Climate Change Challenges in Latin America and the Caribbean[1]

Climate change presents multiple challenges for a region as diverse as Latin America and the Caribbean (LAC). Some LAC countries face challenges related to containing and reducing greenhouse gas (GHG) emissions (mitigation), while others have an urgent need to build resilience to natural disasters (adaptation). On mitigation, without further policy action, GHG emissions in LAC will continue to grow as economic activity continues to expand. LAC policymakers have a variety of mitigation tools at their disposal to curb GHG emissions, including price-based mitigation policies (e.g., reduction in fossil fuel subsidies, introduction of carbon taxes, establishment of emissions trading systems, and feebates) and non-priced-based mitigation policies (e.g., public investment in low-GHG emissions technologies and infrastructure, fiscal incentives and direct current public spending aimed at making low-carbon energy sources more abundant and affordable as well as supportive regulations). Given the large share of emissions from change in land-use practices, cost-effective Nature-based Solutions (NbS) can play an important role in LAC. A broad range of mitigation tools is likely to be needed in LAC countries, taking into account the extensive use of renewable energy in the region, societal preferences, and political economy considerations. Countries should adopt the policy mixes that best suit their specific circumstances, ideally articulated as national strategies. On adaptation, while building resilience to natural disasters is important throughout the region, it is a priority for Caribbean and Central American economies that are highly vulnerable to the impact of climate change. A comprehensive medium-term approach focused on investing in structural (or physical) resilience, boosting financial resilience, and enhancing post-disaster resilience would yield significant long-run benefits for countries in the Caribbean and Central America. In the LAC region as a whole, mitigation and adaptation policies will require significant upfront financing, including importantly support from the international community and the private sector.

Introduction

The transition to a post-pandemic era provides an opportunity to address a different threat to long-term growth and prosperity: climate change. As the international community recognizes the urgency of addressing this issue, and countries update their climate commitments in the run-up to the 26th UN Climate Change Conference of the Parties (COP26), this chapter takes stock of the main challenges related to climate change in LAC and explores a menu of policy options to address them. The appropriate policies or set of policies for individual countries will depend on the challenges and circumstances of each country and will require an in-depth analysis at the country and sectoral level, which is beyond the scope of this chapter.

Climate change presents both challenges and opportunities for the LAC region.

On the **challenges** side:

- ***Physical risks*** arise from the high vulnerability of some of the region's economies to the impact of climate-related phenomena such as higher temperatures, weather-related natural disasters, sea-level rise, coastal erosion, and loss of biodiversity, as well as risks related to the high reliance on climate-sensitive sectors such as tourism and agriculture. Such physical risks can adversely affect both aggregate supply (destruction of physical capital, dislocation of labor markets, and disruption of supply chains) and aggregate demand (reductions in consumption and investment, and disruption of trade flows), leading to lower growth and employment and threatening fiscal sustainability and financial stability.

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- ***Transition risks*** arise from the significant structural changes in domestic and foreign economies needed to achieve climate sustainability goals, in particular, by reducing reliance on high-GHG activities and improving land-use practices. If not managed properly, the global transition to a low-carbon/low-GHG economy[2] could lead to significant economic dislocations due to sectoral shifts in employment, comparative advantage, and trade patterns with repercussions for short- and long-term growth, fiscal positions, inflation, external positions, and financial systems.

To manage these risks, countries can take actions on two fronts: (i) *climate mitigation*, which refers to policies that help reduce emissions of greenhouse gases and (ii) *climate adaptation*, which refers to efforts to adapt to the effects of climate change including through minimizing damages from climate-related natural disasters as well as adapting to the effects of economic transformations at home and abroad aimed at reducing reliance on carbon-intensive activities (often referred to as transition).

On the **opportunities** side, the transition to greener and more resilient economies could help achieve economic, social and environmental sustainability, while fostering opportunities for economic and social development in the region.

- ***Mitigation efforts*** could bring substantial domestic environmental and health benefits even in the short run (e.g., Bollen et al., 2009; Grossman et al., 2011), including reductions in air pollution mortality and morbidity, and in road fatalities. They may also yield direct economic savings (e.g., reduced road damage and traffic congestion).
- ***Investment*** in green technologies and infrastructure could help boost growth and generate new jobs (IMF October World Economic Outlook (WEO) 2020). Efforts to foster green innovation in the energy sector could also generate positive spillovers to the rest of the economy and reduce energy security risks.
- ***Sustainable farming*** can also bring benefits by releasing fiscal resources that are currently used for subsidies (although these resources may be partially used to subsidize sustainable farming, at least initially), increasing external resilience by developing sustainable produce for which global demand has been increasing, contributing to food security, and increasing domestic income sources (Hanley 2014; Boltvinik and Mann, 2016). A shift away from livestock agriculture could free up land that could be used to grow plant-based proteins or for reforestation (Batini, 2021), helping to mitigate the risks from transition and contributing further to emissions reduction.
- ***The shift to green technologies*** could benefit some countries in the region due to their natural endowment of metals such as copper, nickel, cobalt and lithium, which are needed in low greenhouse-gas technologies, including renewable energies, electric cars, hydrogen and carbon capture and storage, which would benefit LAC metal producers (IMF WEO 2021).
- ***Investing in resilient infrastructure*** could yield significant growth and fiscal benefits over time in countries vulnerable to climate disasters.

Maximizing these opportunities and minimizing the risks puts a premium on improving economies' flexibility and adaptability. Policies aimed at supporting the reallocation of labor and capital across sectors, investing in basic skills and human capital, improving transparency and economic governance to encourage investment in technology and know-how, and creating fiscal space to manage the climate transition would help LAC countries position themselves to take advantage of the opportunities afforded by the climate transition.

This chapter assesses the LAC region's climate change challenges and explores a range of policy options for climate mitigation and adaptation. The chapter aims at addressing the following questions:

[2]Throughout the chapter we use the term low-carbon and low-GHG emissions economies interchangeably. GHG emissions include several gasses other than carbon dioxide (footnotes 1 and 2 in Figure 3), including some that do not contain carbon. However, the term low carbon economy is commonly used to loosely define all the economic activities that aim at delivering goods and services while minimizing emissions of GHGs (see, for example, "The Size and Performance of the UK Low Carbon Economy (publishing.service.gov.uk)" UK Department for Business Innovation and Skills, March, 2015).

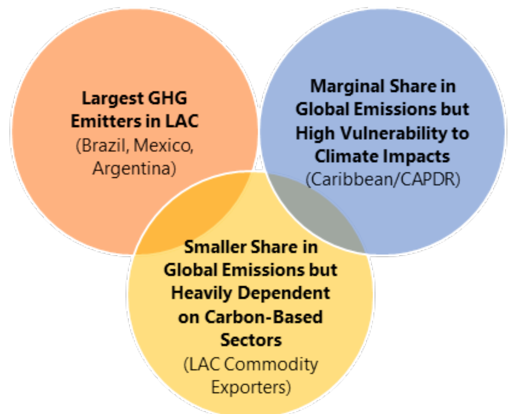
What are the main climate change challenges in LAC? **(Section II)**; What are the policy options in LAC to tackle climate change **(Section III)**, including mitigation **(Section III.1)** and adaptation **(Section III.2)**; and What are the financing requirements to reach LAC's climate goals? **(Section IV).**

Climate Change Challenges in LAC

A diverse region

LAC is one of the most diverse regions with respect to climate-related risks (Figure 1). While Brazil and Mexico do not stand out in terms of per capita net GHG emissions, each of these countries, together with Argentina, contributed more than one percent to total net GHG or net non-CO_2 emissions globally in 2018 just due to their sheer size (Figure 2 and Annex 1).[3] LAC is also home to countries that are especially vulnerable to the impact of climate change (notably in the Caribbean and Central America), and to countries that do not contribute significantly to global GHG emissions but are sensitive to transition risks arising from global efforts to reduce GHG emissions (i.e., fossil-fuel and agricultural exporters). Climate change is macro-critical for the region (Box 1) and both climate mitigation and adaptation are relevant.

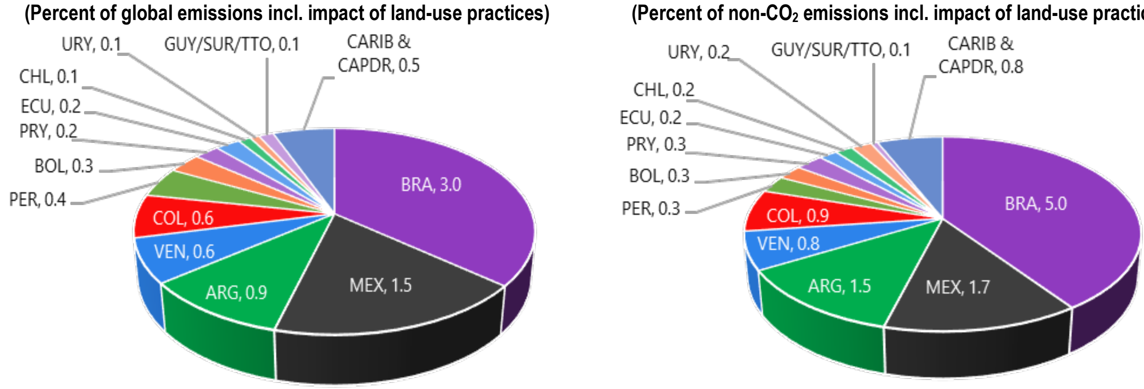
Figure 1. Latin America and the Caribbean: Region's Climate Risk Diversity



Source: IMF staff calculations.
Note: LAC = Latin America and the Caribbean, CAPDR = Central America, Panama, and the Dominican Republic.

Figure 2. LAC: Region's Climate Risk Diversity

1. **LAC: Net Greenhouse Gas Emissions, 2018**
   (Percent of global emissions incl. impact of land-use practices)
2. **LAC: Net Non-CO_2 Emissions, 2018**
   (Percent of non-CO_2 emissions incl. impact of land-use practices)



Sources: World Resources Institute, CAIT Climate Data Explorer; United Nations Framework Convention on Climate Change; and IMF staff calculations.
Note: Greenhouse gas emissions include CO_2, CH_4, N_2O, and F-gases, sourced from energy, industrial, agriculture, LULUCF (land use, land-use change, and forestry), waste, and others. Data labels use International Organization for Standardization (ISO) country codes. CAPDR (Central America, Panama, and the Dominican Republic) = Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua, Panama; CARIB (Caribbean) = Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago; LAC = Latin America and the Caribbean.

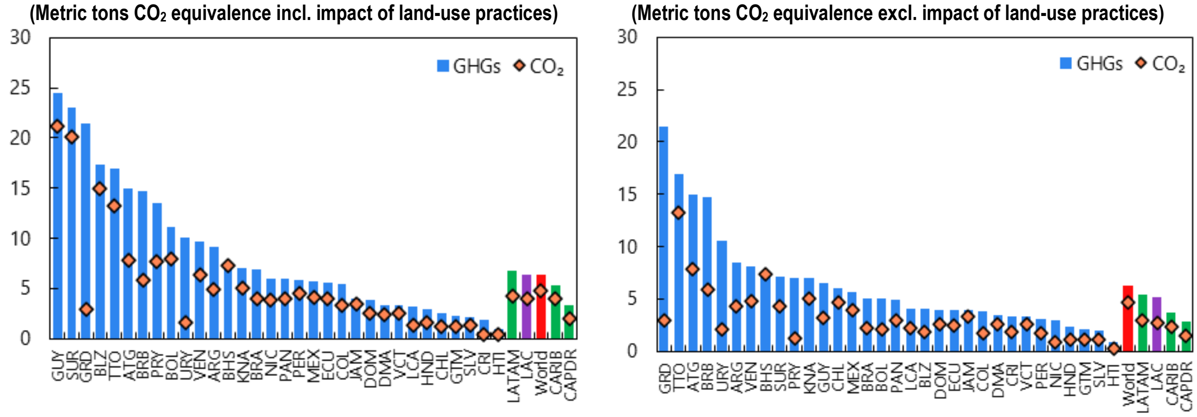
[3] Since emissions constitute an externality that is related to climate change globally, it is total emissions that characterize country's contribution to climate change.

The region's net GHG emissions are in line with its economic size and population. LAC's share of global net GHG emissions, which include the impact of land use practices, of 8.4 percent is broadly consistent with the size of LAC economies (about 8 percent of global GDP and population) so that per capita net GHG emissions of 6.4 metric tons CO_2-eq[4] are close to the world average (Figure 3, panel 1). In contrast, gross GHG emissions per capita (5.2 metric tons CO_2-equivalent), which exclude the impact of land use practices, are below the world average (6.3 metric tons CO_2-equivalent). Higher net (relative to gross) emissions in LAC reflect a positive contribution to net GHG emissions from land use practices largely on the account of deforestation in the region (Figure 3, panel 2). Across countries, LAC's contribution to global net GHG emissions is driven primarily by the three largest emitters in the region (5.4 percent, Figure 2, panel 1). While countries that are heavily dependent on fossil-fuel exports (Bolivia, Colombia, Ecuador, Guyana, Suriname, Trinidad and Tobago, and Venezuela) represent a total of only 1.7 percent of global net GHG emissions, their exports of fossil fuels contribute to emissions in importing countries.

Figure 3. LAC: GHG and CO_2 Emissions per Capita

1. Greenhouse Gas and CO_2 Net Emissions Per Capita, 2018[1] (Metric tons CO_2 equivalence incl. impact of land-use practices)

2. Greenhouse Gas and CO_2 Gross Emissions Per Capita, 2018[2] (Metric tons CO_2 equivalence excl. impact of land-use practices)

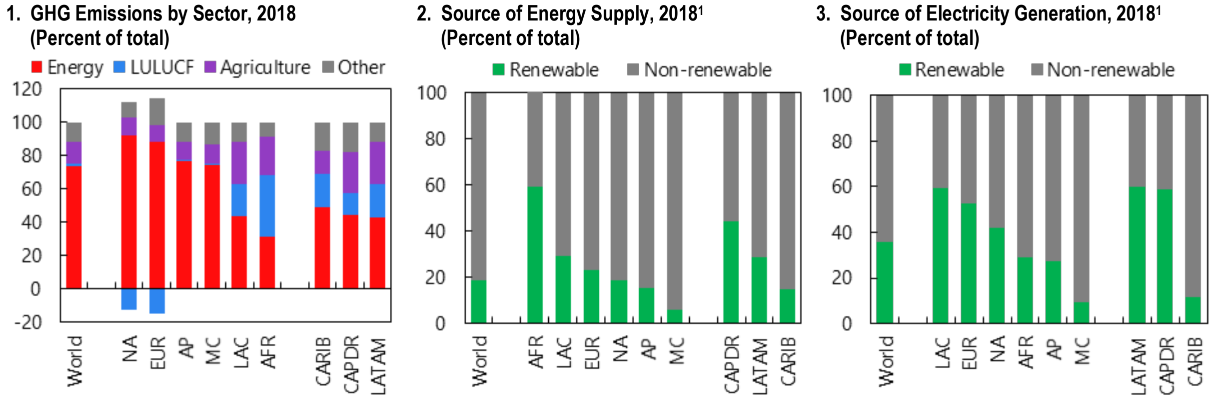


Sources: World Resources Institute, CAIT Climate Data Explorer; United Nations Framework Convention on Climate Change; and IMF staff calculations.
Note: Data labels use International Organization for Standardization (ISO) country codes. CAPDR (Central America, Panama, and the Dominican Republic) = Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua, Panama; CARIB (Caribbean) = Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago; CO_2 = carbon dioxide; GHG = greenhouse gas; LAC = Latin America and the Caribbean; LATAM (Latin America) = South America, Mexico; LULUCF = land use, land-use change, and forestry; NA (North America) = Canada, United States.
[1]Net GHGs emissions include gross GHGs emissions (see footnote 2) plus LULUCF, which can be positive or negative.
[2]Gross GHGs emissions include CO_2, CH_4, N_2O, and F-gases, sourced from energy, industrial, agriculture, waste, and others.

The composition of net GHG emissions in LAC, however, differs notably from that in the rest of the world. The energy sector—still the top single driver of emissions—accounts for 43 percent of GHG emissions in LAC, well below the world average of 74 percent (Figure 4, panel 1) reflecting cleaner sources of energy supply than in most other regions (except Sub-Saharan Africa) (Figure 4, panel 2). In particular, there is a limited use of fossil fuels in electricity generation (Figure 4, panel 3) and extensive use of hydropower[5] and other renewable sources in LAC countries (outside of the Caribbean).[6] LAC, however, stands out for its large share of net GHG emissions (45 percent of total) from agriculture and change in land use and forestry combined, compared to the world average of 14 percent.

[4]CO_2-eq (carbon dioxide equivalent) stands for a unit based on the global warming potential of different GHGs. The CO_2-eq unit measures the environmental impact of one metric ton of these GHGs in comparison to the impact of one metric ton of CO_2.
[5]Hydropower, despite contributing little to GHGs emissions, may give rise to other environmental problems (e.g., related to the dam construction) and, due to its high reliance on water, may also face challenges if water resources become more volatile—another climate change risk—in the region.
[6]Electricity production in the Caribbean is tilted towards non-renewable sources, which comprise 88 percent of electricity generation, in contrast to about 40 percent in the rest of LAC.

Figure 4. LAC: Greenhouse Gas Emissions and An Energy Matrix



Sources: IMF, Carbon Pricing Assessment Tool; International Energy Agency; Organization for Economic Co-operation and Development; World Resources Institute - CAIT Climate Data Explorer; IMF staff calculations.

Note: Data labels use International Organization for Standardization (ISO) country codes. CAPDR (Central America, Panama, and the Dominican Republic) = Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua, Panama; CARIB (Caribbean) = Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Suriname, Trinidad and Tobago; LAC = Latin America and the Caribbean; LATAM (Latin America) = South America, Mexico; NA (North America) = Canada, United States; AFR = Africa; AP = Asia and Pacific; EUR = Europe; MC = Middle East and Central Asia. LULUCF = land use, land-use change, and forestry. Category Other refers to Industrial Processes and Waste.

[1]Energy supply in a country includes total supply of energy for use in four economic sectors, namely, residential, commercial, transportation, and industrial, from both renewable sources (wind, solar, hydro, nuclear, biomass, heat, and other renewable energy) and nonrenewable sources (coal, natural gas, gasoline, diesel, kerosene, LPG, jet fuel, and other oil products). Energy supply is computed as production + imports – exports ± stock and bunker changes; for the world, it is defined as production + imports - exports ± stock changes.

Some LAC countries are highly vulnerable to the impact of climate change. Although the LAC region as a whole is below the world average according to the index of vulnerability to climate change produced by Notre Dame Global Adaptation Initiative (ND-GAIN),[7] there are pockets of high vulnerability. In particular, the Caribbean is one of the most vulnerable regions of the world (Figure 5, panel 1) and also stands out in terms of the frequency and economic impact of weather-related natural disasters per land area, which is not directly captured by the ND-GAIN vulnerability index. In the Caribbean, damages from natural disasters are estimated at 2.5 percent of GDP annually, affecting vast segments of the economy and population, and putting significant pressure on public finances. Central America is also vulnerable in this regard, with estimated annual average damages of 0.8 percent of GDP (Figure 5, panel 2). In addition to weather-related natural disasters, LAC countries are expected to be exposed to higher temperatures, sea-level rise, and possible changes in precipitation as a result of climate change. These may result in lower agricultural production, reduced availability and lower quality of water resources, loss of forested areas and biodiversity, and adverse health effects (IPCC, 2021; Bárcena, 2020).

Large fossil-fuel and agricultural exporters in LAC are sensitive to transition risks. Several LAC countries rely significantly on fossil fuels as a source of income, fiscal revenue, and foreign exchange (Figure 6, panels 1 and 2). The global transition to low-carbon economies can have negative repercussions for fiscal and external sustainability in those countries, making climate change macro-critical (Box 1). Some LAC countries are also important exporters of agricultural products (Figure 6, panel 3) and are therefore vulnerable to transition risks emanating from the potential shift away from animal products[8] that are estimated to contribute 15 percent to net GHG emissions globally (Box 3).

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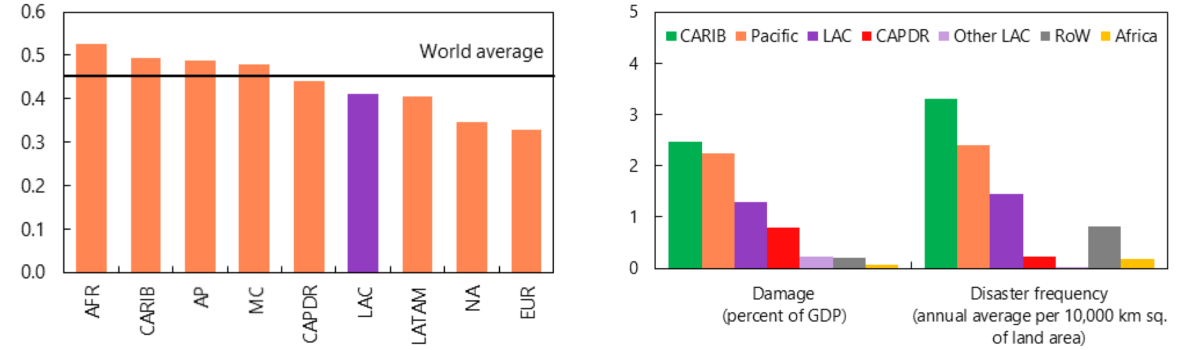
[7]The ND-GAIN index assesses the vulnerability of a country to climate change risks by considering the exposure to climate-related hazards, the sensitivity to the hazards' impacts, and the adaptive capacity to cope with or adapt to these impacts, in six life-supporting sectors: food, water, health, ecosystem services, human habitat, and infrastructure. Raw data are scaled to a range from zero to one and the arithmetic average is used to construct each index. See details in ND-GAIN data technical document.

[8]A growing number of people are recognizing the health benefits of plant-based diets (reflected in increasing numbers of vegetarian restaurants and sales of meat and dairy alternatives). In addition, the FAO is urging governments to advertise sustainable proteins plant-based options) to help curb the consumption of meat and dairy products. More than 80 countries issued food based dietary guidelines (FAO, 2016).

Figure 5. Vulnerability of LAC Countries to Weather-Related Natural Disasters and Climate Change

1. ND-GAIN Index of Vulnerability to Climate Change, 2018[1]

2. Average Annual Effects of Weather-Related Natural Disasters, 1980–2020[2]



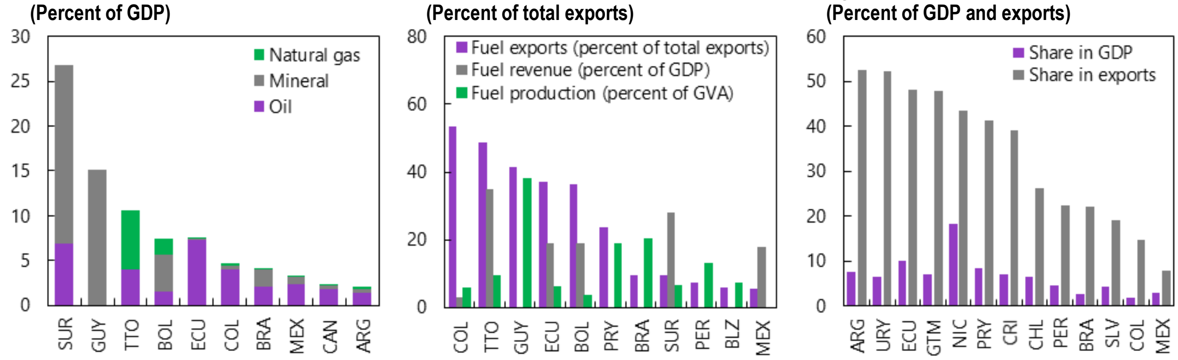
Sources: EM-DAT database; IMF, World Economic Outlook database; Notre Dame Global Adaptation Initiatives (ND-GAIN) database; and IMF staff calculations.
Note: Data labels use International Organization for Standardization (ISO) country codes. CAPDR (Central America, Panama, and the Dominican Republic) = Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua, Panama; CARIB (Caribbean) = Antigua and Barbuda, The Bahamas, Barbados, Belize, Dominica, Grenada, Guyana, Haiti, Jamaica, St. Kitts and Nevis, St. Lucia, St. Vincent and Grenadines, Suriname, Trinidad and Tobago; LAC = Latin America and the Caribbean; NA (North America) = Canada, United States; RoW = rest of the world ; AFR = Africa; AP = Asia and Pacific; EUR = Europe; MC = Middle East and Central Asia; Pacific = Fiji, Marshal Island, Micronesia, Papua New Guinea, Samoa, Solomon Islands, Tonga, Vanuatu.
[1]ND-GAIN assesses the vulnerability of a country to climate change risks by considering the exposure to climate-related hazards, the sensitivity to the hazards' impacts, and the adaptive capacity to cope with or adapt to these impacts, in six life-supporting sectors: food, water, health, ecosystem services, human habitat, and infrastructure. Raw data are scaled to a range from zero to one and the arithmetic average is used to construct each index. See details in ND-GAIN data technical document. Regional average weighted by annual population as of 2018.
[2]Weather-related natural disasters include climatological (includes drought, wildfire), hydrological (includes flood, landslide), and meteorological (storm, extreme temperature). The whole sample covers countries that report at least one weather-related natural disaster incurring positive damage (countries that report the occurrence but with zero damage are excluded). Groups of WHD, Pacific and rest of the world are exclusive. A simple average is taken across country and year, after damage is scaled by GDP annually and disaster frequency is scaled by 2018 land area annually, for each group.

Figure 6. Vulnerability to Transition Risks

1. Natural Resources Rents, 2018[1] (Percent of GDP)

2. Dependence of Fossil Fuels, 2015–19[2] (Percent of total exports)

3. Agricultural Exports, 2019 (Percent of GDP and exports)



Sources: WDI, UN Comtrade, Carbon Tracker, Haver Analytics, National authorities, and IMF staff calculations
[1]Natural Resources Rents are estimated as the difference between the value of natural resources production at world prices and total costs of production.
[2]GUY: all 2020 data. Fuel exports cover exports of mineral fuels, lubricants and related materials (SITC Rev. 3, Section 3). Fuel production is proxied by mining and quarry if petroleum and/or natural gas extraction and/or refinement is not available. Fuel revenue estimates are not available for some countries. Fuel Revenue data, for some countries was not available.

Climate strategies to date

LAC governments have already made considerable efforts to expand the use of renewable energy. Scaling up the use of renewables in the region over the past several decades has been supported by government policies, which were designed to kick-start renewable energy markets, create local supply chains, or consolidate mature renewables such as hydropower and bioenergy (IRENA, 2016; Box 2). Government support included catalyzing financing for renewable energy projects; offering dedicated credit lines, currency hedges, and guarantees; providing grants and subsidized loans; introducing tax incentives for low-carbon industries, renewable energy, and R&D; and promoting renewables through feed-in tariffs[9] (IRENA, 2016).

LAC countries are continuing to adopt and refine their climate mitigation and adaptation strategies. All LAC countries have submitted and ratified their Nationally Determined Contributions (NDCs) commitments under the Paris Accords of 2016 aimed at reducing GHG emissions. In addition to NDCs, nine LAC countries are supporting the goal of carbon neutrality by 2050 and 14 LAC countries have committed to generating at least 70 percent of their electricity from renewable sources by 2030.[10] Many countries have made commitments to implement the Kigali Amendments[11] to phase out climate-warming hydrofluorocarbons by cutting their production and consumption. Many LAC countries have also adopted climate strategies, including action plans for specific sectors (e.g., forestry, energy, agriculture or water sectors) or national action plans (e.g., to address adaptation challenges in the Caribbean). Only some of the strategies (e.g., Chile and Costa Rica) encompass both mitigation and adaptation policies and integrate sectoral action plans into a broader strategy that includes actions to protect the vulnerable.[12]

Governments have also supported their mitigation and adaptation strategies with a range of policy actions. In addition to measures aimed at expanding renewable energy sources mentioned above, sectoral measures are becoming increasingly common in LAC. They include measures related to land-use change and forestry, transport, waste management, sustainable agriculture and livestock practices[13] as well as health. These measures aim at both reducing GHG emissions (mitigation) as well as building resilience to climate change effects (adaptation). On adaptation side, other actions under LAC countries' NDCs include measures geared towards coastal protection, disaster risk management, strengthening food and water security, and conserving biodiversity. Given the large share of GHG emissions from agriculture and land use, as well as the region's many unique ecosystems and species, several LAC countries have included explicit actions targeting NbS in their NDCs with a view to reducing emissions through carbon capture and sequestration and biodiversity protection.

Policy Options

LAC countries have a number of policy instruments available to reach their climate goals. On the mitigation side, policy options include price-based instruments (such as carbon pricing and fossil fuel subsidy reduction) and non-price-based instruments (such as regulation, fiscal incentives, and green public investment).[14] In choosing an appropriate policy mix, countries will need to take into account not only efficiency and equity considerations but also the political and social feasibility of the different options. This section describes a range of policy instruments for mitigation and provides an illustrative scenario to gauge

[9]Feed-in tariffs (FITs) are long-term, guaranteed purchase agreements for green electricity at a price that can provide project developers a reasonable return on investment. Argentina, Brazil, and Ecuador had established FIT schemes, but they are no longer active, either because their levels were set too low (Argentina), or official regulation to implement laws were lacking (Ecuador) or an adequate enabling environment was not in place (e.g., lack of clarity on interconnection rules, lack of standard contracts for IPPs)—IRENA (2016).

[10]Based on 2018 IEA World Energy Statistics and Balances, 8 LAC countries already generate at least 70 percent of their electricity from renewables but not for all these countries it constituted a formal commitment under their NDCs.

[11]The Kigali Amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer is an international agreement that countries ratified to gradually phase out powerful greenhouse gases that deplete the ozone layer known as hydrofluorocarbons.

[12]Climate mainstreaming on the national and sub-national level often occurs via a sector-by-sector approach, as in Germany, France (Mathy, 2007), India (Dubash, 2011; Atteridge et al., 2012), and Brazil (da Motta, 2011; La Rovere et al., 2011).

[13]The FAO defines food and agricultural systems as sustainable if they meet the needs of present and future generations, while ensuring profitability, environmental health, and social and economic equity. Sustainable food and agriculture practices follow 5 key principles: (1) increase productivity, employment, and value addition in food systems; (2) protect and enhance natural resources; (3) improve livelihoods and foster inclusive economic growth; (4) enhance the resilience of people, communities, and ecosystems; (5) adapt governance to the new challenges (FAO, 2018). Low emission sustainable farming has both adaptation and mitigation benefits. Mitigation due to the reduction in GHG emissions from agriculture and livestock practices (for more detail see Box 3) and adaptation due to reductions in negative externalities (such as pollution of ground water, soil conservation, reductions in deforestation).

[14]For a full menu of instruments see (IMF 2919a), (IMF 2919b)

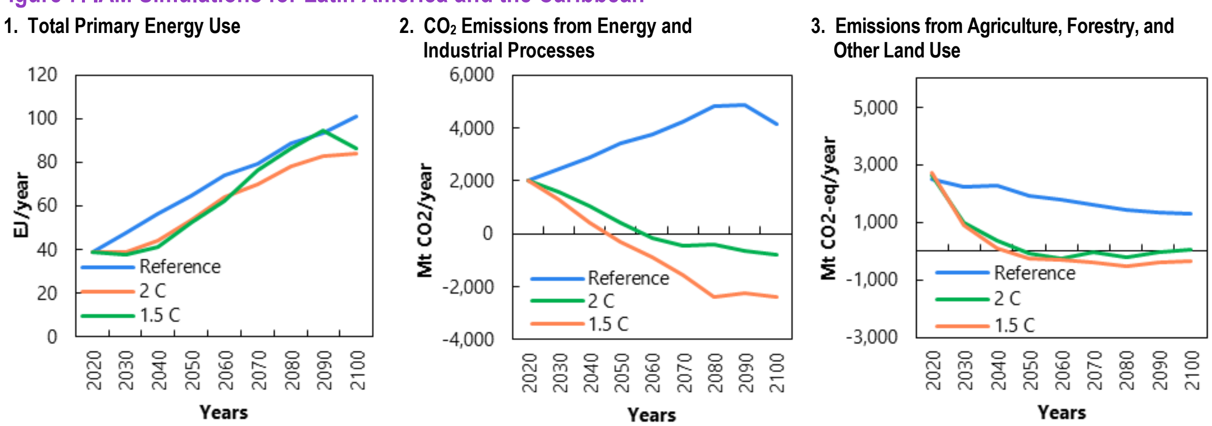
the potential impact of two mitigation instruments (a carbon tax and gradual removal of fossil fuel subsidies) on GHG emissions.[15] On the adaptation side, the section outlines three pillars needed to help LAC's most vulnerable countries prepare for climate-related disasters: structural resilience, financial resilience, and post-disaster resilience. It also highlights the benefits of scaling up investment in structural resilience, a comprehensive layered insurance framework, and deeper private sector contribution to adaptation. The section also briefly touches on issues related to facilitating transition of commodity (both fuel and non-fuel) exporters to low-carbon economies.

Climate Mitigation

Policy Options for Climate Mitigation in LAC

Without stronger policy action, net GHG emissions in the region will continue to grow. Simulations from Integrated Assessment Models (IAMs, Annex 2) under a in Business-As-Usual (BAU) scenario suggest that LAC's CO_2 emissions from energy and industrial processes are expected to more than double by 2030 (Figure 7). While CO_2 emissions per unit of output are expected to decline, this decline will not be sufficient to stabilize total emissions due to continued GDP per capita growth. GHG emissions from agriculture, forestry and other land uses are expected to decline under the assumption that the reduction of deforestation continues following recent trends.

Figure 7. IAM Simulations for Latin America and the Caribbean



Sources: Staff elaboration based on IAMC 1.5C Scenario Explorer release 2.0 (Huppmann et al., 2019; Rogelj et al., 2018; Vrontisi et al., 2018; McCollum et al., 2018; Bauer et al., 2018).
Note: Median of CO_2 emissions from energy and industrial processes, and of CO_2-eq emissions from Agriculture, Forestry and Other Land Uses. For more details see Annex 2.

LAC countries could play an important role in contributing to global mitigation efforts, with substantial potential for net negative emissions after mid-century. Illustrative mitigation scenarios generated by IAM suggest the need for a rapid decline in energy sector emissions and a faster decline in emissions from agriculture, forestry and other land uses than in the recent past to achieve global temperature targets at the least cost. After 2050 the scenarios suggest a large potential for the LAC region to contribute to global mitigation goals with net negative emissions that rely either directly (through afforestation) or indirectly (through electricity production from biomass with carbon capture and sequestration) on forestry and land use. Given its natural endowments—especially its forestry and biodiversity—the LAC region has the potential to reduce net emissions in a cost-effective way. In that regard, these scenarios also illustrate that it may be

[15]See ECLAC, 2020, for a further description of the menu of policy options for emissions reductions with a focus on the LAC region.

more cost-effective for the world to compensate LAC countries for utilizing their lower-cost-mitigation potential than to devote the same resources to scaling up mitigation efforts elsewhere.

Country specifics will play a key role in defining the appropriate policy mix to reduce net GHG emissions and reach commitments under the NDCs. While the energy sector remains a large contributor to total emissions in LAC, the relatively large share of emissions from agriculture and change in land use calls for a multi-pronged approach to emissions reduction. Such an approach could involve a continued focus on increasing energy efficiency and shifting towards renewable energy sources, reduction in emissions from transportation and agriculture (Box 3), and policies directed at protecting or increasing natural carbon sinks such as forests. Furthermore, the region may face a new urgency to invest in alternative energy technologies to mitigate risks associated with its dependence on hydropower. These risks include ecosystem destruction and more frequent and severe weather events, especially droughts, which can render hydropower a more volatile and less reliable energy source. Countries should adopt the policy mixes that best suit their specific circumstances, ideally articulated as national strategies.

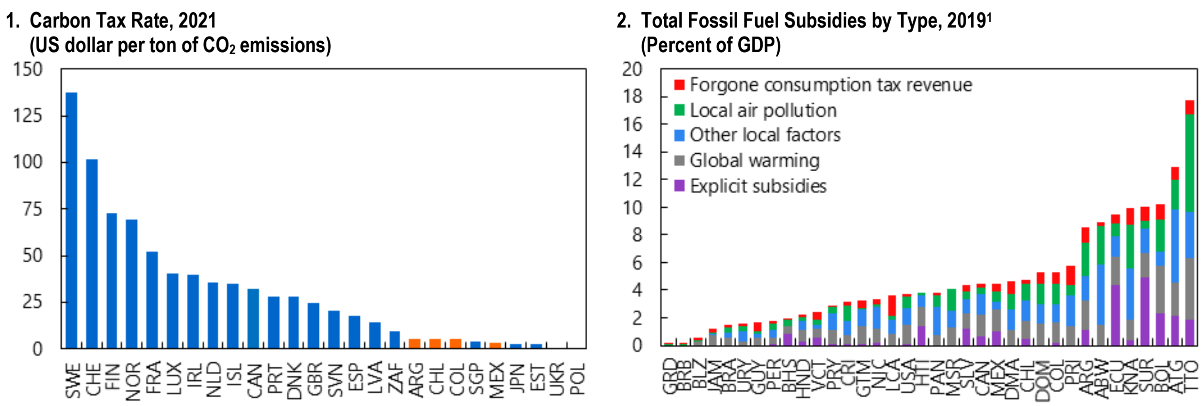
Policymakers in LAC have a variety of mitigation tools at their disposal. These tools can be divided into price-based mitigation policies (PBMP), which incorporate climate change costs in product prices, and non-price-based mitigation policies, which provide incentives to reduce GHG emissions, encourage the shift towards low-carbon activities, and enhance the natural carbon sinks that accumulate and store GHGs such as oceans and forests.

PBMP are effective mitigation policy options.

- *Carbon taxes*—levied on the supply of fossil fuels in proportion to their carbon content—are efficient instruments because they allow firms and households to find the least-cost ways of reducing energy use and shifting toward cleaner alternatives (*IMF, 2019a; IMF WEO, 2020*). Carbon taxes are an efficient tool for reducing demand for fossil fuels, but they may need to be set at high levels to achieve desired emissions reductions in countries with already low carbon content in energy generation and already high fuel prices, which may be politically and socially challenging. *Fossil fuel subsidy removal* increases the relative price of energy products thereby reducing their consumption and encouraging a shift towards low-carbon alternatives. Fossil fuel subsidy reduction is critical for emissions reduction but has proven politically and socially difficult in some countries. This implies that the design, phasing, and communications around a strategy to reduce or remove subsides would need to be carefully crafted to help ensure social acceptance and protection of the most vulnerable.
- *ETS*, which auction or allocate emission permits that are then traded (or provides carbon removal credits to create incentives for carbon capture) can be applied to a wide a range of economic activities, including energy, agriculture and forestry (Rickels, 2020). Implementation of ETSs in forestry and agriculture, however, would require well-defied property rights as well as good measures of agricultural emissions such as methane (CH_4) and nitrous oxide (N_2O).
- *Feebates* could also be applied in sectors that are hard to decarbonize such as transportation, agriculture, and forestry. Feebates tax (subsidize) activities and products with above (below) average emissions intensity (or above(below) the baseline level of carbon storage). Feebates help achieve cuts in emissions without adding a net tax burden on industry or a fiscal cost. They also have advantages over regulations since they provide incentives to adjust to technological change. At the same time, feebates typically have a narrower sectoral reach than carbon taxes and require periodic schedule adjustments to account for changes in consumption and emissions patterns.

PBMP have not been actively used in LAC. Only four LAC countries (Argentina, Chile, Colombia, and Mexico) have carbon taxes in place (Figure 8, panel 1) and, where implemented, the tax rates are low (in the range of US$1-10[16] per ton CO_2-eq) and only a portion of the GHG emissions (20-24 percent) is covered by the carbon taxes.[17] While many LAC countries have environmental taxes, including on energy, fuels and transport, these taxes collect less revenue (1.1 percent of GDP on average in 2018) than those in the OECD (2.2 percent of GDP on average). They are also not directly linked to the carbon content of the product and, hence, are less effective in creating incentives for emissions reduction. Some countries continue to have large fossil fuel subsidies. Explicit subsidies which reflect price deviations from supply costs, are particularly large in oil producing economies in LAC, exceeding 1 percent of GDP in some cases (Figure 8, panel 2). Implicit subsidies that reflect price deviations from efficient fuel prices, including environmental costs, are also large in some countries, particularly, in the Caribbean. Neither ETS nor feebates are actively used in LAC. However, Brazil has conducted voluntary ETS simulations since 2013 and feebates are currently under consideration in Costa Rica.

Figure 8. LAC: Carbon and Environmental Taxes, Fossil Fuel Subsidies, and Mitigation-Adaptation Nexus



Sources: World Bank, Carbon Pricing Dashboard (June 2021); and IMF staff calculations.
Note: Data labels use International Organization for Standardization (ISO) country codes. LAC = Latin America and the Caribbean.
[1]Other local factors" comprise road congestion, damage, and accidents. Fossil fuel subsidies include the following products: gasoline, diesel, kerosine, LPG, natural gas, coal, electricity.

Non-PBMP tools have been the primary focus of LAC policymakers to date and will continue to be important.

- *Public investment* in low-carbon technologies and infrastructure (e.g., electrification of public bus fleets, installation of solar panels and wind turbines, investment in more sustainable farming methods) could lower the cost of switching to sustainable practices. Public investment has the added benefit of directly contributing to a sustainable and inclusive post-pandemic recovery.[18]

- *Fiscal incentives* and *direct current public spending* could also help make low-carbon energy sources more abundant and affordable by tackling market failures such as knowledge spillovers, network externalities, and economies of scale, and thereby increasing demand for and supply of low-carbon products and activities (IMF WEO 2020). These policies could include subsidies and direct public funding for R&D as well as subsidies and price guarantees for low-carbon sectors and activities, potentially generating positive

[16] Since January 1, 2019 Argentina is applying a carbon tax of US$10/tCO2e to most liquid fuels. However, for fuel oil, mineral coal, and petroleum coke, the tax rate in 2019 was set at only 10 percent of the full tax rate (i.e., US$1/tCO2e), increasing gradually by 10 percentage points every year to reach a full rate of US$10/tCO2e by 2028 (see World Bank and Ecofys (2018)). Figure 8, panel 1 reports an average tax rate for Argentina.
[17]Not all countries' strategies rely on carbon taxes; see for instance IMF 2021b.
[18]Studies (e.g., Smulders et al., 2014) find that if economies aim at reducing emissions exclusively by reducing energy intensity, the resulting output contraction may be substantial. In contrast, the growth impact appears to be smaller when countries aim at both greater energy efficiency and low-carbon energy supply. Early investments in renewable energy sources, including public investment, are key to contain the negative supply shock countries otherwise might face.

spillovers to the private sector.[19] Despite government policies to incentivize green R&D in some LAC countries, such investment has remained limited, possibly reflecting the fact that LAC countries, like other emerging and developing economies, have benefited from international technological diffusion (Barret, 2021), which may also remain the case going forward. Government-financed educational programs could also help disseminate knowledge about low carbon technologies, induce change in behavior, and gather public support for climate actions. For example, agriculture extension programs, which disseminate knowledge about sustainable agricultural practices, could promote climate-smart farming practices and increase productivity and resilience of agriculture.

- *Supportive regulations* could encourage reduction in emissions and a shift toward low-carbon activities as well as protect and enhance the region's natural carbon sinks (see below). These could include: *emission standards* for industries, buildings, transport and products; *technological standards* to enhance fuel and energy efficiency; *product standards* to foster phasing out of polluting products and encourage the use of low-carbon products and activities, as well as *land and forest management standards* (Gabel, 2000). Regulations have the advantage of being politically easier to adopt by creating a more customized shadow price for carbon. However, they tend to be less cost-effective than price-based measures, raise no revenue that could be used to compensate the vulnerable, and involve uncertain costs for the consumer. Effective regulations are those that are predictable, impartial, and easily accessible, which requires robust anti-corruption safeguards in place (IMF 2020).

NbS may provide cost-effective opportunities for LAC to manage the region's natural resources in a way that reduces GHG emissions. NbS are innovative approaches that aim at protecting, managing, and restoring ecosystems. These policies can be geared towards addressing both mitigation and adaptation challenges. If grounded in a sound understanding of the ecosystems and biodiversity, NbS could support decarbonization through carbon capture and sequestration while limiting a sharp rise in carbon prices, help address food and water security, reduce natural disaster risk, increase biodiversity, and foster socio-economic development by creating green jobs (IUCN, 2016). Given the abundance of natural resources and ecosystems in LAC, there is room to utilize NbS through a combination of supportive regulations, incentives, feebates, and ETS.

To implement these mitigation policies and benefit from technological diffusion, a conducive business environment will be essential. This includes maintaining macroeconomic and financial stability (Box 5), establishing clear property rights, protecting intellectual property rights, strengthening competition, improving transparency, and fostering financial inclusion. To this end, countries should begin to incorporate climate-related risks and policies into macro-financial and fiscal frameworks and assign roles and responsibilities to public policy institutions in tackling climate change. Given the long-term nature of climate risks, fiscal institutions will naturally take the lead. Nonetheless, central banks can play an important role by incorporating climate risks in financial risk assessments and monetary policy design (e.g., in the assessment of potential output and neutral policy interest rates, or the appropriate policy response to adverse supply shocks emanating from extreme weather events).[20]

When designing climate mitigation strategies, political economy considerations will have to be taken into account (Box 4).[21] While overall climate mitigation policies are expected to yield positive aggregate welfare benefits over time (see below), there will be winners and losers during the transition to a greener economy. For example, the new green jobs may not benefit those workers who were previously employed in traditional energy sectors, given potentially different skill set requirements and geographic locations. The same holds for the shift from livestock to plant-based agriculture. To facilitate the transition,

[19]There is evidence that innovations in green technology, which could be induced by policies, can decrease the size of the carbon tax required to reach net-zero emission (see for instance, Fried, 2018; Acemoglu, 2016).
[20]For example, the Central Bank of Brazil has recently mandated the banks to incorporate climate change-related risks in their stress tests starting in December 2022.
[21]Furceri et al. (2021) shows that market-based climate policies have salient negative effects on popular support.

governments could use cash transfers to compensate households for consumption losses and active labor market policies to support displaced workers and facilitate jobs transition (see Furceri, Ganslmeier, and Ostry, 2021). In this regard, strengthening social safety nets early on would not only help reach and compensate the affected households but also foster trust in governments and help secure public support for climate mitigation policies.

These considerations, alongside the global nature of climate change, call for a national and global dialogue including all stakeholders. Advanced public consultation and careful sequencing and communication of mitigation reforms could help secure broad-based public buy-in. Learning from past unsuccessful attempts to reform fuel subsidies, climate policies should be phased in gradually, the objectives clearly articulated, the tradeoffs well-explained, and the social impact accounted for ex-ante to secure public support. Countries with high fuel subsidies could also consider phasing out fuel subsidies before resorting to other PBMP. Importantly, cooperation among countries for a synchronous move would not only yield high global climate dividends but also reduce the political cost of climate policies at the individual country level, in addition to limiting the risk of carbon leakage. In this context, governments could emphasize the cost of inaction in their national campaigns for climate change.

Price-Based Mitigation Policies in LAC: An Illustration

This section provides an illustrative assessment of the impact of an increase in the price of carbon on emissions and economic indicators in LAC. Economic models of climate change are still evolving and have high degree of model and data uncertainty, which means that the results of these models should be taken as indicative rather than precise numerical estimates. The analysis focuses on selected fiscal policy options using the Carbon Pricing Assessment Tool (CPAT) developed by IMF and World Bank (see Annex 3).[22] The analysis of other policy instruments is beyond the scope of this paper and is an area for future research. The scenarios presented in this section are illustrative and are not meant to be prescriptive: countries will need to choose the mix of tools that is most appropriate for their specific circumstances.

By 2030, under the Business-As-Usual scenario (BAU), model estimates suggest that most countries will retain gaps in emissions reductions relative to their NDC commitments ("NDC gaps"). Under BAU, greenhouse gas emissions excluding LULUCF will increase slightly for most countries by 2030 as a result of two offsetting effects: (i) continued economic growth and, therefore, growing fossil-fuel consumption, which increases emissions; and (ii) reduced energy intensity due to improvements in energy efficiency and rising international petroleum prices, which lower fossil-fuel consumption and, therefore, reduce emissions.

The illustrative analysis follows a two-stage approach to simulate an increase in the price of carbon. First, we analyze the impact on emissions of a gradual and complete removal of existing fossil fuel subsidies between 2022 and 2025. Second, in addition to the gradual and complete subsidy removal, we analyze the impact of a gradual introduction of carbon taxes of \$25/ton, \$50/ton and \$75/ton from 2022 to 2030.[23] The carbon taxes are levied on each unit of GHG emission from fuel combustion.[24] The fiscal revenue from the carbon pricing policies is assumed to be recycled back to the economy, through universal cash transfers to the households.

[22]The impact on emissions from a carbon tax is estimated using Carbon Pricing Assessment Tool (CPAT) developed by IMF and World Bank staff, which evolved from an earlier IMF tool used, for example, in IMF (2019a and b). For descriptions of the model and its parameterization, see IMF (2019b) Appendix III, and Parry et al. (2021), and for further underlying rationale see Heine and Black (2019). The model and data used here were last updated on October 6, 2021.

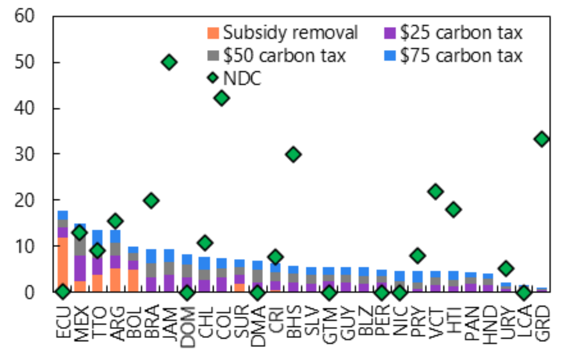
[23]The carbon taxes mentioned are 2030 targets. The starting carbon tax in 2022 is assumed to be 1/3 of the 2030 target. Carbon taxes rise linearly to reach the 2030 target. After 2030, carbon taxes keep rising with the same trend.

[24]For example, combustion of one liter of gasoline emits 2.4kg of CO_2. A \$50/ton carbon tax will translate to \$0.12/liter levy for gasoline.

Model estimates suggest that increasing the price of carbon could help closing NDC gaps in many LAC countries, although some countries in the region would remain far from their NDC goals. Phasing out of fossil fuel subsidies would substantially reduce emissions in countries with large subsidies (Figure 9).[25] Further gradual introduction of $25/ton, $50/ton and $75/ton carbon taxes by 2030 would reduce NDC gaps for many LAC countries (Figure 9). Nonetheless, some countries in the region, including Colombia, Jamaica, and some other Caribbean economies, would remain far from their NDC goals. In the rest of this section, the analysis focuses on a carbon tax of $50/ton.

Figure 9. Reduction of Gross GHG Emissions (excluding LULUCF) from Illustrative Scenario of Subsidy Removal and Carbon Tax

(Percent of 2030 BAU emissions)



Sources: IMF, Carbon Pricing Assessment Tool; and IMF staff calculations.
Note: NDCs are harmonized to 2030, to exclude LULUCF, and to be unconditional, or, where available, the average of conditional and unconditional. For some countries, NDCs are not shown because they are difficult to quantify. Data labels use International Organization for Standardization (ISO) country codes. BAU = business as usual; LULUCF = land use, land-use change, and forestry; NDC = nationally determined contributions.

The analysis suggests that the increase in the price of carbon would raise fuel prices substantially in some cases, but would also mobilize significant fiscal revenues that could be used to compensate vulnerable groups.

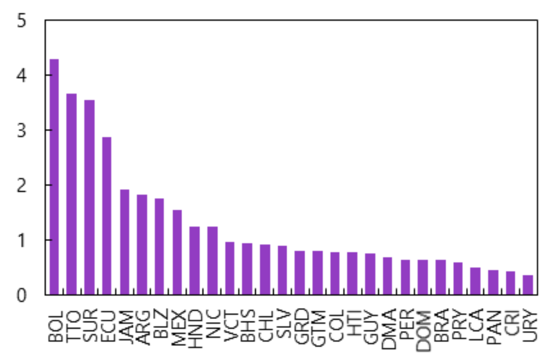
- With fossil fuel subsidy removal and a $50/ton carbon tax, model estimates suggest that, in many countries, gasoline prices would increase by 10–30 percent by 2030, natural gas prices would rise by around 30 percent, and coal prices would double or triple.[26] The price impacts differ across countries depending on initial price levels and the carbon content of products.

- At the same time, countries can raise significant fiscal revenues between 0.5 percent and 4.5 percent of GDP (Figure 10). While staff estimates indicate that the impact of subsidy removal and carbon taxes on growth is generally negative,[27] it could be offset to a large extent by "recycling" of collected revenues back into the economy through cash transfers. Moreover, countries could compensate for the effects on activity with an upfront green investment push as suggested in IMF WEO, 2020.

- In addition, there will be environmental and health welfare benefits not captured by GDP, including lower air pollution mortality and morbidity, reduced road fatalities, direct economic savings due to reduced road damages

Figure 10. Impact on Fiscal Revenue from Illustrative Scenario of Subsidy Removal and Carbon Tax

(Percent of GDP versus 2030 BAU)



Sources: IMF, Carbon Pricing Assessment Tool; and IMF staff calculations.
Note: Data labels use International Organization for Standardization (ISO) country codes. BAU = business as usual.

[25]The analysis in this section includes a removal of explicit fossil fuel subsidies only. A gradual and complete removal of fossil fuel subsidies (both explicit and implicit) by 2025, which would amount to not only removing explicit subsidies but also introducing optimal carbon taxes for each country such that they fully eliminate implicit subsidies, could reduce regional carbon dioxide emissions by 24 percent below the baseline levels in 2025, raise revenues by 1.7 percent of regional GDP, and prevent 35,000 local air pollution deaths annually.

[26]The fossil fuel subsidies are phased out over 3 years (2022–25) and the carbon tax is assumed to rise linearly from $17 to $50/ton between 2022–30.

[27]The negative effects on GDP of carbon taxes in CPAT are similar to those obtained in CGE models. However, the empirical evidence on such effects is rather inconclusive and point to roughly no effect of the tax on GDP or employment growth (Metcalf and Stock, 2020).

and traffic congestion, and fewer extreme weather phenomena associated with climate change (assuming global cooperation). Previous studies[28] suggest that the net welfare effects of these policies will be positive for most countries.

The increase in the price of carbon would, however, have a differential impact across households. Differential energy intensity of household consumption, varying purchasing power, and differential exposure of labor to carbon-intensive sectors will result in an uneven impact from a higher carbon price. The increased carbon pricing would have a direct adverse impact on household consumption due to the outright increase in energy prices. It would also have an indirect effect on consumption through an increase in the price of a broad set of products affected through sectoral linkages as measured by the Input-Output matrix (I/O matrix henceforth) (Annex 4). Third, households employed in the sectors negatively affected during the transition to low-carbon economy may experience a loss of income or employment.

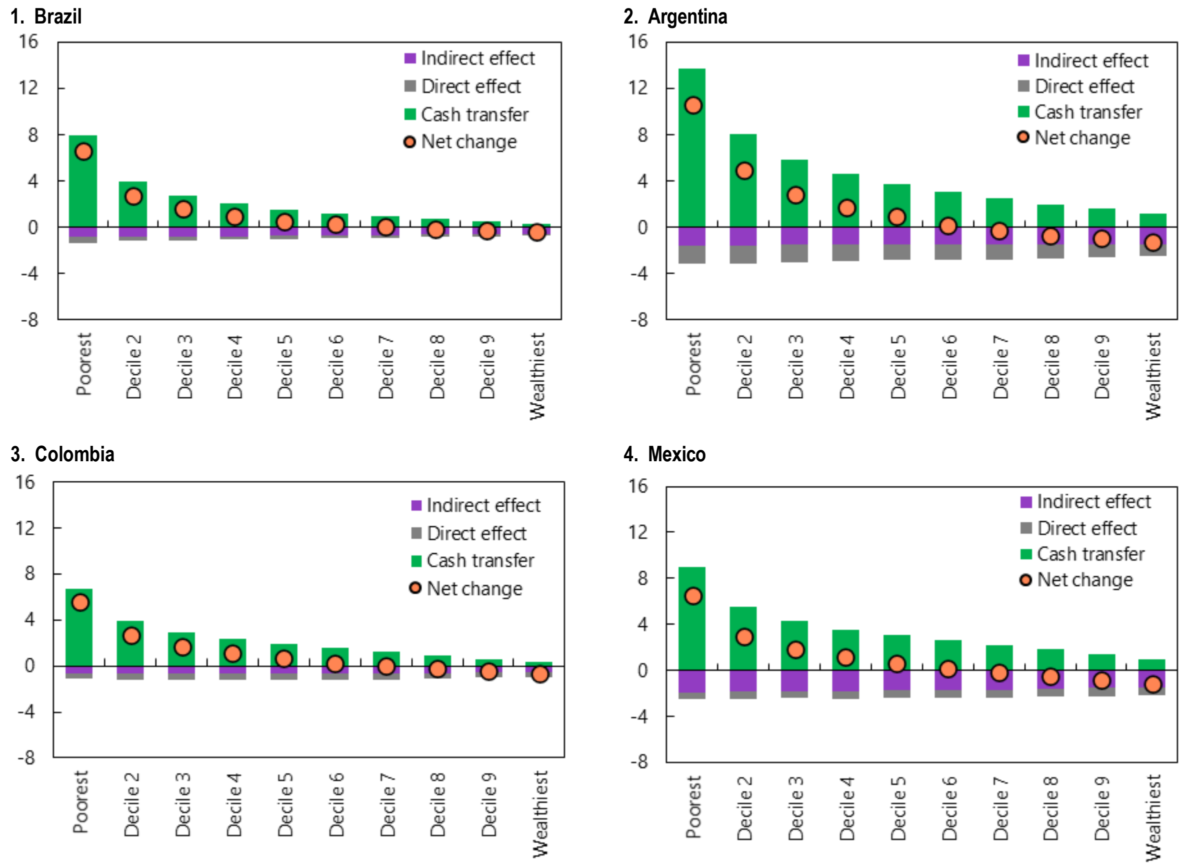
The impact of an increase in the price of carbon would also vary by country. It would depend on the country's initial energy mix, the size of the simulated carbon price adjustment, and the strength of upstream linkages with energy sectors. The size of the simulated carbon price adjustment—which reflects both the removal of fossil fuel subsidies and the introduction of the carbon tax—would be larger in countries that need to phase out relatively high fossil fuel subsidies simultaneously with the introduction of the carbon tax (Annex Figure 4.1). The impact of the simulated carbon price adjustment on the price of goods consumed by households depends on the increase in the price of energy, which will be higher in countries that rely on more carbon-intensive energy sources, and the strength of the transmission of price increases to other sectors (Annex 4 and Figure 11).

Compensatory fiscal policies can go a long way in alleviating the impact of an increase in the price of carbon on low-income households. Governments could use part (or all) of the revenue proceeds from the carbon tax and subsidy removal to compensate households for consumption loss, for example through existing or new cash transfer programs. This could also make the reform more politically and socially acceptable. Simulations based on the CPAT model, household survey data, and I/O matrices (Annex 4), suggest that—absent compensatory policies—the consumption impact of a carbon tax and subsidy removal could be relatively large and somewhat regressive. The overall policy package, however, is estimated to become highly progressive when universal cash transfers are used to compensate households for consumption loss (Figure 11).[29] In fact, the model estimates suggest that universal cash transfers could fully offset the adverse impact of the increase in the price of carbon on household consumption in the first six to seven deciles of per capita household consumption in Argentina, Brazil, Colombia, and Mexico. Positive domestic environmental and health benefits as well as global climate dividends from lower GHG emissions would provide additional benefits to households not captured in this distributional analysis. In practice, governments could adopt a more targeted approach to compensating households by leveraging existing social safety nets to focus on the most vulnerable households.[30] This would allow them to channel part of the increase in fiscal revenues to green public investment.[31]

[28]See for example, Nordhaus (2008), Parry et al (2014), and Stern (2006).
[29]Each person in the economy receives the same amount of transfer (unconditionally) under a universal cash transfer scheme.
[30]Governments could leverage progress in expanding the coverage of cash transfers achieved during COVID-19. For instance, the Emergency Aid program reached up to 60 percent of Brazil's total workforce at the pandemic peak (see Cunha et al., 2021, *forthcoming*).
[31]Our choice of full recycling through cash transfers is motivated by technical considerations; it allows us to fully capture the multiplier associated with the extra revenue in the absence of evidence on the distributional impact of public investment along per capita household consumption deciles for countries in our sample.

Figure 11. Estimated Consumption Impact from a US$50 Carbon Tax and Fossil Fuel Subsidy Removal, Before and After Cash Transfers

(Percent of per capita consumption)



Sources: IMF, Carbon Pricing Assessment Tool; and IMF staff calculations.

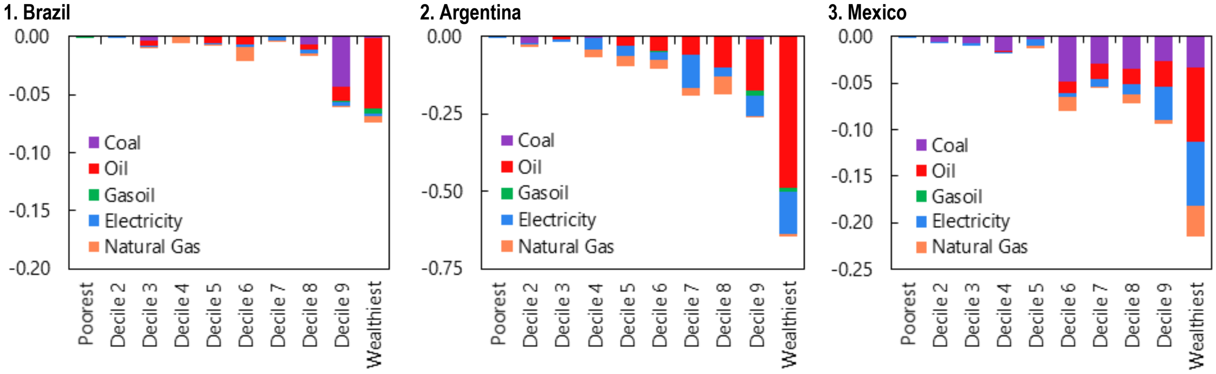
Absent compensatory policies, workers in carbon-intensive sectors may experience an additional loss of income or employment. The increased price of carbon and commensurate decline in the demand of less clean energy products could imply additional loss of income or employment for workers in carbon-intensive sectors.[32] Simulations, using sectoral microeconomic data, suggest that the aggregate impact of an increase in the price of carbon on income would be limited, affecting less than 1 percent of employed persons in Argentina, Brazil, and Mexico, reflecting the small overall size of the energy sectors in these economies.[33] However, the impact would vary by income decile, sector, and region (Figure 12). Notably, the analysis suggests that the impact would remain small in Brazil across all income deciles and larger and more progressive in Argentina in the absence of compensatory measures. The impact is larger in sectors with higher carbon intensity (oil and electricity in the case of Argentina, coal and oil in Brazil, and coal, oil and electricity in Mexico). Important within-country regional disparities are also likely to ensue given the high geographic concentration of energy activities (Annex Figure 4.2).

[32]Our calculations assume a price elasticity of energy products of -0.25, as in IMF (2020). A 100 percent increase in the price of any of the energy products—coal, oil, electricity gasoil, and natural gas—therefore reduces real demand by 25 percent, leading to an equivalent reduction of labor income or employment under the assumption of unchanged labor productivity.

[33]Labor income could also be affected indirectly in other sectors such as transportation and manufacturing.

Figure 12. Estimated Gross Labor Income Loss in the Energy Sector from Carbon Tax and Fossil Fuel Subsidy Removal

(Percent of total labor income of households in all sectors for each income decile)



Sources: National authorities; and IMF staff calculations.

However, these income/job losses could be offset by job gains in the new cleaner energy sectors.[34] Alongside the aforementioned additional health and environmental benefits, the shift to cleaner energy would provide job and income opportunities,[35] including those arising from LAC's potential for exporting "green" commodities (Table 1).[36] A policy mix that balances carbon pricing with a green investment push, as discussed in IMF WEO, 2020, is likely to have positive long-run effects on activity and employment. Specifically, a public green investment push starting with 1 percent of GDP and declining over 10 years, combined with renewables production subsidies, a pre-announced gradual increase in carbon taxes, compensatory transfers to households, and supportive macroeconomic policies, is estimated to increase employment by around 1 percent of the labor force in 10 years.[37] These newly created green jobs could potentially offset income/job losses in carbon-intensive sectors but much would depend on the labor intensity of such industries and the quality of those new jobs that are created. An example of the positive impact of an investment push for renewable energy sources on the creation of low-skilled jobs is Brazil's National Alcohol Program launched in 1975 (Box 2). The green investment push, however, will require substantial financing (Section IV), which could only partially be covered with revenues from carbon tax/fossil fuel subsidy removal.

Table 1. Exports of "Green" Commodities

(Annual average during 2016–19)

Exports of	Percent of GDP	Percent of Exports
Copper		
Chile	6.160	21.829
Peru	5.087	21.206
Brazil	0.120	0.915
Mexico	0.161	0.420
Argentina	0.096	0.689
Dominican Republic	0.063	0.267
Colombia	0.015	0.096
Ecuador	0.024	0.106
Bolivia	0.055	0.219
Nickel		
Guatemala	0.064	0.350
Brazil	0.000	0.004
Lithium		
Chile	0.034	0.122
Cobalt		
Brazil	0.000	0.001

Sources: UN Comtrade; and IMF staff calculations.
Note: Based on some levels of exports of the commodity, Colombia shows potential for lithium and nickel; Ecuador for cobalt and lithium; and Brazil and Panama for lithium.

[34]IEA (2021) estimates that 14 million green jobs and 30 million green and related jobs could be created by 2030 during the green transition, approximately equivalent to 0.4-1 percent of the global labor force. This would translate into 1.2 million green jobs and 2.6 million green and related jobs by 2030 in LAC, based on LAC's share in the global economy.

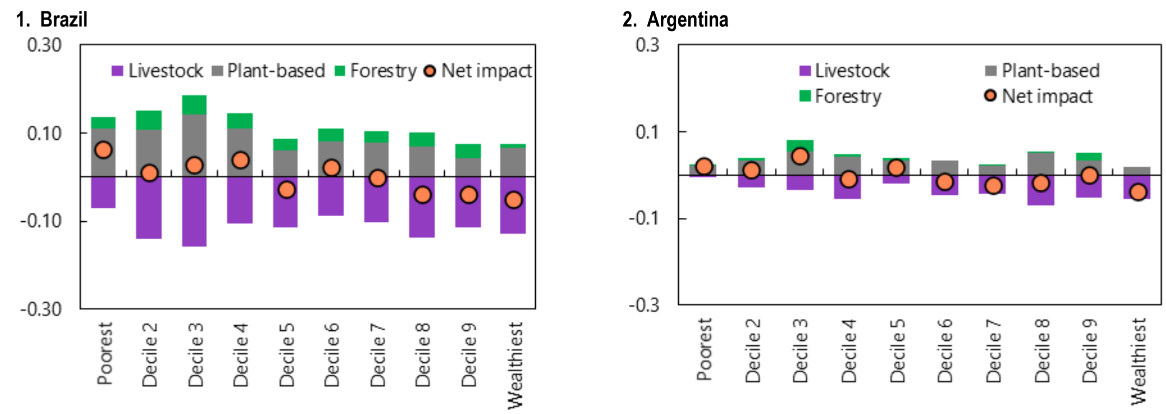
[35]For instance, using firm-level CO_2 emissions data for 31 advanced economies and large emerging economies (including Brazil), Mohommad (2021) finds evidence that while a tightening in environmental policy stringency leads to a reduction in labor demand by high emission-intensity firms, labor demand by low emission-intensity firms increases, which suggests a reallocation of employment. The author finds modest net positive changes in employment for market-based policies and modest net negative changes for non-market policies.

[36]Some LAC countries (e.g., Argentina, Brazil, Colombia, Chile, Peru, Bolivia) are already exporting these "green" commodities such as copper, nickel, lithium, and cobalt, while others (Mexico) may benefit from recently discovered reserves of lithium.

[37]Specifically, the package in IMF WEO, 2020 includes 10-year green public investment program in the renewable and other low-carbon energy sectors, transport infrastructure, and services starting at 1 percent of GDP and linearly declining to zero over 10 years (after 10 years, additional public investment maintains the created green capital stock), 80 percent subsidy rate on renewables production, carbon tax starting at $8-18 per ton of CO_2 (depending on the country) and growing by 7 percent annually, compensatory transfers to households (equal to ¼ of carbon tax revenues) and supportive macroeconomic policies (the policy package above requires debt finance for the first decade and occurs against a backdrop of low-for-long interest rates in the low inflation context).

Policies to reduce GHG emissions could also adversely affect livestock farmers, but a shift to plant-based agriculture would present employment and income opportunities. An ambitious emission reduction strategy in LAC would have to include the adoption of sustainable agricultural practices, especially in livestock for which the emissions intensity is several folds that of plant-based agriculture.[38] Latin America's high food trade surplus (about 3 percent of MERCOSUR's GDP in 2019), exposes the region to shifts in demand for food not only domestically but also from abroad. While the potential global shift from beef consumption towards plant-based diets would adversely affect some livestock farmers, it would present employment and income opportunities in plant-based agriculture.[39] Simulations suggest that the estimated net income impact of the adjustment to low GHG emissions on farmers would be more uniformly distributed across income deciles compared to the progressive impact of carbon tax in the energy sectors (Figure 13).[40] For a given GHG emissions reduction in agriculture, the estimated average gross employment/labor income loss in livestock would be higher in countries with a higher initial level of employment in livestock (e.g., Brazil where livestock accounts for 3.9 percent of employment, as opposed to 1.2 percent in Argentina).[41] The government could support adversely affected livestock farmers by facilitating their transition towards plant-based agriculture (the simulation in Figure 13 does not include such measures). The land released from livestock agriculture can also contribute to afforestation.[42]

Figure 13. Estimated Labor Income Gain/Loss from Reduced Greenhouse Gas Emissions in Agriculture
(Labor income gain/loss; percent of total labor income of households in all sectors for each income decile)



Sources: National authorities; and IMF staff calculations.

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[38]Panel data estimation suggests an emissions intensity ratio of six-to-one between livestock and plant-based agriculture in Latin America. See Batini (2021) for a detailed analysis of economic policies to foster healthy diets while establishing sustainable food practices.
[39]Grocery sales of plant-based foods that directly replace animal products are on the rise in the U.S., according to the Good Food Institute (2021). A recent joint IDB-ILO report estimates that the shift from a meat- to plant-based diet in the move to a net-zero emission economy would lead to a net full-time equivalent jobs gain of 14.7 million in LAC's agri-food industry by 2030 (see Saget et al., 2020). Their simulations assume that two-thirds of household baseline spending on animal-based products is replaced by 2050 with spending on plant-based products, a stronger shift than the one implied by the simulations in this chapter.
[40]We identify farmers in household surveys based on the reported granular sector of employment.
[41]The required emission reduction in agriculture is assumed to come entirely from livestock, given the much higher emission intensity of livestock compared to plant-based agriculture (six-to-one ratio). We assume that livestock is reduced proportionally to the required emissions reduction in agriculture between the baseline and policy scenario, which based on CPAT simulations, corresponds to a decline in livestock by about 3 percent by 2030 in Brazil and Argentina. We also assume that the resources previously used for livestock, including labor, are repurposed for plant-based production, which may require some government's transitory support. The reduction in livestock also leads to a reduction in plant-based feeds for animals, which LAC could recoup by leveraging its comparative advantage in food products. In addition, we assume that forestry activity will increase proportionally with the required emissions reduction, given the important role of afforestation in curbing emissions in LAC.
[42]The scenario presented in this chapter is illustrative—the extent of the shift from livestock to plant-based agriculture and the increase in forestry activity (afforestation) will vary across countries, depending on how constraining it would be to repurpose resources, including land.

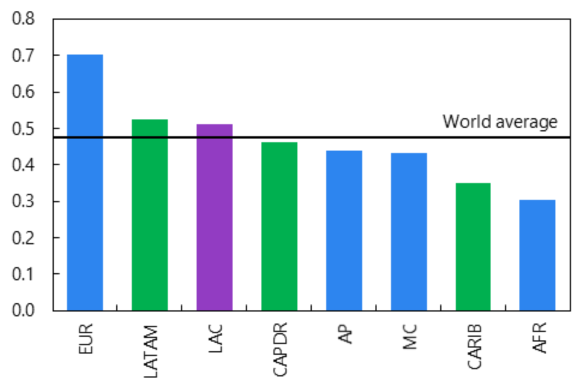
Climate Adaptation

Strengthening Climate Adaptation in LAC

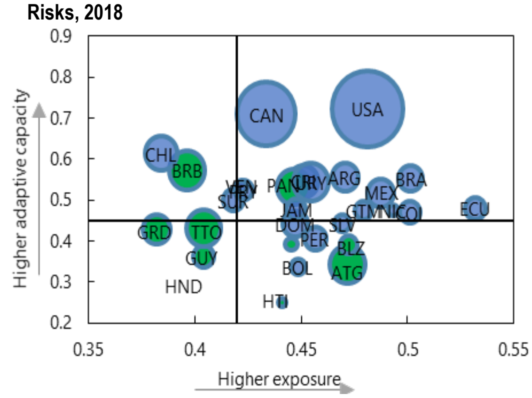
Although all LAC countries face challenges in adapting to climate change, it is a high priority for the vulnerable countries of the Caribbean and Central America. Many LAC economies have adaptive capacity—defined by ND-GAIN as the availability of social resources for sector-specific adaptation—above the world average, partly counterbalancing their high exposure and sensitivity to climate change (Figure 14, panel 1).[43] However, many countries in the Caribbean and Central America have both high exposure to climate risks and low adaptive capacity (Figure 14, panel 2).

Figure 14. Latin America and the Caribbean: Scope to Strengthen Adaptive Capacity

1. **LAC's Overall Adaptive Capacity is In Line with the World Average, 2018**



2. **Many Caribbean and Central American Countries Have Low Adaptive Capacity Relative to Their Exposure to Climate-Related Risks, 2018**



Sources: ND-GAIN database; and IMF staff calculations.
Note: Capacity index is the difference between one and the ND-GAIN capacity indicator so that higher values indicate greater capacity. In 13.1, EUR = Europe; CAPDR = Central America, Panama, and the Dominican Republic; AP = Asia and Pacific; MC = Middle East and Central Asia; AFR = Africa; CARIB (Caribbean) = Antigua and Barbuda, Barbados, Belize, Grenada, Guyana, Haiti, Jamaica, Suriname, Trinidad and Tobago; LAC = Latin America and the Caribbean; LATAM (Latin America) = South America, Mexico. Regional and world averages are weighted by annual population as of 2018. In 13.2, bubble size indicates per-capita GDP in USD (2019), vertical (horizontal) line indicates world simple average for exposure (capacity) indicator, and data labels use International Organization for Standardization (ISO) country codes.

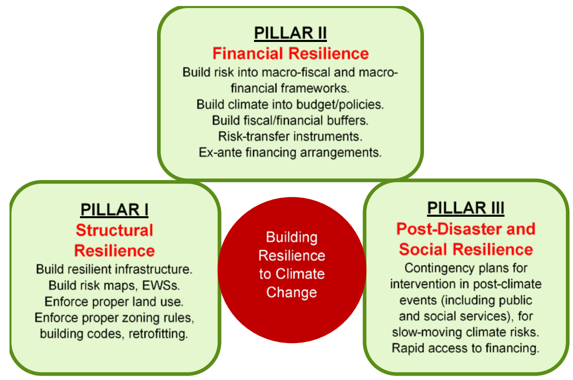
LAC countries are taking steps to build climate resilience, but important gaps remain in countries that are highly vulnerable to physical risks of climate change. More than 60 percent of the region's national adaptation plans include adaptation policies that target upgrading climate-resilient infrastructure, reversing deforestation, and protecting biodiversity and ecosystems. However, many disaster-vulnerable countries in the Caribbean and Central America have invested insufficiently in ex-ante (before a disaster hits) resilience-building and rely heavily on post-disaster recovery efforts which are typically more costly from a public finance standpoint (IMF 2019d). In many countries, upgrading infrastructure (e.g., adequate drainage systems, disaster-resilient roads) has been superseded by other urgent social and development needs, reflecting limited fiscal space and sometimes policymakers' short time horizons. Moreover, cost considerations limit countries' ability to purchase substantial disaster insurance, while inadequate capacity to meet the complex access requirements to obtain financing from international climate funds poses additional

[43] ND-GAIN assesses the vulnerability of a country to climate change risks by considering the exposure to climate-related hazards, the sensitivity to the hazards' impacts, and the adaptive capacity to cope with or adapt to these impacts, in six life-supporting sectors: food, water, health, ecosystem services, human habitat, and infrastructure. Raw data are scaled to a range from zero to one and the arithmetic average is used to construct each index. See details in ND-GAIN data technical document.

challenges to ex-ante investment in resilient infrastructure or setting aside dedicated funds.[44] In countries where climate-related risks are macro-critical, such underinvestment in climate resilience could result in a vicious cycle of depleted fiscal space and persistently weak climate resilience, leading to ever-growing climate vulnerability. For LAC countries where tourism represents a major economic source, resilience building is key to prepare and adapt the tourism sector to climate change. Indeed, IMF-World Bank Climate Change Policy Assessments (CCPAs) conducted for three countries in the Caribbean estimate the investment gaps in resilience building (the difference between required investment for building resilience and current investment levels) at 2–3 percent of GDP a year over a decade or more (IMF 2019d).[45]

A comprehensive medium-term approach is needed to help LAC's most vulnerable countries prepare for climate-related disasters (Figure 15). The IMF's Disaster Resilience Strategy (DRS) framework was created in 2019 to internalize the costs and returns of resilience building into sustainable macroeconomic frameworks consistent with debt sustainability (IMF 2019d). In the Caribbean, Dominica and Grenada have developed such DRS with IMF's support (IMF 2021a). Such a strategy can help quantify financing needs and gaps, provide a roadmap for policy design and sequencing, and promote coordinated international support. A DRS entails a three-pillar approach.

Figure 15. Building Resilience to Climate Risks



Sources: IMF (2019d).

- Enhancing *structural resilience* requires infrastructure and other ex-ante investments to limit the impact of disasters, including "hard" policy measures (e.g., upgrading infrastructure, developing irrigation systems, ensuring resiliency of roads, bridges, buildings and public service infrastructure), and "soft" measures (e.g., early warning systems, customizing building codes and zoning rules) (Pillar I);
- Building *financial resilience* involves creating fiscal buffers and using pre-arranged financial instruments to protect fiscal sustainability and manage recovery costs (Pillar II);
- *Post-disaster and social resilience* require contingency planning and related investments ensuring a speedy response to a disaster (Pillar III).

Scaling up investment in *structural resilience* would yield significant long-run benefits to the most climate-vulnerable countries in LAC. Resilient public capital—such as durable roads, bridges, and sea walls—can reduce future expected losses from natural disasters and, as a result, increase expected returns to private investment and output (even if no disaster occurs). IMF staff simulations, based on a dynamic stochastic general equilibrium model for climate adaptation (Annex 5),[46] suggest that investing in resilient public capital can lead to an increase in employment and wages and a decline in outward migration, which is generally high in countries prone to natural disasters. Higher output and employment would in turn increase tax revenue, improving the fiscal balance. The simulations indicate that such investment can boost the level of GDP in the long run between 2 and 6 percent for Caribbean islands and between 0.2 and 1.4 percent for

[44]For instance, the cost of parametric insurance and catastrophe bonds (or "cat bonds", which are also based on parametric triggers) is estimated to be 1.5–3.2 times the expected annual payout, reflecting, for instance, large tail risks facing vulnerable countries, geographical correlation of risks across potential buyers, and thin insurance markets facing small states (IMF 2019d).
[45]Climate Change Policy Assessments are a joint IMF-World Bank assessment introduced on a pilot basis in 2017 and provide a diagnostic of climate change preparedness (IMF 2016).
[46]The model assumes that resilient infrastructure is a perfect substitute for standard infrastructure but is 25 percent more expensive. Keeping the physical amount of public investment unchanged, countries are assumed to allocate 80 percent of investment in resilient capital. The outcome in terms of output and fiscal performance is then compared with a situation where no resilient capital is in place.

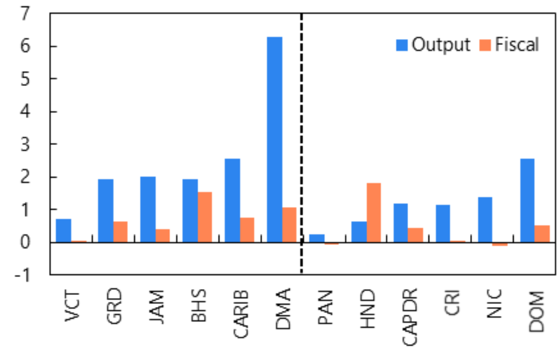
Central American countries (Figure 16). The gains are larger in the Caribbean than in Central America, since the former has higher damages from natural disasters relative to the size of the economy and a larger share of public investment in GDP. Despite higher upfront costs of investing in resilient public capital, there are long-run fiscal gains from these investments that generate lower replacement costs following a natural disaster.[47]

In addition, once structural resilience is achieved, resilient capital also offers important output and fiscal gains in the aftermath of a natural disaster.[48] The model results suggest that—once resilient capital is installed—the level of output would be around ¼ percent higher three years after a natural disaster in the Caribbean on average and around 0.1 percent higher for Central American countries (Figure 17). The level of public debt is estimated to be ¾ percentage point lower after three years in the Caribbean and around ¼ percentage point lower in Central America. The improvement in public debt derives from lower reconstruction spending (as less capital needs to be replaced) and lower revenue losses owing to the smaller decline in economic activity.

Because building structural resilience takes time, *financial resilience* would also be needed to ensure funding for reconstruction while safeguarding public finances. Financial resilience in the form of comprehensive layered insurance should aim to provide adequate coverage against the expected capital and revenue losses after major natural disasters and internalize the expected fiscal costs of post-disaster support. IMF staff simulations based on a stochastic model (Guerson 2020) indicate that insurance coverage of 15–30 percent of GDP for Caribbean countries and 10–20 percent of GDP for Central American countries could cover 99 percent of the fiscal costs related to natural disasters (Figure 18, panel 1). This calculation is based on an illustrative insurance framework with three layers, based on the World Bank risk-layered framework for disaster risk

Figure 16. Output and Fiscal Gains from Resilient Investment in the Long Run

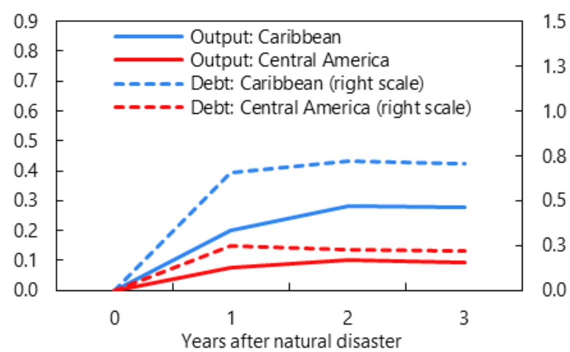
(Change relative to no resilience; Output; percent; Fiscal: percentage points of GDP)



Sources: Caribbean Catastrophe Risk Insurance Facility; EM-DAT database; and IMF staff calculations.
Note: Aggregates are simple averages. Data labels use International Organization for Standardization (ISO) country codes. CARIB = Caribbean (BHS, DMA, GRD, JAM, VCT); CAPDR = Central America, Panama, and the Dominican Republic (CRI, DOM, HND, NIC, PAN).

Figure 17. Output and Public Debt Gains from Resilient Investment After Natural Disaster Event

(Left scale: Percent; Right scale: Percentage points)



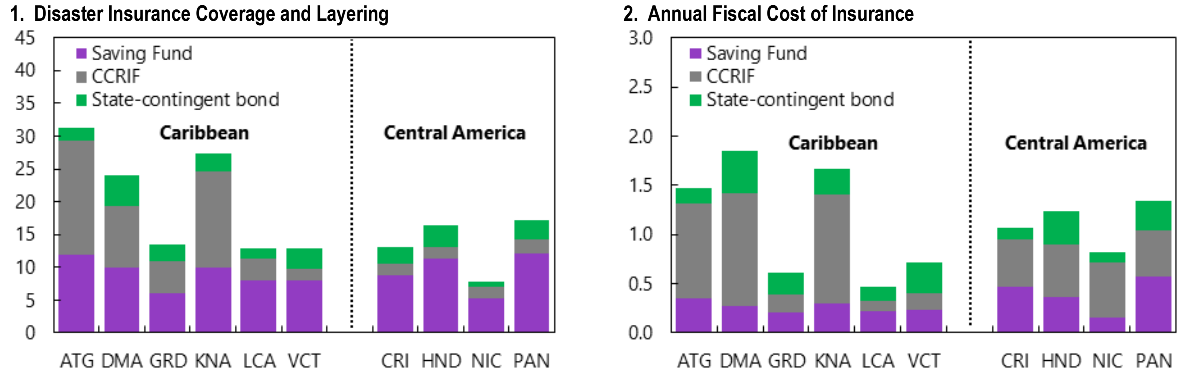
Sources: Caribbean Catastrophe Risk Insurance Facility; EM-DAT database; and IMF staff calculations.

[47]The model includes Bahamas, Dominica, Dominican Republic, Grenada, Jamaica and St. Vincent and the Grenadines in the Caribbean, and Costa Rica, Honduras, Nicaragua and Panama in Central America. The simulation results are consistent with earlier estimates for the ECCU (IMF 2019c). The potential gains from resilience investment are even greater if it can be further scaled up at affordable terms beyond the projected public investment levels. Staff will conduct further analysis on adaptation on larger LAC economies in the future where it is macro-critical. As shown in World Bank (2019), there can be significant net benefits of investing in more resilient infrastructure in low- and middle-income countries around the globe.

[48]Staff estimates that a large increase in investment rates with concessional financing for 10 to 20 years would be needed to build resilience to natural disasters, using concessional financing. Without such additional concessional financing and maintaining current investment rates, it would take twice that time to achieve resiliency. For instance, using the standard inventory method and capital depreciation rate assumption for the accounting of the capital stock, staff estimates that without concessional financing, it would take 30 to 40 years of investment in resilience to achieve 80 percent of capital resiliency (see IMF 2019c). However, the rewards from adaptation (in terms of lost output following a natural disaster) accrue as soon as resilient capital starts being stalled, increasing with the share of resilient capital.

financing (World Bank 2017). Ranked by their incremental costs, the layers include: (i) building a precautionary government savings fund for immediate post-disaster liquidity needs against relatively less damaging but more frequent natural disasters; (ii) scaled-up access to parametric insurance under the Caribbean Catastrophe Risk Insurance Facility (CCRIF) against less frequent but larger natural disasters with damages beyond the scope of the savings fund;[49] and (iii) issuance of state contingent bonds to provide debt relief for extreme events.[50]

Figure 18. Financial Resilience Simulations: Disaster Insurance Coverage and Cost
(Percent of GDP)



Sources: National authorities; and IMF staff calculations.
Note: Authorities' data and disaster loss function estimates from CCRIF. Calibrated to achieve coverage of 99 percent of disaster loss. Includes risk of tropical cyclones and earthquakes. Data labels use International Organization for Standardization (ISO) country codes. CCRIF = Caribbean Catastrophe Risk Insurance Facility.

The simulations also suggest that, while comprehensive insurance coverage is expensive, insurance needs and fiscal costs would decline significantly over time. The simulated annual cost of the illustrative insurance coverage above would initially be in the range of 0.5-2 percent of GDP per year (Figure 18, panel 2). As structures become more resilient, insurance requirements for the same coverage would decline in the long run to about one-fourth of the current level.

The near-term fiscal costs of structural and financial resilience would open a transitional financing gap for governments, since the benefits of climate resilience accrue over the medium and long-term.

- Building structural resilience involves upfront costs that can be very large relative to countries' fiscal capacity and economic size, while the returns in terms of higher output and fiscal revenue accrue over time. For small Caribbean states like Dominica, the total cost of building resilience is estimated at US$2.8 billion (about 500 percent of GDP) and would require over a decade to fully execute (IMF 2021a). Meanwhile, damages from natural disasters are projected to intensify significantly in a BAU climate scenario.
- In terms of financial resilience, while CCRIF has been a valuable instrument to improve the region's insurance coverage, the coverage remains low for many countries due to high upfront costs of insurance products, concerns that significant damages may not trigger payouts, and competing developmental

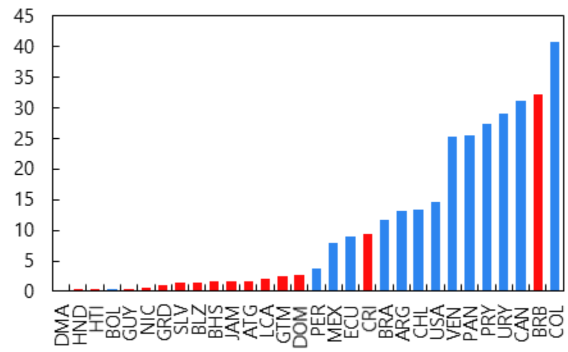
[49]CCRIF is a segregated portfolio company providing short-term liquidity to Caribbean and Central American governments when a parametric insurance policy is triggered. Current CCRIF members are Anguilla, Antigua and Barbuda, Bahamas, Barbados, Belize, Bermuda, British Virgin Islands, Cayman Islands, Dominica, Grenada, Guatemala, Haiti, Jamaica, Monserrat, Nicaragua, Panama, St. Kitts and Nevis, St. Lucia, Sint Maarten, St. Vincent and the Grenadines, Trinidad and Tobago and the Turks and Caicos Islands. Parametric insurance is a type of insurance contract that insures a policyholder against the occurrence of a specific event by paying a set amount based on the magnitude of the event.
[50]The saving fund size has been calibrated to cover the fiscal cost of natural disasters in 95 percent of the events, and access to CCRIF and issuance of CAT bonds is added to reach coverage of 99 percent. The simulations incorporate the impact of natural disaster shocks on output, tax revenue, grants and other non-tax revenue, recurrent expenditure, and capital expenditure. They also consider re-prioritization of expenditures (reconstruction largely replaces pre-existing projects).

needs. Use of innovative state-contingent instruments such as catastrophe bonds has remained limited, given their complexity, high setup costs, and capacity/regulatory constraints.[51]

- In the near term, as the scale of the region's adaptation investment is likely to depend heavily on availability of external concessional financing, including international climate funds, preparing a DRS is key.[52] In order to address fiscal sustainability, countries would need to create fiscal space with a combination of structural fiscal measures to generate savings, spending prioritization, and access to concessional financing and donor assistance. Additional efforts are needed to further enhance countries' capacity to meet the administrative requirements to obtain financing from climate funds.

Private sector investment in adaptation can have an important role in building resilience against climate risks, but it is held back by credit constraints and limited access to affordable insurance. This is particularly the case in the vulnerable Caribbean and Central American countries, where the private sector is mainly comprised of households and small businesses dependent on traditional banking and insurance services and faces a lack of alternative saving and financing instruments suitable for climate adaptation investment (Figure 19).[53]

Figure 19. Insurance Penetration Relative to Average Climate-Related Damages
(Percent of GDP, latest available)



Sources: EM-DAT database; World Bank, October 2019 Global Financial Development database; and IMF staff calculations.
Note: Insurance penetration represents the latest available annual data of nonlife insurance for each country (mostly 2017-2019). Average climate-related damages is for the period 1980–2020. Data labels use International Organization for Standardization (ISO) country codes.

- ***Credit constraints:*** High interest rates and shortages of qualifying collateral (mostly limited to fixed assets) represent long-standing impediments to credit access for households and small firms. The composition of bank credit is also skewed away from sectors most vulnerable to physical disaster risks (e.g., tourism and agriculture), which may in part reflect an organic response by lenders to these sectors' more uncertain risk-return profile.

- ***Limited access to affordable insurance:*** Vulnerable countries face high property insurance costs due to its high susceptibility to natural disasters. The costs may be further amplified by the small size of the primary insurance market which relies heavily on overseas reinsurance, implying a high regional pass-through of disaster-sensitive reinsurance pricing.[54] For instance, reinsurance costs in 2018 increased by 20–40 percent for countries hit by disasters the preceding year in the Caribbean, and 10–20 percent for other countries.

Governments could foster private sector adaptation investment through technical support, incentives, and policies to improve access to financial services. Climate risk information dissemination and services to support the evaluation of adaptation options could encourage broader private sector

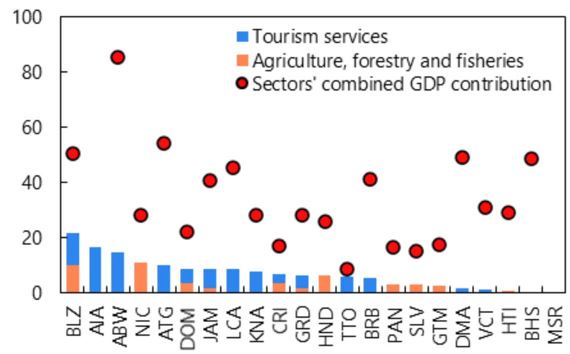
[51] Jamaica issued the first catastrophe bond that is independently sponsored by a Caribbean government in July 2021.
[52] For instance, as noted in IMF (2019c), a country with a public investment rate of 5 percent (the average of the Caribbean countries in Figure 16), increasing resilience to 80 percent would imply a fiscal deterioration of 1 percent of GDP each year if resilient capital is 25 percent more expensive as assumed in the simulations above. For countries in the Eastern Caribbean Currency Union (ECCU), which include Dominica, Grenada and St. Vincent and the Grenadines, IMF (2019c) estimates that the additional cost of resilience would increase the public debt by 4-20 percentage points of GDP in the ECCU countries by 2030. These would translate into additional financing gaps of 0.4 to 1.5 percent of GDP relative to historical levels.
[53] Larger hotels and resorts in the tourism sector are mostly foreign-owned and benefit from access to international financial services.
[54] In the ECCU for example, an estimated 60-75 percent of insurance premiums are ceded to reinsurance, and the ceded share is even higher for property insurance. The markets are a mixture of several local companies and a few cross-border conglomerates affiliated with international insurance groups.

engagement, while regulatory and fiscal incentives (e.g., targeted taxes, subsidies, or service pricing) could support a more attractive risk-return profile for adaptation investments. Introducing or scaling up partial public credit guarantee schemes or frameworks supporting use of alternative collateral (e.g., machinery or inventory) could both mitigate collateral constraints to financing and better leverage the regional financial systems' (excess) liquidity to support climate adaptation efforts. Facilitating risk pooling among private insurers, for instance through a public guarantee for any excess liability from natural disasters, can help mitigate costs and expand the availability of coverage.[55]

Efforts to boost private sector investment in adaptation would need to be accompanied by stepping up climate risk resilience of the financial system. In the Caribbean and Central America, direct financial sector exposure to natural disasters has so far been limited due to high insurance coverage gaps and limited lender credit exposure to the most vulnerable sectors, while losses from affected exposures have been mitigated by primary insurers' high reliance on reinsurance and lenders' high reliance on (insured) property collateral (Figure 20). However, greater use of local financial services to scale up adaptation investment would increase the system's direct physical risk exposures, particularly if reinsurers refrain from providing sufficient coverage.

Figure 20. Banking System Credit Exposures to Vulnerable Sectors

(Percent of total loans; latest available)



Sources: National authorities; World Bank; World Travel and Tourism Council; and IMF staff calculations.
Note: Anguilla and Montserrat's GDP contribution data are not available. El Salvador, Guatemala, Haiti, Honduras, Nicaragua, and Panama's tourism credit exposure data are not available. Information by country regarding exposure range from Dec. 2019 to May 2021. GDP exposures are based on data as of 2018 and 2019. Data labels use International Organization for Standardization (ISO) country codes.

Financial systems also need to adapt to intensifying indirect effects of physical climate risks. These include (i) risks emanating from natural disasters' impact on the broader macro-economy, which may be amplified in countries with high dependency on vulnerable sectors such as tourism or agriculture; (ii) (re)insurance pricing and counterparty risks, including the systemic tail risk of reinsurer's exit from the market;[56] and (iii) sovereign exposure risks, especially in countries where public sector linkages to the local financial systems are significant.

Strengthening supervision, reporting and regulatory frameworks could help build financial system resilience. Physical climate risks should be incorporated in existing supervisory frameworks, supported by reporting structures that allow for more granular monitoring of the various risk transmission channels and strengthened oversight arrangements of inter-institutional exposures. This could be accompanied by regulatory measures to support climate risk-aware lending practices, exposure diversification and prudential risk buffers, and ex-post asset recovery. Physical climate risks scenarios should also be integrated in the authorities' financial system crisis management plans to ensure adequacy of any necessary intervention frameworks.

Finally, timely and targeted policies will be also essential to prepare the fossil-fuel exporters of the region to a low-carbon environment and mitigate adverse macroeconomic consequences. Venezuela and Guyana are assessed to be among the least prepared economies for a low-carbon world, while other LAC fossil-fuel exporters are either moderately prepared (e.g., Bolivia) or relatively better prepared for low-carbon transition (e.g., Brazil, Colombia, Mexico) (World Bank 2020). Measures to improve export competitiveness

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[55]Examples include the National Flood Insurance Program (US), Florida Hurricane Catastrophe Fund, California Earthquake Authority, and New Zealand's Earthquake Commission.

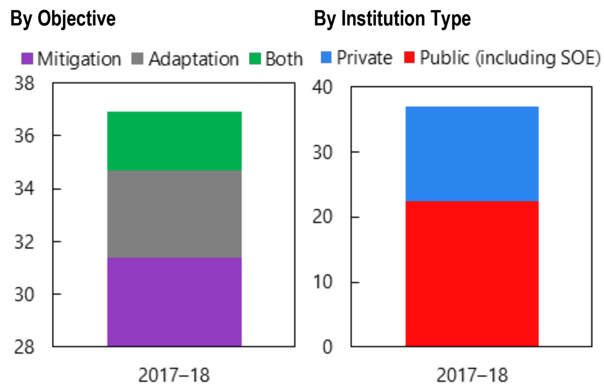
[56]The Caribbean experienced extreme tightening of the reinsurance market in 1993-94 with series of hurricanes in prior years leading to sharp price increases and refusal by some service providers to extend coverage to the Caribbean. The crisis required CARICOM intervention and led to the establishment of CCRIF.

and lower trade costs will be essential in this context to reduce over-dependence on fossil-fuel revenues and reduce output variability and fiscal/external sustainability concerns. Efforts to foster innovation in green technologies could provide positive spillovers to other sectors that directly or indirectly stimulate economic growth and jobs, as well as reduce energy security risks if renewable energy sources fail to replace robust demand for fossil fuels—a relevant issue for both exporters and importers of fossil fuels (e.g., in ECCU, Jamaica, El Salvador, Guatemala, Panama, Uruguay; World Bank 2020).[57] Enabling policies could help countries with large reserves of "green" commodities such as lithium benefit from the transition in the medium to longer run. For some LAC countries, climate adaptation and mitigation are intertwined, in that proper management and protection of the region's natural resources, ecosystems, and biodiversity as part of adaptation actions would also help reduce GHG emissions in a region where land-use change remains a major driver of emissions. To mitigate the impact of transition risks on fiscal revenues and position, fiscal policies in a country's climate mitigation and adaptation strategies should put an emphasis on improving social and political acceptability (e.g., through a targeted use of revenues) and effectiveness (e.g., through international carbon price floors and supporting policies for technologies) (IMF 2019a).

Financing Climate Mitigation and Adaptation in LAC

Countries in the region will require additional financing to achieve their climate mitigation and adaptation goals. For the region as a whole, implementing mitigation and adaptation measures will entail high upfront costs, notably with respect to public investment in infrastructure and technology. A recent report by the Energy Transitions Commission[58] estimates that US$1.475–1.8 trillion in new investment (public and private) in green energy generation, transmission, and storage capacity will be needed annually, at the global level, to reach net zero emissions by 2050. On the basis of this global assessment and the share of LAC region in global GDP, annual investment costs for climate mitigation in LAC would be estimated at US$75–92 billion. A further US$14–17 billion annually could be needed for adaptation investment in the region, if the recent historical relationship of adaptation to mitigation spending continues to hold (Figure 21). The resulting estimate for the investment needed to reach NDC goals and strengthen structural resilience for climate adaptation, of US$90–110 billion per year for the LAC region, is around 1.7–2.1 percent of the region's 2019 GDP. This simple estimate does not include some potential sources of savings—such as shifting some public investment in oil and gas to renewable energy—and possible additional expenditures—such as transfers to households adversely affected by the transition.

Figure 21. LAC: Climate Financing
(Billions of US dollars)



Sources: Climate Policy Initiative, Updated View on the Global Landscape of Climate Finance 2019; and IMF staff calculations.
Note: LAC = Latin America and the Caribbean; SOE = state-owned enterprises.

External financing for climate mitigation and adaptation in the LAC region will be essential, given the limits to domestic resource mobilization. Governments should endeavor to create fiscal space to respond to climate challenges by reprioritizing some expenditures (e.g., by shifting away from public

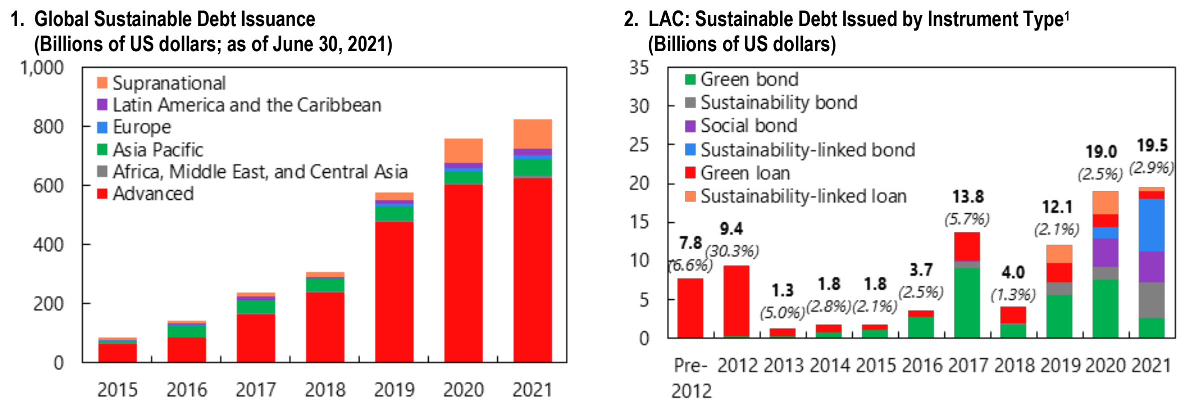
[57]Moreover, structural reforms addressing the main impediments to growth in sectors other than fossil fuels and improving the domestic economic environment could support economic diversification and offset any void left by lower fossil-fuel production. Possible measures in this respect include increased investment to address infrastructure bottlenecks, regulatory and administrative reforms to reduce bureaucracy and red tape and labor market policies to reduce informality and increase skilled labor.
[58]Often referred to as the "Turner Report." See "Making Mission Possible: Delivering a Net Zero Economy," September 2020. The International Energy Agency (IEA) provides similar estimates, focusing on net rather than gross additional investment.

investment in fossil fuels[59] and reducing fossil fuel subsidies, where appropriate) and enhancing revenues where possible (e.g., by considering carbon or other environmental taxes, where appropriate; see also WHD-REO Chapter 2). However, for most countries, even a concerted effort to increase public and private savings would not be sufficient to cover the bulk of the needed spending on climate mitigation and adaptation policies. Most of these resources would likely need to be obtained from external private or public sources. For the most vulnerable LAC countries, it will be essential that this financing be provided on highly concessional terms, including in the form of grants.

On the private funding side, the rapidly developing markets for sustainability-linked debt and equity have the potential to support climate mitigation and adaptation efforts.

- The sustainable debt market has reached US$2.3 trillion with net new issuance of US$760 billion in 2020 (Figure 22, panel 1), of which 2.5 percent or US$19 billion was issued by LAC countries (Figure 22, panel 2). The most significant component of this market, in terms of size and potential environmental impact, is that of green bonds, accounting for just over US$1 trillion in cumulative global issuance by the end of 2020.[60] Green bond sales have been growing rapidly in LAC, with the region accounting for US$7.6 billion of around US$300 billion in global issuance in 2020.

Figure 22. Global Sustainable Debt Issuance



Sources: Bloomberg NEF; and IMF staff calculations.
Note: LAC = Latin America and the Caribbean.
[1]Numbers in parentheses refer to the share of LAC to world total.

- Equity funds focused on environmental, social, and governance investments (ESG funds) represent another private sector funding opportunity. Estimates of the total size of this market vary widely, however, from US$3.5 to US$10 trillion or more, as standards are inconsistent, and some supposedly green funds may also hold large amounts of conventional equities, such as major tech stocks.[61] However, ESG equity investment in LAC represents a small share of the total market.

- Both green equity funds and sustainable debt may be susceptible to so-called "greenwashing"—misrepresenting non-green holdings (e.g., in natural gas or even coal) as environmentally responsible. Setting transparent, verifiable, standards for green financing, supported in many cases by measures to improve domestic business climates and strengthen regulatory frameworks, would be crucial to maintain investor confidence and market demand.

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[59]Presently, about two-thirds of oil and gas investment in the region is carried out by the public sector, largely by state-owned enterprises.
[60]See Climate Bonds Initiative, at climatebonds.net. Bonds are classified as green based either on the entity that issues them ("issuer-based") or the activity that they are meant to finance ("activity-based").
[61]See the October 2021 Global Financial Stability Report, Chapter 3, "Investment Funds". The report estimates that the total value of sustainable investment funds at end-2020 was US$ 3.6 trillion.

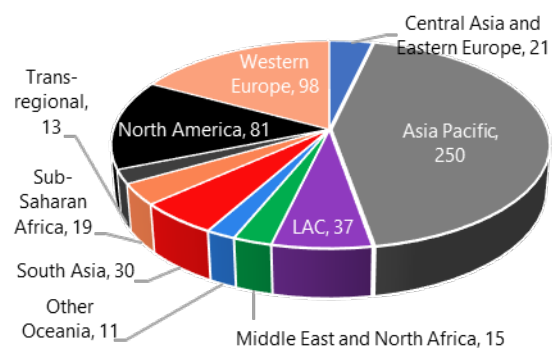
State-contingent instruments can also support climate mitigation and adaptation. Catastrophe bonds, as discussed in the section on adaptation, and hurricane clauses (like in Barbados and Grenada' debt restructurings) constitute an underused but potentially important source of state-contingent financing. Further developing state-contingent debt instruments outside of debt restructurings could help countries better manage their debt-service payments at times of natural disasters (Guerson 2021). Other useful risk-sharing mechanisms include the provision of loan guarantees for investment in sustainable energy projects and other green projects. Compensation schemes such as "debt-for-nature" swaps, or outright compensation payments to preserve tropical forests (financing for NbS), can also help contain transition costs.

Bilateral and multilateral support will need to play a key role in financing LAC's mitigation and adaptation efforts. In the wake of the Paris Accords, advanced economies committed to provide US$ 100 billion a year in climate finance to developing economies. These funds will be crucial to supplement the resources available from private external and domestic sources. Most of this necessary funding from advanced economies is expected to be channeled through international financial institutions, including the IMF.

In many LAC countries, bilateral and multilateral institutions will continue to be important sources of capital for renewable energy investment. National and multilateral development banks (MDBs) have provided significant climate financing (25 percent and 53 percent of total financing, respectively (ECLAC 2020), largely to support mitigation actions (notably in renewable energy),[62] although the share of LAC in overall financing has been fairly limited (Figure 23). Among the available sources of funding, MDBs and overseas development agencies have been influential in kickstarting deployment of some renewable technologies by combining risk mitigation funds, dedicated investment credit lines with long-term tenors, and technical assistance. MDBs have also supported nascent off-grid markets (e.g., in Argentina, Bolivia, and Nicaragua) and built related capacity, including for regulators, financial institutions and developers across the region.

Figure 23. Breakdown of Global Climate Finance by Region of Destination

(2017–18 average; billions of US dollars)



Sources: Climate Policy Initiative, Updated View on the Global Landscape of Climate Finance 2019; and IMF staff calculations.
Note: LAC = Latin America and the Caribbean.

The IMF is exploring options to create a new Resilience and Sustainability Trust (RST). The RST—financed through a rechanneling of SDRs from countries with strong external positions to more vulnerable countries—would support policy reforms to help build economic resilience and sustainability, including possibly through policies to address climate change. The RST would aim to support low-income countries and small states, as well as vulnerable middle-income countries. It would support policy reforms to help build economic resilience and sustainability, including by providing financing at cheaper rates and with longer maturities than the IMF's traditional lending terms.

[62]The remaining climate financing has been allocated to transport (13.9 percent); agriculture, forestry, land use (8.9 percent); energy efficiency (4.4 percent); and waste and wastewater (3.7 percent). The limited adaptation financing goes primarily to water sources, wastewater, and disaster risk management (3 percent); agriculture, forestry, land use (0.7 percent); energy, transport and other environmental constructions and infrastructure (0.6 percent); intersectoral investment (0.4 percent); infrastructure (0.3 percent); and other adaptation (11.9 percent) (ECLAC 2020).

Conclusions

LAC is one of the most diverse regions in the world with respect to climate-related risks. Some LAC countries face challenges related to containing and reducing GHG emissions (mitigation), while others have an urgent need to build resilience to natural disasters (adaptation). The region's net GHG emissions are in line with its economic size and population, with a relatively clean energy mix counterbalanced by large emissions from agriculture, land use, and forestry.

To meet their climate mitigation goals, LAC policymakers have a variety of policy tools at their disposal. These include price and non-price-based mitigation instruments. Price-based mitigation instruments include carbon taxes, removal of fossil fuel subsidies, ramping up ETS, and establishing a system of feebates. Non-price-based mitigation measures include public investment in low-carbon technologies and infrastructure, fiscal incentives and direct current public spending aimed at making low-carbon energy sources more abundant and affordable as well as supportive regulations encouraging reduction in emissions, a shift toward low-carbon activities as well as protection and enhancement of LACs natural carbon sinks. In regard to the latter, NbS present important cost-effective opportunities in LAC, given the region's abundance in natural resources and ecosystems.

LAC countries should adopt the policy mixes that best suit their specific circumstances, taking into account the extensive use of renewable energy in the region, societal preferences, and political economy considerations. A broad range of mitigation tools is likely to be needed in LAC countries. An illustrative scenario suggests that an increase in the price of carbon could help closing NDC gaps in many LAC countries, although some countries would remain far from their NDC goals. The revenues from these policies could help compensate a large portion of the population and, with targeted cash transfers, additional resources could be invested in green infrastructure and used to support the labor market transition. A policy mix that balances carbon pricing with a green investment push could have positive long-run effects on activity and employment. Advanced public consultation and careful sequencing and communication of the mitigation reforms will be needed to garner broad public support and secure sufficient financing. A conducive business environment will also be essential to successfully implement mitigation policies and to benefit from global technological diffusion.

On adaptation, while building resilience to natural disasters is important throughout the region, it is a priority for Caribbean and Central American economies, which are highly vulnerable to the impact of climate change. A comprehensive medium-term approach focused on investing in structural resilience and boosting financial resilience would yield significant long-run benefits for these countries. Scaling up investment in structural resilience could support macroeconomic sustainability and enhance the long-term macroeconomic performance of the economies in the Caribbean and Central America. Building structural resilience, however, takes time, and financial resilience in the form of a comprehensive layered insurance framework would need to be put in place to ensure financing for reconstruction while safeguarding public finances. The upfront fiscal costs of structural and financial resilience, however, would open a transitional financing gap. Deeper private sector contributions to adaptation investment could ease the burden on public finances and can be facilitated by incentives, and policies to improve access to financial services. Efforts to boost private adaptation investment would need to be accompanied by stepping up climate risk resilience of the financial system, which can be strengthened by fortifying supervision, and bolstering reporting and regulatory frameworks. Timely and targeted policies would be essential to prepare the fossil-fuel exporters of the region to a low-carbon environment and mitigate adverse macroeconomic consequences.

In the LAC region as a whole, mitigation and adaptation policies will require significant upfront financing, including importantly support from the international community. External financing—from both official and private sectors—will be essential, given the limits to domestic resource mobilization. On the private sector side, the rapidly developing markets for sustainability-linked debt and equity have the potential to support climate mitigation and adaptation efforts, but actions need to be taken to avoid so-called "greenwashing". State-contingent instruments, such as catastrophe bonds, can also play an important role. On the official sector side, bilateral and multilateral support will be essential in financing LAC's mitigation and adaptation efforts.

Box 1. Climate Change is Macro-critical for LAC

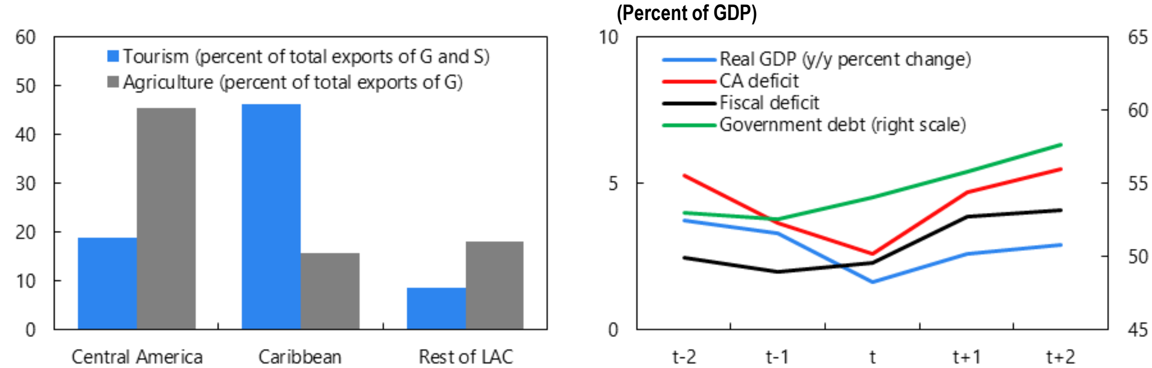
Climate change is macro-critical in LAC—a region home to some countries that are vulnerable to climate change and some that face significant transition costs from policies that reduce GHG emissions.

Severe and frequent weather-related natural disasters and global warming represent considerable macroeconomic shocks, particularly in the Caribbean and Central America. Moreover, many economies depend on climate-sensitive activities such as tourism and agriculture, which contribute significantly to output, employment, and FX earnings. Event analysis suggests that growth declines when a severe weather-related natural disaster strikes—though it recovers the following year possibly reflecting reconstruction efforts, the fiscal deficit and debt level rise and remain higher thereafter (Box Figure 1.1). Over the longer term, global warming impacts the region's economies mainly through lower tourism flows, agriculture production, and labor productivity due to health effects (IMF, 2016).

Box Figure 1.1. Reliance on Agriculture and Tourism and Macroeconomic Impact of Weather-related Natural Disasters

1. Agriculture and Tourism, 2015–19 (Average)

2. LAC: Macroeconomic Indicators Around Largest Weather-related Natural Disasters, 1990–2019[1] (Percent of GDP)



Sources: IMF, World Economic Outlook database; UN Comtrade; World Bank, World Development Indicators database; World Trade and Tourism Council; EM-DAT database; and IMF staff calculations.
Note: CA = current account; G = goods; LAC = Latin America and the Caribbean; S = services y/y = year-over-year.
[1]One largest natural disaster is identified for each country over 1990–2019, in a sample of countries where fatalities plus 0.3 times the affected persons (reported in the EM-DAT database) exceed one percent of the population.

Policies to advance transition to a low-emission environment do impose costs on many LAC countries, although the costs of inaction are even greater.

- Fossil-fuel industries and their associated value chains will decline globally, directly affecting producer countries with job losses and lower tax revenues. Lower FX generation may affect external sustainability, hinder the ability to service debt, and complicate defending currencies under pegged or managed exchange rate regimes.
- As clean technologies advance and decarbonization gathers pace, companies along value chains of "dirty" industries may lose competitiveness to "clean" ones. For instance, declining upfront investment for an electric bus promotes greater use of this means of transportation, affecting producers of non-electric buses and relevant parts. Governments may have to play a role in facilitating this transition.
- Policies to reduce non-energy emissions, which may include measures to gradually replace non-sustainable farming and forest management practices, may also have significant transition costs for countries reliant on these practices. For example, policies to reduce deforestation may involve opportunity costs for the loss of incomes from alternative activities in the short to medium term but have larger long-run benefits.

This box was prepared by Leo Bonato and Huidan Lin.

Box 1 *(continued)*

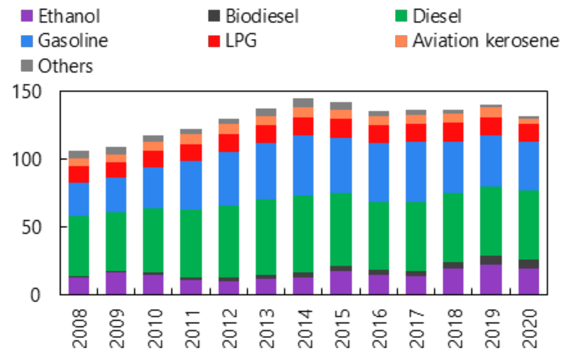
Climate change exacerbates poverty and inequality, as lower-income groups are particularly vulnerable to food price increases, health shocks, and falling agriculture and ecosystem-related incomes. *Migration* (already a policy challenge, particularly in the Northern Triangle) may increase further due to rising sea levels, floods, food insecurity, water scarcity, and falling incomes.

Climate change events pose challenges to financial stability through property damage and business disruptions if proper insurance is not already in place, while financial institutions exposed to sectors going through transition could face higher nonperforming loans or a drop in asset values. In either case, profitability and solvency could subsequently deteriorate, constraining lending and hampering investment. Financial exposure to agriculture and tourism varies, while resident banks of LAC commodity exporters do not appear to have large exposures to fossil-fuel sectors, possibly reflecting the large use of external financing (or from the parent company). Harmonized and granular data on banks exposures are essential to assessing credit and liquidity risks more thoroughly, calling for stepped-up compilation efforts at the international and national levels.

Box 2. Brazil's Sugarcane-based Ethanol Fuel Program

Box Figure 2.1. Brazil: Consumption of Fuels

(Million cubic meters)



Sources: Agência Nacional do Petróleo, Gás Natural e Biocombustíveis; and IMF staff calculations.
Note: LPG = liquefied petroleum gas.

Brazil is both the second largest producer and consumer of biofuels. Renewables (mostly ethanol) represent 20 percent of energy use in transport (Box Figure 2.1); a direct result of policies established in the mid-1970s. In the motor fuels market, the share of ethanol use rises to about 40 percent. Biofuels foster economic development and employment in rural areas. Sugarcane mills usually produce both sugar and ethanol, with specific allocations chosen only after the harvest. This allows flexibility in adjusting to relative price movements. Renewable electricity is also generated from burning bagasse, a sugar cane residue.

The Brazilian National Alcohol Program *(Proálcool)* was launched in late 1975, following the oil crisis, to promote substitution of imported fossil fuels for biofuels. The program also aimed to foster profitability in the Brazilian sugar market. *Proálcool* included subsidized-interest loans and government credit guarantees for the construction of refineries, the purchase of ethanol at favorable prices by state trading companies, and gasoline pricing policies which granted ethanol a competitive advantage. It was accompanied by a forceful marketing program and investments in infrastructure for the widespread distribution of ethanol by the state-owned Petrobras. At a later stage, the Brazilian government provided incentives for the production and conversion of cars to allow up to 100 percent ethanol use. According to (Brookings, 2006), the Brazilian production of ethanol quintupled from mid to late 1970s and tripled in the following 6 years.

Ethanol remained a substantial source of transport energy in Brazil even after the end of *Proálcool*. With the fall in international oil prices and reduced fiscal support to the sector, Brazilian ethanol production leveled off in the late 1980s and 1990s. However, several factors continued to render sugarcane-based ethanol production economically attractive in Brazil: a regulatory minimum of 20 percent ethanol content in all gasoline sold, developed infrastructure for production and distribution of ethanol, favorable climate conditions, and a large unskilled labor force. The invention of the flex-fuel car –now the vast majority of light vehicle sales – provided new impetus to the sector, but the subsequent discovery of pre-salt oil reserves, in the mid-2000s, diverted resources and attention from investments in biofuels.

As part of its strategy to meet NDC commitments under the Paris Agreement, the Brazilian government has created new instruments to promote investments in biofuels. Brazil's NDC foresee a 10% reduction in greenhouse gas emissions from transport by 2028 and an 18% share for sustainable biofuels in the country's overall energy mix by 2030 (including by expanding biofuel consumption and ethanol supply). A new flagship biofuel policy, RenovaBio, was launched in 2016 in support of this goal. It establishes annual carbon intensity reduction targets for the fuels' sector, provides a framework for certification of biofuels production according to its efficiency in reducing GHG emissions, and creates "decarbonization credit" market mechanism[1] to foster production and consumption of biofuels.

This box was prepared by Joana Pereira.
[1]"Decarbonization credits" are certificates sold by certified biofuel producers, traded in the Brazilian stock exchange. Buyers (fuel producers) can use them to meet mandatory decarbonization targets.

Box 3. Agricultural Mitigation Policies

LAC stands out for its large share of net GHG emissions (45 percent of total) from agriculture and change in land use and forestry, compared to the world average of 14 percent (Figure 4, panel 1). The FAO estimates that livestock alone is responsible for about 15 percent of the annual global GHGs which is almost equivalent to the global emissions from cars, planes, and ships combined. Successful measures[1] to contain agriculture and change in land use and forestry emissions are:

Sustainable land and forest management that targets afforestation, stops deforestation, protects and conserves areas at risk of conversion, and enforces deforestation policies together with civil societies, the private sector, and governments. These measures provide the largest potential to reduce agriculture and change in land use and forestry emissions (IPCC, 2019). Historically Brazil has been most successful in achieving strong deforestation reductions[2] driven by the private sector 2006 Soy Moratorium in the Amazon and the Brazil Forest Code, although recently there has been a partial reversal of these achievements (Americas Quarterly, 2021). Other LAC countries that reduced deforestation and increased forest area include, among others, Argentina, Colombia, Costa Rica, and Chile. These efforts should be combined with international coordination, like the New York Declaration on Forests that 10 LAC countries[3] also endorsed.

Educational programs that highlight health and environmental benefits of plant-based diets and the removal of tax expenditures for emission intensive products (e.g., lower VAT rates or subsidies for meat and dairy products) (Cline 2020; FAIRR 2017). Taxing emission-intensive foods, aligning public procurement practices, and launching educational programs to induce dietary changes towards more plant-based diets, would be key steps to reduce demand for emission-intensive agricultural products, which is estimated to increase by 50 percent by 2050 relative to 2013. A result of growing population and income levels translating into higher animal protein consumption in low- and middle-income countries (FAO 2018). The adoption of healthy,[4] sustainable diets would increase food security, lower emissions, enhance the food system's resilience and free up land to meet agricultural demands (Batini, 2021). Reducing food loss and waste, accounting for about 10 percent of food systems' GHG emissions, could provide additional mitigation potential (IPCC 2019).

Incentives to contain livestock emissions and increase agricultural efficiency, through targets for reducing and taxing CH_4 emissions to boost investments in emission-efficient meat and milk production and biogas generation and leveraging the sequestration potential of soil management (IMF 2020). Biogenic, agricultural emissions should also be included in ETS and biogenic credits provided for bioenergy with carbon capture and storage installations thereby incentivizing the removal of GHG from the atmosphere while addressing the issue of carbon leakage (Rickles, 2020). Incentives to use anaerobic digesters could also reduce CH_4 emissions via proper manure management. Reductions could reach as high as 90 percent (U.S. EPA, 2013). Anaerobic digestion systems capture CH_4 from manure lagoons and stockpiles and allow farmers to use it in a beneficial way such as generating biogas, fertilizers, animal bedding and other products.

Supportive regulation and standards in the agricultural sector that focus on reductions in the number of animals (with increased productivity by hectare), reductions in emissions from rice paddies by rewetting, drying, and other appropriate agricultural practices, changes in the animal feed composition and precision feeding, updated manure management systems, reduction of synthetic fertilizers from production and transport, standards for land use and limitation of conversion area, expansion of organic soils and wetlands as well as limiting or eliminating tillage via specialized equipment that prepare the seedbed without disrupting the soil.

This box was prepared by Diane C. Kostroch.

[1]IPCC, 2018 provides a comprehensive summary of sector policy instruments and standards.

[2]From 2004-2012 Brazil reduced deforestation by an average 5 percent per year, amounting to a decline in the national deforestation rate of 84 percent. Returning to 2012 developments would allow to reverse recent trends and reach zero deforestation by 2030.

[3]Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guyana, Mexico, Panama, Peru.

[4]Diets that are high in plant-based produce are healthier and have lower land, water use and GHG emissions than average animal protein diets (Swinburn et al. 2019; Willett et al. 2019; Springmann et al. 2016b, Tilman and Clark 2014).

Box 4. Political Economy Considerations of Climate Mitigation Policies

A national climate mitigation strategy impacts a multitude of sectors, activities, and vested interests. It thus requires a large amount of coordination, consultation and buy-in from the authorities, politicians and civil society. In fact, although the net welfare impact of climate policies are estimated to be positive (Nordhaus (2008), Parry et al (2014), and Stern (2006)), their economic impact would be different across various socio-economic groups and regions within countries. Because of the negative externalities of GHG emissions and the fact that the environmental benefits of sustainable environment policies accrue only in the long term, all stakeholders and generations should be brought into the climate change dialogue. Reflecting the lessons from past unsuccessful attempts to reform fossil fuel subsidies, climate policies should be phased, clearly anchored to improve predictability, and their social impact accounted for ex-ante to secure public support.

Advanced public consultation, international cooperation and careful communication would help secure broad-based buy-in for climate mitigation policies. Ensuring a sustainable environment is a far-reaching undertaking that involves considerations of inter-generational equity and calls for an open dialogue and possibly a national pact to firmly anchor the transition to a green economy. Cooperation among countries for a synchronous move would not only yield high global climate dividends but also mitigate the political cost of climate policies at the individual country level. In this context, governments could emphasize the cost of inaction in their national campaigns for climate change. For instance, a border adjustment tax (BAT) contemplated by the European Union could make LAC's products equally expensive as if the tax were levied within the region's borders without the corresponding revenue benefits. This might help strengthen the argument for carbon taxes and other mitigation instruments in LAC. Strengthening social safety nets early on (or even before the implementation of climate change mitigation strategies) could foster trust and help secure household support for climate policies and reforms.[1] Adequate compensatory mechanisms should take into account the concentration of risks in certain socio-economic groups and regions within LAC's countries.

Sequencing of policies would also be important. Some countries with high fossil fuel subsidies could consider smoothing the burden of the transition to a greener economy by first phasing out fossil fuel subsidies, and after that hiking the carbon tax. Even in small emitting countries, there could be merit in gradually increasing carbon taxes in parallel to fossil fuel subsidy removal, leveraging the favorable global drive towards emissions reductions to mitigate the risk of reform backlash at home. An early move towards carbon taxes would also help prepare the tax system for the administration of the new tax while allowing firms and households to adjust to the new low emissions reality. While compensatory measures should help facilitate the transition to low-carbon economies (e.g., through cash transfers to affected consumers and training for displaced workers in the short term), eventually, carbon-related support to households should be folded into the country's broader social safety net and standard labor market transition mechanisms such as unemployment insurance schemes, where available.

This box was prepared by Constant Lonkeng.
[1]Progress achieved in social protection during COVID-19 could be leveraged further.

Box 5. Implications of Climate Risks for Financial Stability

As the leading long-term threat to the global economy, climate change poses important risks to financial stability. Physical risks to the financial system include damage from extreme weather events and long-term degradation of capital and land, either of which may affect financial firms through loan portfolios. Physical risks to the financial system are particularly high in tourism-dependent economies in the Caribbean. Transition risks, on the other hand, may arise from the implementation of a carbon tax or other tax on fossil fuels, or from the adoption of specific green mandate. Firms with carbon-intensive product portfolios may shoulder many of these costs, affecting the financial institutions that support them. Financial institutions supporting commodity exporters in South America may be especially exposed to transition risks.

Financial authorities in several countries have already taken significant steps to incorporate both physical and transition risks into financial stability monitoring. These include stress-testing the financial system for climate risks, posting guidelines for managing risks from climate change, and strengthening climate-related disclosure requirements. A stress test conducted by the ECB showed that European financial institutions are subject to significant physical risks from climate change, with default probabilities rising 1–2 percent over the next 30 years in a “hot house world” scenario in which temperatures continue to rise unabated. In Norway, by contrast, where carbon taxes are among the world’s highest at US$45 a ton and oil is an important revenue source, an analysis by the Norges Bank indicates that transition risks are salient. In Canada, banks are expected to consider climate risks in assessing possible loans, potentially assigning higher risk weightings for loans to firms in oil, gas, and other fossil-fuel related industries.

Using Colombia as a case study, Sever and Perez-Archila (forthcoming) conduct stress tests for a transition to a low-carbon economy. They find that agriculture, manufacturing, electricity, wholesale and retail trade and transportation sectors appear to be the most important in the transmission of risk to the banking system in Colombia. A sudden increase in the carbon tax of US$70 per ton (from the current level of US$5 per ton) results in sizeable, but potentially manageable, risks for the banking system (with at-risk bank loans as large as 13.6 percent of total outstanding corporate loans). However, lower rates of increase in the carbon tax carry lower transition risks to the financial system, suggesting that an incremental strategy of increasing the carbon tax towards the target of US$75 per ton over a span of several years may be advisable (as suggested in IMF WEO 2020).

In Latin America, strengthening supervision, reporting, and regulatory frameworks could help build financial system resilience. Climate risks should be incorporated in existing supervisory frameworks, supported by reporting structures that allow for more granular monitoring of the various risk transmission channels and by strengthened oversight of exposures between institutions. This could be accompanied by regulatory measures to support climate risk-aware lending practices, exposure diversification and prudential risk buffers, as well as ex-post asset recovery. Climate risk scenarios should also be integrated in the authorities’ general financial system crisis management plans.

This box was prepared by Chris Walker and Serhan Cevik.

Annex 1. Identifying the Largest GHG Emitters in Latin America and the Caribbean[1]

The chapter identifies the three largest emitters in LAC based on two criteria: a country's share in global total GHG emissions and a country's share in global non-CO_2 GHG emissions (the latter criteria captures the importance of non-CO_2 emissions in the region). Total GHG emissions data cover six key sectors: (i) energy; (ii) industrial processes and product use, (iii) agriculture, (iv) land-use, land-use change and forestry (LULUCF), (v) waste, as well as (vi) others.[2] The data allows evaluating gross and net GHG emissions defined as follows:

Gross GHGs emissions comprise CO_2, CH_4, N_2O, and F-gases, sourced from energy, industrial, agriculture, waste, and others.

Net GHG emissions include gross GHGs emissions plus LULUCF, which can be positive or negative.

Brazil, Mexico, and Argentina are the three largest emitters in LAC, using the threshold of 1 percent contribution to the global total GHG emissions (gross or net) or the global non-CO_2 GHG emissions (gross or net). The first table below lists top 10 LAC countries based on their share in global total GHG emissions, and the second table lists top 10 LAC countries based on their share in non-CO_2 GHG emissions.

Top 10 Largest Emitters Considering the Share of Total GHGs, 2018

Country	Gross GHGs	Country	Net GHGs
Brazil	2.3	Brazil	3.0
Mexico	1.5	Mexico	1.5
Argentina	0.8	Argentina	0.9
Venezuela	0.5	Venezuela	0.6
Colombia	0.4	Colombia	0.6
Chile	0.2	Peru	0.4
Peru	0.2	Bolivia	0.3
Ecuador	0.1	Paraguay	0.2
Bolivia	0.1	Ecuador	0.2
Paraguay	0.1	Chile	0.1

Top 10 Largest Emitters Considering the Share of Non-CO_2 GHGs, 2018

Country	Gross Non-CO_2 GHGs	Net Non-CO_2 GHGs
Brazil	5.1	5.0
Mexico	1.7	1.7
Argentina	1.6	1.5
Colombia	0.9	0.9
Venezuela	0.8	0.8
Peru	0.4	0.3
Paraguay	0.3	0.3
Bolivia	0.3	0.3
Uruguay	0.2	0.2
Ecuador	0.2	0.2

[1]This Annex was prepared by Tessy Vasquez-Baos.
[2]The underlying data sources are the World Resources Institute (WRI), UNFCCC, and the CAIT climate data explorer.

Annex 2. The Use of Integrated Assessment Models for Climate Mitigation Policy Analysis[1]

<u>Integrated Assessment Models</u>

The transition to low or zero emissions is expected to take several decades, and it requires transformations across all sectors of the economy because Greenhouse Gases (GHGs) emissions are released in virtually all economic activities.

As the effect of GHGs on temperature is approximately linear in the stock of GHGs in the atmosphere, scientists use the concept of "carbon budget" to convey the important message that what matters most is cumulative emissions rather than the exact trajectory of emissions over time. This leaves ample flexibility to design emissions transition pathways that are compatible with a certain change of global mean temperature in the future. However, socio-economic systems cannot easily adjust to replicate all these transition pathways. Some may require immediate fast emission reductions that are either technologically infeasible, or too expensive, or both. Other pathways may delay action into the future, but then require excessively fast emission reductions. Yet other pathways rely on large "negative emissions"—the absorption of carbon from the atmosphere – to compensate for slow emission reductions.

To assess the physical, economic, and technological feasibility of transition pathways to low emissions it is thus necessary to build models that provide a consistent representation of the climate system, of the economy, of energy systems and of land use. These models are called Integrated Assessment Models (IAMs) and have been developed since the 1980s. They have grown in popularity and in number in the 1990s and have been extensively used in the past twenty years by the research community to provide insights on transformation pathways towards a low or zero emission future. While some IAMs include the feedback of the climate system on the economy, using "damage functions", and can be used to study efficient transition pathways, most IAMs do not study economic damages from climate change and limit their analysis to the simpler problem of finding the cheapest mix of emission reduction over space and time to attain a long-term mitigation goal. Alternatively, these models are used to study the amount of emission reductions, and thus the long-run temperature change, that would emerge if certain policies are implemented, such as a carbon tax or a subsidy to research in clean energy.

There are numerous IAMs run by research groups around the world. They differ in their modeling choices (e.g., energy technologies, integration of land use), solution methods (e.g., simulation vs. optimization), geographic resolution (e.g., global vs. regional), and time horizon (e.g., mid-century vs. 2100). Most models trade cross-sectional richness – e.g., countries, sectors – and sophisticated descriptions of the economy – most models assume exogenous growth rates – to focus on the long-term nature of the mitigation problem, and to integrate key sectors, such as land and forestry. There is no money in these models, thus no inflation. Taxes are recycled lump-sum into the economy. The workforce is assumed to be a stable fraction of the population. Trade is limited to energy resources. Our calculations use data from six climate models and three modeling comparison exercises: Advance (Reference, 2020_WB2C, 2020_1.5C-2100), CD-Links (NPi, NPi2020_1000, NPi2020_400), and EMF33 (Baseline, WB2C_full, 2020_1.5C-2100). Models assume continuation of present trends in emissions, population growth and economic growth. Assumptions on population growth are similar across models and follow the United National Population Projections. Population growth continues until approximately mid-century, then it reaches a plateau. GDP per capita is assumed to increase six- to eight-fold over the remaining part of the century. As a result of population and economic growth dynamics, total GDP grows ten-fold during the century. All GHGs are transformed in CO_2 equivalents using 100-year global warming potentials without including the climate-carbon feedback (GWP equal to 28 for CH_4 and GWP equal to 265 for N_2O). Models use a uniform global carbon tax on all GHGs

[1]This Annex was prepared by Emanuele Massetti.

emissions to simulate these cost-effective transformation pathways. The carbon tax grows over time and is adjusted so that the long-term climate goal is met. The scenarios where climate goals are achieved imply continued economic growth but with smaller increase in energy use, compared to BAU, thanks to improved energy efficiency. A major driver of the decarbonization in these scenarios is electrification with carbon free sources. Hydropower would remain a major source of carbon-free electricity in LAC while solar, wind and biomass would help meet additional demand.

To facilitate collaboration and exchange of results a modeling consortium has been established (Integrated Assessment Modeling Consortium) to collect results from modeling teams from across the world. One of the main success stories of this effort was the development of a shared template to distribute model results so that they can be easily compared across models and studies. In many cases modeling teams conduct modeling comparison exercises in which they simulate the impact of the same policy scenarios – for example the same carbon tax – to compare results more easily across models. In some cases, models adopt similar assumptions on exogenous trends to further limit the amount of arbitrariness in the results.

The large set of scenarios collected using the IAMC protocol is routinely used by the IPCC authors to provide an aggregate analysis of low-emission transition pathways in their Assessment Reports. By collecting evidence from many studies these syntheses allow to highlight areas where consensus emerges and areas where there is still uncertainty. As it is impossible to derive objective probabilities for these scenarios, this is a problem with *deep uncertainty*. The distribution of results from different modeling teams cannot be interpreted as an objective probability distribution. The mean across models cannot be interpreted as an expected value. However, these distributions provide a useful information on the range of results and on areas of convergence in the literature.

Annex 3. The Description of Carbon Pricing Assessment Tool (CPAT)[1]

This chapter analyzes the effect of carbon pricing in reducing greenhouse gas emissions in Latin America and Caribbean using the Carbon Pricing Assessment Tool (CPAT). The tool is a spreadsheet based "model of models" aimed at economists in IMF, World Bank and finance ministries (via *Coalition of Finance Ministers for Climate Action*). It allows rapid estimation of country-by-country greenhouse gas emissions and distributional effects.

The tool mainly uses an elasticity approach to model emissions in the energy sectors (power, industrial, transport, residential and subsectors). Roughly speaking, the consumption change of each fossil fuel in each non-power generation energy sector is the product of exogenous energy efficiency change, GDP change and fuel price change, each raised to the power of their respective elasticities, as shown in the illustrative equation below. The power generation sector is projected separately with an engineering model. The energy consumption projection is then converted to carbon emissions with emission factors.

$$\frac{Y_t^{Ei}}{Y_{t-1}^{Ei}} = \left(\frac{1}{1+\alpha^{Ei}}\right)^{\eta_1} \left(\frac{GDP_t}{GDP_{t-1}}\right)^{\eta_2} \left(\frac{p_t^{Ei}}{p_{t-1}^{Ei}}\right)^{\eta_3}$$

In the equation, Y_t^{Ei} is the fossil-fuel consumption of energy E in sector i at time t; α^{Ei} is the exogenous technology growth of the particular energy and sector; GDP_t is the gross domestic product for the country; p_t^{Ei} is the retail price of the fossil fuel of the particular energy and sector; and η_1, η_2, η_3 are the respective elasticities.

In the policy scenario, the price is affected directly, and the income is affected indirectly through fiscal multipliers, by carbon pricing policies such as subsidy removal and carbon tax. These affect fossil-fuel consumption and ultimately greenhouse gas emissions.

The tool models GHG emissions in non-energy sectors (industrial processes, agriculture, LULUCF, waste, and fugitive emissions) assuming a flat growth adjusted for existing or new additional mitigation policies (efficiency of these measures scale with energy-related emissions). For countries with existing mitigation policies in the baseline, the assumption is that these policies affect both energy and non-energy related emissions. For countries without existing mitigation policies, non-energy GHG emissions would stay flat in the baseline and decrease at the same rate as energy-related emissions in the policy scenario.

The different reduction in emissions of same carbon pricing across countries mainly come from different baseline energy price levels and different carbon contents in the fuels. Countries tend to be more sensitive to carbon pricing if their fuel prices are relatively low so that carbon pricing induces a more dramatic price increase. Countries also tend to be more sensitive to carbon pricing if their fuels have higher carbon contents, so that they are more heavily taxed. For example, the price of coal is typically lower than oil or natural gas. Moreover, to produce the same amount of energy, burning coal emits more CO_2 than oil or natural gas. Therefore, countries consuming more coal tend to be more sensitive to carbon pricing from both channels.

In CPAT, recent fuel use by country and sector is from the International Energy Agency (IEA). Each country's GDP projection is taken from the *October 2020 World Economic Outlook*. Historical energy taxes, subsidies, and prices for each type of fuel in each sector are compiled from the IMF and publicly available sources, with inputs from proprietary and third-party sources. They are projected forward with the information of international energy prices for coal, oil, and natural gas prices, which are averages of IEA and

[1]This Annex was prepared by Chao He.

IMF projections. Assumptions for elasticities are chosen to be broadly consistent with the empirical evidence and results from energy models.

CPAT is developed by IMF and World Bank staff. For a further introduction of the model and its parameterization strategy, see IMF (2019b Appendix III), and Parry et al. (2021). For further underlying rationale, see Heine and Black (2019).

Annex 4. Methodology for Estimating the Distributional Impact of Price-based Mitigation Policies[1]

The assessment of the distributional impact of a carbon tax hike and/or fossil fuel subsidy removal on per capita consumption follows two sequential steps. First, the change in the cost of production in each of the 57 industries in the Global Trade Analysis Program (GPAT) is evaluated for each country as explained below. Second, 13 items[2] commonly consumed by households are mapped into GPAT industries and their corresponding prices changes computed, assuming a full pass-through of changes in production costs to consumers. The consumption loss for households in each consumption decile is then evaluated based on consumption patterns in household budget surveys.[3] We also evaluate separately the income impact of climate mitigation policies in energy and agriculture based on the granular industry of employment and labor income of workers as reported in household surveys.

Evaluating the change in costs. The Input-Output (I-O henceforth) matrices are used to evaluate the impact of higher energy prices on the cost of production of each industry in the economy. The I-O matrices describe the sale and purchase relationships between different sectors of the economy and therefore reflects linkages between industries. CPAT traces both direct and indirect impact of carbon price increases. The direct impact is the increase in production costs from higher prices of energy inputs, namely coal, oil extraction, fuels, natural gas, and electricity. The indirect impact for each downstream sector reflects the increase in the cost of all its intermediate inputs induced by higher energy prices. As an illustration, a higher price of electricity (e.g., following a carbon tax) will "directly" increase the cost of processed food given that electricity is used in food processing. The increase in fuel prices will increase the cost of food processing "indirectly" through the increase in the cost of agricultural products (used in food processing), as the cost of transporting them from the farm to the processing facility rises with fuel prices increases. I-O matrices for all countries are from GTAP which has the advantage of providing consistent disaggregated data for 141 world regions.

The increase in the cost of production in industry j of county k is given by the following expression:

$$C_{j,k} = \underbrace{\gamma_{j,k}^{e}\delta_{k}^{e}}_{direct\ effect} + \underbrace{\sum_{i=1}^{N}\gamma_{i,j,k}\,\delta_{i,k}}_{indirect\ effect}$$

Where δ_k^e is the "direct" price increase induced by carbon tax on the source of energy e in country k and $\delta_{i,k}$ is the cost increase induced by carbon tax in industry i in country k, either directly or indirectly (N is the number of industries). $\gamma_{i,j,k}$ is the share of industry i in the total cost of intermediate inputs used in industry j, as computed from the I-O table of each country in the sample. A full pass through of cost increase in each industry i (e.g., due to carbon tax) to downstream industries j is assumed. It should be noted that the cost change in industry i ($\delta_{i,k}$ in the equation above) in turn depends on the change in the cost of its intermediate inputs (recursive system).

Evaluating the income impact in energy sectors. We evaluate how the reduced demand for energy products affects workers in energy sectors. As a starting point, the price increase in each energy product resulting from carbon tax/fossil fuel subsidy removal is computed based on the above methodology. We then assume a price elasticity of energy products of -0.25, like in IMF (2020), so that a 100 percent increase in the price of any of the identified energy products—coal, oil, electricity gasoil, and natural gas—reduces its real

[1]This Annex was prepared by Constant Lonkeng.
[2]Non-fuel items include food, clothing, transportation, communication, housing, appliances, chemicals, education, health, housing, paper, pharmaceuticals and medicine, transport, etc.
[3]Household surveys are harmonized to ensure cross-country comparability.

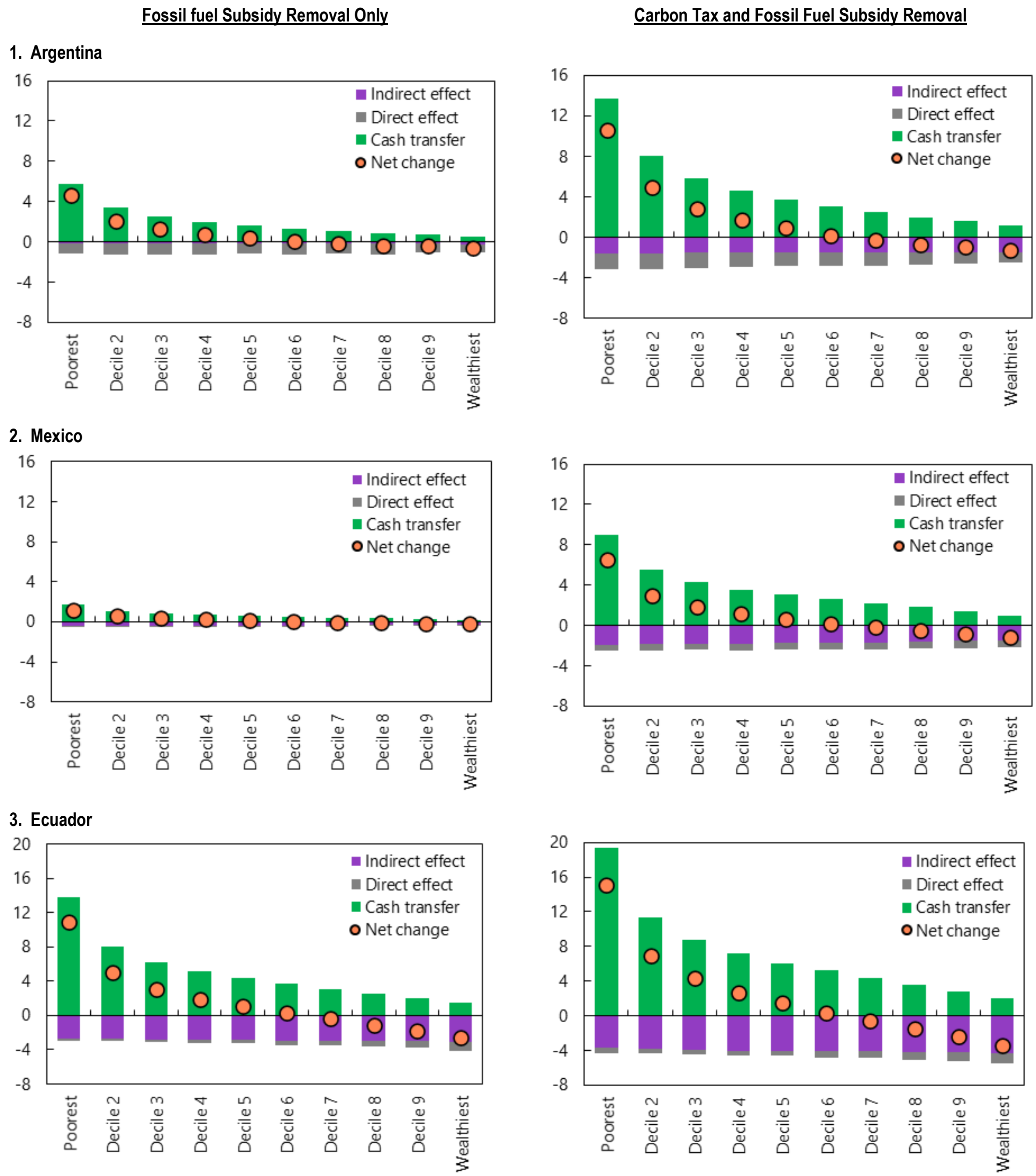
demand by 25 percent, leading to an equivalent reduction of labor income or employment under the assumption of unchanged labor productivity.[4] Using the granular sector of employment as reported in household surveys, we identify persons employed in energy sectors and express the income loss in percent of households per capita consumption. We evaluate the impact on each per capita income decile (distribution portrayed in Figure 11). We also use the information provided on the geographical location of households in household surveys to aggregate the consumption loss at the level of regions for the purposed of examining regional disparities (left panel maps, Annex Figure 4.2).

Evaluating income impact in agriculture. This assessment used as starting point the required emission reduction in agriculture from CPAT.[5] Our simulations assume that emissions reduction in agriculture will come entirely from livestock, an assumption that is motivated quantitatively by the fact that the emission intensity of livestock is much higher than that of plant-based agriculture (six-to-one ratio according to our estimates based on global data on livestock and plant-based production and total emissions in agriculture). We subsequently assume that the resources previously used in livestock, including labor, are repurposed for plant-based production to maintain comparable levels of overall production in agriculture.[6] The farmers in livestock and plant-based agriculture are identified using the granular sector of employment reported in household surveys (as above), and the income loss evaluated and expressed in percent of per capita income for each income decile (Figure 13). The results are also aggregated at the level of regions (right panel maps, Annex Figure 4.2).

[4]Energy sector firms adjust to reduced demand for energy by either lowering wages or cutting jobs (or a combination of the two). As such, the numbers in Figure 12 represent income loss, which is the total impact.
[5]It is assumed in CPAT that emissions in agriculture grow at the same rate as energy CO_2 emissions.
[6]It should be noted that, because the starting level of livestock and plant-based agriculture is different across countries (e.g., livestock accounts for 3.9 and 1.2 of total employment in Brazil and Argentina respectively, against 1.3 and 2 percent for plant-based agriculture), the percentage increase in plant-based agriculture induced by the decline in livestock needs not be the same across countries (base effect).

Annex Figure 4.1. Relative Consumption Impact of Carbon Tax and Fossil Fuel Subsidy Removal

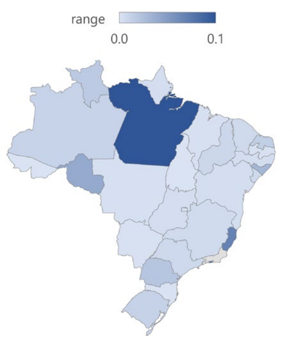
(Percent)



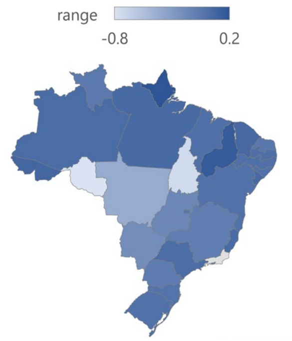
Sources: IMF, Carbon Pricing Assessment Tool; and IMF staff calculations.

Annex Figure 4.2. Spatial Distribution of Estimated Gross Income Loss in Energy Sectors and Net Income Gain/Loss in Agriculture from Climate Policies

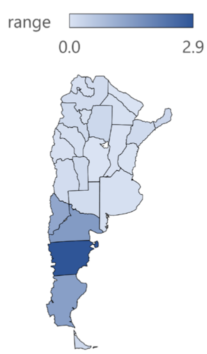
Brazil: Energy Sectors (Gross Negative Impact)



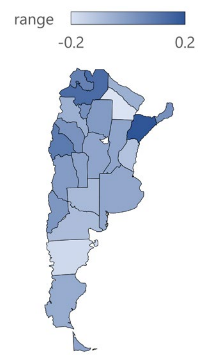
Brazil: Agriculture (Net Impact)



Argentina: Energy Sectors (Gross Negative Impact)



Argentina: Agriculture (Net Impact)



Annex 5. Model Description of the DSGE Model for A Small Open Economy Vulnerable to Climate-related Risks[1]

The model expands previous IMF work on climate change. This model (Fernandez-Corugedo, Gonzalez, and Guerson, 2021) is similar to IMF (2019c) but accounts for the stochastic nature of ND shocks similar to Cantelmo et al. (2019) who allow for the presence of extreme shocks. The model extends these papers by considering a number of real and financial frictions consistent with the characteristics of Caribbean and Central American countries.

The model comprises four key sectors: households, firms, government, and an external sector. There are two types of households: investor households that invest in non-resilient capital and hire labor, and worker households that supply labor, receive remittances but cannot save. There are two types of firms: firms that produce a final good using capital and labor and firms that transform the final good to both capital and consumption goods. The government collects revenues from taxes (consumption, firms' profits, wages, and lump-sum taxes) and external grants, spends on purchases goods and services, transfers to households, interest on public debt, and investment. Crucially, public investment can be of two types: resilient and non-resilient to NDs. It is assumed that investment in resilient public capital is costlier relative to the non-resilient type (assuming a premium of 25 percent over non-resilient investment based on estimates of Ex-Post Damage Assessments from the World Bank), and that both types are perfect substitutes in production. Keeping the physical amount of public investment unchanged, countries are assumed to allocate 80 percent of investment in resilient capital. The external sector uses final goods to export and imports both consumption and investment goods. The model includes costs to adjusting investment and wages, and the presence of financial frictions captured by both an interest rate spread on public debt relative to a safe global interest rate, and a spread between corporate interest rates and those for public debt. Both spreads increase as the balance sheets of the government and corporate sector deteriorate.

Exogenous natural disaster events are modelled through their impact on three key channels. The model assumes that there is an exogenous probability of being hit by ND event and at each point in time the economy can be in one of two regimes: one where there is no ND and another when the economy is hit by a ND. Once the ND occurs the economy is affected through three channels: First, a ND affects the economy's supply capacity: a proportion of non-resilient capital and total factor productivity (TFP) are destroyed by the ND. Second, both remittances and grants increase to support both households and the public finances following a natural disaster. Finally, the external risk premium can increase in response to the ND. Financial frictions act to amply the impact of the ND.

Fiscal policy is anchored by a debt rule and does not follow an optimization process. All government expenditures, including public investment, are set as a constant share of nominal GDP and marginal tax rates are assumed unchanged in response to a ND. Other than the aforementioned increase in grants in response to the ND, (non-distortionary) lump-sum taxes levied on households are used to raise revenue to allow to match the public debt target over the medium term.

Households

All households maximize a standard utility function comprising consumption and labor. Labor is differentiated across households but not across households' types as in Gali, Lopez-Salido and Valles (2007). Under this labor market structure wages are set in a centralized manner by an economy-wide union. The equilibrium level of hours in the economy is thus determined by firms given the wage set by the union. While

[1]This Annex was prepared by Emilio Fernandez-Corugedo, Andres Gonzalez, and Alejandro Guerson.

the problem faced by unconstrained households is not directly affect by climate shocks, that of worker households is affected, since they are permitted to receive remittances from abroad:

$$(1+\tau^C)C_{i,t}^W = (1-\tau^l)W_{jt}N_{i,t} + T_{i,t}^{GW} + z_t T_{i,t}^*(s) \tag{1}$$

where τ^C, τ^l are consumption and labor income taxes respectively, $C_{i,t}^W$ denotes consumption of worker households, W_{jt} is the real wage, $N_{i,t}$ is the number of hours worked, $T_{i,t}^{GW}$ are government transfers and $z_t T_{i,t}^*(s)$ are foreign remittances with z denoting the real exchange rate. Crucially, remittances are dependent of the state of economy, s, and are assumed to increase during a natural disaster.

Firms

Firms produce a homogenous good that can be transformed into consumption, investment, and export goods. Production firms choose their labor and capital inputs, taking as given the stock of public capital, real wages and the price of output. Firms must borrow to finance investment and labor input expenses and use the value of its capital as collateral. The existence of credit constrains in the economy amplify the impact of adverse climate shocks on the economy. The destruction of capital associated with the climate event tightens the credit constrains affecting both labor and investment decisions.

Domestic output, Y_t^H, is produced with

$$Y_t^H = z_t^Y A_t \left(K_{t-1}^G\right)^{\alpha_g} (K_{t-1}^Y)^{\alpha_K} N_t^{1-\alpha_K} \tag{2}$$

where $\alpha_K \in (0,1)$ is the capital share of private total output, z_t^Y is a temporary productivity shock, K_{t-1}^Y , K_{t-1}^G are the stocks of private and public capital available. α_g measures the importance of the public capital on the production function. A_t is a permanent productivity shock:

$$\frac{A_t}{A_{t-1}} = g_t^A = (1-\rho_G)\mathrm{g}^\mathrm{A}(s) + \rho_G g_{t-1}^A + \epsilon_t^{gA} \tag{3}$$

with $0 \le \rho_G < 1$. Thus, any shock, ϵ_t^{gA} will have a permanent effect on the level of at output. $\mathrm{g}^\mathrm{A}(s)$ is the mean growth rate of output which crucially is state dependent such that adverse climate events can entail temporary losses to the growth rate of the economy.

Firms must finance its investment and labor input expenses. However, the firm faces a financial constraint because lenders will only allow a firm to borrow up to a fraction of its debt. That is:

$$W_t N_t + p_t^I I_t^Y \le \sigma(Q_t K_{t-1}^Y) \tag{4}$$

$W_t N_t$ denotes total wage payments, $p_t^I I_t^Y$ the cost of investment goods and p_t^I is the relative price of the investment good. Q_t is the price of a unit of installed capital. It is assumed that adjusting investment is costly and thus the stock of private capital evolves as:

$$K_t^Y = (1-\delta_Y(s))K_{t-1}^Y + I_t^Y - \frac{\psi_y}{2}\left(\frac{I_t^Y}{K_{t-1}^Y} - \delta_Y(s)\right)^2 K_{t-1}^Y \tag{5}$$

The parameter ψ_y controls the speed of the adjustment cost and $\delta(s)$ is the depreciation rate of capital which is dependent on the state of climate events.

Public Sector

The government collects taxes on consumption, profits $\tau^\pi \Pi_t$, and labor, receives grants $T(s)^{Grants}$ and lump-sum taxes from savers, T_t^G. The government purchases public consumption goods and services, C_t^g, non-resilient public investment, I_t^{Gn} and resilient public investment, I_t^{Gr}, which have different prices.

Additionally, it can issue public debt denominated in foreign currency, B_t^{G*}, to finance its overall balance. The government pays a nominal interest rate R_t^* on is debt. The government's budget constraint is

$$\tau^C C_t + \tau^L W_t N_t + \tau^\pi \Pi_t + T_t^G + z_t T(s)^{Grants} + z_t B_t^{G*} = p_t^H C_t^g + T_t^{GW} + p_t^I I_t^{Gn} + p_t^{Gr} I_t^{Gr} + z_t R_{t-1}^* B_{t-1}^{G*}, \quad (6)$$

where $\Pi_t = (p_t^H Y_t^H - W_t N_t - p_t^I I_t^Y)$ denote firms' profits. To guarantee the stability of the public debt, all lump-sum taxes to savers households to respond to the public debt level according to the following rule[2]

$$T_t^G = \bar{Tr}\left(\frac{B_t^{G*}}{Y_t} - \frac{B_t^{G*}}{Y_t}\right)^{\phi_b} \quad (7)$$

Public investment is used to build public capital. The government accumulates resilient, K_t^{Gr}, and non-resilient capital, K_t^{Gnr}, according to the following equations:

$$K_t^{Gr} = \left(1 - \delta_g\right) K_{t-1}^{Gr} + I_t^{Gr} \quad (8)$$

$$K_t^{Gnr} = \left(1 - \delta_g(s)\right) K_{t-1}^{Gnr} + I_t^{Gnr} \quad (9)$$

and the total stock of public capital is $K_t^G = K_t^{Gnr} + K_t^{Gr}$. Resilient investment involves an additional transformation that increases the cost of each unit of investment. The government produces resilient investment by buying investment good from the investment producers and transforming through a linear production function. The problem of the production of the resilient investment good is as follows:

$$\max \quad p_t^{Gr} I_t^{gr} - p_t^I I_t^g \; s.t. I_t^{Gr} = a^{Gr} I_t^g \quad (10)$$

with $0 < a^{Gr} < 1$. The solution of the optimization problem is $p_t^{Gr} = \frac{p_t^I}{a^{Gr}}$ implying a constant mark-up of between the price of investment goods and the prices of the resilient investment.

External Sector and Current Account

The external interest rate is the sum of an external risk-free rate and an endogenous risk premium:

$$R_t^* = \bar{R}_t^*(s) + \Omega_u\left(\exp\left(\frac{z_t(B_t^* - B_t^{G*})}{GDP_t} - \frac{z(B^* - B^{G*})}{GDP}\right) - 1\right) \quad (11)$$

$\bar{R}_t^*$ is an external risk-free rate that depends on the state of the economy. The country risk premium is a negative function of NFA to GDP and Ω_u is the elasticity of the country risk to the NFA to GDP ratio where $GDP_t = p_t^h y_t^h$.

Finally, the current account balance, CB, is given by

$$CB_t = \left(p_t^H X_t - z_t C_{F,t} - z_t I_{F,t}\right) + z_t T_t^*(s) + z_t T(s)^{Grants} \quad (12)$$

where the term in brackets is the trade balance, defined as the difference between exports, $p_t^H X_t$ and imports of consumption $z_t C_{F,t}$ and investment goods, $z_t I_{F,t}$.

[2]Other taxes or expenditures could be used.

Model Solution

The model is solved using the perturbation methods for regime-switching rational expectations models developed by Maih (2015). Importantly, the solution method allows for the decisions of agents in the economy consider the presence of natural disasters even when not confronted by a ND event. Two states are considered: state 1 is where there are no NDs, and state 2 is where a ND event occurs. A transition matrix through states s_t is considered

$$P_{s_t,s_{t+1}} = \begin{bmatrix} p_{1,1} & p_{1,2} \\ p_{2,1} & p_{2,2} \end{bmatrix}$$

$p_{1,2}$ probability of transitioning from the state where there are no NDs in period t to a ND in t+1, $p_{1,1} = 1 - p_{1,2}$ is the probability of remaining in the state without a ND, $p_{2,1}$ is the probability of going from the state with a ND in period t to the state without NDs in period t+1, and $p_{2,2} = 1 - p_{1,2}$ is the probability of remaining in the ND state in t+1. These probabilities are calibrated to replicate the frequency of NDs observed in each country.

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