management of water resources through digital platforms that contain hydrological, climate, and water use data and analytics.

Smart water technologies are beginning to revolutionize service provision. Whereas traditionally utilities depended on manual labor to carry out simple system monitoring activities, such as checking reservoir levels, shutting off valves to control water pressure, and reading meters to calculate consumption or to bill customers, utilities embracing smart water are fully automated. They rely on gauges and robotics, running on an integrated platform with real time data collection, cloud computing, and data analytics to monitor and operate the system remotely. The "smart water" approach is moving from reactive management to proactive operational efficiency. Sensors and meters can seamlessly feed information to monitor water flow, water pressure, or even changes in quality levels. These data can inform timely intervention to prevent leakages and prioritize the repair of pipes before they burst, reducing water losses and maintenance costs.

The smart water utility customer can find in water and sanitation services the same user interface that characterizes electricity and other digitized services (see Chapters 5 and 9). Smart meters allow customers to track the quality of the water they receive, monitor their consumption, learn about their water use patterns, pinpoint ways to be more efficient, and better understand their bills. Current evaluations of the effects of consumption feedback from smart meters in water use are still incipient. While the tool is promising (Yoeli et al., 2017), it has been found to have small and short-lived effects (Sønderlund et al., 2016) unless it provides real-time information that allows for an immediate response in behavior (Tiefenbeck et al., 2018). This last option is increasingly more likely with digitalization. Customer service platforms, in turn, mean convenient payment options and an open channel to voice problems and concerns. They allow utilities to communicate with users about their consumption patterns, general conditions of supply sources, and to encourage rational use and reuse through incentives and awareness.

Technological advancements will strengthen the adoption of distributed systems. The homes and buildings of the future will be built with technologies that allow graywater to be separated out for reuse in flushing, garden irrigation, and other uses that do not require potable water. Domestic and industrial reuse can drastically reduce consumption (Otterpohl, Braun, and Oldenburg, 2003) and, therefore, transport and treatment costs. Supply can then be ensured during droughts and polluting discharges reduced. Users play a key role in the water and sanitation service of the future (Otterpohl, Braun, and Oldenburg, 2003). They know the value of protecting the environment and make their consumption choices with care. They favor eco-friendly soaps and detergents to make reuse of graywater safer and easier, and they buy products with a low water footprint (see Box 11.1) bought in quantities that reduce waste.

The practice of reuse by households, buildings, and industry also reduces the quantities of wastewater requiring treatment. But even where the use of wastewater treatment plants is appropriate, they are changing from facilities that process waste to protect the environment to water resource recovery plants (Energetics, 2015). They turn nutrients and organic matter in wastewater into valuable resources such as energy, fuel, and fertilizers, and they recover purified water. Singapore, for example, currently supplies one-third of its potable water from treated wastewater (Leong and Li, 2017).

Box 11.1

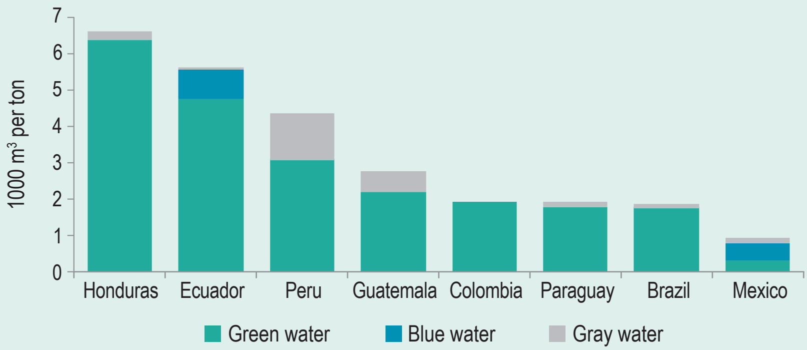
Water Footprint

It is common to think of domestic water consumption as the quantities of water supplied by the utility to meet household needs. This vision leaves out the much higher levels of consumption that take place indirectly through food and manufactured products purchased by the household. In 2011, Mekonnen and Hoekstra (2011) estimated how much water goes into producing a large number of food items around the world. These estimates, which measure the "water footprint," are the sum of all the different types of water needed to produce the items. These types of water are: "green water" (rainwater); "blue water" (surface and groundwater); and what is termed "gray water," which is the amount of freshwater required to dilute the pollutants that result from the production process, so that the water body where they are being discharged does not suffer a decline in water quality. In other words, the more chemicals and other pollutants are used in production, the more water is required to dilute these substances to protect nearby rivers and aquifers from a drop in water quality.

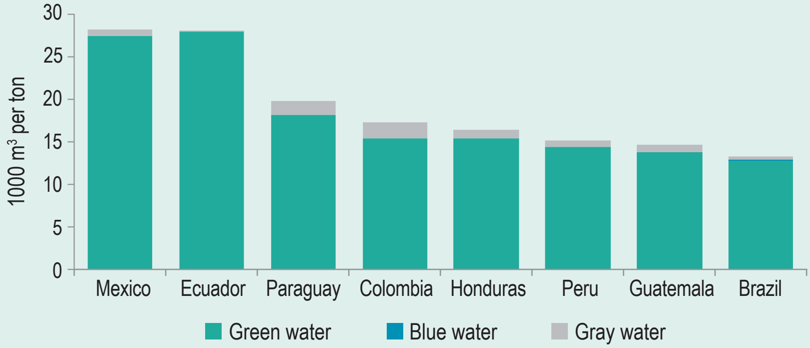
Based on these estimates, a simple breakfast in the region consisting of a cup of coffee and two slices of wheat bread can require anywhere from 389 liters of water to a whopping 920 liters. These figures are high compared to the water estimates required to meet most basic human consumption needs, which vary between 50 and 100 liters per person per day (Ki-moon and UN General Assembly, 2015). These rough estimates highlight the importance of consumer awareness and their choices in helping address water scarcity.[a]

Figure 11.1.1
Water Footprint of Selected Food Items

Panel A. Wheat Bread



Panel B. Coffee



Source: IDB calculations based on Mekonnen and Hoekstra (2011).
Note: Data correspond to the average water footprint between 1996 and 2005. The water footprint among countries varies due to a number of factors, among others: the climate in the planting area, irrigation and fertilization practices, and crop yields.

[a] Assuming 21.2 grams of ground coffee per 12 oz cup, and 20 oz in a wheat bread loaf of 20 slices. These estimates are mostly based on models calibrated based on data for the developed world and adapted to the Latin American and Caribbean conditions using limited available data (De Oliveira et al., 2009).

Green infrastructure (Chapter 8) and other types of distributed systems are a common feature in the future landscape. Rather than rely solely on water provided by utilities, commercial and domestic buildings are, for example, equipped to collect and treat rainwater. Besides saving on transportation costs, excess water collected from rain can help replenish aquifers through controlled infiltration, thereby mitigating floods and pollution caused by uncontrolled run-off. Green roofs and constructed wetlands—engineered systems that use natural components (soil, plants, organisms) to filter water—add to the beauty of urban areas while reducing heat island effects caused by excess gray construction. Together, these technologies and practices increase urban capacity to meet growing demand without large disruptions and with increased resilience to extreme events (Daigger, 2012; Howard and Bertram, 2010; Smith, 2009).

Users outside the reach of conventional systems, such as those in remote rural areas, are no longer isolated. Oftentimes, these remote areas fall under the jurisdiction of the urban provider but end up neglected due to the distance and low population density. Under the new approach, distributed systems similar to the ones used in urban centers can meet the needs of remote communities. They can be closely monitored through digital technologies, such as sensors that collect information on water availability and consumption, and also in the operation of the built systems. This allows them to be connected to the urban platform for an integrated service provision over the entire territory.

This network monitoring can also be integrated with external data about upstream water sources, rain patterns, and temperature fluctuations to prepare for and mitigate the impacts of extreme weather on water quality and availability, as well as on sewage and drainage networks. The redundancy created by the combination of conventional and distributed systems means back-up services are available in case any one component is disrupted.

Under the new approach, the water and sanitation services of the future are fully integrated with water use in agriculture, energy production, mining, and ecosystems, in order to guarantee quality and availability at the source. Resource use is planned and monitored through remote sensing and ground gauges for climate, water quality, and water extraction data. Remote sensing in particular covers a large time and geographical span, in addition to being public, transparent, and politically neutral. Therefore, actions such as deforestation, depletion of groundwater (NASA, 2020), and certain kinds of pollution of surface water (Schaeffer et al., 2013) can no longer be kept hidden. This increasingly accurate information (Karimi and Bastiaanssen, 2015) is then scientifically analyzed through hydrological, climate, and economic models to produce both current and projected estimates of water supply and demand. This technical complexity can be translated to the lay person through realistic simulations and platforms that allow decision-makers to explore the effects of various policies, such as decision-making under deep uncertainty methods (Chapter 6).

A Region Awash in Opportunities

The new integrated approach offers many opportunities for Latin American and Caribbean countries to address lingering problems from the past, while preparing to face the future. At the service provision level, integrating service chain components, incorporating distributed systems, and adopting digital technologies can help close the access gaps, improve service quality, and boost wastewater treatment rates. It can also make service provision more resilient to extreme events and better prepared to handle increasing water demand. Service provision, however, would still depend and have an effect on the quantities and quality of available water resources. Integrating water and sanitation services with other water uses, in particular ecosystems, is vital. Adopting an integrated water resource management approach, properly fed with data and analytics, can help countries in the region improve resource planning and allocation, raise water use efficiency, and reduce water pollution.

Box 11.2

Scenarios for the Future

The future of the water and the sanitation sector can be mapped into four broad scenarios depending on the organization of service provision and water resource management and on climatic and socioeconomic conditions. The former is a matter of choice or political will and focuses on the organization of the sector. The latter is a function of broader trends in population, economic growth, changes in lifestyles, technologies, and the consequences for greenhouse gas emissions. It is largely exogenous to the water sector, although it is a function of policies to mitigate climate change.

If little is done regarding climate change, and population and lifestyle trends continue unabated (the pessimistic column in Table 11.2.1), and the water sector remains with low integration, then water scarcity will widen and deepen. The sector will remain inefficient and be increasingly vulnerable to extreme events, especially if infrastructure deteriorates.

If climate change mitigation is more aggressive (the optimistic column) and lifestyle trends moderate but integration within the sector remains low, then with some luck, scarcity and vulnerability may not rise too much. While this scenario may buy countries time, changes would still need to be made eventually. The sector would remain deeply inefficient and sustainability would remain threatened.

A change in paradigm toward greater integration of the service chain components and water resource management can enhance efficiency. Even under more pessimistic climatic and socioeconomic conditions, this new paradigm of sector organization could contribute to mitigate the impacts of climate change and socioeconomic trends and increase resilience.

Under optimistic climate and socioeconomic conditions and with the new paradigm of integration, with consistent policies across all aspects of the water sector, efficiency would improve, vulnerability to extreme events would be reduced, and sustainability enhanced.

Table 11.2.1
The Scenarios

		Climatic and socioeconomic conditions	
		Pessimistic	**Optimistic**
Level of integration of services and water resource management	**Low**	Scarce, vulnerable, and inefficient	Inefficient and pushing our luck
	High	Mitigation and resilience	Sustainable, and resource efficient

Cleaning Up Water and Sanitation Services

Deficits in service access, quality, and wastewater treatment rates in urban and in more remote areas have been traditionally addressed separately. These two worlds differ in significant ways, especially under the traditional optic, since remote areas are unsuited for conventional centralized systems. Under the new integrated approach, they would differ mainly in the degree to which they rely on distributed versus centralized systems. Digital technologies are making it increasingly easy to closely monitor the distributed systems, and connect them to the urban platform for an integrated service provision over the entire territory. Examples range from sensors that measure and transmit information about the quality of rainwater collected in tanks or the effluents from constructed wetlands to ingenious devices that collect information on usage rates and hygiene practices. One example is the use of sensors for tracking hygiene practices in remote rural households. Many rural water and sanitation projects fail due to the inadequate use and poor operation and maintenance of the built infrastructure. New devices that record soap use together with flushing allow analysts to monitor both the operation of the system and the accompanying practice of hand washing, which is essential for households to derive the health benefits from service provision (Thomas et al., 2018).

Challenges: How the New Approach Can Help in Remote Areas

Access and service quality tend to be low in rural areas (Chapter 4). These areas are susceptible to the threats of water scarcity and extreme weather events and suffer from the problem of low-quality water sources due to lack of proper wastewater handling (Kresch, Lipscomb, and Schechter, 2019; Thebo et al., 2017). Offering high-quality services in remote or difficult to reach areas is challenging. Conventional centralized systems are not appropriate, and these areas tend to be characterized by low income, low educational attainment, and high vulnerability. Building the infrastructure is rarely enough to ensure the population derives the benefits from service provision. This can be the result of a lack of buy-in due to social (Kresch, Lipscomb, and Schechter, 2019) or cultural reasons (Verbyla, Oakley, and Mihelcic, 2013), or difficulties in operating and maintaining the system (Álvarez Prado, 2015; Altafin, 2020; Kresch, Lipscomb, and Schechter, 2019).

The new integrated approach to service provision can help ensure access to quality services, including proper wastewater treatment, through a variety of distributed systems. One example is rainwater harvesting for water supply. Since 2003, the federal government of Brazil has been financing the construction of water tanks for rainwater collection and storage, targeting low-income rural households living in areas of water scarcity(Ministério da Cidadania, 2020). This type of intervention has been shown to decrease the vulnerability of poor households in addition to reducing clientelistic practices (Bobonis et al., 2017). Filtering technology for these systems still needs improvement to reach potable quality. Household practices in storage must also be monitored to avoid contamination (Meera and Ahammed, 2006). This system has been evaluated for use in other countries in the region, like El Salvador (see Box 11.3).

Box 11.3

Pennies from Heaven? A Rainwater Harvesting System in El Salvador

Rainwater harvesting systems (RHS) collect and store rainwater for domestic consumption. They offer one example of a distributed system that is less vulnerable to breakdowns and that can be of higher quality than many groundwater and surface water sources. Capital costs of an RHS are low when compared with alternatives, such as expanding the water network or developing local water systems from wells or boreholes, which makes it an attractive option to reduce demand on already stressed water grids. The operating costs for the household are low relative to the cost of fetching water from distant sources, or of purchasing water from commercial providers. An RHS thus has the potential to improve equity in access and quality of water services (Rovira, Sánchez, and Rovira, 2020).

Some of its potential drawbacks include contamination from airborne pollutants and from material accumulated in the rooftop and gutters (including bird droppings and organic material); vulnerability to dry spells; and maintenance and repair costs. Rovira, Sánchez, and Rovira (2020) evaluated the potential of this system to become an alternative source of water in communities without reliable water service in El Salvador. Results from a model applied to three distinct localities suggest that RHS can satisfy all water needs of a household during the rainy season but is a limited resource during the dry season. It is, however, a cost-efficient water source, even when combined with purchased water to cover demand during the dry season.

Table 11.3.1
Cost per Cubic Meter by Alternative (US$)

	San Salvador	Comalpa	San Miguel
Rainwater harvesting	2.20	2.15	2.10
Purchased water	5.00	10.00	7.50
Expansion of water grid	10.48	10.48	10.48
Water fetched from a close source (less than 500 meters)	15.62	15.62	15.62
Water fetched from a source farther than 500 meters from house (4 hours for 200 liters)		31.25	31.25
RHS plus purchased water (per m^3)	3.60	5.97	4.67

Source: IDB based on Rovira, Sánchez, and Rovira (2020).

To increase wastewater treatment rates, constructed wetlands are emerging as sustainable, high-quality, low-maintenance solutions that can be highly cost-effective (Altafin, 2020; Kivaisi, 2001; Rovira, Sánchez, and Rovira, 2020). They perform particularly well in tropical climates, where most natural wetlands are found. They are easy to maintain and become financially sustainable if used to create products with an economic value for the communities. Two examples are Ponte dos Leites in Brazil and Lago de Patzcuaro in Mexico. In the first, the wetland produces floating plants, which are used by a nearby community to produce arts and crafts and eco-friendly fertilizer from composting the excess produced (Franco and Moura, 2017). In the case of Mexico, the wetland includes water lilies and plants that can be used to weave baskets, yielding an extra source of revenue (García García, Ruelas Monjardin, and Marín Muñiz, 2015).

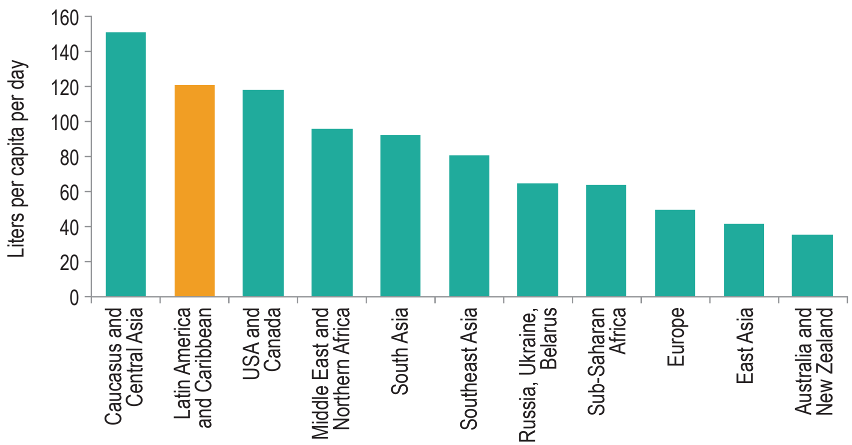
Challenges: How the New Approach Can Help in Urban Areas

In urban areas, the universalization of quality services, including wastewater treatment, also has its challenges. Most urban households and industries are currently served by conventional centralized systems. Thus, service coverage and quality depend on the performance of these systems. Often, however, they do not perform up to potential, mostly because of poor management practices (Cox and Börkey, 2015). But even the best-performing conventional centralized systems are ill-equipped to singularly solve the growing challenges of disorderly urban sprawl, increasing water demand, and extreme events. In addition to streamlining the management of existing conventional systems, urban service provision in Latin America and the Caribbean could benefit from distributed systems and the integration of all service chain components—supply, drainage, and sanitation—for water reuse and resource recovery.

A big share of water and sanitation utilities in the region find themselves in a vicious cycle. Aging infrastructure, often coupled with poor operation and maintenance practices, means high rates of nonrevenue water (NRW)—the amount of water produced that is either lost through leaks in distribution or is used but not billed. This leads to poor service with frequent interruptions, lower water quality, and dwindling revenues for the provider. Customer satisfaction declines as a consequence, bringing increased risk of payment defaults. Unable to recover costs or make enough to invest in the rehabilitation and extension of the network, problems worsen, thereby threatening the financial sustainability of service provision (Cox and Börkey, 2015), the coverage and quality of services delivered, and customer trust. Water is wasted, while its value declines, further impairing resource sustainability.

Data on utility performance are scarce in the region, often only available for small samples of utilities that are willing to provide the information voluntarily. Even in such samples, the magnitude of the problem can be staggering (Figure 11.2). According to Liemberger and Wyatt (2019), Latin America and the Caribbean loses an average of 120 liters of water per capita per day, which roughly corresponds to average consumption between 100 and 250 liters per capita per day. The International Water Association suggests setting acceptable NRW levels to the point where the costs of recovering the water lost equals the value of the quantities recovered. Thus, the threshold varies by city and time, as it depends on resource availability, production costs, and technological advancements. Great performers, like Singapore, can reach low levels at about 5 percent or 16 liters per day per person. In Brazil, variation across cities is tremendous, ranging from 10 percent to 75 percent of water produced. The average for the country is about 38 percent, which corresponds to yearly losses equal to 14 years (2004–2017) of total sector investment (Trata-Brasil, 2019).

Figure 11.2
Nonrevenue Water (NRW), 2016



Source: Liemberger and Wyatt (2019).
Note: Data estimated for 2016.

LATIN AMERICA AND THE CARIBBEAN IS THE SECOND MOST WATER WASTEFUL REGION IN THE WORLD.

Smart water technologies can help pull utilities out of this vicious cycle (Wyatt, 2018).

They can help raise customer awareness about the importance of water conservation (Sønderlund et al., 2016) and increase the efficiency and transparency of service provision. Installing smart meters and using machine learning to identify leaks has helped reduce NRW in one of Brasília's wealthy neighborhoods from 60 percent to 15 percent (Edreira, 2020). In The Bahamas, similar smart water technologies have reduced NRW by 58 percent in 3 years, increased the cost-recovery ratio from 0.65 to 0.82, and reduced government transfers to the utility by 63 percent (Wyatt, 2018).[3]

Wastewater Treatment: Anything but a Waste

The region also suffers from low wastewater treatment rates, estimated at between 30 percent and 40 percent of collected wastewater (Rodríguez et al., 2020).[4] These low rates, coupled with primary reliance on traditional wastewater treatment plants, mean many localities in Latin America and the Caribbean face a high risk of pollution and contamination. Wastewater treatment is a costly process that is seldom charged accordingly. Wastewater treatment services are often provided at no explicit charge to users or based on a flat rate charge. Irrespective of the rate scheme used, the bill is often lower for treatment than it is for water (Figure 11.3), even though it is significantly more expensive to provide. Customer perceptions are key in this regard, in particular, the willingness to pay to treat wastewater.

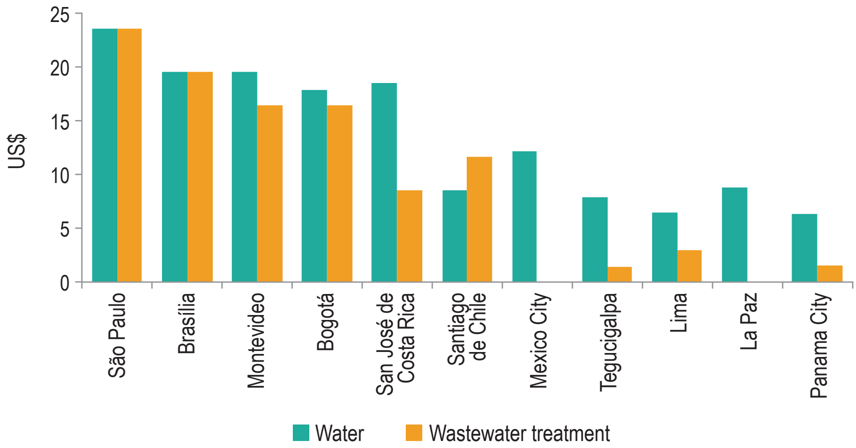
The operation and maintenance of conventional sewage systems are often plagued by a host of problems (Pacheco-Vega, 2015). Little emphasis is placed on training operators to ensure proper management in the long run, not enough resources are allocated to the maintenance of facilities, and cost-recovery is rarely met (Metcalfe, Guppy, and Qadir, 2018). According to a study by UNEP (UNEP, 2016) the estimated efficiency of wastewater treatment plants, in terms of rates of contaminants removed, is 47 percent in the region. In other words, over half of the contaminants in wastewater end up discharged in water bodies. This is below the estimated efficiency of treatment plants in Africa.

The new integrated approach can help break this negative cycle by leveraging reuse and resource recovery combined with the power of digital

3 The benchmark for cost recovery in the sector is around 1.3 (Ducci and García, 2013).

4 In the countries of the Organisation for Economic Co-operation and Development (OECD), 77 percent of people are connected to a wastewater treatment plant (Rodríguez et al., 2020).

Figure 11.3
Estimate Cost of Water and Wastewater Treatment, 2019



Source: Datshkovsky and Machado (2020).
Note: The estimated costs are based on 18 cubic meters of water delivered and 18 cubic meters of wastewater serviced. Amounts are calculated based on the local utility's most recent fare and then adjusted for Inflation to 2019 prices.

WASTEWATER TREATMENT IS OFTEN CHEAPER THAN WATER BUT COSTLIER TO PROVIDE.

transformation (Energetics, 2015). Resource recovery from wastewater can generate a new revenue stream for utilities to help offset the costs of treatment, while considerably reducing resource waste and environmental contamination. As in the case of remote areas, where no conventional wastewater treatment plants exist, low-scale distributed systems can be an affordable (Nansubuga et al., 2016) and more resilient solution.

An important advantage of the new integrated approach is that it promotes portfolio diversification. Water sources need not be limited to surface water and groundwater; they can include rainwater harvesting, desalination plants, fit-for-purpose reuse, and treated wastewater, from which even potable water can be extracted. Treatment options are expanded to include small-scale local systems in addition to large-scale centralized systems. Portfolio diversification can increase access to services and the quality of services provided by reducing water demand, creating redundancies in case a component malfunctions, and building resilience to extreme events. These are relevant advantages in a region considered to be the second-most disaster prone in the world (OCHA, 2020).

The Transition, Drop by Drop

There are a number of challenges to changing the paradigm guiding the sector and to adopting the new technologies and solutions that are aligned with it. They range from broad institutional and policy reforms, to utility management practices and individuals' perceptions and attitudes.

Institutional and Policy Environment

At the broad policy and institutional level, a key challenge is to put in place the right incentives and to ensure the means to adopt the new approach. This includes financial resources (Cox and Börkey, 2015; Sønderlund et al., 2016), but also the capacity to select and implement solutions (Aguilar-Barajas, 2015; Mejía-Betancourt, 2015). Strong regulation can help set the incentives through clear and enforceable service targets and quality standards. Under the new paradigm, the system has more components in need of regulation (Johnson Foundation at Wingspread, 2014), in particular reuse and resource recovery. In very few countries, however, regulation addresses "fit-for-purpose" use to make resource recovery and reuse legal practices.

Regulation can also encourage efficiency through the collection of detailed utility data that make service provision transparent, enable benchmarking exercises (Cox and Börkey, 2015), and inform the calculation of service fees so that they cover operating costs. To keep up with digital transformation, utilities must feel compelled to adopt the technologies (usually to gain efficiency), be capable of choosing the appropriate technologies, and be able to afford them. To meet all these conditions, both regulation and utility management need to be skilled and autonomous, that is, insulated from political interference.

The region varies widely in terms of where the sector stands in each of these conditions. Many countries, states, and municipalities in the region lack a regulator (Ferro, 2020). Where a regulator is present, it is not always free from political pressure or capable of defining, monitoring, and enforcing rules. Chile, for example, has a national regulator that sets service parameters and is endowed with the power to monitor and enforce them. But the head of the agency is directly appointed, and may be removed, by the president (Ferro, 2020).

Other countries, like Brazil and Argentina, have no national regulator; instead, they have state and municipal ones that do not cover the entire national territory. Service quality parameters and the institutional capacity of these different regulatory agencies vary significantly within these countries. Only Brazil, Chile, and Colombia have a database with basic information about service providers, and the practice of performing some form of benchmark exercise is even less frequent. Bolivia has developed a system of indicators for technical and commercial performance and Chile uses a model utility to set service fees and encourage efficiency (Arias, Rud, and Ruzzier, 2019). The regulatory challenges faced by countries in the region thus range from creating to strengthening and standardizing regulation at the national level.

Adopting the new integrated approach also requires a policy environment that is conducive to innovation. This involves eliminating a number of obstacles to the adoption of risky new technologies. These obstacles can be easily identified by local firms struggling to make the change. They can range from procurement laws that are not flexible enough to allow for the purchase of risky innovative practices and technologies, to unrealistic quality standards for products that can be recovered from wastewater for resale—such as energy, fertilizers, and even treated water itself.

Utility Management

Public utilities are the most common type of ownership in the region. While there are many modalities of public management, it is not uncommon for directors and CEOs to be appointed, and dismissed, by political figures. In Brazil, for example, 59 percent of utilities are under direct public management. For a random sample of utilities serving about three-fourths of the Brazilian population, Gómez-Vidal, Machado, and Datshkovsky (2020) identify that for half of them, the mayor or the governor directly appoints the CEO and directors. Moreover, many depend on government transfers to cover their operation and maintenance costs, their investment needs, or both (Cox and Börkey, 2015). Financial and decision-making autonomy together with cost-recovery tariffs are essential to the utilities' capacity to choose and ability to cover the costs of acquiring new technologies.

However, of paramount importance is the capacity of utility management to choose from the innumerable new technologies available. For that, management needs to be in the hands of capable people with the appropriate skills. For new technologies and innovation to yield benefits, they have to be chosen to solve the utilities' priority problems, rather than be adopted for their own sake. A good example of problem-driven innovation in the region is the Pitch-Sabesp (SABESP, 2020). Every year, the utility serving the mega city of São Paulo, Brazil, releases a call for innovative solutions to a list of problems that were prioritized by management. The winning proposals, chosen by a panel of experts including academics and sector professionals, receive financial support to pilot their ideas that, if successful, may be adopted by the utility. This not only invites the targeted presentation of innovation that meets the utility's needs, but also encourages new, needed technologies to emerge in order to improve the quality of services.

Implementation of the new approach would also require re-thinking management modalities and financing mechanisms in order to incorporate distributed technologies into the main system. Investment in training and skills development is key. Distributed facilities can be owned privately, which entails well-defined sharing of responsibility for their maintenance and operation. In terms of financing, the small-scale distributed systems differ from conventional ones in important ways. They are riskier, smaller, require less up-front capital and tend to be planned for the shorter-term, rather than the decades-long horizon of conventional systems. Traditional financing mechanisms are likely inadequate. Peru has come up with an interesting source of financing for projects that provide environmental services, such as green infrastructure. The funds are collected through a fee added to service rates (see Box 11.4).

Box 11.4

Financing Ecosystem Services in Peru

Peru has adopted two novel approaches to deal with environmental degradation and the challenges of climate change. In 2013, Peru enacted Law Nº 30045, which allows water companies to include an environmental service fee in water tariffs. The proceeds from this fee are assigned to a special purpose account and can only be used in investment projects to restore and protect water sources, including rural wastewater treatment plants. The last tariff-setting process for SEDAPAL, the public water utility in Lima, established an investment plan for environmental services for the 2015–20 period, which involved green infrastructure development and treatment of rivers. Although the scale of this environmental fee is still modest (the total amount to be invested in the 2015–20 period is just over US$12 million, which represents 0.4 percent of projected company revenues during the period), it is an interesting mechanism that can be scaled up and used to finance projects to protect water supply sources from the negative effects of climate change (SUNASS, 2020).

Consumer Behavior

Last, but not least, individuals play an important role in transitioning to the new approach. A change in perception, habits, and incentives are needed to promote resource protection and conservation in general (Tiefenbeck et al., 2018) and the take-up of distributed systems in particular (Johnson Foundation at Wingspread, 2014). On the one hand, educational and behavioral interventions can help raise awareness about the risks to the sustainability of water resources and promote decisions that are aligned with their conservation (Yoeli et al., 2017). On the other, tax incentives, like the ones practiced by California, can encourage specific actions, such as the adoption of green infrastructure on private properties. The U.S. Environment Protection Agency lists five types of incentive programs that can be adapted to local needs and conditions (EPA, 2020). They range from process incentives, such as expedited permitting and lower fees to developers building green infrastructure, to grants and rebates. Education is also a key aspect to promote a change in practices. As part of their efforts to combine "gray" and "green" infrastructure, many utilities (Thames Water, 2020; DC Water, 2020) and government agencies provide guidance to customers on how to save water and how to implement systems such as rainwater harvesting and green roofs, including the sale of installation kits.

Navigating the Challenges of Water Resource Management

Good water and sanitation service provision depends on the quality and availability of water resources. This means service providers have a responsibility toward resource sustainability that is shared with other water users. To avoid the depletion and contamination of the common pool of resources, coordination of water-related activities across sectors is a key aspect of the new integrated approach to water management.

Water is a decentralized resource that is challenging to manage. Political-administrative boundaries do not coincide with the boundaries of water basins, which is the most appropriate delimitation for managing the resource and its competing uses. Different sectors depend on and compete for water but are usually regulated and managed independently from each other (Dutra, 2020; Mejía-Betancourt, 2015; Aguilar-Barajas, 2015). Given that water is a limited resource, it is easy for one sector to encroach on the needs of the other. But distributive issues are just one part of the problem; the location of competing uses also matters. Water flows one way. This means users upstream enjoy an advantage over users downstream that needs to be properly monitored and managed.

The ability of current water resource management practices in the region to deal with these complexities is very limited (Mejía-Betancourt, 2015). The region is characterized by overlapping jurisdictions and dispersed responsibilities, with each entity or group making decisions independently from the other and looking after particular interests. This often leads to resource depletion and conflict between users, especially when their combined withdrawals exceed availability. Allocation decisions are also frequently made on a "first come, first serve" basis instead of prioritizing efficiency, and in the absence of data and estimations regarding current and future availability.

Poor resource management is also detrimental to water quality. The region is characterized by poor land planning, with informal settlements in areas of environmental conservation or close to water bodies where the risk of floods and contamination by untreated wastewater is high. Uncoordinated decisions taken locally produce suboptimal outcomes. In a study on Brazil, Lipscomb and Mobarak (2017) show that decentralization leads to increasing pollution as rivers approach the municipal downstream borders, and that this problem becomes worse as the number of jurisdictions involved in decisions increases. One example of detrimental decisions taken is the propensity of municipal governments to allow informal settlements, which often lack water and sanitation services, downstream.

The threat of water scarcity posed by this state of affairs may seem irrelevant to the second most resource rich region in the world (FAO, 2020). Latin America and the Caribbean holds about 33 percent of the world's renewable freshwater resources and receives about 29 percent of global precipitation (Flachsbart et al., 2015). But a closer look reveals a different and grimmer reality. The resource is unevenly distributed. While the estimated availability in Peru is double that of the regional average (5,921 cubic meters), the one for Haiti is a paltry 1,231 cubic meters. But even in Peru, the country's richest source—the Amazonian basin—is sparsely populated. Most of its people live on the hotter and much drier Pacific coast. In fact, many areas of high economic activity and population density in the region are located in areas with limited available water. Such is the case in Mexico, the Dominican Republic, Chile, Peru, and all the countries of Central America.

But the risk of water scarcity is not limited to these areas. High demand, poor planning, and wasteful use can deplete resources even where sources are abundant. In addition to the high quantities of water lost in domestic supply, the region displays important inefficiencies in agricultural water use. The agricultural sector is responsible for about 70 percent of total water abstractions. According to data from the Food and Agriculture Organization (FAO), the most common type of irrigation in Latin America and the Caribbean is surface irrigation,[5] accounting for over three-fourths of the irrigated area in a majority of countries. Surface irrigation relies on the field surface and its grading to distribute water to crops. It tends to be very water intensive. Sprinkler irrigation, in contrast, in which most gains from efficiency can be achieved with new technologies, accounts for just around 11 percent of irrigated land. This is the lowest rate among all regions in the world.

Incentives to use less water in agriculture are strictly linked to water rights and water pricing. Most water rights were allocated in times when

[5] With the exception of Brazil, Ecuador, and Trinidad and Tobago.

water scarcity was not a concern. They tend to be generous, often on a "use it or lose it" basis, or be tied to the land, giving the owner the right to fully exploit both surface and underground water within the property boundaries. Taking or buying back these acquired rights is politically difficult, which makes the setting up of incentives for rational use ever more important. Charges for water used in agriculture are low in the region, which provides little incentive to save water. While agriculture accounts for most water use, it tends to be the sector that pays the lowest bills, sometimes none at all. In Brazil, for example, agriculture consumes about 60 to 70 percent of the water, but accounts for a mere 1 to 5 percent of total water charges collected (Dutra, 2020).

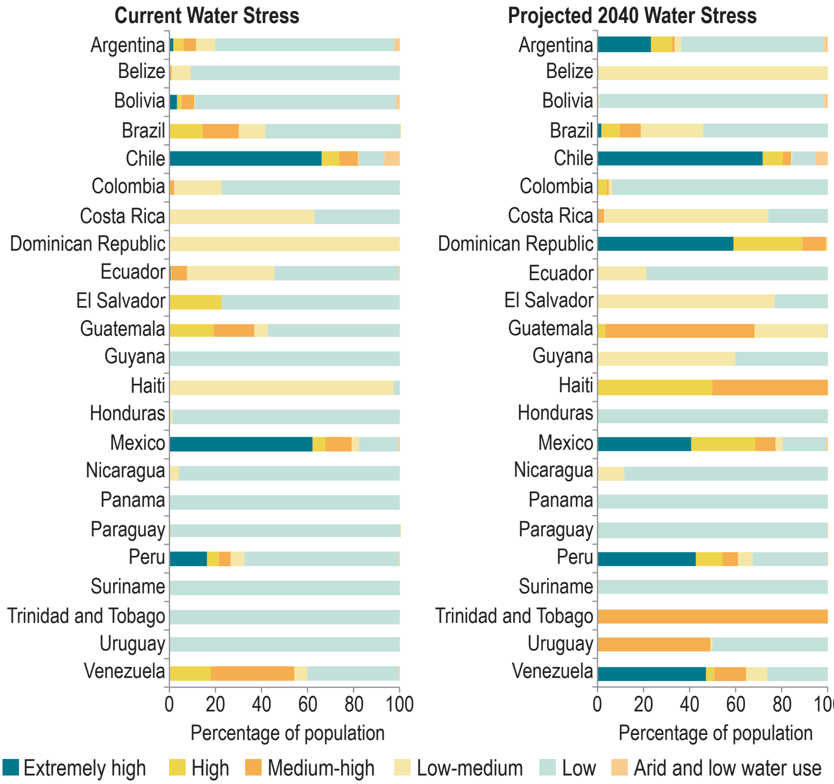
The region also faces significant water quality problems. According to a study by UNEP (2016) based on data between 1990 and 2010, while levels of pollution decreased considerably in the developed world, they increased significantly in Latin America. Around one-fourth of Latin American river stretches contained excessive levels of fecal coliform bacteria, one-tenth displayed severe levels of organic pollution, and a good percentage suffered from overload of phosphorous and nitrogen, which causes plants to overgrow and oxygen in the water to decrease, killing the animal life.

More recent estimates of contamination from agriculture indicate severe overload of phosphorous and nitrogen in rivers in areas of Mexico and Central America and along the coast of South America (Mekonnen et al., 2015). According to data from Brazil's Health Ministry collected between 2014 and 2017, one in every four cities in Brazil delivers water that contained 27 different types of pesticides to consumers (Aranha and Rocha, 2019). It is worrisome that many of these samples were within the limits permitted by law, which is much less strict than those allowed in Europe. Among the 27 approved pesticides in the Brazilian legislation, 21 are prohibited in Europe due to their health and environmental risks. Also, Brazil has independent limits for each type of pesticide—which can be 300 to 5,000 times higher than those in Europe (Bombardi, 2017)—rather than imposing limits to their sum.

Another important source of anthropogenic contamination is land clearing and deforestation, which can increase the frequency and severity of floods leading to the sedimentation of water bodies. While sedimentation is a natural process, in excess it can alter the course of waterways and turbidity, which can kill fish and aquatic plants. Sediment is difficult and expensive to remove. Most importantly, however, the removal of landcover leaves ground and surface water more vulnerable to all types of contamination, including runoff from agriculture. Cleared land is stripped of the filtering benefits of vegetation in general and of specific ecosystems such as wetlands.

As a result of all these practices, despite overall water abundance, the region faces important threats to water availability. Based on the World Resource Institute's (WRI) baseline water stress estimates (Hofste et al., 2019)—the ratio of domestic, industrial, and agricultural withdrawals over total available resource—around 15 percent of Latin America and the Caribbean's territory and 35 percent of its population are currently located in areas of moderate to extremely high levels of water stress. Under a business as usual scenario, by 2040 about 43 percent of the population in the region will be living in areas of moderate to extreme water stress (Figure 11.4).

Figure 11.4
Share of Population Living in Water Stressed Basins



Source: Authors' calculations based on water stress estimates from WRI Aqueduct 3.0 (Hofste et al., 2019) and population distribution from Worldpop (2020).
Note: The values indicate the percentage of the population living in areas with water stress (the proportion of demand/availability), ranging from extremely high water stress (>80 percent) to high water stress (40-80 percent); medium-high water stress (20-40 percent); low-medium water stress (10-20 percent); low water stress (<10 percent); and arid regions with low water use. The data representing 'today' consider the latest available data, which range from 2015 to 2017. The 2040 data correspond to the "business-as-usual" scenario as modelled by WRI Aqueduct 3.0 using the Climate Change Scenario IPCC RCP 8.5 ("Temperatures increase 2.6–4.8°C by 2100 relative to 1986–2005 levels"). Projected 2040 water stress for Trinidad and Tobago has been forecasted for 95 percent of the population given data restrictions.

These estimates do not account for the quality of the available water, the strength and appropriateness of the institutional and regulatory setup, and the risks of extreme events, such as floods and droughts. Taking all of these factors into account—WRI's "overall water risk" index—it is currently estimated that 44 percent of the territory and 61 percent of the population in the region are located in areas of moderate to extreme stress.

Adopting the new paradigm can help address these problems by integrating all water users via digital platforms and innovative technologies to gather and process the necessary data. Ground gauges combined with satellite imagery can be used to compile information about climate and hydrological conditions, and land and water use for all sectors and basins. When processed through hydrological, climatic, and economic models, these data provide critical information that help plan resource allocation and pollution discharges and monitor decisions. This information can be used to estimate water needs and to find opportunities to reduce waste. It can be communicated to decision-makers through easy-to-use platforms that translate the complexities of the models into easy-to-visualize policy scenarios. Most importantly, the new paradigm incorporates a sector long excluded from water decisions: the environment.

Getting to the Future: Anything but Smooth Sailing

The level of integration advocated by the new paradigm requires clearly defined roles, responsibilities, and guiding principles coupled with the capacity to monitor and enforce them (Aguilar-Barajas, 2015). The set of rules and guiding principles should preferably be set at the national level to ensure consistency across basins within the national territory and to facilitate cooperation in the management of transboundary basins. The entire organization needs to count on rich data, analytical expertise, and decision-making tools that contribute to an evidenced-based approach to management.

Decisions about water use—in particular the setting of abstraction limits and allocation across competing uses—and about water quality need to be based on robust data, a correct understanding of water flows and availability patterns, and clear and transparent allocation mechanisms. Ground-based gauges and observatories to collect data are, however, sparse in the region. In their absence, technologies for capturing and processing satellite imagery are greatly improving governments' capability to monitor water resources. It also allows countries to keep track of forest cover, monitor changes over time, and estimate the effects of conservation and reforestation policy. Satellite remote sensing and their use in hydrological, climatic, and economic models can help the region make up for some of the holes in information required for sound decision-making, but they are not sufficient to provide a full picture of the state of water resources. Investment in ground gauges and observatories are required.

The new approach also calls for setting up the right incentives for the efficient and non-detrimental use of water resources. One key instrument for that is prices. Setting them in a way that reflects resource scarcity and promotes efficient use is a complex enterprise, especially given the variability and uncertainty in resource availability and the need to acquire private information about resource valuation from different users. One solution, adopted across the globe with varying degrees of success (Olmstead, 2010), is the creation of water markets. Based on the same cap and trade principles of carbon emission markets, buyers and sellers trade water rights, permanently or on a fixed-term basis, with water flowing to the use of highest economic return, thus encouraging efficiency gains. These markets can be set up within a given sector, such as the well-developed agriculture water markets in the Murray–Darling Basin in Australia, or be used to allocate water across sectors.

To work properly, these markets require strong institutions—well-defined and monitored water rights and caps; good governance—for fair competition and clear rules; a well-designed technological platform—for accurate price adjustment; and the necessary physical infrastructure to transfer water between sellers and buyers. Strong, capable institutions are also critical to address equity concerns and guarantee a minimum flow to where water is needed but has low economic value. Some examples are the preservation of ecosystems and human consumption among low-income people. This often requires setting water abstraction limits for sectors like agriculture that are below previously granted rights (in particular where the government cannot afford to buy back these rights).

Generating incentives to improve water resource quality is even less straightforward, in particular contamination from agriculture. A first step is to require a revision of lawful products and their quantities and the ability of governments to enforce the rules. That would not, however, prevent pollution from using too much of the allowed substances. Imposing a ban on quantities of pesticides and fertilizers, for example, would harm producers whose crops, soil, or terrain call for larger amounts. Soil degradation and land clearing also contribute to contamination. Pollution abatement is better achieved if tailored to local conditions, such as soil types, terrain inclination, and proximity to water bodies. It is, therefore, extremely difficult to design and monitor. It would require the voluntary participation of agricultural producers (Centner et al., 1999). But many of the best practices to reduce this kind of contamination require costly private investments with no other return than reducing contamination to all water users. As in service provision, this requires greater individual awareness and willingness to contribute their share.

Overall, the successful adoption of an integrated water resource management system requires more than the right institutional setup, gauges, and platforms to gather the needed data. It requires tremendous capacity to process the information collected and to make decisions based on the produced evidence. In addition to the needed investments in data collection, countries must strengthen and expand the training of their labor force to meet the growing demand for high technical skills. An ever-evolving world requires appropriately trained, but also committed, individuals who can turn lessons learned and information into better practices. It takes between 15 and 20 years for new technologies to take hold in the water sector (Daigger, 2019). But the significant changes in preferences and practices that are required for their widespread adoption can take much longer. Governments, industries, and ordinary citizens have an important part to play in making the transition a reality.

12

Digging Deeper: Uncovering the Impact of Services on Growth and Well-being

Firms need infrastructure assets to function and consumers need them to live healthy and productive lives. It is thus unsurprising that much research has sought to quantify the extent to which investment in infrastructure propels economic growth.[1] But while building up infrastructure assets can support economic growth, the impact of infrastructure on the economy goes beyond the role of investment. Infrastructure sectors are connected to the rest of the economy in many ways.[2] Investment in infrastructure contributes to increasing output via aggregate demand and supply. But within the region, while countries may have similar levels of infrastructure assets to provide services (i.e., electricity, potable water and sanitation, and transportation), the accessibility, quality and affordability of those services may vary significantly (see Chapter 1).

Infrastructure services are used as intermediate production inputs by other economic sectors with varying intensities. Therefore, if electricity provision is intermittent, for example, sectors that use energy intensively

1 The aim of the research agenda has been to assess how much additional infrastructure investment is required to increase growth and/or close infrastructure gaps in countries that have fallen behind. A meta-study (García et al., 2017) identified more than 150 studies published since the 1990s that estimate the effects that increases in the stock of infrastructure have had on the growth rate of the economy.

2 Infrastructure investment affects economic growth directly as an element of gross fixed capital formation, and indirectly as a means to increase productivity (i.e., enabling factors of production to become more productive; facilitating human capital accumulation; providing basic services that allow the economy to function; and complementing private investment).

have higher productive costs and, therefore, are less competitive. Similarly, workers who do not have access to potable water and sanitation services at home may be less healthy and productive at work, which hurts them as well as their employers.

This chapter assesses the impact of increasing efficiency in infrastructure sectors on the economy and expands the set of economic outcomes to be taken into account. First, the chapter focuses on the potential of improving services through efficiency gains for increasing economic growth. The results complement the evidence on the importance of investment in the growth process, which has received greater attention in the literature.[3] Second, this chapter explores the impact of improving services on sector-level output and income distribution. These less explored economic outcomes determine how, and under which conditions, infrastructure contributes to strong, productive, and more equitable economies.[4] Finally, previous chapters have analyzed how the main technological disruptions envisioned in the transport, energy, and water and sanitation sectors can change the way the sectors operate in the future. This chapter complements that analysis by assessing the costs and benefits of technological disruptions on the broader economy, focusing on economic growth, sector-level output, and income distribution.

Efficiency Gains: Powering Growth and Reducing Inequality

Infrastructure can support the economy in various ways. For example, a new highway can spur economic growth by increasing the demand for construction inputs, by stimulating the demand for vehicles to use it, and by reducing travel times. At the same time, a new highway can open new markets, allow firms to implement innovative business models,

3 In the literature, a significant number of papers have analyzed the effects on economic growth of investment in structures. See for example, Calderón and Servén (2016), and Estache and Garsous (2012). García et al. (2017) provide a meta-analysis of related research. In Latin America and the Caribbean in particular, previous research identified infrastructure as the most significant priority when it comes to increasing the likelihood of reaching higher income per capita levels for middle-income countries (see Izquierdo et al., 2016).

4 Ahumada and Navajas (2019) provide a literature review of the few studies assessing the sector-level impact of infrastructure investment. They also assess how sector-level labor productivity shocks in three infrastructure-related sectors affect labor productivity in other sectors of the economy using a panel dataset of 25 countries from across the world. The literature on the distributional impacts of infrastructure is larger (see for example, Hooper, Peters, and Pintus, 2018); however, most of the analysis is based on evidence from advanced economies.

and facilitate trade, all of which may benefit the economy beyond the initial investment. Similarly, car-sharing services using digital platforms, which are becoming increasingly popular around the world, create new and potentially more efficient means of transportation. Service providers have implemented new business models that create new jobs and the services provided can save users time and money, thereby improving their quality of life.

The CGE models described in Box 12.1 provide a means to quantify the potential gains that greater efficiency in infrastructure sectors represent

Box 12.1

A Bird's Eye View of Infrastructure and the Economy

An economy is a complex array of connections between people, firms, governments, and institutions. To assess the impact of infrastructure services on the economy, this chapter uses a computable general equilibrium model (CGE) (see Brichetti et al., 2020). The model provides a useful toolkit that is calibrated for Argentina, Bolivia, Colombia, Costa Rica, Chile, Ecuador, Jamaica, and Peru—a set of countries with different growth experiences and economic structures and for which the necessary data to perform the analysis were available.

The basic structure of the model consists of approximately 30 productive sectors on the supply side of each economy, including four infrastructure sectors: production and distribution of energy, water and sanitation, transport, and telecommunications.[a] On the demand side are five representative households (with different income levels) and the government. Economies are open to commercial and financial trade with the rest of the world and are assumed to be small economies (therefore, they cannot affect international prices). In each of the markets, production and consumer utility functions govern the behaviors that determine how producers and consumers interact. Prices of goods and services are computed every period to clear all markets simultaneously. Producers and consumers carry out transactions for goods and productive factors. For example, on the production side, firms purchase intermediate inputs from other sectors, earn revenue from domestic and foreign sales, remunerate the factors of production, and pay taxes. On the demand side, workers receive their salaries—which are an important component of household income—consume, and invest. The government collects revenues from taxes and consumes and invests. The model estimates the changes in relative prices needed to clear the markets. Those price changes in turn influence the path of economic growth in each economy by reallocating resources among the economic sectors. They also lead to modifications in the structure of the economy, and in income distribution.[b]

The first step in "calibrating" the model to a specific country is to construct a social accounting matrix (SAM). The SAM is a representation of the flow of all economic transactions that take place within an economy in a year. At its core, it is a matrix representation of the national accounts of a country.[c] SAMs refer to a single year and provide a static picture of the economy, which is the starting point for the analysis. For the models used in this report, the base year is 2015.[d]

Using each country's SAM,[e] an initial path (or equilibrium) is obtained for the variables, providing a benchmark for growth with a ten-year horizon. In this solution to the model, the calibrated parameters governing the production functions of the sectors (i.e., the "efficiency" with which goods and services are produced) are determined by the country's input-output tables and national accounts as reflected in the corresponding SAM. In other words, the initial equilibrium is the "business-as-usual" (or baseline) scenario. It provides a benchmark against which to compare the counterfactual scenarios. In the counterfactuals, new equilibria are simulated assuming a variety of productivity and technological shocks that perturbate the baseline scenario.

The advantage of CGE models is that they provide a general equilibrium framework that allows for tracing the impact of changes on the economy considering the interconnectedness of the parts via budget constraints and the price system. Consequently, it is possible to assess the impacts of the simulated technological changes on multiple outcomes simultaneously from the demand and the supply sides of the economy.

[a] In some cases, the sectors are split into subsector according to the individual country SAM.
[b] The model is recursive dynamic, meaning that economic growth is the result of the savings of the agents who, in turn, make investment decisions following their current (rather than future or anticipated) income and factor remuneration.
[c] The SAM is represented in the form of a double entry box (or matrix) with the income of each sector in the rows, and the expenses in the columns.
[d] The accounting of the entries in the matrix must comply with the basic budget restrictions: i.e., income equal to expenses.
[e] A SAM represents flows of all economic transactions that take place within an economy.

for the economy. The production process in each sector uses a combination of productive factors (labor, physical and financial capital, land) and intermediate inputs (goods produced by other sectors). The exercise considers three types of efficiency gains in the infrastructure-related sectors simultaneously. The first is cost-saving *efficiency improvements* within infrastructure sectors that reduce the intermediate input requirements of those sectors per unit of output. An example from the energy sector is a thermal generation plant that employs energy-efficient technology and, as a result, uses less gas to produce the same amount of electricity. The second type is *productive efficiency gains* within infrastructure sectors that reduce the productive factor requirements of those sectors per unit of output. An example is a thermal generation plant that implements a labor (capital)-saving technology and, as a result, produces more output with the same amount of labor (capital). The third arises from positive spillovers from infrastructure to other sectors: given better-quality services, other economic sectors require fewer intermediate inputs from infrastructure-related sectors to produce a unit of output. Taking the manufacturing sector as a case in point, the gains from increasing the quality of infrastructure services can be interpreted in two ways: (i) the manufacturing sector receives better-quality electricity (i.e., fewer interruptions/black-outs) and, therefore, can produce the same amount of output using fewer inputs, or in less time; or (ii) the manufacturing sector improves the production process, for example by adopting energy efficient equipment, and as a result demands less electricity.[5]

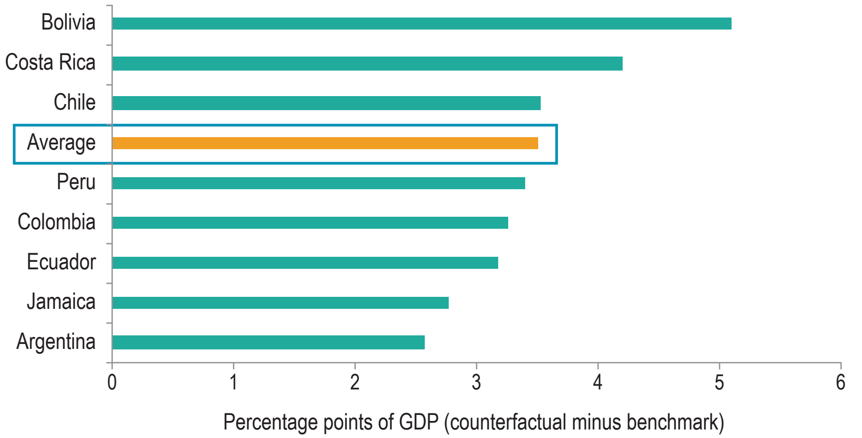
For each of the eight countries for which the model was calibrated, an initial equilibrium was obtained providing a benchmark for GDP growth over a 10-year horizon. This is the "business-as-usual" scenario. In the counterfactual exercises, a new equilibrium was simulated assuming efficiency gains in infrastructure sectors equivalent to 5 percent permanent improvements in the technological coefficients of the production functions starting in the first year of simulation. Those gains accrue simultaneously in all three dimensions: cost-saving efficiency improvements, productive efficiency gains, and service quality gains. Thus, countries increase the efficiency of providing infrastructure services by reducing the demand for intermediate inputs in the four infrastructure sectors by 5 percent, reducing labor and capital requirements per unit of output in infrastructure sectors by 5 percent, and improving the quality of services rendered, thereby enabling all economic sectors to reduce infrastructure-related costs by 5 percent below the initial equilibrium.

Relatively small increases in efficiency can yield significant growth benefits (Figure 12.1). On average, the selected countries would experience a 3.5 percentage point increase in growth rates over a 10-year period. Extrapolating to Latin America and the Caribbean, this represents approximately US$200 billion of incremental output over ten years.[6] Approximately 40 percent of the average estimated gains accrue from

5 Efficiency gains can be achieved in different ways including technological improvements, upgrading production processes, and changing behaviors/social norms. See Fay et al. (2017) for a useful discussion on Latin America and the Caribbean. See also Ferraro and Price (2013), Fielding et al. (2012), Habyarimana and Jack (2011), Schultz et al. (2007), and Datta et al. (2015) for insights from behavioral interventions to increase efficiency or lower demand in infrastructure.

6 Based on 2019 current GDP figures for Latin America and the Caribbean.

Figure 12.1
Impact of Efficiency Gains in Infrastructure on GDP Growth



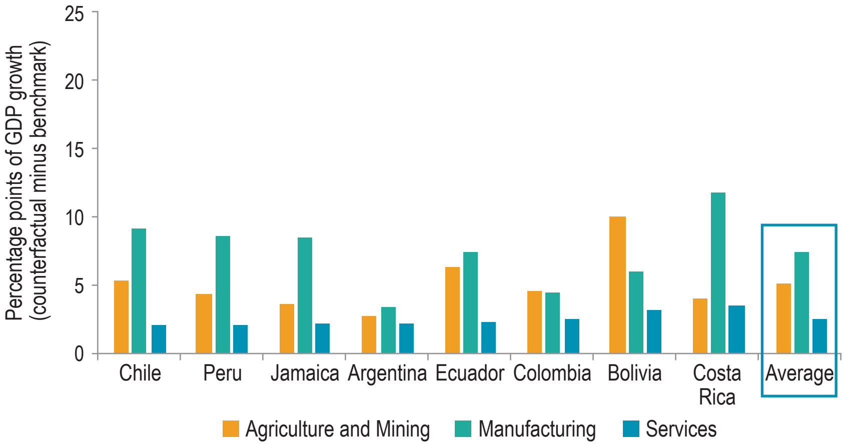
Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of GDP, of the counterfactual (i.e., higher efficiency) minus the benchmark (i.e., business as usual) growth rates over 10 years.

productive efficiency gains, and 30 percent each from cost-saving efficiency improvements and quality gains, respectively. The impacts vary across countries depending on various factors: their economic structures, the weight of infrastructure services in consumption baskets and intermediate input requirements for other economic sectors, the extent to which reallocation of resources is feasible among different productive sectors, the efficiency of the investment, and the growth rates of each country. These benefits may be as high as 4 and 5 percentage points of incremental growth in Costa Rica and Bolivia.

The estimated positive impacts of higher efficiency in infrastructure would be largest in the manufacturing sectors in all countries except Bolivia (Figure 12.2), where the mining sector predominates. These estimated impacts are consistent with the weights of infrastructure sectors' output, which are intermediate inputs in other productive sectors, over the value of production of the three aggregate sectors.[7] In other words, the manufacturing sector uses the most infrastructure services in the production process, according to the countries' SAMs, and accordingly it is the sector that benefits the most from improved efficiency in the provision

[7] The weights of infrastructure sectors' output on other sectors' value added are: 5.5 percent in agriculture and mining, 6.5 percent in manufacturing, and 4.3 percent in services.

Figure 12.2
Impact of Efficiency Gains on Sector-Level GDP



Source : Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of sector-level output, of the counterfactual (i.e., higher efficiency) minus the benchmark (i.e., business as usual) growth rates over 10 years.

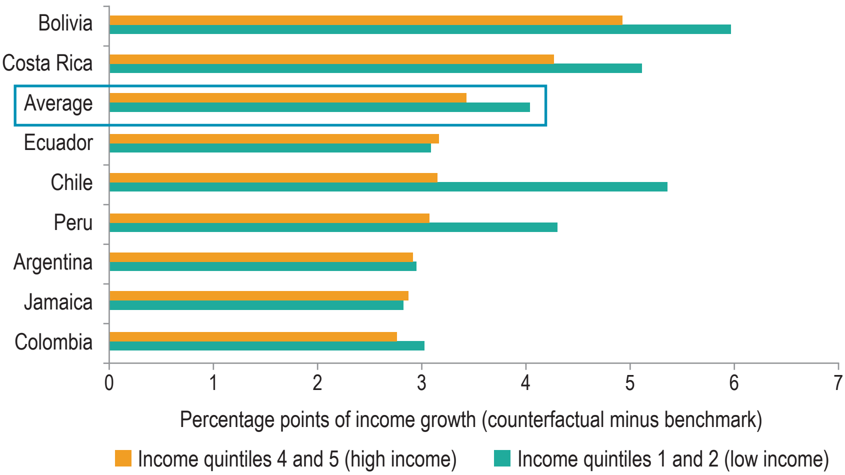
of services.[8] Thus, improving efficiency is more than just about increasing headline economic growth rates; it is a conduit to increase growth potential because the manufacturing sector is a high-productivity sector worldwide.[9]

The results also show that efficiency gains in infrastructure services boost the real income of every quintile of the income distribution, ranging from 2.8 percentage points for the average citizen in Jamaica up to 5.4 percentage points in Bolivia. In addition, improving efficiency in infrastructure benefits low-income households more than high-income households (Figure 12.3). For all the countries in the sample, except

[8] A caveat is in order because the relevance of infrastructure services on other economic sectors may be underestimated in the national accounts. In the case of extractive industries, and in agriculture, a large share of infrastructure services is self-provided and, therefore, is not incorporated into the SAM (see Coremberg, 2018).

[9] See Ahumada and Navajas (2019) for further analysis. Note, however, that the nature of the exercise in Ahumada and Navajas is different and, therefore, the results are not directly comparable. Ahumada and Navajas study the impact of labor productivity growth in infrastructure sectors on labor productivity growth in other economic sectors. Their study is useful to assess which investments (i.e., in which sectors) can help reduce productivity gaps in the economy. The exercise in this chapter is different because it assesses the impact of increases in efficiency on sector-level value added, without direct implication for productivity growth on other sectors and, therefore, on productivity gaps.

Figure 12.3
Impact of Efficiency Gains on Household Income



Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of real income, of the counterfactual (i.e., higher efficiency) minus the benchmark (i.e., business as usual) growth rates over 10 years.

Jamaica and Ecuador,[10] the income of the two poorest quintiles increases proportionally more than that of the two richest quintiles. The relative growth differential in favor of the poor is 28 percent on average. This effect is particularly notable in the case of Chile (where increases in the incomes of the poorest 40 percent of the population are 70 percent higher than those experienced by the two upper quintiles) and in Peru (40 percent).

Several factors combine to explain why the real incomes of the poor increase by more than those of the wealthy. On the one hand, household spending on infrastructure services represents a greater share of income for the poorest than for the richest quintile; therefore, the poor benefit more from the lower service prices resulting from higher efficiency in the infrastructure sectors. In addition, labor markets tighten as the economy grows faster, pushing real incomes higher, especially for the poor, who derive a larger share of their incomes from labor.[11] Finally, all the countries analyzed have some type of transfer targeted to poor. Therefore, another channel

[10] Jamaica and Ecuador are exceptions: the upper quintiles receive slightly larger benefits from the efficiency gains than the lower-income households.

[11] On average, the two poorest quintiles of the population in the analyzed countries receive 72 percent of their income from labor and transfers, while the richest quintile receives only 47 percent from the same sources.

that benefits the poor more than the rich is transfers, which likely expand thanks to an increase in government revenues associated with higher economic growth.

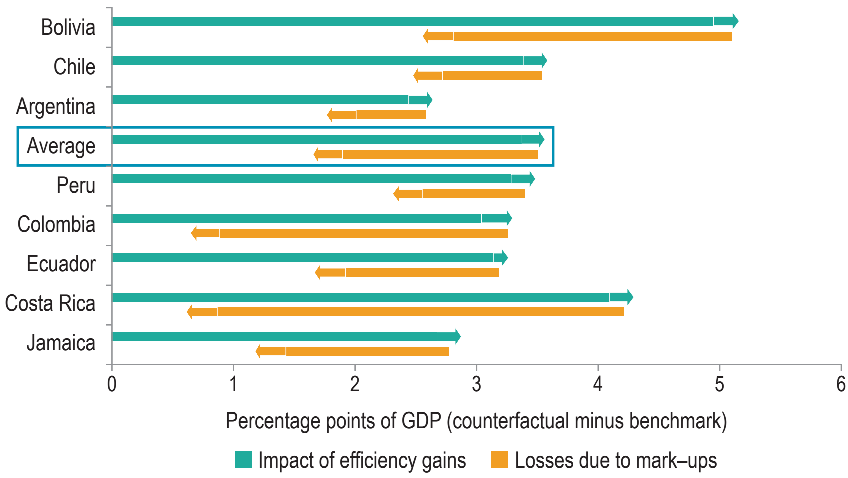
The bottom line is that increasing efficiency in infrastructure would likely raise aggregate output, support the high-productivity sectors in the economy, and reduce income inequality.

Regulation: The Key to Sharing the Benefits of Higher Efficiency

The simulated efficiency gains are assumed to trickle down into lower prices for infrastructure services. In turn, the economy is assumed to operate with a competitive price formation mechanism in all sectors. However, infrastructure services are usually provided in regulated markets with predetermined, or even fixed (contractual), prices that may inhibit efficiency gains from translating into lower prices for service users promptly. This section introduces an alternative price formation mechanism to assess the implications that different price adjustments have on the transmission of efficiency gains to the economy. In this exercise, counterfactual simulations were carried out restricting price reductions associated with efficiency gains. In particular, it was assumed that the suppliers of infrastructure services impose 15 percent mark-ups over the marginal costs of production (i.e., in the counterfactual scenario, the prices for services are 15 percent above the prices that would prevail if prices were fully flexible and markets were competitive). This mechanism allows the providers of infrastructure services to capture a bigger share of the efficiency gains in the form of profits, by restricting the transmission of the efficiency gains to consumers via lower prices.

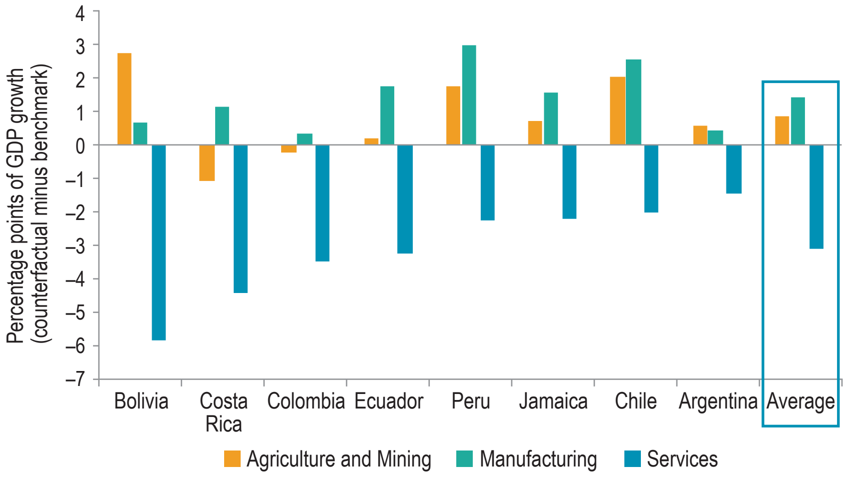
Figure 12.4 shows the difference in growth trajectories, in percentage points, between the baseline scenario (i.e., efficiency gains without mark-ups) and the 15 percent mark-up scenario (i.e., efficiency gains with price mark-ups). On average, in the counterfactual scenario with the price mark-ups, countries lose 1.8 percentage points of GDP over 10 years compared to the case without mark-ups. Losses would reach 3.5 percentage points in Costa Rica and 2.5 percentage points in Bolivia and Colombia. Notably, the countries that are most negatively affected are those that under competitive markets and full price flexibility would benefit the most from the simulated efficiency gains. The intuition is that the passthrough to prices of the efficiency improvements in infrastructure is lessened where mark-ups prevail. If those noncompetitive market conditions are maintained over time, then the result is lower GDP growth.

Figure 12.4
Impact of Efficiency Gains on GDP Growth with and without Price Mark-ups



Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of real income, of the counterfactual (i.e., higher efficiency with mark-ups) minus the benchmark (i.e., higher efficiency without mark-ups) growth rates over 10 years.

Figure 12.5
Impact of Efficiency Gains on Sector-Level GDP with Price Mark-ups

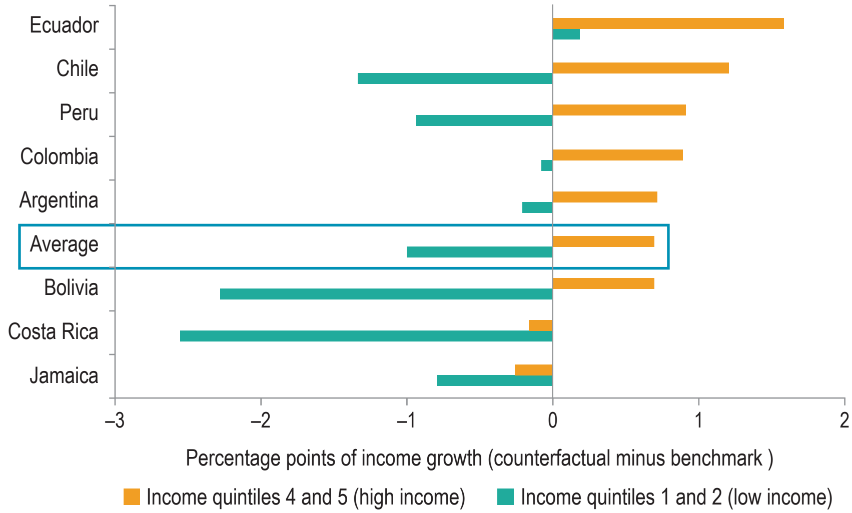


Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of sector-level output, of the counterfactual (i.e., higher efficiency with mark-ups) minus the benchmark (i.e., higher efficiency without mark-ups) growth rates over 10 years.

At the sectoral level, the service sector is the most affected by the mark-ups because the higher resulting prices for infrastructure services—which are part of the broader services sectors in the economy—make them less attractive to consumers. Consequently, demand for services is reduced (Figure 12.5).

As consumers, all households would be negatively impacted by the mark-ups because prices would go up. The poorest households would see their real incomes decline as service prices would be higher with mark-ups than without them (Figure 12.6). For wealthier households, the

Figure 12.6
Impact of Efficiency Gains on Household Income with Price Mark-ups



Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of real income, of the counterfactual (i.e., higher efficiency with mark-ups) minus the benchmark (i.e., higher efficiency without mark-ups) growth rates over 10 years.

impact is more nuanced; high-income households own a larger share of the capital stocks and would thus benefit from higher rents generated by the mark-ups. In six of the eight countries, the income-increasing effect from mark-ups would be strong enough to offset the negative impacts and, as a result, real incomes of the rich would increase on net. This, in turn, implies that the distributional impact of the mark-ups is regressive.

These results highlight the need for regulation to balance the incentives of service providers to pursue and embrace efficiency gains, with the need to allow those improvements to translate into lower prices for consumers. Without such a balance, the efficiency gains may not materialize, or the impact of those efficiency gains on the economy may be reduced, muted, or even reversed. Achieving the balance is not trivial in practice; it highlights regulation of infrastructure services as an indispensable component in the policymaking mix (see Chapter 13).

Disruptive Technologies: A Bridge to the Future

Disruptive technological advances are difficult to predict by their very nature. However, experts agree that increased digitalization of services can potentially generate significant efficiency gains in service provision. Experts also expect service providers to increasingly adopt environmentally clean technologies that can reduce energy generation costs and support clean and efficient transportation options.[12]

In the preceding exercises, the simulated efficiency gains were assumed to be exogenous, meaning they were introduced into the analysis as if they were "gifts" to the economy. However, in practice, either service providers, or the government, or both, would have to make investments in order to implement the technological changes to enable those efficiency gains. The simulations are useful to explore the potential impact of efficiency gains, but they are incomplete because they do not consider the costs inherent in achieving those gains. For example, adopting solar technologies requires investing in the panel equipment; it also requires improving the power transmission and distribution networks, and investing in maintenance and repairs for the solar technology. Therefore, evaluating the benefits and costs to the economy of improving efficiency in infrastructure services requires identifying the actual technological changes that may generate the gains, and assessing the costs associated with those changes.

This section assesses the possible impacts on the economy of three incipient technological disruptions with the potential to change the way infrastructure services are provided, leading to efficiency gains in the sectors. The disruptions are: (i) increased digitalization of infrastructure services, (ii) adoption of a larger share of nonconventional renewables in the electricity generation matrix, and (iii) introduction of electric vehicles and car-sharing services through digital platforms.

12 See U.S. Energy Information Administration (2019); IEA (2019b); IEA (2019c); IRENA (2019).

Digitalization of Infrastructure Services

The digitalization of infrastructure services encompasses digital technologies to expand the supply of infrastructure services, to improve demand management, and to improve the quality of services rendered.[13] The concept covers technologies such as smart meters to control and manage the consumption of residential electricity, smartphone applications to monitor the consumption of household appliances, remote digital sensors to measure and manage water pressure,[14] and digital screens at bus, metro, and train stops to inform passengers about when the next vehicle is expected to arrive, among many others (see Chapter 5).

Digital technologies are more likely to be applied if those technologies help suppliers save on intermediate input costs (i.e., cost-saving efficiency improvements) or increase output per unit of labor and capital (i.e., productive efficiency gains).[15] Therefore, in the exercises below, it is assumed that the digitalization of infrastructure services would render cost-saving efficiency improvements and productive efficiency gains equivalent to 15 percent above industry benchmarks in the infrastructure sectors over a 10-year period.

Investments will be required to enable providers to adopt digital technologies; new equipment (i.e., smart meters) and digital infrastructures (i.e., building 5G networks) will be needed. Taking this into account, it was assumed—based on industry forecasts—that capital requirements would increase by 10 percent above the baseline levels over 10 years in infrastructure-related sectors.

Demand for telecommunication services would increase above baseline levels following adoption of digital technologies. Therefore, it was assumed that the demand for telecommunication services—which is one of over 30 productive sectors in the economy according to each country's SAM—increases by 2 percent relative to the baseline values during the first

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13 See Milner and Yayboke (2019).

14 The use of networks of micro and macro meters connected to operational management systems has allowed Aguas Andinas, the provider of potable water and sanitation services in Santiago de Chile, to better control losses and perform predictive maintenance ("repair before it breaks"), thereby improving productivity, reducing costs, and conserving water (see Aguas Andinas, 2015).

15 It would be impractical to model the expected benefits and costs of each of those developments separately. Instead, the route taken herein is to incorporate some common characteristics of those changes into the parameters of the general equilibrium models in order to generate a set of counterfactual simulations based on the adoption of the technological disruptions in infrastructure sectors.

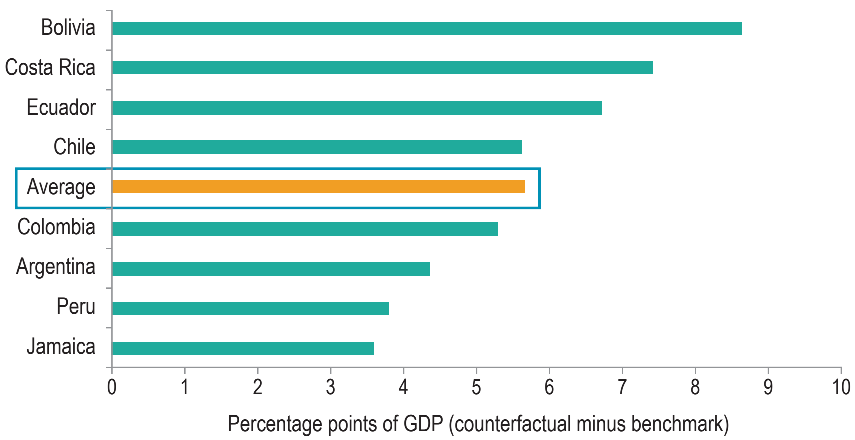
three years of simulations, then jumps up to 3.5 percent in the subsequent three years, and finally by 5 percent for the remaining years of the decade.

The specific assumptions regarding the magnitudes are based on experts' assessments of uncertain scenarios and, therefore, are subject to forecasting error and expert biases. Notwithstanding the modeling dilemmas, the results provide a primer on the possible impact that digital technologies in infrastructure services may have on the economy considering the interconnectedness between sectors and other complexities accounted for in a general equilibrium framework.

The results show that the digitalization of infrastructure services in Latin America and the Caribbean can boost economic growth while favoring the poor. Figure 12.7, Panel A shows that GDP would increase in all countries in the region in the counterfactual scenario. The estimated expansion of GDP from digitalization in infrastructure sectors would increase over time. On average, GDP declines 0.10 percentage point compared to the baseline in the first year of simulations due to the higher investment costs (Figure 12.7, Panel B). Efficiency gains begin to materialize in year two and accumulate over time, reaching 5.7 percentage points of higher growth, on average, if the policy persists over 10 years. Bolivia, Costa Rica, Ecuador, and Chile show above average performance, accumulating 8.6, 7.4,

Figure 12.7
Impact of Digitalization of Infrastructure Services on GDP

Panel A. Impact of digitalization on GDP, cumulative effects over 10 years

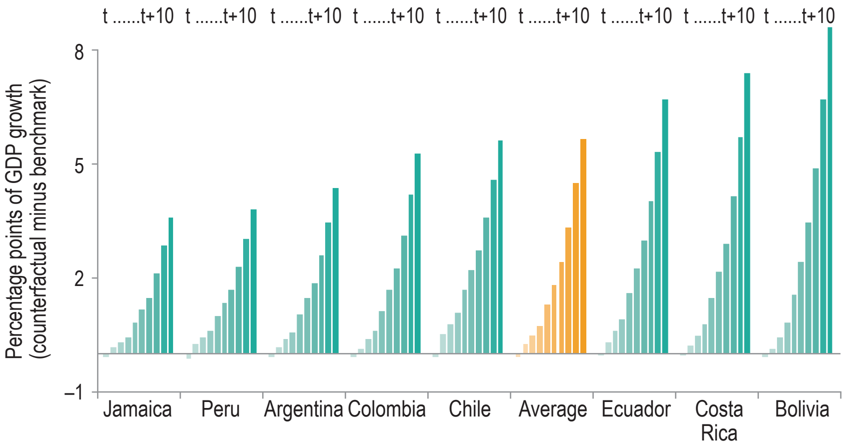


Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of GDP, of the counterfactual (i.e., digitalization) minus the benchmark (i.e., business as usual) growth rates over 10 years.

(continued on next page)

Figure 12.7
Impact of Digitalization of Infrastructure Services on GDP *(continued)*

Panel B. Impact of digitalization on GDP over time



Source: Authors' elaboration.
Note: Figure shows the annual change, in percentage points of GDP, of the counterfactual (i.e., digitalization) minus the benchmark (i.e., business as usual) growth rates over 10 years.

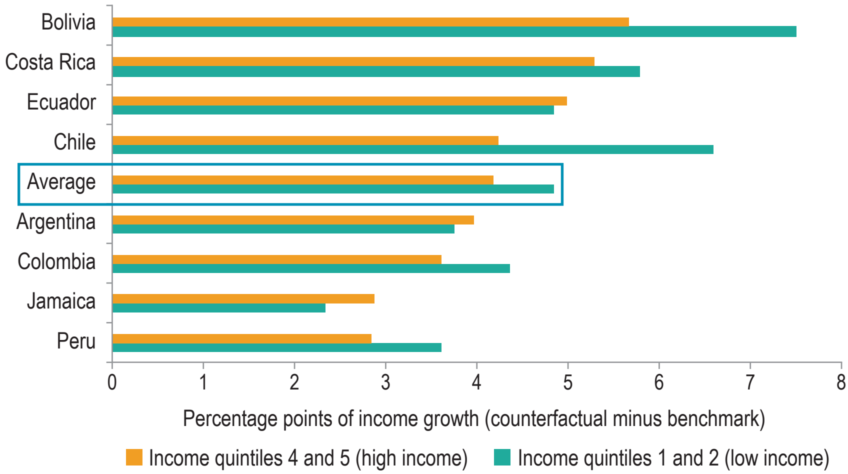
6.7, and 5.6 percentage points of GDP above their trend growth respectively.[16] The increase in the growth rate is accompanied by improvements in income distribution. The models show that in all countries, on average, the real incomes of the two poorest quintiles would increase by 16 percent more than those of the two richest quintiles (Figure 12.8).

Considering the possible impacts on both output and income distribution, the digitalization scenario is an example of what in the preceding section was labeled as an efficiency gain to the economy. Digitalization of infrastructure services would affect the economy through a combination of factors that are tantamount to those efficiency gains. For example, the poor would probably benefit more than proportionally from the decline in service prices occasioned by digitalization because the poor spend more of their income on infrastructure services than the rich and would therefore benefit the most from falling prices.[17] Moreover, incremental

[16] The estimated impacts of digitalization vary by economic sector. On average, they are largest in manufacturing (industrial sectors)—except for Bolivia where mining predominates—and are lowest in services.

[17] On average, the total expenditure on infrastructure services (transportation, energy, and water and sanitation) represents 14.1 percent of the disposable income of the two poorest quintiles, while it represents only 11 percent for the richest 40 percent of the population.

Figure 12.8
Impact of Digitalization on Household Income



Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of real income, of the counterfactual (i.e., higher efficiency) minus the benchmark (i.e., business as usual) growth rates over 10 years.

economic growth brought on by digitalization would reduce the unemployment rate and increase labor income, which is the main source of income among the poor.

The bottom line is that digitalization has the potential to generate efficiency gains that benefit the economy, even when considering the costs of adoption: it could boost economic growth; it could help increase long-run growth by channeling growth to high-productivity economic sectors; and it is likely to be pro-poor. This area, therefore, requires a supportive policy framework that ensures that the potential benefits are realized and spread across the economy.

Nonconventional Renewables: A Powerful Alternative

Latin America and the Caribbean is rapidly increasing the share of nonconventional renewable sources in its energy mix (see Chapter 7). The policy decision to foster nonconventional renewables responds to the need to decarbonize economies and comply with mitigation targets set out in the Paris Agreement. The introduction of nonconventional renewable sources of energy, particularly solar and wind, promises a revolution in the cost structure of the sector by enabling electric power to be generated at low marginal cost.

This section evaluates the possible impacts on the economy of increasing the share of wind and solar energy in the electricity-generating matrix of Latin America and the Caribbean from an average of 5 percent in the first year of simulations to 40 percent of the total over 10 years.[18] The exercise assumes that as the electricity sector increasingly relies on solar and wind for generation, it saves on fossil fuels (coal, oil, and gas) in proportion to the amount of fossil-fuel generation that is displaced every year by the renewable sources. This proportion varies by country according to the energy matrix depending on the mix of fossil fuels consumed and the installed capacity of renewables at the time of the simulations.[19,20]

The simulations vary according to the investment required to incorporate nonconventional renewables to the generating matrix. There is no unique way to calibrate the investment needs because the costs of the associated technologies decline over time, in some cases rapidly (Figure 12.9), raising uncertainty regarding the future costs of nonconventional renewables.

Against this background, two simulations are performed. The first uses estimates based on the current cost of capital in the different economies; the second assumes a 40 percent reduction in capital costs over a 10-year period. For the first scenario, it was assumed that the infrastructure sectors must increase capital investments between 5 and 7.5 percent of GDP over a decade in order to incorporate renewables.[21] In the second scenario, the increase in capital investment varies between 3 and 4.5 percent of GDP; as expected this value is much lower because of the 40 percent reduction in costs of nonconventional renewables.

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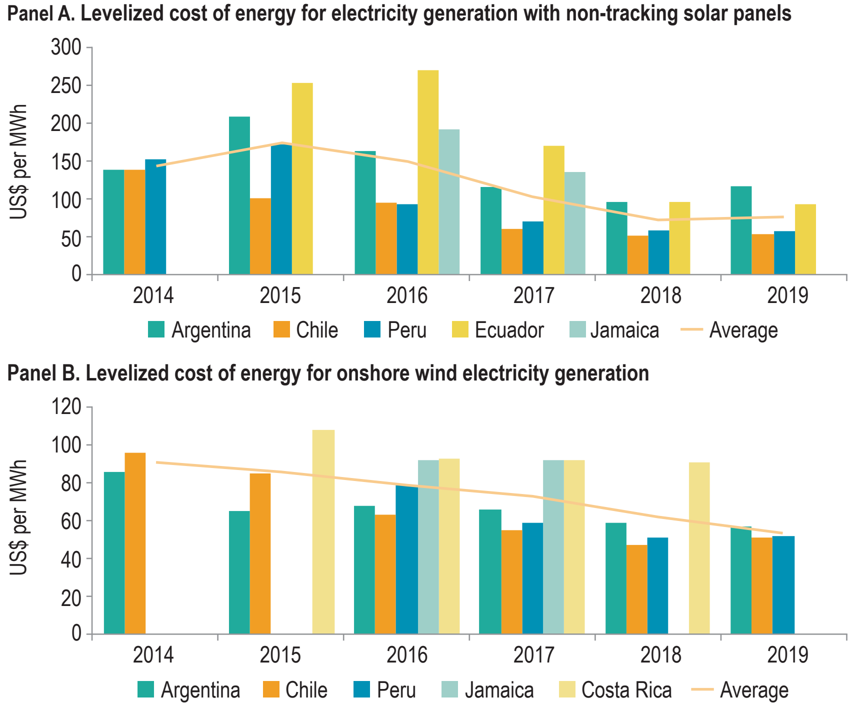
18 The choice of the 40 percent share of nonconventional renewables in the electricity matrix responds to the objective of converging to a fully renewable electricity matrix to comply with the Paris Agreement and a net zero emissions economy. Latin America and the Caribbean's use of renewable resources exceeded 55 percent in 2018 (see Chapter 9), mostly due to the use of hydropower to generate electricity. The 40 percent would then place Latin America and the Caribbean close to or at the objective of a fully renewable matrix. The regional average masks differences among countries; however, the same assumption was used for all countries to facilitate the estimation of the model.

19 See Brichetti et al. (2020).

20 Costa Rica is exempted from this exercise since it has already made the transition to a fully renewable electric generation matrix.

21 To perform the investment needs calculations, two types of data are required: on the one hand, the so-called "capacity factor" that determines the installed capacity needed to generate the required electric power (note that the capacity factor is lower in renewable energies given the intermittence in generation); on the other hand, it is necessary to estimate a cost of capital per megawatt (MW) of installed capacity using renewable technologies. For this exercise, the source for both types of data is the Model for Electricity Technology Assessments (META) of the World Bank for the year 2012. See Brichetti et al. (2020).

Figure 12.9
The Cost of Nonconventional Renewables

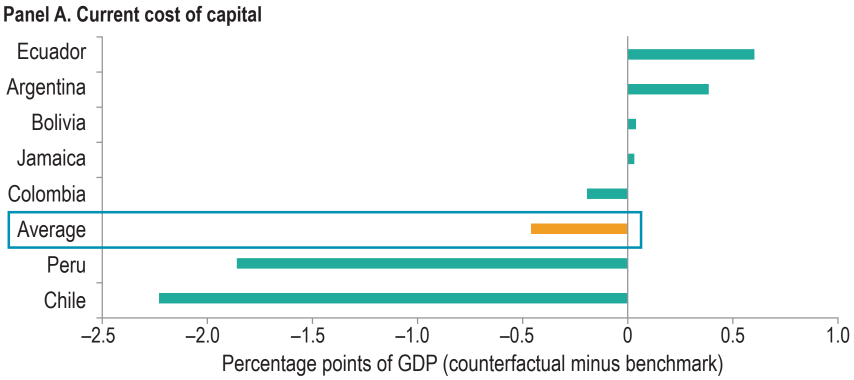


Source: Bloomberg New Energy Finance (BNEF).
Note: The levelized cost of energy represents the long-term offtake price on a MWh-basis required to recoup all project costs and achieve a required equity hurdle rate on the investment. For the most competitive photovoltaic and onshore wind markets, BNEF uses proprietary price indexes to build bottom-up capex assumptions, paired with region-specific data for financing, macroeconomics, and resource. The full capex also accounts for regional permitting and land acquisition costs. For photovoltaic and onshore wind projects in less competitive markets, BNEF uses a combination of reported project-level costs (as captured in Bloomberg Power Plant Database, local input from regional analysts, and data from publicly available sources).

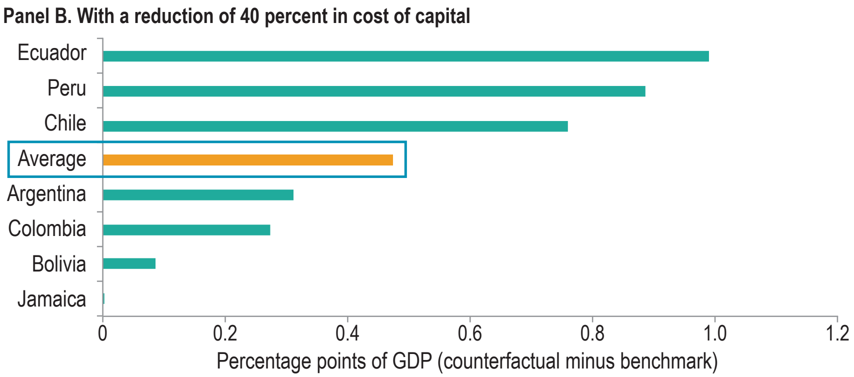
The estimated impacts of increasing the share of solar and wind to 40 percent of the electricity-generating matrix on GDP vary across countries: in Argentina, GDP expands by approximately 0.5 percentage points above the initial equilibrium in 10 years; in Bolivia and Jamaica, the increase is smaller. On the other hand, GDP would contract by approximately 2 percentage points in Peru and Chile, and 0.2 percentage points in Colombia (Figure 12.10, Panel A) relative to the initial equilibrium.[22] These results reflect the resource base of these particular countries (coal in Chile and

[22] This implies that the economy would grow less than in the baseline, which is not necessarily at negative growth rates.

Figure 12.10
Impact of the Increase of Nonconventional Renewable Generation on GDP



Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of GDP, of the counterfactual (i.e., increasing the share of renewables to 40 percent of the total) minus the benchmark (i.e., business as usual) growth rates over 10 years.



Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of GDP, of the counterfactual (i.e., increasing the share of renewables to 40 percent of the total assuming lower investment needs than in Panel A) minus the benchmark (i.e., Panel A counterfactual scenario) growth rates over 10 years.

Colombia, and gas in Peru). By displacing contaminating but cheap sources of energy with nonconventional renewables, the cost saving benefits of a "green" electric generation matrix are reduced.[23] The estimated impacts on sector-level outputs and income distribution also vary across the region.

[23] In this exercise, the fossil-fuel generation capacity is already in place; therefore, the results can be interpreted as a byproduct of the stranded assets problem. Moreover, as the cost of electric generation with nonconventional renewables continues to decline, the cost disparities between renewable and nonrenewable sources will also shrink (see Chapter 9).

Figure 12.10, Panel B, shows that when investment needs are 40 percent lower than in Panel A, the estimated impacts on GDP of increasing the share of renewable energy sources in the electricity-generation matrix are higher than in Panel A, particularly in Ecuador, Chile, and Peru.

The reason the results vary reflects two countervailing forces. On the one hand, less dependence on fossil fuels results in lower electricity prices; on the other hand, because new capital investments are required, prices must increase to generate the returns to entice those investments. In every simulation, one of the two forces prevails depending on country specific conditions. In addition, the need to increase investment in the electricity sector in order to transform the generation matrix competes with investment needs in other sectors of the economy and may crowd out investment and create other tensions in the economy that are captured in the simulations.

Notwithstanding the intrinsic difficulty of estimating future investment needs precisely, developments in the renewable energy market suggest that investment needs may decline rapidly as the technology evolves. The costs of renewable generation technologies have fallen substantially and continuously in the region over the last decade. Chile, for example, reached in 2017 the milestone of obtaining one of the cheapest auctions for solar energy in the world, with an average price of US$32.5 per MWh. Technological advances, coupled with improvements in institutional capacities, will likely reduce the investment needs of adopting a larger share of non-traditional renewables in the region over time, which in turn implies that it may become increasingly more feasible and profitable to make the transition, increasing the gains in terms of growth and welfare.

New Avenues in the Transport Sector

Replacing part of the fleet of existing combustion engine motor vehicles with electric vehicles and car-sharing services are expected to generate efficiency gains in the transportation sector. New models of electric vehicles can travel longer distances per unit of energy than comparable combustion engine vehicles.[24] Car-sharing services, in turn, can raise productivity by increasing the number of riders per trip, and by freeing up passenger time for work or leisure.[25]

[24] According to the EPA/DOE (2020) the most efficient electric vehicles (BMW i3 BEV) in the market in 2019 could reach up to 124 miles per gallon equivalent, while the average internal combustion cars sold (Ford Fusion) could travel only 25 miles per gallon.

[25] See Luan et al. (2018) for a comprehensive list of benefits of car-sharing technologies.

The exercises in this section evaluate the potential economic impacts of increasing the share of electric vehicles and the spread of car-sharing services in Latin America and the Caribbean. The two technological disruptions are independent of each other; however, they both impact the transportation sector directly, and are thus evaluated jointly. The assumptions are that the share of electric vehicles will increase to 30 percent of the total car and bus fleet in 10 years,[26] and that over the same period, 50 percent of private car trips will be performed using a car-sharing modality. Electric vehicles will reduce the demand for fossil fuels, while increasing the consumption of electricity. Introducing electric vehicles will require investment in equipment to build up the fleet, and additional investment to upgrade the energy distribution networks. For the simulations, it was assumed that the transport sector will increase investment by 10 percent compared to the baseline scenario.

The expansion of car-sharing services, in turn, will reduce demand for cars and fuel by households, and boost productivity in transportation through a more intensive use of vehicles (i.e., more riders per trip).[27] The costs are the investment required by transport firms to accommodate the increased ridership, and the fees paid by riders for the transportation services. The sector's increased investment was assumed to be equivalent to 50 percent of the reduction in the demand for cars by households. This assumption reflected the belief that fewer cars would be required under the car sharing modality because each vehicle would carry more passengers than private cars.

The results from the simulations are reported in Figures 12.11 through 12.13. The increase in the share of electric vehicles and the expansion of car-sharing services are expected to have a positive but quantitatively small impact on GDP in Latin America and the Caribbean over 10 years (Figure 12.11). On average, by the end of the 10th year, GDP would be 1.2 percentage points higher in the economies included in this exercise relative to the baseline. The small quantitative impact on GDP is not surprising since the weight of the transportation sector, which is the most affected by these changes, is about 5 percent of GDP in Latin America and the Caribbean, on average. This, however, may be underestimated because it does not consider the self-provided transportation services of households and firms, which would increase the relative weight of the transportation sector in national accounts by approximately 50 percent (Coremberg, 2018; see Box 12.2).

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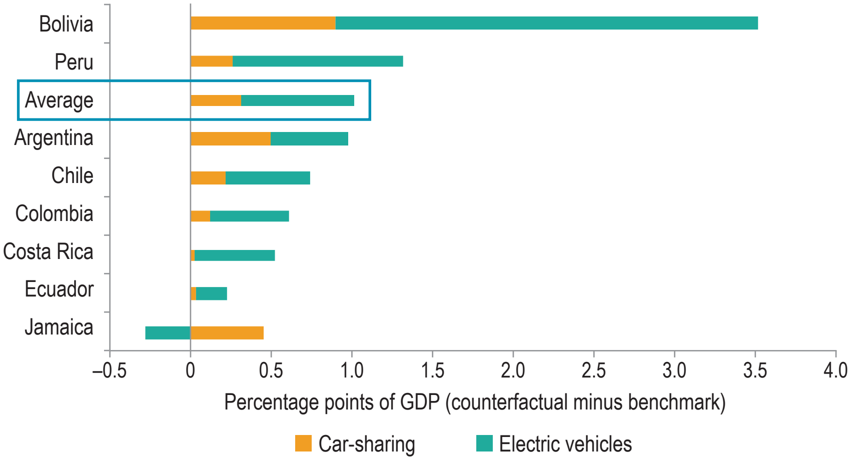
[26] This is an optimistic assumption based on estimates for the International Energy Agency, IEA (2019b).

[27] For the simulations, it was assumed that productivity in the transportation sector would increase by 15 percent over ten years relative to the base year.

Figure 12.11
Impact of Electric Vehicles and Car-Sharing Services on GDP



Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of GDP, of the counterfactual (i.e., with electric vehicles and car-sharing services) minus the benchmark (i.e., business as usual) growth rates over 10 years.

Box 12.2

Gauging the Economic Magnitude of Infrastructure Services

Do Latin America and the Caribbean adequately measure the role of infrastructure services in the economy? The answer is no, and the problem lies with the reporting methodology used by national statistics bureaus. Reporting in all infrastructure sectors (energy, transport, water and sanitation) seriously underestimates the magnitude of infrastructure services. Coremberg (2018) calculated the role of infrastructure services in Argentina, Brazil, and Mexico, which together account for 55 percent of the region's GDP. Borrowing from the technical terms of the national accounting methodology, Coremberg compiled an "infrastructure services satellite account" by reclassifying the activities (production, consumption, and investment) carried out by firms and households, either via the market or for their own account, related to energy, transportation, telecommunications, and water and sanitation. Coremberg's compilation of the satellite account marks the first such exercise in Latin America and the Caribbean.

The contribution of infrastructure services to GDP increases almost 50 percent, from 7.25 percent to 11 percent, when services supplied in house are counted—that is, when they are imputed to the infrastructure sector rather than to the sector of the firm self-supplying the service.

The increase in the weight of infrastructure sectors in the economy is explained in large part by the transportation sector. Similar results are reported for the few

Table 12.2.1
The Economic Magnitude of Infrastructure Services in Latin America and the Caribbean by Mode of Provision (as percentage of GDP)

	Energy		Transportation		Water and sanitation		Total		
	For hire	In-house provision	For hire	In-house provision	For hire	In-house provision	For hire	In-house provision	Total
Argentina	2.35	0.01	4.79	2.96	0.17	N/A	7.31	2.97	10.28
Brazil	1.8	0.01	4.82	3.57	0.84	N/A	7.46	3.58	11.03
Mexico	1.13	0.03	5.61	4.53	0.35	N/A	7.09	4.56	11.65

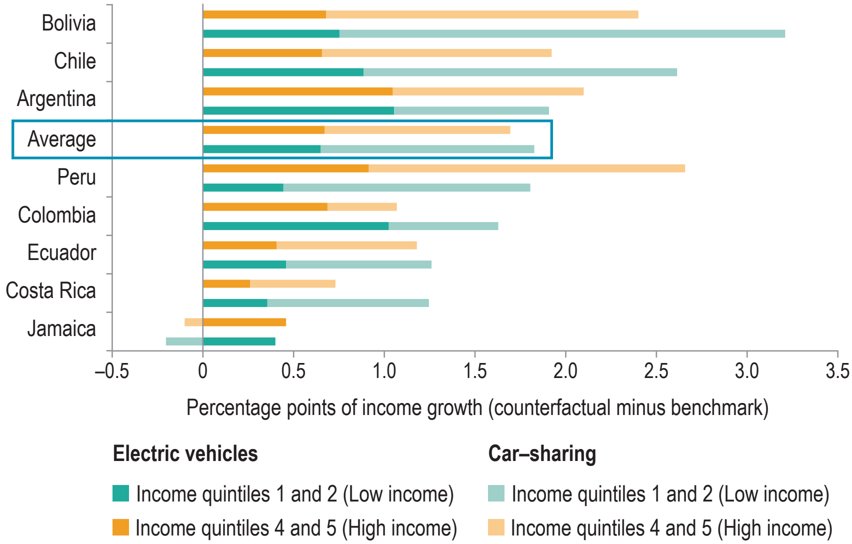
Source: Coremberg (2018).
Note: National accounts classify self-supplied infrastructure services (those provided in house) not in the corresponding infrastructure sector but in the sector of the firm self-supplying the service.

developed countries (Belgium, Canada, France, and the United States) where transport satellite accounts have been calculated. Instead, the estimated value of energy supplied in house is comparatively low because: (i) the costs of inputs to in-house generation of electricity, principally fuels, are recorded as general expenses in corporate accounts and thus, they could not be properly identified in the exercise; and (ii) self-generation of electricity with unconventional renewable energy (i.e., solar and wind) had very low values in the three countries analyzed up to 2012, which was the year for which the satellite account was compiled. In the future, self-generation of electricity at the firm and household levels is also expected to increase. This will probably affect the calculations and, therefore, the estimated sizes of the energy sector, and of the transportation sector, which is expected to rely more heavily on electricity (see Chapters 9 and 10).

The distributional impacts of the increase in the share of electric vehicles and the spread of car-sharing services in Latin America and the Caribbean are quantitatively small and heterogenous.[28] On average, the introduction of electric vehicles has a progressive bias, increasing more than proportionally the real incomes of the poorest quintiles compared to the wealthiest quintiles by the end of the simulation period; the expansion of car-sharing services has the opposite effect but is quantitatively smaller (Figure 12.12).

[28] The results are in line with the vast literature on the distributional impacts of disruptive technologies and R&D (see Aghion, Akcigit, et al., 2019; Aghion, Bergeaud, et al., 2019; Lucking, Bloom, and Van Reenen, 2018), which focuses on evidence from the United States and other advanced economies.

Figure 12.12
Distributional Effects of Electric Vehicles and Car-Sharing Services

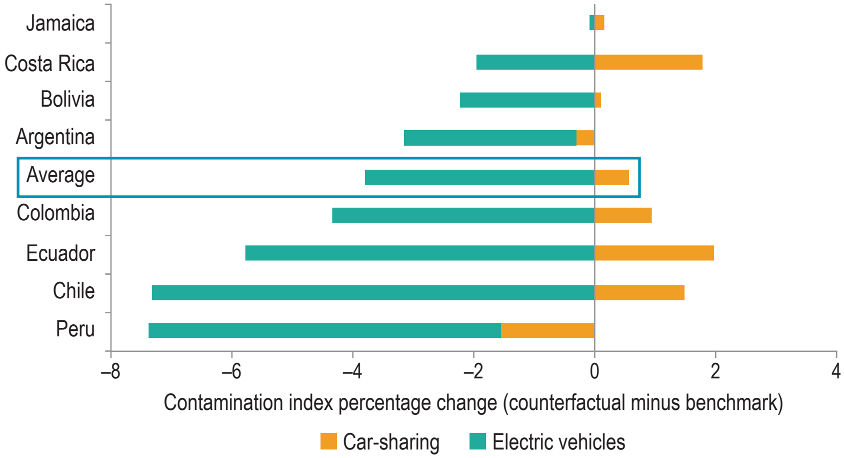


Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of real income, of the counterfactual (i.e., with electric vehicles and car-sharing services) minus the benchmark (i.e., business as usual) growth rates over 10 years.

Another dimension of the exercise relates to the environmental impacts. The increase in the share of electric vehicles is expected to reduce the emission of CO_2 contaminants into the atmosphere. The CGE model employed includes a contamination index constructed based on the degree of contamination emitted by each sector.[29] Introducing electric cars would reduce total emissions in the region: the simulations indicate that emissions would decline by 3.4 percent on average compared to the initial equilibrium, and by more than 4 percent for Chile and Peru (Figure 12.13). The exception is Jamaica, a country with an electricity generation matrix that relies more heavily on fossil fuels.[30] However, even if total emissions were not reduced, introducing electric vehicles would redistribute the emissions from densely populated urban areas (where most vehicles circulate) to less densely populated areas (where electric power is usually generated), thereby reducing the impact of emissions on the health and well-being of

[29] See Chisari, Maquieyra, and Miller (2012).
[30] As a result, the increase in the demand for electricity from electric vehicles would increase the demand for fossil fuels to generate that electricity under the current electricity-generation matrix.

Figure 12.13
Impact of Electric Vehicles and Car-Sharing Services on Pollution



Source: Authors' elaboration.
Note: Figure shows the cumulative change, in percentage points of CO2 emissions levels for the year 2016, of the counterfactual (i.e., with electric vehicles and car-sharing services) minus the benchmark (i.e., business as usual) growth rates over 10 years.

citizens.[31] Recent studies reveal that particulate pollution (highly correlated with internal combustion engine exhaust emissions) reduces the life expectancy of the average person on the planet by 1.8 years, which is more than the losses associated with smoking (1.6 years) or alcohol and drug abuse (11 months).[32] In the case of expanding car-sharing services, the results on contaminant emissions are indeterminate because of offsetting forces. On the one hand, using vehicles more efficiently (more riders per trip) may help lower emissions on a per passenger basis, but greater demand—as prices decline—may offset those gains leading to higher overall emissions.

The bottom line is that the aggregate impacts on the economy of the increase in the share of electric vehicles and the spread of car-sharing services in Latin America and the Caribbean would be quantitatively smaller than the other technological disruptions that were modeled. This lesser impact is because the gains accrue mainly within the transport sector and, in turn, the weight of the transport sectors in each country's SAM is relatively small because national accounts do not include self-provided

31 See May (2018) for a review of the potential reduction on local environmental impacts as a result of the introduction of electric transportation.
32 See Greenstone and Fan (2018).

transport. The good news is that despite the small quantitative effects, the technological disruptions are expected to have positive impacts on growth and are pro-poor. Moreover, considering the concomitant reductions in CO_2 emissions, the potential impacts of the technological disruptions on the economy may be significantly larger than what has been presented.

Building Stronger, more Equitable Economies

Policymakers in Latin America and the Caribbean may be keenly aware that the region's crumbling roads, inefficient energy systems, and inadequate water and sanitation hold their countries back. But efforts to improve infrastructure services usually get the short end of the stick. This may be unsurprising considering the paucity of evidence on the economic impact of public policies that improve the efficiency and quality of infrastructure services.

This chapter seeks to bridge that knowledge gap by considering three dimensions through which improving infrastructure services can result in stronger economies. Increasing efficiency in infrastructure sectors can boost economic growth; it can do so in ways that increase potential (long-run) growth because it supports the most dynamic economic sectors; and it helps the poor proportionally more than the rich because the poor devote a larger share of their incomes to pay for infrastructure services. The assessment is based on results of a novel exercise that assesses the impacts of efficiency and quality gains in infrastructure services on the economy considering the interconnections among economic sectors and agents in the economy (see Table 12.1 for a summary of chapter results).

The chapter considers three types of efficiency gains: cost-saving efficiency improvements, whereby the infrastructure sectors implement cost-saving technologies; productive efficiency gains, whereby the sectors upgrade production processes; and service quality gains, whereby infrastructure sectors create positive externalities on other sectors by providing better services and lowering their costs.

While simulation results are compelling, they beg the question of how those efficiency gains would materialize. The infrastructure sectors are dynamic. Some technological disruptions that change traditional business models are already happening and more are expected to come. While the future is uncertain, the good news is that some of the anticipated changes in the sectors—digitalization of services, the adoption of a larger share of nontraditional renewables in the electricity generation matrix, and changes in the transport sector including the adoption of electric vehicles and car-sharing services—could have positive impacts on the economy

Table 12.1
The Impacts of Technological Changes in Infrastructure Services on GDP and Income Inequality

				Real income		
			Economic growth	Poorest 40%	Richest 40%	Diff poor-rich
'Windfall" shocks	Gains in efficiency	Argentina				
		Bolivia				
		Chile				
		Colombia				
		Costa Rica				
		Ecuador				
		Jamaica				
		Peru				
	Mark-up	Argentina				
		Bolivia				
		Chile				
		Colombia				
		Costa Rica				
		Ecuador				
		Jamaica				
		Peru				
Technological Shocks	Digitalization of infrastructure services	Argentina				
		Bolivia				
		Chile				
		Colombia				
		Costa Rica				
		Ecuador				
		Jamaica				
		Peru				
	Increasing non-conventional renewable electric generation	Argentina				
		Bolivia				
		Chile				
		Colombia				
		Ecuador				
		Jamaica				
		Peru				

(continued on next page)

Table 12.1
The Impacts of Technological Changes in Infrastructure Services on GDP and Income Inequality *(continued)*

		Economic growth	Real income		
			Poorest 40%	Richest 40%	Diff poor-rich
Electrification of transportation and introduction of car-sharing technologies	Argentina				
	Bolivia				
	Chile				
	Colombia				
	Costa Rica				
	Ecuador				
	Jamaica				
	Peru				

Legend

Economic growth						
>4%	2% to 4%	0.3% to 2%	–0.3% to 0.3%	–2% to –0.3%	–4% to –2%	>4%

Real income						
>4%	2% to 4%	0.3% to 2%	–0.3% to 0.3%	–2% to –0.3%	–4% to –2%	>4%

Source: Authors' elaboration.
Note: Economic growth column represents the actual change in GDP of the counterfactual (i.e., with electric vehicles and car-sharing services) minus the benchmark (i.e., business as usual) growth rates over 10 years. Real income columns represent the actual change in the real income in the counterfactual (i.e., with digitalization of infrastructure services) minus the benchmark (i.e., business as usual rates) over 10 years. The color scale indicates that the more positive (negative) the values, the more intense the color in the cell (green for positive values, orange for negative values).

that are akin to the efficiency gains simulations. However, realizing those potential gains requires a framework that stimulates those technological changes, while enabling benefits to accrue across economic sectors and people. In regulated markets such as the ones in which infrastructure services operate, achieving the right balance implies setting a pricing mechanism that allows service providers to internalize part of the gains, while allowing enough flexibility so that consumer prices fall as a result of efficiency gains in the sectors. This is a topic addressed in chapter 13.

The quality of infrastructure in Latin America and the Caribbean conspires against the region's aspirations of joining the ranks of upper-income countries. In that context, upgrading infrastructure and improving services is not an option; it is a necessity—but one with potentially immense payoffs.

13

Regulation: The Springboard to Better Services

The services delivered by infrastructure in Latin America and the Caribbean are of poor quality, not accessible to all, and unaffordable to many. Undoubtedly, the region's failure to invest enough in infrastructure helps explain this situation. But blaming low investment alone is equivalent to viewing reality with one eye. This chapter argues that regulation is the springboard to better services in the region. The failure to design, implement, and enforce a regulatory framework that drives service providers, both public and private, to be efficient, fair, sustainable, and accountable is a fundamental cause of the poor quality of infrastructure services.

Regulation is vital to set the right type and level of incentives for service providers to produce high-quality infrastructure services. Unless governments establish institutions (ministries, commissions, independent agencies), processes, and instruments to set the rules and incentives that govern the operating and investment decisions of firms providing services, quality will be subpar and will not meet expectations. Governments' most important objective in regulating infrastructure is to assure that services satisfy demand both in terms of quantity and quality, and do so at affordable rates. Financial sustainability and, increasingly, environmental and social concerns are also objectives of regulators. Governments want service providers to achieve the highest levels of operational efficiency so they can deliver services at the lowest possible cost.

The job of the regulator is not easy. It has a limited set of instruments (prices, quality standards, penalties, investment requirements, subsidies) to achieve many objectives, simultaneously. It must guarantee that service providers recover the costs of delivering services either through users' fees or government subsidies (financial sustainability). The regulator must also provide incentives to minimize costs (productive efficiency) and avoid the overconsumption of services by setting prices equal to costs (allocative efficiency). Attempting to pursue multiple objectives can sometimes have undesirable consequences. Such is the case of the ideal pricing scenario, which requires consumers to pay the full cost of providing services. But that pricing rule ignores differences in consumers' capacity to pay, and can result in people in rural or peri-urban areas (where low-income consumers tend to live in Latin America and the Caribbean), paying more than high-income consumers for the same service. This pricing strategy illustrates the trade-off between allocative efficiency and social equity. Regulators must do their best to balance all trade-offs and to do so, their decisions must be evidence-based and result from meaningful consultation.

The most powerful instruments at the disposal of regulators are:

- *Prices* (not only their level, but how they change according to the level of consumption, income, or location of the customer);
- *Quality standards* (measuring, for example, if water is potable or electricity is of the right voltage); and
- *Investment requirements* (mandating additional investment in new capacity when demand is high; for instance, expanding an airport terminal when passenger volumes exceed a predefined level).

Since the early 1990s, most countries in Latin America and the Caribbean have adopted regulatory reforms in infrastructure sectors relying on these instruments to improve the provision of services. Additional reforms included introducing competition, restructuring state-owned enterprises, and introducing private participation in the provision of services, using schemes ranging from management contracts to outright concessions and privatization.

Despite the importance of these reforms, market structures have not changed as much as initially expected. In most infrastructure markets, the prevailing technology and market size at the time of reforms justified the provision of services by one firm, a monopolist, as the most efficient market arrangement. Until now, this has remained unchanged. What changed was that some of these monopolies have become private or remained public but operated commercially.

To monitor the performance of these monopolies, reforms included the creation of new regulatory agencies, either at the national or subnational levels, that in most cases were by design independent from line ministries. As an example of the extent of institutional reform, 18 countries in Latin America and the Caribbean created new regulatory institutions in the water and sanitation sector between 1990 and 2005 (Bertoméu-Sánchez and Serebrisky, 2019).[1]

While well-intended, many of the regulatory reforms were unable to fulfill the objectives set forth when they were designed. For instance, competition *in* and *for* services increased in some markets, allowing the entry of many new actors, but the quantity, quality, and prices of the services still present deficiencies and challenges (see Chapters 1 and 4).

To some extent, governments failed to protect regulators from the risks of capture by political processes or business interests (Foster and Rana, 2019). But, just as important, they failed to adapt regulation to evolving contexts. Technological disruptions, a changing climate, and growing political and social demands for more affordable and higher-quality services are expected to radically change the provision of infrastructure services. Previous chapters presented possible scenarios, and despite significant uncertainty regarding the scope of change, the consensus is that the traditional model of strong, often monopolistic providers and passive consumers that do little more than consume the service they are offered, will disappear. These changing roles are likely to have fundamental implications for public policy. Regulation will have to adapt.

How should regulation change today to foster innovation and business practices that can generate the largest gains in the quantity and quality of services? What is the right set of institutions, policies, and tools for the most effective regulation of infrastructure services in the future? This chapter presents the emerging regulatory challenges and alternatives for policy reform (Table 13.1). It does not prescribe what must be done; instead it identifies areas of reform, leaving many open questions that can be answered only by examining the complexities of each infrastructure service and market.

The Context: Trends Affecting the Regulator's Job

While many factors are likely to influence how regulators seek to improve the quantity and quality of regulated services and what users, investors, and taxpayers expect from them, three seem to dominate experts' discussions:

- Technological change, in particular the growing role of digitalization
- Rising local and global pressure to address climate change concerns

[1] Andrés et al. (2013) present a thorough analysis of the performance of utilities in Latin America and the Caribbean. Estache and Serebrisky (2020) provide a literature review of the impacts of the reforms of the 1990s.

- Growing social demand for more affordable and higher-quality services

Each of these is likely to demand changes in regulatory institutions and processes, all of which call for strong political commitment if the expected improvements are to be delivered.

Technological Change

The evolving role of digitalization, the many applications of artificial intelligence and machine learning, and the growing presence of mobile applications are having measurable, direct consequences on the production and consumption of most regulated services. Smart meters, smart billing, and smart phone applications are increasingly becoming standard management tools in regulated industries, an expected change since those technologies will improve the profit levels of service providers.

Despite a lack of evidence for Latin America and the Caribbean on the payoffs of adopting comprehensive digital strategies in services, there

Table 13.1
Emerging Trends that Will Impact the Regulator's Job, and Changes Required in the Regulatory Compact (Policies, Institutions, and Instruments)

Trends that will affect the regulator's job		
Technological change	**Climate change**	**Social demands**
• Decentralization and digitalization will disrupt supply and demand: new market structures will emerge • Services will become more capital intensive • Digital services will foster integration among infrastructure sectors	• Upstream planning is needed to develop sustainable infrastructure services • Climate change mitigation targets need to be complied with • Resilient infrastructure requires additional investment	• Access to affordable and high-quality services • Technology to reduce information costs and encourage consumer participation and accountability • Users' privacy needs to be protected
Changes in the regulatory compact required to adapt to new trends		
Policies	**Instruments**	**Institutions**
• Infrastructure-specific policies: labor, entry, and capacity regulations • Economywide policies: trade, taxation, global agreements, and procurement	• Price structures, cross-subsidies, quality standards will have to adapt • Behavioral interventions as a complement to traditional regulation	• Reform of sector regulators: merger? • Creation of a data agency? • Enhanced role for competition policy in infrastructure sectors? • New "upstream" planning and auditing institutions?

are estimates at the sector level.[2] While not precise, these estimates point toward potentially large cost savings. Consider the case of the electricity sector. According to the IEA (2017), the world will achieve savings from the sector's digitalization on the order of 5 percent of total annual power generation costs. About 25 percent of these gains will be achieved through a drop in maintenance costs (notably thanks to better predictive maintenance). Digitalization will extend the operational lifetime of power plants and network components. On average, cuts in the investment needs of power plants and networks could explain, respectively, about 42 percent and 25 percent of the annual gains. In the water and sanitation sector, many processes have already largely been automated, and remote-control technology and digital office communications are well integrated in best management practices. There are no global estimates of the related cost savings, but there are already good indications of where the improvements come from. For water utilities, technological improvements should help reduce water losses due to leaks and bursts, which amount to more than 30 percent of the water produced, or US$8 billion per year in Latin America and the Caribbean (Liemberger and Wyatt, 2019). Digitalization can help save a big fraction of those losses. In the transport sector, Chapter 10 reports that if autonomous vehicles replace private internal combustion engine vehicles in Latin America and the Caribbean, a middle-income household could save the equivalent of 17 percent of its annual income. Significant gains could also come from trucking. Nowak et al. (2018) estimate that logistics costs, thanks to digitalization, will fall almost 50 percent by 2030 largely through the reduction of labor induced by automation.

The technological innovations transforming these sectors have regulatory implications. Market structures will change. Box 13.1 provides a glimpse of the universe of service providers that are likely to change significantly and abruptly in a few years' time. Once supply and demand are disrupted, service provision will see the entry of new firms, most prominently large "tech" companies. Also, in many markets supply and demand will be blurred as prosumers become increasingly important. But traditional utilities might also expand their businesses and enter other infrastructure sectors. For instance, electricity companies might enter the urban transport market through the financing of electric buses and subsequent contracts to provide electricity.

These changes will likely require a reallocation of responsibilities among regulators and competition agencies. As the sectors become more competitive, the regulator will move from a strong emphasis on prices and

2 This section draws from Estache and Serebrisky (2020).

standards of quality regulation to setting and enforcing access rules and consumer protection regulations.

However, in markets where utilities will likely remain monopolies or where the transition to a competitive market will take a long time, the challenge is how to share the dividends of digitalization. Digitalization will likely cut costs at all stages of service production, which would in turn lead to higher markups (the difference between costs and prices) if monitoring regulated industries remains unchanged (Gal et al., 2019). Chapter 12 shows that when regulation allows for higher markups, the benefits of technological innovation negatively impact economic growth, and the regulation is regressive as infrastructure services account for a larger share of the income of low-income households. Thus, in a region characterized by high income inequality, productivity-enhancing technological change will improve income distribution only if the economic regulator is effective in maximizing how cost reductions are shared with consumers. If no gains are shared, policies aimed at promoting technology adoption (particularly when subsidies are involved) will likely become a source of tension with operators and consumers and, hence, governments.

Box 13.1

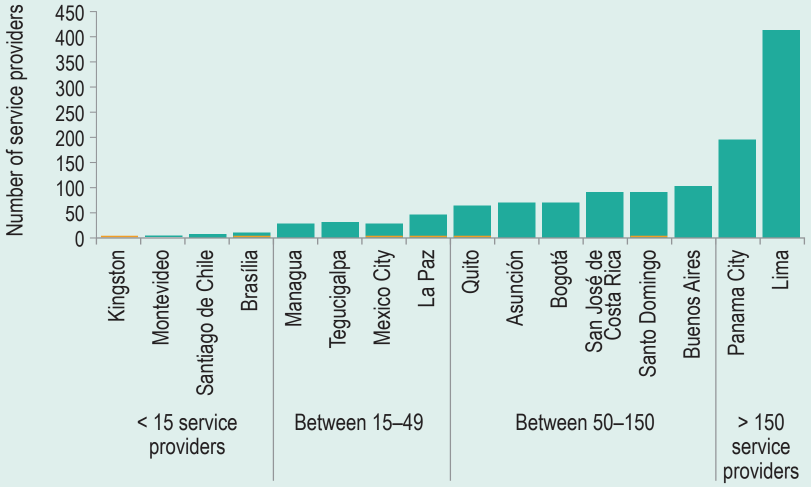
The Universe of Regulated Service Providers

A regulated firm providing infrastructure services is most commonly conceived of as a utility that serves a large number of consumers across a vast geographical area. In many countries and cities this is the case, but a closer look at the universe of service providers presents a variety of cases. Latin America and the Caribbean instituted reforms in the 1990s that vertically separated service providers along the supply chain (most typically in electricity) and decentralized the responsibility for service provision to subnational governments, leading to the creation of local service providers. Additionally, some services were deregulated and opened up for competition, leading to the entry of many new service providers. The air transport sector is a case in point.

The landscape of service providers varies across sectors, cities, and countries. Differences in the number of service providers do not match differences in the size of countries or cities. In economic terms, the number of firms in each market does not respond to a calculation of an optimal number obtained by analyzing economies of scale to minimize the cost of providing services. And ownership (public or private) varies across sectors. Figure 13.1.1 shows the high prevalence of private operators in urban transport, a mixed composition in electricity distribution, and mostly public provision in water and sanitation. This variety reflects varying political preferences that determine the organization of the market, competition, and attitudes toward private participation in service provision.

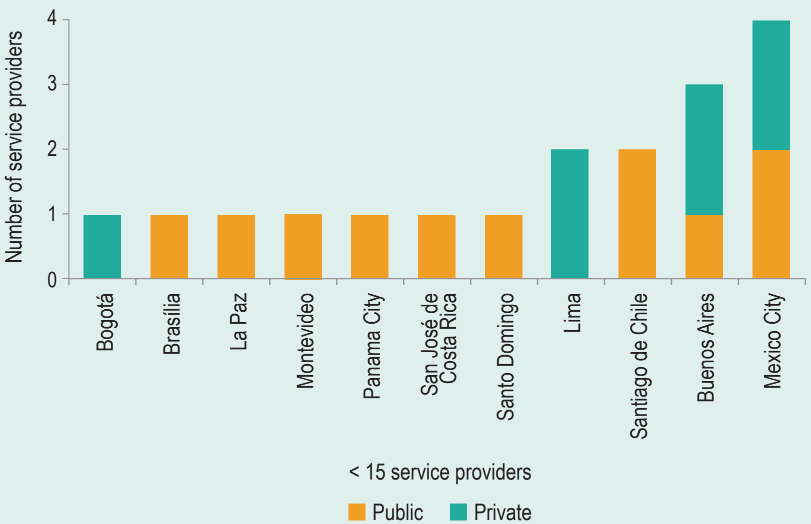
Figure 13.1.1
Number of Service Providers in Selected Cities or Countries, by Sector and Ownership, 2018

Panel A. Buses



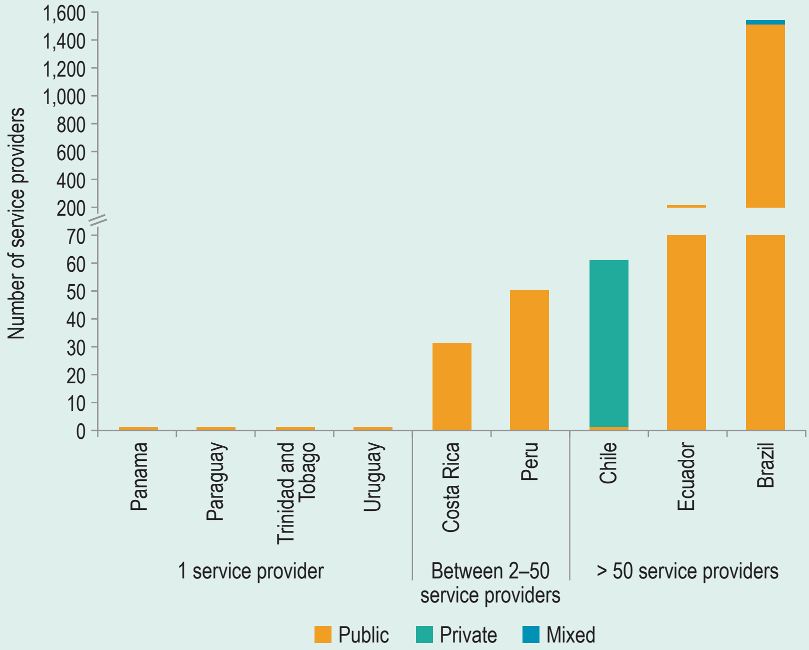
Source: Countries' and cities' transport authorities.
Note: Only formal service providers are included in the sample. 2018 data for all cities with the following exceptions: La Paz, Managua, and Santo Domingo: 2017, Lima: 2016, Panama City and Asuncion: 2014.

Panel B. Urban railroads, metros, and cable cars



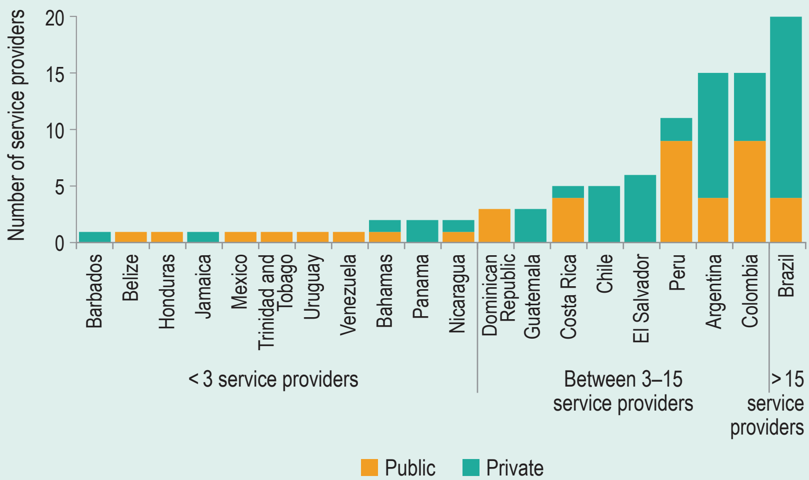
Source: Countries' and cities' transport authorities.
Note: Only formal service providers are included in the sample.

Panel C. Water and sanitation



Source: Latin American and Caribbean water regulators, SNIS, ADERASA, AyA, IDAAN.
Note: Service provider data for all countries do not include committees, associations, informal providers, or small water companies.

Panel D. Electricity distribution



Source: Bloomberg and countries' regulatory agencies.
Note: Service provider data for all countries do not include providers with less than 2 percent market share.

The trends shaping service provision and the regulator's job are directly impacting the number of service providers. Technological change is reducing the barriers to entry for many service providers. Ride-hailing services are reshaping the provision of urban transport services, and prosumers, aggregators, and ancillary service providers will exponentially increase the number of economic agents supplying electricity services, making the regulation of prices and service quality much more difficult.

Climate Change

A changing climate adds layers of complexity to the regulator's job, as it adds uncertainties to the supply of and demand for services. The availability of resources for some services is expected to become increasingly uncertain. For example, the availability of water to feed hydroelectric power plants or the predictability of wind patterns and sun exposure is critical to quantify the effective capacity of renewable electricity. Demand will also be more uncertain and will change, sometimes to a large degree, as temperatures rise. For instance, more air conditioning equipment will be bought in areas where the weather did not require it in the past. Extreme weather events will require infrastructure to be more resilient, as explained in Chapter 6. Technical designs will have to be frequently updated so that services are not interrupted. Road drainage facilities will have to be expanded to accommodate changes in road and flood patterns, and overhead electricity cables may need to be buried.

Beyond adaptation, complying with mitigation targets has direct consequences for how services are provided. Regulators will have to incorporate mitigation objectives in the planning stage of infrastructure investment and price externalities associated with carbon dioxide emissions, as well as deal with stranded assets (see Chapter 7). Prices, quotas, and more stringent upstream planning institutions and processes will have to be put in place to ensure that service provision complies with the ultimate goal of decarbonizing the economies of the region.

Regulators must set the prices of services at a level that allows providers to get a fair return on the capital invested. Infrastructure that is more resilient and compatible with mitigation targets will be more capital intensive. Additional investment in adaptation is estimated at 5 percent of total investment in infrastructure (see Chapter 6). Nonconventional renewables are an example of how the capital intensity of infrastructure service provision will increase. Wind and solar generation technologies require high capital investment but have extremely low operating costs, in sharp contrast with thermal plants, which have higher marginal costs because they rely on fossil fuels to generate electricity.

Amid a growing population and a changing climate, regulators will have to provide the right incentives to invest in a technology-neutral way by making sure producers' and consumers' preferences are matched. As a result, pricing structures may change radically; for example, the electricity sector will have to shift from a pricing scheme based on the volume demanded to one with a higher fixed component to cover the investment required to expand and maintain the electricity transmission and distribution network (detailed in Chapter 9 and Box 13.2).

Social Demands for Better, Affordable Infrastructure Services

Most countries in Latin America and the Caribbean are characterized by high income inequality, especially when compared with developed economies (de la Torre, Messina, and Silva, 2017). Income inequality is reflected in the services delivered by infrastructure. As documented in Chapters 1 and 4, the quality of water services is lower in low-income areas, whereas access to water and electricity is almost universal across high-income households. The remaining challenges in access are concentrated among the poorest households, who are difficult to reach because they are located either in rural and remote areas or in slums where they have no formal rights to their dwellings. Transport services are also very unequal. Peri-urban areas with a high incidence of poverty tend to receive low-quality formal services and consequently have to rely on informal service providers. In large urban areas, the poor have less access to formal jobs due to the inadequate supply of transport services. Beyond access, affordability remains a problem, not only for the poorest households but also for the middle class. The region's middle class has grown more than 50 percent in the 2000s, and its demand for high-energy appliances like air conditioners and washing machines is far from saturated, even if limited by its ability to pay for them (Fay et al., 2017).

Thus, it should come as no surprise that changes in the pricing of services can trigger countrywide protests and social unrest—witness the recent social demonstrations triggered by an increase in transportation fares in Brazil in 2013 (8 percent in bus fares) and in Chile in 2019 (3 percent in metro fares).

The evolution of democratic processes, notably the way users and, more generally, citizens voice their concerns regarding the effectiveness of regulatory policies must be internalized by regulators. Civil society is increasingly keen on influencing the policymaking process. Technology, through social media, is rapidly reducing information costs and increasing demand for service providers to be held accountable. In practice, a more active civil society will create "shadow regulatory monitoring" in a region where regulators do not actively engage users in decision-making processes. Andrés et al. (2013) document the widespread shortfalls of social accountability among the region's regulators, but this is not exclusive to Latin America and the Caribbean. Australia, a country on the cutting edge of infrastructure regulation, recently acknowledged that users are not at the center of its infrastructure planning and decision making. More than 80 percent of Australians urged the government to improve consultation with users when planning new investments or changes in service standards (Infrastructure Australia, 2019). Meaningful consultation and engagement remain pending tasks for regulators in Latin America and the Caribbean.

An emerging social concern in service delivery is how to protect consumer privacy. Most technological changes in the infrastructure sector are welcome as they improve quality, reduce prices, and introduce new options. But they also raise questions about data privacy and ownership. For instance, demand-response technologies rely on large quantities of consumer-specific, real-time usage data, giving anyone with access to these data a lot of information on people's daily routines. How much of these data should be confidential, how well they should be protected (e.g., how much data collection can be outsourced or shared and under what conditions), and who has the property rights on these data are all topics to be considered when redesigning regulation.

Toward a New Regulatory Architecture: Changes in the Regulatory Compact

The previous section documented how emerging trends will change the provision of infrastructure services. To respond to these trends, countries will have to rethink and adapt the regulatory compact: the policies, institutions, and regulatory instruments that regulators have at their disposal. This section reviews ideas and proposals on how to adjust the regulatory compact.

Adapting Policies

Policies can be specific to an infrastructure sector (for instance, a law that prohibits selling incandescent light bulbs) or have economywide relevance (a new trade agreement between countries). Though the latter do not usually have infrastructure services as their main focus, they can have a profound impact on the quantity and quality of these services.

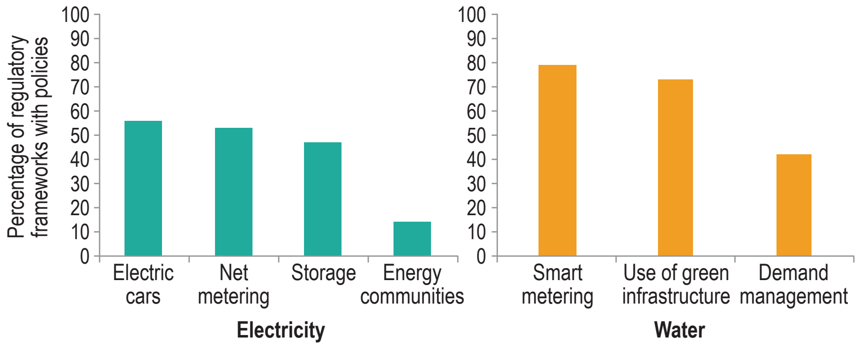
Energy, transport, and water regulators usually evaluate policies that impact sectoral performance directly, such as the number of beneficiaries of an integrated transport fare, or compliance with a policy that mandates treatment of wastewater. However, regulators of services seldom evaluate the effects of economywide policies, thereby missing the opportunity to provide evidence-based opinions to the policymaking process.

The following are not specific recommendations on how regulators can better intervene in the policymaking process or how they should evaluate policies. Instead, they are examples of how sector-specific and economywide policies impact the provision of services in Latin America and the Caribbean. The aim is to show that regulators in the region should take a much more active role in policy design and evaluation, activities that will be increasingly important to adapt to emerging trends.

Gaps in Sector-Specific Policies

Do regulators in Latin America and the Caribbean have at their disposal the policies and tools required to respond to emerging trends? A survey implemented in 2018 (Pastor, Serebrisky, and Suárez-Alemán, 2019) shows that regulators in the region have important gaps in their ability to respond, in most cases because the policies are nonexistent. Almost half of the electricity regulators declared that they lack specific policies to work with utilities and consumers on the rules to adopt and use technologies such as net metering, storage, and electric cars. Similar policy gaps exist in the water sector. And having policies in place is just the first step, because impact on the availability and prices of services critically depends on the effectiveness with which policies are enforced (Figure 13.1).

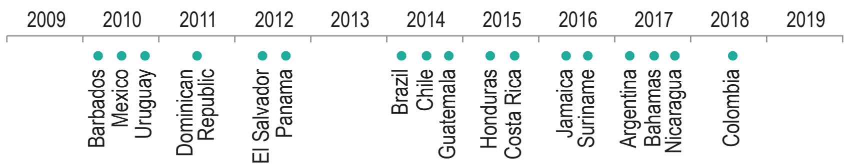
Figure 13.1
Share of Regulatory Frameworks in Latin America and the Caribbean with Policies in Place to Respond to Emerging Trends, 2018



Source: Pastor, Serebrisky, and Suárez-Alemán (2019).
Note: A survey of regulators carried out in 2018 was used to determine how many regulatory frameworks have related policies in place. Total responses: 21 electricity regulators and 15 water regulators.

Despite these gaps, policies are being updated, at least in the electricity sector. López-Soto et al. (2019) tracked the evolution of net metering policies that enable the proper development of prosumers as actors in electricity markets. Almost all countries in Latin America and the Caribbean had adopted a net metering policy by 2019 (Figure 13.2).

Figure 13.2
Timeline of Net Metering Policies' Adoption



Source: López-Soto et al. (2019).

The Case to Reform Procurement

In a context of accelerating digitalization and declining costs of gathering and processing data, procurement becomes an area of reform to improve the regulation of services. The adoption of e-procurement has become the norm in many public administrations at the national level and has delivered many advantages. However, there is significant scope for improvement as these procurement practices have not been effective in curbing the prevalence of bid-rigging and corruption, as made evident by the Odebrecht scandal (Campos et al., 2019). Procurement inefficiencies are not exclusive to Latin America and the Caribbean. In the United States, cities whose procurement rules did not specify mandatory standards for water pipe replacement benefited from capital cost savings of 30 percent (Anderson, 2018). As the thrust of infrastructure shifts from structures to services, procurement must adjust accordingly. From bidding standards and processes to purchase inputs to construct assets, procurement systems must shift their focus and prioritize criteria that allow contracting services (performance-based contracts). Such services give the contractor the freedom to choose which technology is the most cost-effective to deliver the service standards required by the contracting entity.

Digitalizing Regulation

Digitalization will disrupt the provision of infrastructure services, as discussed in Chapters 9, 10, and 11. But for the digitalization of services to enable substantial improvements in users' experience and quality of life, the region needs to increase digital inclusivity—and to do this implies digitalizing regulation itself. Unless regulation joins the digitalization trend of the markets it is supposed to influence, its effectiveness is likely to drop further. And the main losers in this equation will likely be, as usual, the poorest users.

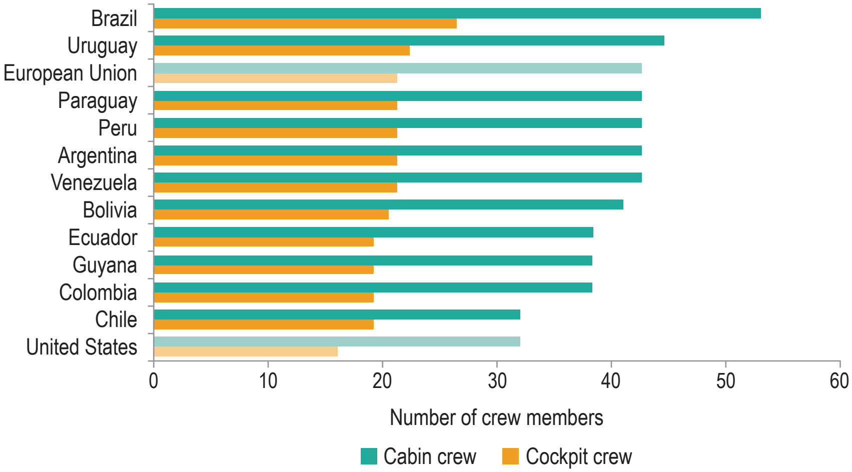
The digitalization of regulation has many implications. Two are particularly important for Latin America and the Caribbean, as detailed in Chapter 5. First, digital literacy must be fostered across user types and groups. Second, ministries and agencies that regulate energy, transport, and water will have to update their legal and regulatory frameworks to ensure that sectors make the most of digitalization opportunities in the interest of all users and that the pace of digital inclusivity does not hinder technological progress in the provision of services. Surprisingly, just one-third of the countries in the region enacted or updated laws to regulate the communications sector after 2010, while half of the countries have laws that were enacted in the 20th century and have been only partially updated since (Prats and Puig, 2017). More and faster policy action is needed.

Reforming Labor and Capacity Allocation Policies

The regulatory barriers to developing the potential of infrastructure services can vary in nature. The most studied are legal barriers to entry that pave the way for monopolies and prevent competition from delivering more options and lower prices, thereby harming consumers. But there are regulations that increase the cost of providing services, preventing the full development of a market. Cases in point are ground cargo trucking and commercial air transport. Backhauling restrictions (legal or informal restrictions that a truck return load cargo to its destination, forcing it to go back to base empty) are ubiquitous in Latin America and the Caribbean, and result in many international trips such as from Haiti to the Dominican Republic, Colombia to Ecuador, and Panama to countries in Central America. In air transport, countries set labor regulations that specify the minimum number of crew members required to operate a flight as well as the times the crew can work. In Latin America and the Caribbean, as a result of labor regulations, the crew size required to operate flights varies significantly. As detailed in Figure 13.3, even though labor regulations in most countries in the sample are not more restrictive than in the European Union, they are more restrictive than in the United States. Given the favorable comparison of the safety track record of the U.S. air transport market, it is evident that more stringent labor regulations cannot be justified on that ground, and compromise cost competitiveness among airlines in Latin America and the Caribbean.

Figure 13.3

Minimum Crew Requirements for Domestic Flights in Latin America and the Caribbean, the European Union, and the United States, 2018



Source: Ricover, Serebrisky, and Suárez-Alemán (2018).
Note: Parameters used to calculate the required minimum crew: four daily round-trip domestic flights. Each flight has a total turnaround time of 115 minutes, and the aircraft is a Boeing 737-800.

Economywide Policies

Trade Policy

Trade policy could have an important impact on the adoption and diffusion of new technologies. For a region that is not a leader in research and development, opening the economy to allow entry of the newest, most efficient, and cleanest technology seems to be an effective policy to improve the provision of infrastructure services. However, there may be trade-offs on several dimensions that should be dealt with in the policy-making process.

Chapter 10 shows that the probability of significantly reducing the price of electric vehicles is high, and augurs well for a fast transition to autonomous vehicles as the main provider of mobility services. Any of these scenarios would leave a large stock of internal combustion engine vehicles in advanced economies (more than 180 million cars in the United States alone, according to Arbib and Seba, 2017). Such a stock would be fully depreciated but with higher residual value in developing countries, where the transition to electric and autonomous vehicles will most likely be slower. The policy question then is, should developing countries, and in particular those in Latin America and the Caribbean, allow the importation of internal combustion engine vehicles? Trade-offs exist, as cheaper imports can benefit households wanting to purchase a car but can have negative consequences on emissions levels, demand in the local car industry, and the transition to more sustainable mobility options.

Subsidy and Tax Policy

Many countries in Latin America and the Caribbean subsidize infrastructure services, and such subsidies recently reached a regional average of 0.7 percent of gross domestic product (see Chapters 1 and 4). These subsidies are usually justified by the need to guarantee an adequate level of consumption to the most vulnerable population. However, most analyses of subsidies ignore the various taxes and fees that are included in service bills, even though imposing taxes means prices and total bills will be higher. The lack of identification, measurement, and analysis of tax typologies and rates charged to infrastructure services in the region is striking. Heterogeneity across countries and even for income levels is high in Latin America. Taxes on electricity are in most countries higher than taxes on water services. Taking Spain (a country usually used in Latin America and the Caribbean as an aspirational benchmark for infrastructure services) as a comparator, taxes in the region are, in most cases, lower (Figure 13.4).

Figure 13.4
Taxes and Fees as a Share of Electricity and Water Bills, by Income Quintile, 2018

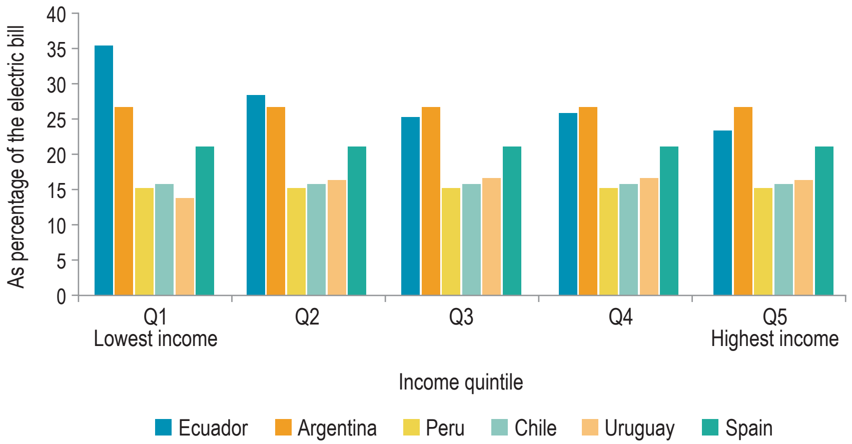


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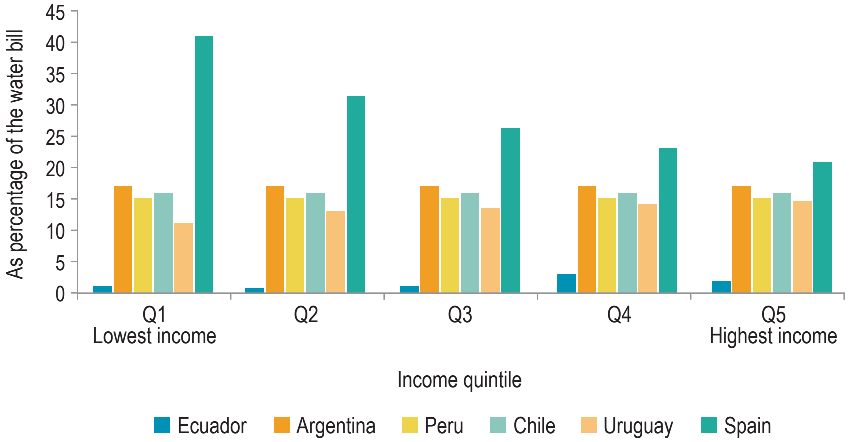
Figure 13.4
Taxes and Fees as a Share of Electricity and Water Bills, by Income Quintile, 2018 *(continued)*



Source: Pastor, Serebrisky, and Suárez-Alemán (2018).
Note: The amounts reported include only fixed fees that are not related to service provision. For instance, a fee directed to fund a fire department.

Taxation should receive more attention from decision makers in light of future technological changes. The taxation of services has traditionally been justified by the low elasticity of demand, as households have no other option but to continue to buy services. However, at least in the case of electricity, high taxes provide incentives to disconnect from the grid at a time when growing numbers of users can generate their own electricity (Navajas, 2018; Pastor, Serebrisky, and Suárez-Alemán, 2018). Unless governments and regulators consider explicitly the interactions between the impact of technological changes and the net effect of fiscal policies on the sector, it is unlikely that producer and consumer adjustments will be efficient, fair, or fiscally sustainable.

Adherence to Global Agreements

Closer adherence to global agreements can help boost technological adoption as well as improve infrastructure planning and regulations. The most transformational global agreement for providing infrastructure services is the Paris Agreement, which implies an ambitious commitment to radically curb emissions in the coming decades (see Chapter 7). The vast changes outlined in the agreement require countries to adopt a renewable electricity matrix and, simultaneously, electrify as much of the delivery of transport and water services and treatment as possible. But compliance also requires behavioral change for consumers to adopt more efficient devices and switch from using private cars to public transportation. Global agreements can act as a strong commitment device for regulators to foster innovation and reduce barriers to increase competition and embrace new business models. At the upstream planning level, the Paris Agreement can help change the way infrastructure is planned and projects selected. What is required is to develop sustainable infrastructure, understood as infrastructure assets that are planned to take into account environmental and social impacts while at the same time delivering economic returns to future generations.[3]

Adapting the Instruments

The explicit regulation of prices, standards of quality, and investment obligations will continue to be the most visible components of regulatory toolkits. Basic regulatory rules such as matching the allowed rate of return to the cost of capital, spelling out explicit rules to assess the regulatory asset bases, and explicitly defining efficiency targets will continue to be central to the effectiveness of regulatory processes. The new technologies, the new opportunities offered by the explosion of data availability, the need to improve coordination with environmental agencies to address climate change concerns, and the need to correct the mistargeting of efforts to make regulated services accessible and affordable to all, beg for the development of new regulatory instruments (like the use of behavioral tools) and for efforts to adapt existing instruments.

The trends outlined in this chapter will force regulators to rethink how they use available regulatory instruments. Decentralization of infrastructure services will challenge the financing of networks, which is the backbone of service provision. Distributed energy, circular use of water, or emerging mobility alternatives threaten the reliance on networks, their financing, as well as the sustainability of service providers.

Probably the most dramatic changes in instruments will be in pricing regimes. The prevailing pricing structure is incompatible with the emerging technological disruptions that are decentralizing service production, notably in electricity as households and industries generate their own energy. The pricing structure will have to change, and this is the time for regulators

[3] IDB (2019) defines sustainable infrastructure as infrastructure projects that are planned, designed, constructed, operated, and decommissioned in a manner that ensures economic, financial, social, environmental (including climate resilience), and institutional sustainability over the life cycle of the project.

to act, because distributed electricity and decentralized water systems are in their infancy. The sustainability of service provision in the electricity and water sectors hinges on regulators' ability to guarantee that the distribution networks are properly funded. Box 13.2 presents the results of recent studies that calculated pricing structures compatible with the emergence of solar photovoltaic as a cost-competitive option for households to generate electricity in Colombia and Argentina. These studies show that shifting

Box 13.2

The Future of Electricity Pricing

Electricity tariffs in Latin America and the Caribbean take many forms, but a common feature is their inability to expose users to prices that reflect the various costs of service provision. If correct price signals are not provided, users may not make proper use of electricity services. This dynamic can occur in any of several ways. For example, heavily subsidized prices encourage futile overconsumption of electricity, or when large consumers face high electricity prices, they could seek solutions to disconnect from the grid.

The electricity sector is facing a huge transformation led by the exponentially decreasing costs of decentralized generation technologies and digitalization of services. As generating electricity at home becomes cheaper every year, prosumers can be expected to proliferate. In this context, setting prices wrong creates two perverse incentives:

a. When the price per kilowatt-hour faced by the user is higher than the marginal cost of production, households have greater incentives to become prosumers and adopt rooftop solar photovoltaic or other technologies, even if that would not be optimal for the society as a whole. Furthermore, as the number of prosumers increases, the ability to finance the grid deteriorates due to a fall in the electricity demanded of utilities.
b. When the price per kilowatt-hour is higher than the marginal cost of production, benefits for the users of electricity decline and prevent them from making the investments needed to substitute the use of fossil fuels for transportation, heating, or cooking.

The first perverse incentive has important implications in terms of affordability for the poor and cost-recovery, and in general the survival of the electricity system as we know it. If high-income households increasingly invest in new technologies to produce electricity on their own, and become more and more efficient in their consumption, their dependence on the electricity grid will decrease. The consumption of these households ensures cost recovery, as they usually pay higher tariffs and finance cross-subsidies for low-income households that benefit from social tariffs. With the current pricing scheme and without the participation of high-income households, poor households would need to sustain the costs of the grid by themselves, and the grid would become underfunded.

The second perverse incentive hinders a fast transition to the electrification of infrastructure services, such as the adoption of electric vehicles, a much needed transformation to comply with the mitigation targets of the Paris Agreement (see Chapter 7).

To avoid the perverse incentives that current pricing schemes create, electricity pricing should have consumers pay the marginal cost of supplying electricity while the remaining costs of providing the service are covered by a fixed charge, independent of the level of consumption. A "social tariff" should then consist of a lump-sum transfer (eventually in the form of a discount on the fixed cost), conditional on income.

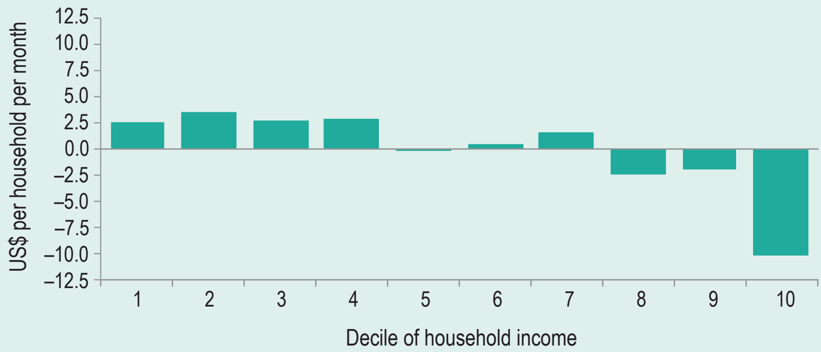
The difficulty of implementing optimal pricing is threefold: i) for low-consumption households, their willingness to pay may be lower than the optimal price if the fixed component of the tariff is high; ii) distributional concerns may conflict with optimal pricing if not implemented together with conditional cash transfers to reduce the burden of the fixed component; and iii) transitioning to this type of tariff may be politically challenging since many households could end up worse off.

Two papers, commissioned by the Inter-American Development Bank, propose alternatives to reforming the electricity pricing structure in the residential sector.

Urbiztondo, Navajas, and Barril (2020) analyze who would be the winners and losers of a transition from the heavily subsidized tariff regime in the Metropolitan Area of Buenos Aires, Argentina, to a scheme in which users pay for electricity according to the optimal pricing described above. To conduct this exercise, the authors set a fixed charge equal for all consumers in order to cover fixed costs (estimated to be 70 percent of total costs or service provision) and set the price per kilowatt-hour equal to its marginal cost of production. The results show that restructuring tariffs this way increases the average bill for the first seven income deciles, while it decreases the average bill for the three richest deciles (Figure 13.2.1). While the proposed scheme provides incentives to use electricity efficiently, such a transition is politically difficult since most users end up paying more and the plan does not address inequality concerns. To tackle this issue, a subsidy is proposed to cover part of the fixed costs for the lowest three deciles of population to avoid increasing their current bills. The authors find that this new subsidy would cost the government 30 percent less (US$50 million per year) than the amount spent on subsidies in 2018 (US$70 million per year). This result crucially depends on finding an adequate targeting mechanism.

McRae and Wolak (2020) advance on the inequality issue by proposing a solution for the Colombian case. As in the Argentine exercise, the authors first conduct a simulation by setting a fixed charge equal to US$5 for all households (a level that would cover utilities' costs), and the kilowatt-hour price equal to the marginal cost, calculated as the wholesale electricity price without any

Figure 13.2.1
Average Change in the Electricity Bill of Households with the New Pricing Scheme in Buenos Aires, Argentina, 2018



Source: Based on Urbiztondo, Navajas, and Barril (2020).

prevailing subsidy. Figure 13.2.2 shows that households in the first decile lose about US$9 each month and all other deciles are worse off except for the richest in the tenth decile, who are better off by nearly US$3. Similarly, they find that transitioning to an optimal two-part tariff is unlikely to be politically feasible.

To overcome this limitation, the authors propose setting the fixed charge equal to the predicted willingness to pay of each household (based on observable dwelling characteristics already at the disposal of authorities), unless the

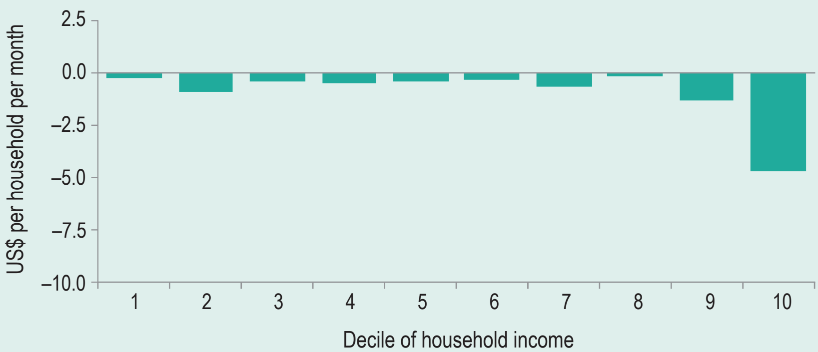
Figure 13.2.2
Average Change in the Electricity Bill of Households with the Efficient Pricing Scheme (without Compensation Mechanism) in Colombia, 2018

Source: McRae and Wolak (2020).

household receives government-subsidized health insurance, in which case they set the fixed charge to zero. Figure 13.2.3 shows that now households in every decile are better off. It is thus possible to implement an optimal pricing structure whereby no household is negatively affected.

These studies highlight the importance of properly targeted mechanisms to implement pricing structures compatible with upcoming technological changes in the provision of electricity.

Figure 13.2.3
Average Change in the Electricity Bills of Households with the Efficient Pricing Scheme (with Compensation Mechanism) in Colombia, 2018



Source: McRae and Wolak (2020).

from current pricing structures to a new one with higher fixed costs may impact different income groups in different ways, which, if not addressed properly, could increase inequality.

Psychology and Regulation: Making the Most of Behavioral Tools

Behavioral interventions are emerging as a complement to traditional regulatory tools such as prices, taxes, subsidies, and quality standards. Traditional instruments have not always encouraged consumers to act in their best interest or aligned with social goals. Multiple sector diagnostics (OECD, 2017b) show that consumers do not always adopt the behavior that benefits them the most, like using electricity-saving bulbs or time-saving nonmotorized transport modes. Infrastructure regulators in Latin America and the Caribbean have a long but promising avenue to develop and implement behavioral interventions.

Behavioral economists have developed various methods to identify, analyze, and use psychological biases to design policies, including regulatory policies. In a nutshell, these behavioral interventions consist of giving a "nudge" or gentle push to consumers to make the best choice for them, without income- or price-driven incentives. Since nudging consumers is simple and has low administrative costs, these interventions receive positive media coverage, making it easier to obtain political endorsement. Table 13.2 lays out behavioral biases relevant for infrastructure services and some interventions to reduce or eliminate the identified biases.

Latin America and the Caribbean have a significant margin to adopt behavioral interventions to improve the effectiveness of regulation. Many countries have been conducting experiments in education, health pensions,

Table 13.2
Behavior Interventions in Infrastructure Services

Psychological bias	Interventions (nudges)
Framing: Drawing different conclusions depending on how information is presented.	Use positive language and refer to benefits. **Example:** A smiley face when electricity or water is conserved.
Satisfying/cognitive overload: Exert efforts to reach a satisfactory outcome instead of the optimal one.	Make desired actions easier to accomplish using new technologies and promote them using a trustworthy source. **Example:** Send reminders to switch off appliances through an app; provide suggestions of optimal itineraries that combine motorized and nonmotorized public transport trips.
Status quo, inertia, and anchoring: Resisting change or deferring making a decision.	Set defaults aligned with optimal behavior. **Example:** Set washing machines on short cycle or turn water heaters off during the night.
Sunk-cost effect: Irrational fixation on recovering losses already incurred.	Reduce saliency of costs already incurred and increase saliency of future returns on investment. **Example:** Cash-back bonuses for upgrading appliances.
Loss aversion: Weighing losses more heavily than equal-sized gains.	Frame messages in terms of loss avoidance. **Example:** Explain water lost in leakages or tolls for truancy in public transport.
Social norms, comparison, and reciprocity: People are influenced by the behavior of others	Frame energy savings as socially desirable, and focus on immediate social groups. **Example:** Datta et al. (2015) show that the social comparison of water consumption with the average of the neighborhood reduced consumption between 3.4 percent and 5.6 percent in Costa Rica. A similar intervention in Colombia reduced consumption 6.8 percent (Jaime and Carlson, 2016).
Saliency: Likelihood of events is assessed considering the most readily available events in memory.	Use recent, frequent, or emotionally salient information to convey a message. **Example:** Gilbert and Zivin (2014) find that average daily electricity consumption fell between 0.6 and 1 percent in the first week after receiving a bill with information on how to reduce consumption.

and tax collection efforts but few have been attempted in infrastructure, at least on a scale significant enough to be statistically robust and, hence, relevant. A study by Nemati and Penn (2018) carried out a meta-analysis of 117 behavioral interventions to reduce residential electricity, natural gas, and water consumption and reported only four such interventions in Latin America. This may be the right time for infrastructure regulators in Latin America and the Caribbean to join the efforts made by their colleagues in other sectors. This would demand trials, initially, to fine-tune the design and targeting of tools. And once the specific design of the new tools has been chosen, it may be helpful to introduce legal and administrative changes to accommodate the adoption of the new instruments into the general regulatory framework.

Adapting Institutions

The formal regulatory architecture in Latin America and the Caribbean varies widely. In most countries, regulatory functions are carried out by regulatory agencies separated from line ministries. But while some countries have sector-specific regulatory agencies, others have opted for multisectoral agencies, an approach usually followed by smaller, subnational governments.

The exponential increase in the use of data made possible by digitalization, coupled with technologies that facilitate decentralized service delivery, is blurring regulatory frontiers. Chapter 9 documents how electricity is becoming increasingly interrelated with transportation, water, and telecommunications. For instance, electric vehicles can be considered batteries on wheels. How electricity storage and flows are regulated (in terms of both price and quality) will help decide how quickly electric vehicles are adopted, which in turn will impact the investment needs of the grid. This interaction calls for coordinated regulation, integrating planning, instrument design, and impact assessments.

Reshape Agencies

Regulatory agencies need to adapt to better respond to the increasing role of digitalization and data management. Since data are often provided and managed by firms subject to the regulation of the telecommunications regulator—but end up being used by electricity, transport, or water regulators—the division of mandates becomes blurred. And to the extent that data management is subcontracted to companies competing in the data market, competition issues can add to the complexity of the institutional regulatory adjustments required to deal with information management in infrastructure services.

This intersectoral nature of digitalization is why collaboration across regulatory institutions has become more important than ever. It also suggests that among the required institutional changes, mandates may need to be reassigned across institutions. Options include the possibility of merging sector agencies (a process that is already underway in the financial sector), the allocation of authority over all data-related issues to the competition agency, or the creation of a stand-alone data regulator. The most desirable solution will depend on the country context and account for technical capacity and the risks of political reversals of decisions. The importance of matching institutional setups with these dimensions may be one of the most underestimated lessons of the large volume of contract renegotiations—almost 70 percent of all infrastructure concession contracts—in the last 20 years (Guasch et al., 2016).

Rethink Regulators' Accountability

The fast-paced technological disruption that is expected to reshape service provision will necessitate more dynamic regulators, independent of the shape institutions take. Regulation needs to become a dynamic and ongoing process that adapts to as well as fosters new technologies and ensures regulators' credibility. Regulators, meanwhile, will need to change their mindsets to empower consumers (not just protect them) and treat them as active players, especially in energy markets. The existence of formal regulators will not be enough to ensure that regulation is adequate and effective. Dynamic and resourceful institutions will be necessary to set in motion a process of regulatory evolution based on the following pillars:

- ***Invest in technical capacity.*** Capacity building and training create awareness among regulators of best practices and innovation trends, and enable the early identification of key regulatory issues. They also lead to the development of innovative and effective customized solutions to further accelerate technological progress. For example, artificial intelligence can predict failures and forecast preventive maintenance requirements in electricity grids, thereby improving the quality of services.
- ***Rely on ex ante regulatory impact assessments.*** Once solutions for a regulatory problem are identified, regulators should conduct qualitative and quantitative assessments of the alternatives. They should

generate cost-benefit assessments, and consider the short- and long-term impacts as well as the effects of the proposed solution on stakeholders to come up with a best-fit solution that reduces the risk of regulatory failure. It is important that regulators use empirical data-driven approaches to improve these assessments.

- ***Use regulatory pilots ("sandboxes"*) *to test innovative regulations.*** In view of the multiple sources of changes stimulating the demand for regulation, data on experiments should be gathered and tested to allow for broader regulatory changes on a better and more informed basis and to reduce the risks of costly political and social regulatory adaptation. Sandboxes are controlled environments where regulators can partner with service providers to test new services and business models without having to comply with existing regulations that may become quickly obsolete due to fast-changing technologies. An example of a sandbox would be an area of a city to test autonomous cars.
- ***Conduct ex post evaluation of regulatory performance.*** Monitoring regulatory performance and learning from experience in a structured analytical manner can ensure early identification of potential innovation impacts. This helps the regulator adjust and correct regulatory interventions to mitigate risks. Some of this has been done, often informally, through regulatory networks. For ex-post assessments to be effective, data need to be generated and analyzed. It is also important to involve academia and think tanks in the evaluation process, and to encourage a more open, transparent culture in the regulation of infrastructure services.
- ***Formalize the institutional monitoring of data use.*** Independent of what institutional arrangement best responds to data-motivated changes, one of the most basic decisions to take when consumption produces new data is to assess how much of these data can become a source of rent for the service provider. The answer to this question drives the choice between an opt-in or opt-out approach to the authorization of data usage by consumers. Maximum protection is provided by "opt-in" programs, which are preferred by a fair share of users, as they require specific client authorization to share data. In contrast, most firms prefer "opt-out" programs because they allow them to collect data that can be used for pricing and service targeting to maximize profits.
- ***Consider the scope for independent auditing of regulatory decisions.*** The decisions of regulatory agencies usually have a legal recourse. Beyond the normative processes established to

guarantee the fairness of regulatory decisions, reviews carried out by national centers of infrastructure expertise provide another layer of accountability. These institutions (described in Chapter 2), which are well established in Australia and the United Kingdom, provide valuable information to regulators to identify trends and needs, and could become key players in the regulatory architecture.

Building the New Regulatory Architecture

This book highlights the meaningful opportunities to improve service quality, to stimulate more and greener investment, and to make services more accessible and affordable to those who need them the most in Latin America and the Caribbean. However, identifying the reforms required for opportunities to become a reality is not enough. The process to adapt regulatory policies, institutions, and instruments is paramount. Underestimating the transitional challenges associated with reforms is one of the reasons why regulations and regulatory institutions have disappointed more often than expected since the 1990s (Estache, 2020). The large number of contract renegotiations and international arbitration cases suggests that reformers misjudged the relevance of country- and sector-specific contexts.

Managing Transitions with More Stakeholders

Many governments have made efforts to address some of their local institutional limitations. For instance, since 2017, as a consequence of the Odebrecht case, a growing number of countries have put together commissions to track the weaknesses in regulatory and procurement processes. Simultaneously, structural changes in the way regulated infrastructure markets operate such as the growing role of e-procurement and the opportunities offered by the digital revolution are creating a steady flow of new demands on regulation. For both, institutional and technology driven changes, speed of adjustment of regulation, and flexibility to adapt are of the essence. Markets and societies are changing rapidly and, to accompany this process, regulators need to allow themselves to catch up as fast as possible while still offering a reliable, predictable, and fair framework to induce outcomes in the interest of all stakeholders.

New actors, whether on the financial, production, or consumption side of the market, call for action to change the regulatory architecture. Latin American and Caribbean regulators have an opportunity to learn from experiences inside and outside the region. There is an obvious need to adjust regulation to account for the emergence of new stakeholders as different as international asset managers, new local digital service providers, new users or producers, or simply new small local service providers keen on competing with the traditional large foreign operators. Furthermore, the evolution of the way civil society voices its concerns over the behavior of service providers or with regulatory decisions that discriminate against some user groups is also changing the way reforms need to be implemented. Social networks are de facto increasing the number of stakeholders because they are allowing fast mobilizations of individuals or groups. This larger and louder volume of voices have often produced information useful to regulators. Much of this information is increasingly processed faster by the media than by regulators, prompting changes in the regulatory mechanisms by which information is fed in the decision-making process.

Unless Latin American governments progressively adjust their regulation more systematically, to anticipate and address how these new stakeholders impact the way markets function, they will be unlikely to deliver on their promise to improve service quantity, quality, and affordability.

Catching the Train

The infrastructure sector is evolving at breakneck speed. To make the most of the opportunities to adapt for the better in a timely matter, governments will have to manage the transition much more systematically than they have thus far. For now, no country has adopted a systematic approach to actively and realistically manage the next wave of regulatory reforms. Moreover, there are no general policy guidelines to direct the transition from old regulation to new regulation based on the international experience to structure the management of the change. However, a good place to start is to conduct detailed sector-specific diagnostics equivalent to those in the 1990s and early 2000s. These diagnostics are needed to ensure that physical, institutional, and financial bottlenecks as well as opportunities are clearly identified in each country, and often, within each region of each country.

Infrastructure markets and their economic, financial, social, and technological environments have indeed changed so much in the last 10–15 years that a stock-taking exercise is a good place to start. Diagnostics of the initial conditions are the basis of any action plan and determine the design and timing of transition. They need to clarify the local institutional constraints that limit the adoption of standardized approaches to much needed reforms. They need to internalize the evolution of technology, of financing sources, and of social pressures. They must identify the evolution in the number and types of local and global stakeholders contributing, or potentially contributing, to the financing and operations of the sector as well as those likely to contribute to designing, implementing, and enforcing regulation. Finally, they need to account for the risks and limitations of the new local and global business environment in which regulated industries operate.

These diagnostics will allow regulatory tools to be better matched to institutional capacities. With this matching, a realistic timeline can be developed to implement reforms that will often differ across countries and across sectors within countries. Regulators are likely to continue lagging regulated firms in their ability to make the most of the evolving context. But they need to upgrade their ability to measure and identify the tools to close the gap if infrastructure services are to improve.

For most countries, the ability to close the gap will require a willingness to experiment with regulatory changes on a small scale before adopting large-scale changes. Targeted pilots or sandbox approaches to try out adjustments are part of the necessary transition process. These pilots can help minimize the risks of making large-scale mistakes by either not adjusting at all or adjusting too fast in the wrong direction because the effects of the changes brought by technology or new actors have been misunderstood.

In sum, governments in the region have an opportunity to make the most of the sector's transformation, to avoid some of the failures of past regulatory practices, and to capitalize on the numerous opportunities to do better. To do so requires updating regulatory policies, institutions, and instruments. It also requires a good dose of humility to recognize that no one has a ready-made solution to adapt well to the fast- evolving contexts. This, is turn, demands a culture of permanent evaluation, a willingness to test and measure the impact of options and actions, and an ability to consult meaningfully with consumers, service providers, and other stakeholders.

As Latin America and the Caribbean speeds from structures to services, regulators must act now to catch the train and keep the process on track to better infrastructure in the region.

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Index

To close its infrastructure gap, Latin America and the Caribbean needs more than investment in new structures. It needs to become more efficient at investing in infrastructure and regulating a new range of services that have the potential to disrupt the energy, transport, and water sectors. The technological revolution makes a future with quality services possible, but not inevitable. This book offers policy options for countries to improve the access, quality, and affordability of services today, to ensure that they will be sustainable in the future, and to harness emerging technological advances for the benefit of all. This report aims to provoke discussion and further research on those many important issues and mark a path that helps the region move from structures to services and improve infrastructure for all.

"This Development in the Americas (DIA) report has the potential of becoming a landmark publication, it is a veritable goldmine. The long-neglected problem of poor-quality infrastructure services in Latin America is untenable. Grim growth prospects, climate risks, and the post-Covid-19 recovery should catalyze decisive actions. This book provides a timely roadmap on what needs to be done to improve both the "hardware" and the "software" of the sector. Leaders should pay close attention to its recommendations and adopt new standards in planning, procurement, regulation, and management of infrastructure. Social unrest will increase if lack of access to safe water, high traffic congestion, and costly public utilities are not rapidly—and effectively—addressed."

Mauricio Cárdenas
Senior Research Scholar, Center on Global Energy Policy, Columbia University
Former Minister of Finance, Energy, and Transportation, Colombia

"The great contribution of this book is to focus our attention on the services that infrastructure provides rather than on the facilities themselves. This is important because experience cautions that few countries in Latin America and the Caribbean can or will invest as much in infrastructure as development experts recommend. The focus on services, however, reminds us that there are more ways to improve the access, quality and affordability of infrastructure than by simply investing more. And the study is rich with examples of how this might be done."

José A. Gómez-Ibáñez
Derek C. Bok Research Professor of Urban Planning and Public Policy, Harvard University

"This book strongly calls for an increase in both public and private investment to help close the infrastructure gap in Latin America and the Caribbean. It also highlights the importance of improving access to infrastructure whilst also creating better infrastructure that is more sustainable and resilient. To do this, more innovation is needed to reduce costs and improve the quality of infrastructure. Whilst challenges lie ahead, particularly in a post-Covid-19 world, there is enormous potential to boost economic growth and change lives, particularly the vulnerable."

Marie Lam-Frendo
Chief Executive Officer, Global Infrastructure Hub

The Inter-American Development Bank (IDB) is an international institution created in 1959 to foster economic and social development in Latin America and the Caribbean.

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