INTERNATIONAL MONETARY FUND

Waiting for Godot? The Case for Climate Change Adaptation and Mitigation in Small Island States

Serhan Cevik

WP/22/179

2022
SEP

WORKING PAPER

 WP/22/179

IMF Working Paper

European Department

Waiting for Godot?
The Case for Climate Change Adaptation and Mitigation in Small Island States

Prepared by Serhan Cevik*

Authorized for distribution by Alfredo Cuevas

September 2022

Abstract

Global warming is the most significant threat to ecosystems and people's health and living standards, especially in small island states in the Caribbean and elsewhere. This paper contributes to the debate by analyzing different options to scale up climate change mitigation and adaptation. In particular, the empirical analysis indicates that increasing energy efficiency and reducing the use of fossil fuel in electricity generation could lead to a significant reduction in carbon emissions, while investing in physical and financial resilience would yield long-run benefits. From a risk-reward perspective, the advantages of reducing the risks associated with climate change and the health benefits from higher environmental quality clearly outweigh the potential cost of climate change mitigation and adaptation in the short run. The additional revenue generated by environmental taxes could be used to compensate the most vulnerable households, building a multilayered safety net, and strengthening structural resilience.

JEL Classification Numbers:	O40; O44; Q40; Q48; Q51; Q54; Q58; H23
Keywords:	Climate change; decarbanization; energy efficiency; mitigation; adaptation; carbon tax; green financing
Author's E-Mail Address:	scevik@imf.org

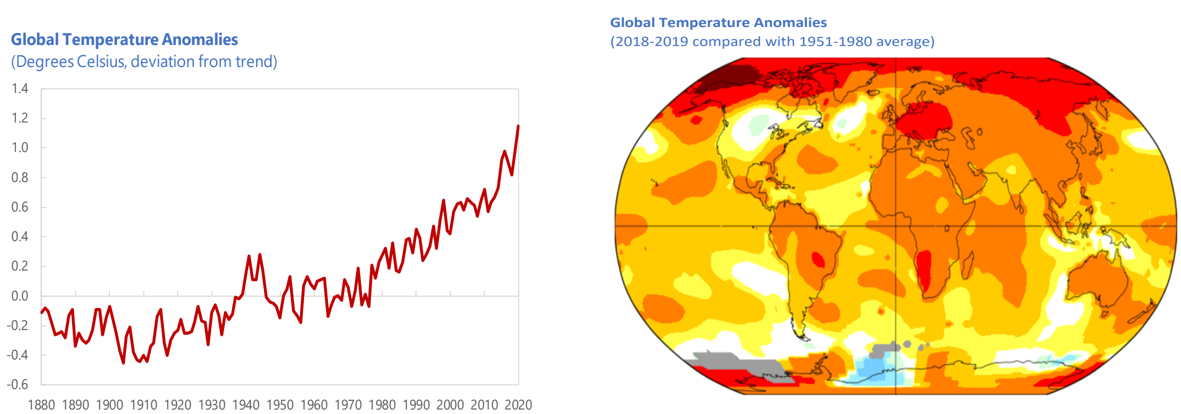
* The author would like to thank Antoine Arnoud, Bas Bakker, Simon Black, Edgar Buckley, Chen, Emilia Magdalena Jurzyk, Diane Kostroch, Cheng Hoon Lim, Emanuele Massetti, Annapurna Mitra, Natalija Novta, Joanna Swirszcz, Tessy Vasquez, Nate Vernon, and Anke Weber for their insightful comments and suggestions.

I. Introduction

Global warming is the most significant threat to ecosystems and people's health and living standards in the coming decades. The global average surface temperature has already increased by about 1.1 degrees Celsius (°C) compared with the preindustrial average, escalating the frequency and severity of extreme weather events and contributing the rise in sea levels (Figure 1). Furthermore, climate change is truly a global phenomenon, with weather shifts already affecting 85 percent of the world's population (Callaghan and others, 2021; IPCC, 2021). Projections show that more rapid and intense climate change will increase the risk of heat waves, wildfires, droughts, flooding, and severe storms and inflict greater harm on the environment, lives, and livelihoods. If greenhouse gas (GHG) emissions continue increasing at the current rate—the so-called Representative Concentration Pathway 8.5 (RCP8.5) scenario, global warming is projected to reach 4-6°C by 2100, an unprecedented shift with greater probability of larger and irreversible environmental changes unseen in millions of years (Hansen and others, 2013).

Climate change poses an existential threat to the Caribbean, a region of low-lying islands and cays spread over the Atlantic Hurricane Belt. Recent research by the World Bank estimates that climate-related events will push more than 132 million people into extreme poverty by 2030 (Jafino and others, 2020). If the world's climate is not stabilized over the next decade, the socioeconomic costs of climate change will be more than three times larger than if countries act now, and consequently threaten the survival of humanity (Sanderson and O'Neill, 2020; Bhattacharya and others, 2021). However, small island states in the Caribbean are disproportionally more exposed and vulnerable to climate change and natural disasters due to its location within the Atlantic Hurricane Belt. For example, the costs of Hurricane Ivan for Grenada in 2004 amounted to 148 percent of GDP and those of Hurricane Maria for Dominica in 2017 reached 260 percent of GDP, reflecting both the intensity and range of damage of extreme hurricanes and the relatively small size of these economies. Caribbean countries are thus considered highly vulnerable to climate change, according to the latest ND-GAIN Index, which assesses countries in relation to vulnerability and resilience to climate change (Figure 2).

Figure 1. Climate Change and Weather Anomalies

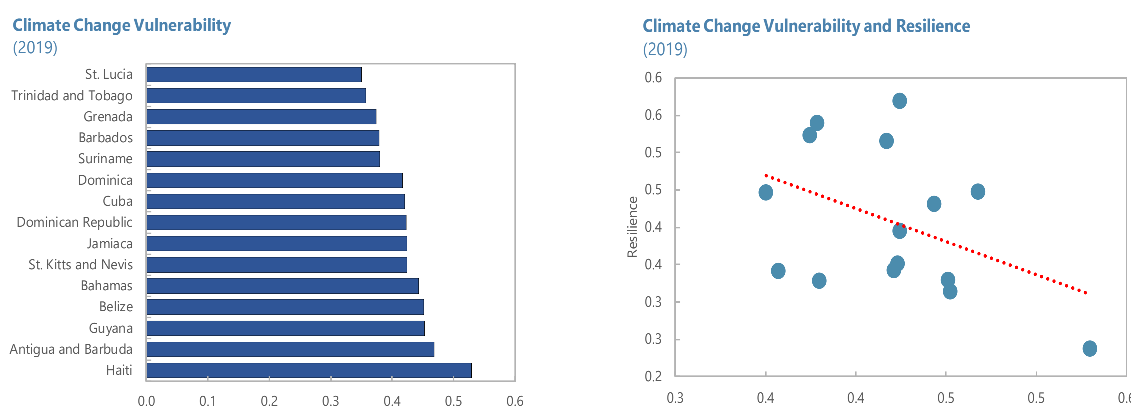


Source: NOAA; author's calculations.

The Caribbean faces some of the highest disaster risk in the world, and these are projected to intensify as the climate changes. Without substantial efforts to mitigate climate change across the world, the Caribbean is projected to experience significant warming over the next century, against the baseline conditions under the RCP8.5 high-emission pathway. Increases in annual maximum and minimum temperatures are expected to be larger than the rise in average temperature, which will put greater pressures on human health, livelihoods, and ecosystems. Caribbean countries are highly exposed to hurricanes and flooding, with hurricanes appearing to have greater intensity and increasing number of flooding events, which are causing coastline erosion. In the case of The Bahamas, for example, a one-meter increase in sea level would place more than a third of tourism properties at risk, as well as 38 percent of airports, 14 percent of road networks and 90 percent of seaports. These projections, however, should be treated with caution in the case of Caribbean countries due to large spatial scales used in modelling, which make it difficult to discern ocean cover from land cover over many of the region's smaller islands.

Caribbean countries are already dealing with a multitude of physical and transition risks associated with climate change. Climate change is likely to have a broad-based impact on the economy through climate-sensitive sectors like agriculture, energy and tourism, and reshape public finances by increasing the cost of borrowing in vulnerable countries (Cevik and Jalles, 2020; 2021; 2022). Physical risks arising from high vulnerability of economies to the impact of climate change include higher temperatures, sea level rise, coastal erosion, extreme hurricanes and rainfall, and loss of biodiversity, especially in an economy that is highly dependent on a climate-sensitive sector like tourism. Physical risks can therefore negatively affect both supply (destruction of physical capital and disruption of labor and supply chains) and demand (damage to household and corporate balance sheets, reduction in consumption and investment, and disruption of trade and tourism flows) sides of the economy, reducing growth and employment and undermining fiscal sustainability and financial stability. Transition risks arise from structural changes at home and abroad aiming to achieve environmental sustainability, especially by reducing reliance on high-carbon activities. If not managed properly, the transition to a greener economy could lead to significant economic dislocation due to sectoral restructuring and

Figure 2. Climate Change Vulnerability and Resilience



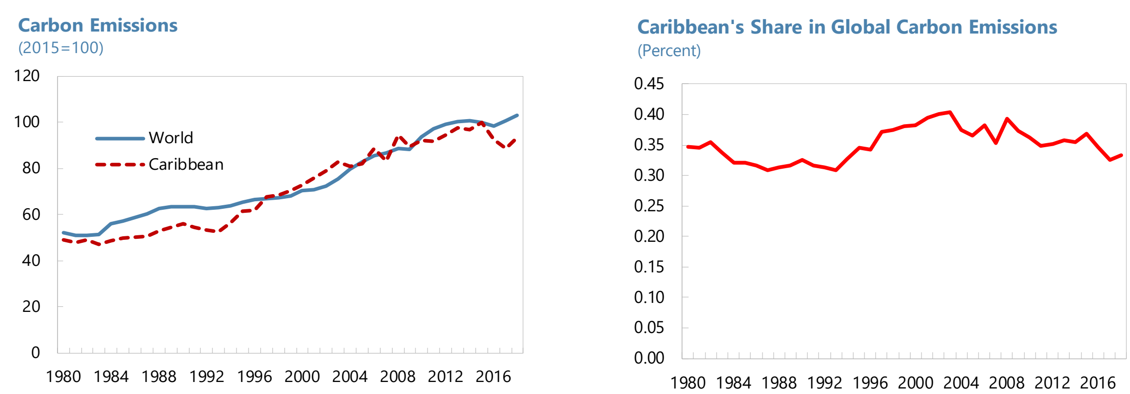
Source: ND-GAIN; author's calculations.

adaptation and shifts in employment and trade patterns with repercussions for short- and long-term growth, fiscal positions, inflation, current accounts, and financial systems.

Balancing climate change mitigation and adaptation strategies would provide diverse ecological, economic and social benefits and opportunities. The 2015 Paris Climate Accord, ratified by 189 countries, seeks to contain global warming below 2°C compared to the preindustrial level through Nationally Determined Contribution (NDC) commitments to reduce emissions. CO_2 emissions continued to increase since the Paris Agreement by 2.9 percent across the world, but declined 6.8 percent in the Caribbean, which accounts about 0.3 percent of the total (Figure 3).[2] According to the latest Emissions Gap Report, however, GHG emissions will decline by only 7.5 percent by 2030, whereas keeping global warming below 1.5°C requires a reduction of 55 percent (UNEP, 2021a). This paper contributes to the debate by analyzing different options to scale up climate change mitigation and adaptation in small island states, where well-designed policies and reforms would help reduce CO_2 emissions and guard against threats associated with climate change. While there are trade-offs between investing in climate change mitigation and adaptation, these investments could be complementary elements of a broader strategy to respond to climate change. An important illustration of mitigation-adaptation interlinkages in the Caribbean is energy supply and consumption, which is determined to a great extent by tourism-related activities. Therefore, balancing climate change mitigation and adaptation strategies would provide diverse ecological, economic and social benefits and opportunities.

The empirical analysis indicate that increasing energy efficiency could lead to a significant reduction in CO_2 emissions in the Caribbean. The estimation results presented in this paper suggest that a 10 percentage point increase in energy efficiency is associated with lower CO_2 emissions of 6 percentage points in the long-run, after controlling for economic, demographic and

Figure 3. Evolution of Carbon Emissions



Source: EIA; author's calculations.

[2] The post-Paris pace of decarbonization in the Caribbean is limited to only about 1 percent excluding the large drop in Cuba.

institutional factors. Accordingly, if energy efficiency in the Caribbean had increased at the same rate of the world average over the past three decades, CO_2 emissions in the region would have already been 25 percentage points lower. Therefore, policies and reforms should aim to improve energy efficiency in commercial and residential use and shift the energy matrix away from fossil fuels to mainly renewables.

While large carbon-emitting countries have a greater responsibility for the emissions correction, smaller island states would benefit no less from mitigation efforts. There is no doubt that large carbon-emitting countries are responsible for the great majority of emissions correction the world needs. This creates a policy tension between climate change mitigation and adaptation in smaller countries with potentially high marginal returns to adaption (due to greater physical risks) and smaller marginal returns to mitigation (as they are not large emitters). Nevertheless, all countries including small island states need to pursue policies and reforms aimed at reducing CO_2 emissions, as well as adapting to the worst effects of climate change. From a risk-reward perspective, the benefits of reducing the risks of climate change and the health benefits from higher environmental quality outweigh the potential cost of climate change mitigation in the short run. A carbon tax and "feebates"—fees on products with high emissions combined with rebates on products with low emissions—could raise considerable revenue, which can support revenue mobilization and provide additional funding to compensate the most vulnerable households, build a multilayered safety net, and strengthen structural resilience.

Small island states must also carry out adaptation strategies and become more resilient to climate change. Long-term climate risks cannot be completely eliminated, and thus governments must take decisive action to strengthen physical, financial, institutional and social resilience. A variety of adaptation measures have been introduced to enhance resilience to climate change in the Caribbean, but there are still significant gaps that keep the region vulnerable to threats associated with climate change. Strengthening structural resilience requires infrastructure and other ex-ante investments to limit the impact of disasters, while building financial resilience involves creating fiscal buffers and using prearranged financial instruments to protect fiscal sustainability and manage recovery costs. These measures will have upfront fiscal costs, but the lack of action on the climate front would have even a greater cost for generations. Furthermore, strengthening physical and financial resilience would reduce damages from natural disasters and increase expected returns to private investment and output. With well-designed policies and reforms, economic recovery could be stronger and faster, and the adverse impact on public finances would be significantly lower after a climate-related shocks.

The remainder of this paper is organized as follows. Section II provides an overview of risks associated with climate change. Section III describes potential macroeconomic effects of climate change. Section IV discusses climate change mitigation strategies and presents an empirical assessment of energy efficiency and CO_2 emissions in the Caribbean. Section V discusses climate change adaptation strategies, with a focus on macro-fiscal costs. Section VI provides an overview of green financing. Finally, section VII offers concluding remarks with policy recommendations.

II. SPECTRUM OF CLIMATE CHANGE RISKS

Climate risks fall into two categories—physical risks and transition risks—that could also have cross-border spillovers. Climate refers to a distribution of weather outcomes for a given location, and climate change describes shifts in the distribution of weather outcomes towards extremes. Accordingly, climate risks reflect the probability or likelihood of occurrence of weather-related hazardous events in the foreseeable future or trends multiplied by the impacts of these events or trends occur over a long period of generations. Risks associated with climate change fall into two categories: (i) physical risks; and (ii) transition risks.

- **Physical risks of climate change** relate to damages caused by current weather-related events, such as hurricanes, heat waves, droughts or flooding, which are projected to increase in frequency and intensity, and long-term changes in climate such as global warming and sea-level rise. Extreme changes in climatic conditions could significantly reduce the productivity of coastal areas and agricultural land due to an increase in sea level and changes in precipitation patterns, respectively. Hence, physical risks associated with climate change may lead to significant economic and financial losses due to potentially severe damages to the income flow and asset portfolio of households, nonfinancial firms, banks, and insurers (Batten, Sowerbutts, and Tanaka, 2016; Battiston and others, 2017; Campiglio and others, 2018; IMF, 2020b, 2021; Ramírez, Thomä, and Cebreros, 2020; Monasterolo, 2020). Physical risks of climate change may also have significant impact on the fiscal position and debt sustainability, with negative repercussions throughout the economy (Cevik and Jalles, 2020; 2021; 2022).

- **Transition risks of climate change** emanate from efforts to build a green economy. Transition risks materialize when changes in technology, standards, taxation, and other policies turn carbon-intensive assets into stranded assets and amplify losses through financial interconnectedness (Batten, Sowerbutts, and Tanaka, 2016; Battiston and others, 2017; Caldecott, 2018; Campiglio and others, 2018; Pointner and Ritzberger-Grünwald 2019; IMF, 2020b, 2021). There is an additional liability risk, which refers to the legal risks from parties adversely affected by climate change and climate change policy (Kunreuther and Michel-Kerjan, 2007; Ackerman, 2017). Therefore, transition risks capture the uncertainties related to the timing and speed of the adjustment to a low-carbon economy. While moving towards a greener economy is the beneficial objective, it generates significant financing needs and results in structural changes.

Cross-border spillovers stemming from the occurrence of physical and transition risks in other countries should also be taken into account. Cross-border spillover of climate risks occur through international trade and supply chain linkages as well as changes in standards, taxation and other policies in trading partners (Benzie and others, 2019; Carter and others, 2021; Feng, Li, Prasad, 2021). One important cross-border spillover risk, especially in the context of tourism-dependent economies, is related to the introduction of a carbon tax on international aviation and maritime, which constitutes a significant shock that would lower export earnings and have an immediate impact on the balance of payments.[3]

Box 1. Effects of Climate Change

More destructive hurricanes. Tropical storms are growing stronger with more rainfall as the global surface temperature continues to increase relative to the preindustrial average. The number of hurricanes reaching the highest categories with more destructive effects has increased in recent decades, and this trend is expected to continue, especially if global warming reaches beyond 1.5°C.

Sea level increase. Sea level is rising at an increasing rate, worsening the extent of high-tide flooding and storm surge around the world. Even if global warming stays below 2°C, sea levels are projected to surge 2-3 meters by 2300 and by 5-7 meters with faster global warming. By 2100, once-in-a-century coastal flood events will occur at least once per year at more than half of coastlines across the globe.

Widespread flooding. Climate change is intensifying the risk of floods as wells as droughts. While more intense evaporation will lead to more droughts, warmer air can produce extreme rainfall. On average, the frequency of heavy downpours has already increased by about 30 percent and they contain about 7 percent more water.

Extreme heat waves. Extreme heat waves, such as the deadly one that occurred in many parts of North America in summer 2021, are already about five times more likely to occur with existing warming of 1.2°C. With global warming of 2°C, this frequency increases to 14 times as likely to occur. Heat waves are getting hotter, and with 2°C of global warming, the hottest temperatures would reach nearly 3°C higher than previous heat waves.

Severe droughts. Climate change is increasing the frequency and severity of droughts. Severe droughts that used to happen at an average of once per decade are now occurring about 70 percent more frequently. If global warming reaches 2°C above the preindustrial average, severe droughts will occur between two and three times as often.

Weather whiplash. Climate change is not just increasing the severity of extreme weather events, but it is also interrupting the natural patterns and creating a "weather whiplash"—wild swings between dry and wet extremes—destructive floods in one year and extreme droughts in the next.

Source. IPCC (2021).

III. Macroeconomic Effects of Climate Change

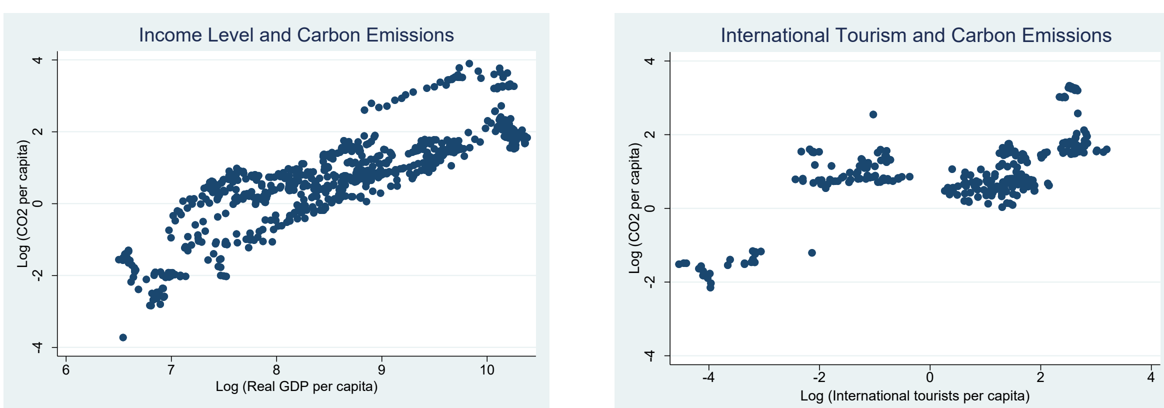
Small island states in the Caribbean—and beyond—are particularly vulnerable to potentially cascading effects of climate change. According to the World Meteorological Organization, the number of weather-related disasters around the globe had already increased fivefold during the period 1970-2019, with the total losses amounting to US$3.6 trillion and 2 million deaths (WHO, 2021). Looking forward, the IPCC projects the global sea level to increase

[3] For example, Tol (2007) finds that a carbon tax on international aviation would "induce a shift from long flights to medium distance ones and a shift from medium distance flights to short distance holidays, [and thereby] disproportionally hit island nations [if] the tax is applied regionally rather than globally."

by 52-98 centimeters by 2100 with significant local variation. An analysis based on historical sea-level trends puts the rate of increase at 1.5 meters by 2100 in the Caribbean and identifies the region as the most vulnerable in the world (Strauss and Kulp, 2018). Furthermore, a recent study finds that hurricane-related damages would tripled in the Caribbean if protective ecosystems such as coral reefs and mangrove forests are degraded or lost due to climate change (Silver and others, 2019). Therefore, these complex developments with numerous environmental and economic interconnections make climate change a macro-critical destabilizing risk to small island states with limited human capital, institutional and fiscal capacity and economic diversification.

Tourism—the most important sector in the Caribbean—will face the full onslaught of climate change. Tourism is the main engine of economic activity across the Caribbean, but it is also one of the most vulnerable to climate change. A recent study show that climate change vulnerability already has a statistically and economically significant negative effect on international tourism revenue in Caribbean countries (Cevik and Ghanzanchyan, 2021). Coastal areas are the most visited tourist destinations as well as the most vulnerable to climate change due to hurricane and inundation risks throughout the region (UNDP, 2010; Scott, Simpson, and Sim, 2012; Pathak and others, 2021).[4] In the long-term, the dual combination of rising sea levels and of coastal erosion is projected to reduce the quantity and quality of available beach space without significant adaptation measures and could therefore diminish the attractiveness of the region as high-end tourism destination. As shown in Figure 4, it is also important to take into account its negative externalities due to carbon-intensive energy production and consumption of material resources in accommodation, transportation and other tourist activities, and changes in land use associated with tourism investments (Cevik, 2022). Finally, if other countries put in place a carbon tax on international aviation and maritime for climate change mitigation, that could lead to a reduction in

Figure 4. Income, Tourism and Carbon Emissions



Source: IMF; World Bank; author's calculations.

[4] For example, with approximately 80 percent of the land lying less than 1.5 meter above sea level, The Bahamas is one of the most vulnerable countries in the region to extreme weather hazards exacerbated by climate change.

international tourism demand, especially from long-distance markets such as Europe, and have a significant impact on the balance of payments.

Domestic agriculture and fisheries and food imports are vulnerable to threats associated with global warming. Climate change influences food production via direct and indirect effects on crop production, due directly to changes in CO_2 availability, precipitation and temperatures, as well as because of indirect effects such as soil erosion, new pest and diseases, and desertification. The agriculture sector in the Caribbean accounts for about 5 percent of GDP and 23 percent of employment, and consequently 90 percent of food is imported, which makes the region highly vulnerable to changes in international food prices. Domestically, the submergence of coastal areas and the increased likelihood of droughts will likely further reduce the available land for cultivation and agricultural productivity. The impact of climate change globally is also expected to be increasingly negative on key staple crop yields, disrupt the global food trade market, and have a direct effect on oceans and fish populations throughout the Caribbean.

IV. CLIMATE CHANGE MITIGATION

Caribbean countries have pledged to reduce GHG emissions by a range of 15 to 70 percent by 2030, conditional on financial and technical assistance. As presented in Table 1, Caribbean countries have also made similar commitments to cut GHG emissions by 15 to 70 percent by 2030, relative to a no-policy-change scenario, as long as international financial and technical assistance is provided, or other conditions are met.[5] While there has been some progress toward climate change mitigation, notably by increasing the share of renewable energy in some countries (UNFCCC, 2020), the current trajectory indicates that the Caribbean cannot meet the NDC commitments by 2030 with existing policies.

Stronger and more comprehensive policies are necessary to close the emissions mitigation gap in the Caribbean. The Caribbean's share of global CO_2 emissions is only 0.3 percent, but the average level of CO_2 emissions on a per capita basis has increased from 3.5 tons in 1990 to 5.1 tons in 2019 compared with the current global average of 4.6 tons. Countries in the region have ample opportunities to reduce CO_2 emissions through broad-based policies and reforms. In particular, there are five areas where more ambitious and comprehensive initiatives could make a significant contribution towards net-zero emissions: (i) eliminating distortionary energy subsidies; (ii) introducing a carbon tax and fees on high-emission products combined with rebates on low-emission products; (iii) improving energy efficiency and decarbonizing the energy sector with higher share of renewables; (iv) electrifying mobility and transportation; and (v) developing sustainable land-use practices and smarter urbanization with better rules and regulations.

[5] Some Caribbean countries, including Barbados, Haiti, Jamaica, and St. Vincent and the Grenadines, have also made unconditional NDC commitments that could be met without any conditions and based on countries' own resources and capabilities. Countries also adopt non-GHG and action-based targets as well as sector-specific emissions reduction targets, such as such as generating a given amount of all electricity from renewables, using renewable energy sources in street lighting, and cutting GHG emissions in the agriculture sector, respectively.

Energy subsidies amount to as much as 18 percent of GDP in some Caribbean countries, distorting economic incentives and contributing to environmental degradation. Subsidies on fossil fuels and electricity amount to significant amounts in some Caribbean countries, but there is considerable variation in the size and types of energy subsidies. Fossil fuel subsidies are larger in energy-rich countries, such as Suriname and Trinidad and Tobago, while electricity subsidies are more prevalent in the rest of the Caribbean. The prevalent use of energy subsidies undermines fiscal sustainability, divert resources away from more productive areas (such as education and healthcare), benefits the rich more than the poor, and discourages efficiency improvements in the energy sector. Consequently, energy subsidies become a distortionary burden on long-term economic growth and the environment due to overconsumption. More efficient pricing of energy, on the other hand, would reduce CO_2 emissions by more than a third relative to the baseline level, keep global warming below 1.5°C, raise additional revenues, and improve environmental quality (Parry, Black, and Vernon, 2021).

Table 1. Caribbean NDC Commitments Under the Paris Agreement

Country	Conditional Emissions Reduction Target	Unconditional Emissions Reduction Target	Target Year
Antigua and Barbuda	-	-	2030
Aruba	-	-	-
Bahamas	30 percent	-	2030
Barbados	70 percent	35 percent	2030
Cuba	-	-	2030
Dominica	35 percent	-	2030
Dominican Republic	25 percent	-	2030
Grenada	40 percent	-	2030
Guyana	-	-	2030
Haiti	26 percent	5 percent	2030
Jamaica	25.4 percent	28.5 percent	2030
St. Kitts and Nevis	35 percent	-	2030
St. Lucia	23 percent	-	2030
St. Vincent and the Grenadines	-	22 percent	2025
Suriname	-	-	2030
Trinidad and Tobago	15 percent	-	2030

Note: Emissions reduction targets are set relative to the no-policy-change ("business-as-usual") scenario. "-" denotes the lack of overall GHG emissions reduction target, but those countries may still have non-GHG and action-based targets as well as sector-specific emissions reduction targets. Conditional contribution refers to whether countries would meet the NDC target as long as international financial and technical assistance is provided, or other conditions are met. Unconditional contribution refers to the NDC target countries could meet without any conditions and based on own resources and capabilities.

Fiscal measures, including a carbon tax on fossil fuels, are the most efficient tool for climate change mitigation. Even a modest carbon price can help mobilize investment in renewable energy, encourage greater energy efficiency, and thereby induce significant abatement in CO_2 emissions within a short period (IMF, 2020a; Black and others, 2021; Gugler, Haxhimusa, and Liebensteiner, 2021; Parry, Black, and Roaf, 2021). As long as CO_2 emissions remain free, there is no effective incentive for the emitters to alter behavior. In contrast, imposing a tax on CO_2 emissions relays a powerful signal throughout the economy. Carbon-intensive goods and services would become more expensive and rebalance consumption patterns toward low-carbon options. Black and others (2021) proposes a range of carbon taxes for advanced, high-income emerging markets and low-income emerging markets—$75, $50 and $25 per metric ton of CO_2 emissions, respectively.[6] It is also necessary to consider other measures such as "feebates"—fees on products with high emissions combined with rebates on products with low emissions—in carbon-intensive sectors.

Simulation exercises with a carbon tax as the main mitigation tool indicate a wide range of tax rates to achieve the NDC targets. The simulation analysis, based on the Climate Policy Assessment Tool (CPAT) framework developed by IMF and World Bank (IMF, 2019; Parry, Black, and Vernon, 2021), shows that fossil fuels are underpriced in Caribbean countries relative to negative externalities.[7] A carbon tax would therefore help attain the optimal price that takes into account negative externalities and leads to convergence towards the emissions reduction target. Table 2 presents two alternative scenarios with a carbon tax set to gradually increase to (i) US$50 per metric ton of CO_2 emissions and (ii) US$75 per metric ton of CO_2 emissions by 2030. Assuming that a carbon tax of US$50 per ton of CO_2 emissions is the only policy instrument used, the simulation results suggest that some Caribbean countries, such as Dominica, Haiti, St. Lucia, and Trinidad and Tobago, can achieve or come very close to meeting the mitigation targets by 2030. For others, however, a higher level of carbon tax would be necessary to cut CO_2 emissions in line with the NDC commitments.[8]

The economic impact of a carbon tax varies from country to country according to the initial energy matrix and upstream linkages in the energy sector. Simulations based on the

[6] Only 17 percent of emissions were covered by a carbon price, which was at a global average of US$3 per ton.

[7] The CPAT provides country-specific projections of fuel use and CO_2 emissions by the energy, industrial, transportation (excluding international aviation and maritime), and residential sectors. The CPAT model is parameterized using data compiled from the International Energy Agency (IEA) on recent fuel use by country and sector. Real GDP projections are from the latest IMF forecasts. Data on energy taxes, subsidies, and prices by energy product and country is compiled from publicly available and IMF sources, with inputs from proprietary and third-party sources. International energy prices are projected forward using an average of IEA and IMF projections for coal, oil, and natural gas prices. Assumptions for fuel price responsiveness are chosen to be broadly consistent with empirical evidence and results from energy models.

[8] This dispersion reflects cross-country differences commitments and in the energy mix, which leads to differences in the responsiveness of emissions to prices. Furthermore, since the CPAT uses price elasticity assumptions to determine changes to the energy mix, if a country initially has a very low level of renewable energy, changes in fossil-fuel prices will not elicit a large increase in renewables. Non-tax policies may be needed to introduce renewable energy and these policies are not covered in the CPAT framework.

CPAT model, presented in Table 2, also show that there would be substantial revenue gains from the introduction of a carbon tax, with no significant negative impact on economic growth, except in the case of oil-producing countries, such as Suriname and Trinidad and Tobago, which is still marginal especially considering the broader positive effects on health and environment. These macro-fiscal effects will vary from country to country according to the initial energy matrix and upstream linkages in the energy sector. For example, at US$50 per metric ton of CO_2 emissions, a carbon tax would yield additional revenues amounting to 0.8 percent of GDP in Jamaica and as much as 1.8 percent in the case of Belize. The impact on economic growth, on the other hand, appears to be insignificant—nil in Jamaica and -0.1 percent in Belize, assuming that additional revenues are recycled back into the economy through lower taxes or higher spending. Data constraints prevent estimating the impact on employment, but evidence from other countries in Latin America suggests that carbon-intensive sectors may experience a loss of employment with the decline in demand for less clean energy products. However, there would be employment gains in clean-energy sectors as well as significant improvements in environmental conditions and living standards. Furthermore, compensatory policies designed to recycle additional revenue through lowering other taxes and increasing targeted cash transfers and public investment can alleviate adverse effects on disposable household income.[9]

Table 2. Alternative Carbon Taxes for Climate Change Mitigation

	Carbon Tax of US$50 by 2030			Carbon Tax of US$75 by 2030		
Country	Proportion of Emissions Gap Narrowed by Policy (percent)	Additional Revenue (percent of GDP)	Growth Impact (percentage points)	Proportion of Emissions Gap Narrowed by Policy (percent)	Additional Revenue (percent of GDP)	Growth Impact (percentage points)
Antigua and Barbuda	-	-	-	-	-	-
Aruba	-	-	-	-	-	-
Bahamas	11.2	0.4	-0.1	14.3	0.6	-0.1
Barbados	-	-	-	-	-	-
Belize	-	1.8	-0.1	-	2.7	-0.2
Cuba	-	-	-	-	-	-
Dominica	115.5	0.5	0.0	138.0	0.7	0.0
Dominican Republic	68.2	0.6	0.0	85.9	0.8	0.0
Grenada	28.8	0.4	0.0	31.4	0.6	0.0
Guyana	-	0.7	0.0	-	1.1	-0.1
Haiti	75.6	0.6	0.1	83.8	0.9	0.2
Jamaica	54.5	0.8	0.0	68.1	1.2	-0.1
St. Kitts and Nevis	-	-	-	-	-	-
St. Lucia	74.5	0.1	0.0	78.6	0.2	0.0
St. Vincent and the Grenadines	24.4	0.6	0.0	30.1	0.8	0.0
Suriname	-	1.6	-0.1	-	2.4	-0.2
Trinidad and Tobago	82.2	2.8	-0.6	111.6	4.1	-0.8

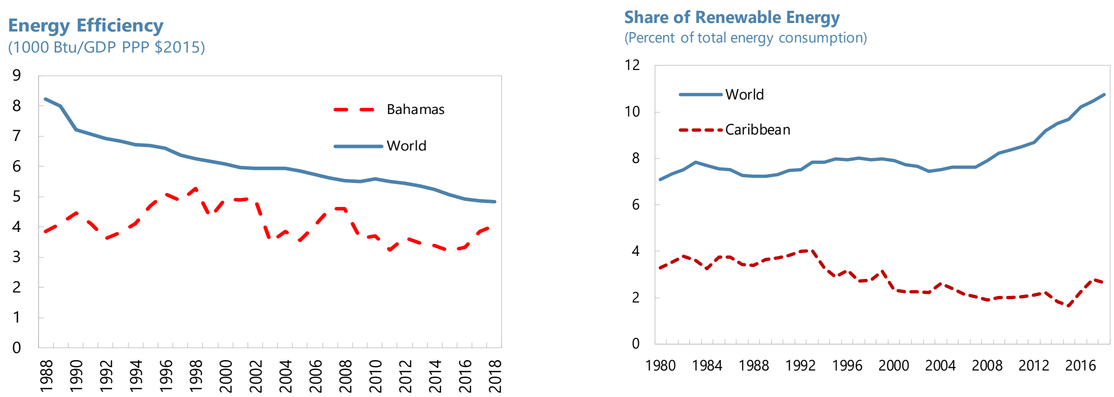
Note: The impact of a carbon taxes per ton of CO2 is determined according to the CPAT framework as outlined in IMF (2019) and Parry, Black, and Vernon (2021). "-" denotes either the lack of NDC commitment or data required for simulations.

Decarbonization must start in the energy sector, which is responsible for more than 70 percent of CO_2 emissions in the Caribbean. CO_2 emissions are a result of (i) population, (ii) GDP per capita, (iii) carbon content of energy resources, and (iv) energy consumption per unit

[9] Vogt-Schilb and others (2019) find that 30 percent of revenues generated by a carbon tax of $30 per metric ton of CO_2 emissions could be enough to compensate poor and vulnerable households on average in Latin America and the Caribbean, leaving 70 percent of additional funds for other expenditure priorities.

of GDP. Reducing CO_2 emissions requires the reduction of one or more of these four factors, which implies that policies should focus on decarbonizing the energy matrix (lower CO_2 emissions per unit of energy) and enhancing energy efficiency (lower energy consumption per unit of GDP). Globally, the amount of energy used to produce a unit of GDP declined by 41.3 percent over the past three decades, owing to more energy-efficient production processes and greater energy efficiency of consumer goods and services (Figure 5). During the same period, however, energy efficiency in the Caribbean improved by merely 1.7 percent (and declined by 16.1 percent between 2000 and 2018). Improving energy efficiency is therefore key to reduce CO_2 emissions and become more resilient to climate change, especially considering the strain on energy generation systems put by global warming (Santamouris and others, 2015). Another critical consideration is the energy matrix, which is currently shaped by extreme dependence on imported fossil fuel. Almost 90 percent of electricity is produced using fossil fuels, compared to 57 percent in the rest of Latin America. Only Belize and Suriname have hydro-electric capacity, and renewable energy sources account for 2.7 percent of the total electricity consumption, compared to more than 10 percent in the rest of the world (Figure 5). As a result, most Caribbean countries are not only completely reliant on imported fossil fuels that leave it vulnerable to global price fluctuations, but the energy mix is also highly damaging to the environment.

Figure 5. Energy Efficiency and Renewable Energy



Source: EIA; author's calculations.

The empirical analysis shows that improving energy efficiency in the Caribbean could bring a significant reduction in CO_2 emissions. Improved energy efficiency—measured as energy intensity of economic activity—can make a big contribution to efforts in the Caribbean toward meeting the climate commitments by reducing carbon emissions. Accordingly, I empirically investigate the impact of energy efficiency on CO_2 emissions in a panel of 15 Caribbean countries over the period 1980–2019, employing a fixed effects model of the following specification:

$$CO2_{i,t} = \beta_1 + \beta_2 EE_{i,t} + \beta_3 X_{i,t} + \eta_i + \mu_t + \varepsilon_{i,t}$$

where $CO2_{i,t}$ denotes the logarithm of CO_2 emissions per capita in country i and time t; $EE_{i,t}$ is the logarithm of energy efficiency as measured by energy consumption per unit of real GDP; $X_{i,t}$

is a vector of control variables including the logarithm of real GDP per capita, trade openness, the logarithm of population, and the share of urban population, which are commonly used in the literature (Narayan and Narayan, 2010; Piaggio and Padilla, 2012; Özbuğday and Erbaş, 2015; Tajudeen, Wossink, and Banerjee, 2018; Xia and others, 2020; Cevik, 2022).[10] The η_i and μ_t coefficients denote the time-invariant country-specific effects and the time effects controlling for common shocks that may affect inflation across all countries in a given year, respectively. $\varepsilon_{i,t}$ is the error term. To account for possible heteroskedasticity, robust standard errors are clustered at the country level.

Table 3. Empirical Model of Energy Efficiency and CO_2 Emissions

	Fixed Effects	
	[1]	**[2]**
Energy efficiency		**-0.590*****
		[0.077]
Real GDP per capita	0.994***	0.364***
	[0.421]	[0.092]
Trade openness	-0.001	-0.001
	[0.004]	[0.001]
Population	-1.024*	-0.896***
	[0.543]	[0.146]
Urbanization	0.010	0.013
	[0.010]	[0.004]
Number of observations	478	332
Number of countries	15	15
Country FE	Yes	Yes
Year FE	Yes	Yes
Adj R^2	0.66	0.72

Note: The dependent variable is CO2 emissions per capita. Robust standard errors, clustered at the country level, are reported in brackets. A constant is included in each regression, but not shown in the table. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Econometric results, presented in Table 3, show that improving energy efficiency could make a significant contribution to reducing CO_2 emissions across the Caribbean. The estimated coefficient on energy efficiency is statistically highly significant with a magnitude of 0.59, which is in line with estimates in previous studies. In other words, a 10 percentage point increase in energy efficiency is associated with lower CO_2 emissions of 6 percentage points in the long-run, after controlling for economic, demographic and institutional factors.[11] These findings indicate that improving energy efficiency can play a fundamental role in mitigating CO_2 emissions towards the NDC targets adopted by Caribbean countries. For example, if energy efficiency in the Caribbean had increased at the same rate of the world average over the past three decades, CO_2 emissions in the region would have already been 25 percentage points lower. Therefore, to decarbonize economic

[10] The dataset of annual observations used in this analysis are drawn from the IMF's International Financial Statistics and World Economic Outlook databases, the World Bank's World Development Indicators database, and the U.S. Energy Information Administration. Summary statistics are presented in Appendix Table A1.

[11] The estimated coefficients on control variables have the expected signs and some are also statistically significant.

activity, policies and reforms should aim to improve energy efficiency in commercial and residential use and shift the energy matrix away from fossil fuels to mainly renewables.

Electrifying mobility and transportation is particularly important in Caribbean countries, which rely on low-efficiency vehicles running on gas or diesel. Transport is a critical facilitator for economic development, but it also accounts for more than one-third of oil consumption and over 20 percent of CO_2 emissions on average in the Caribbean. The region has great potential to take advantage of technological improvements for the electrification of transportation systems.[12] First, second-hand cars imported mostly from advanced countries are a major environmental problem in Caribbean countries, while the pricing of new motor vehicles does not take into account relative energy or CO_2 intensities. Therefore, a "feebate" system for motor vehicles could incentivize cleaner automobiles by raising the cost of more polluting vehicles. Second, options for both basic transportation and more flexible human mobility are now being electrified, with an increasing number of all types of traditionally fossil-fueled vehicles making the transition to electrification. Third, shorter distances across the archipelago, compared to other geographies, make it easier for electric-powered motor vehicles, especially as renewable energy resources become more abundant (Gay, Rogers, and Shirley, 2018). Electrifying mobility and transportation brings many benefits, including diversifying the fuel portfolio, lowering total cost of ownership, improving price stability, strengthening energy independence, and attaining a healthier environment.[13] Furthermore, with a vehicle-to-grid approach, the electrification of the transportation system creates a significant opportunity to bring more renewable energy onto the grid by managing and leveling periods of intermittency in solar and wind.

Decarbonizing the energy sector, improving efficiency and building a transportation infrastructure with clean energy require new cost-effective technologies. Because of limited domestic research and development (R&D) capacity in small island states, international technology and knowledge transfers would help fast-track investments for climate change mitigation and adaptation. Nevertheless, economic and environmental sustainability necessitates the development of domestic capacity for innovation in low-carbon products and processes, which in turn depends on competition in energy, infrastructure and transportation sectors. Industrial policies and structural reforms can streamline the regulatory burden and enhance competition to unchain private investment into the green transition, while subsidies and direct public funding for R&D can promote technological change towards green technologies in the Caribbean.

Sustainable land-use practices and urbanization with better rules and regulations can complement green taxes to reduce CO_2 emissions. The shift to more sustainable forms of agriculture and tourism, combined with stronger protection and restoration of ecosystems, can be a potent climate solution, while creating jobs, improving food security, and diversifying the

[12] Electric vehicles still only make up about 1 percent of the global fleet of passenger cars, but sales are increasing rapidly across the world including the Caribbean.

[13] Air pollution caused by CO_2 emissions is associated with serious health problems, including respiratory and cardiovascular diseases (Halkos and Argyropoulou, 2020).

tourism sector. In addition, restoration of natural capital, especially forests and coastal ecosystems, can make our societies resilient to extreme weather events, as well as slow onset changes like desertification or sea level rise. Transition to low-carbon economy also requires smarter urbanization with zoning practices and building standards that are designed to reduce vulnerability to climate change, expand green areas, strengthen emission management in new projects, and improve energy efficiency in commercial and residential buildings.

V. CLIMATE CHANGE ADAPTATION

Caribbean countries must mainstream adaptation into development plans to become more resilient to climate change. Long-term risks associated with climate change cannot be completely eliminated, which means government must take decisive action to strengthen physical, financial, institutional and social resilience. A variety of adaptation measures have been introduced to enhance resilience to climate change, but there are still significant gaps that keep the region vulnerable to threats associated with climate change. To this end, the IMF's Disaster Resilience Strategy (DRS) framework recommends a three-pillar approach to internalize the costs and returns of resilience building into sustainable macroeconomic frameworks consistent with debt sustainability. Enhancing structural resilience requires infrastructure and other ex-ante investments to limit the impact of disasters, including "hard" policy measures (e.g., upgrading public infrastructure), and "soft" measures (e.g. developing early warning systems and strengthening zoning and building codes); building financial resilience involves creating fiscal buffers and using prearranged financial instruments to protect fiscal sustainability and manage recovery costs; and post-disaster and social resilience requires contingency planning and related investments ensuring a speedy response to a disaster.[14]

There will be upfront fiscal cost of climate change adaptation, but investing in structural resilience would yield long-run socioeconomic benefits. With the average public debt ratio standing above 100 percent of GDP, Caribbean countries have limited fiscal space to finance climate adaptation needs. Tiedemann and others (2021) estimate that infrastructure spending alone would need to be scaled up by an additional 3.7 percent of GDP per year in small developing states to close the adaptation gap by 2030.[15] However, although climate change adaptation has significant upfront costs, the lack of inaction on the climate front would have even a greater cost for generations. Investing in climate-resilient infrastructure would reduce damages from natural disasters and increase expected returns to private investment and output. Well-designed policy measures could also have sustained expansionary effects through higher growth in employment and wages and lower migration, which tends to occur in countries prone

[14] In the Caribbean, Dominica and Grenada have developed such DRS frameworks with IMF's support.

[15] The sample of small developing states in this study includes Antigua and Barbuda, The Bahamas, Belize, Bhutan, Cabo Verde, Comoros, Djibouti, Dominica, Fiji, Federated States of Micronesia, Grenada, Guyana, Kiribati, Maldives, Mauritius, St. Kitts and Nevis, St. Lucia, St. Vincent and the Grenadines, Samoa, Sao Tome and Principe, Seychelles, Solomon Islands, Timor-Leste, Tuvalu and Vanuatu. With a broader perspective, another recent report estimated annual adaptation costs in developing countries at US$70 billion, which is expected to reach US$140-300 billion in 2030 and US$280-500 billion in 2050 (UNEP, 2021b).

to natural disasters. Staff simulations, based on a dynamic stochastic general equilibrium model for climate change adaptation, indicate that investing in climate-resilient infrastructure can boost the level of GDP in the long run between 2 and 6 percent for Caribbean islands (IMF, 2021). Furthermore, strengthening structural resilience would help keep the level of output around ¼ percent higher and the level of public debt about ¾ percentage points lower on average three years after a natural disaster, thanks to lower reconstruction spending and less revenue losses owing to the smaller decline in economic activity.

A multilayered insurance framework plays a critical role in supporting climate adaptation while safeguarding public finances. As a region subject to significant threats associated with the fast-changing climate, Caribbean countries need to have a comprehensive insurance strategy for post-disaster recovery and reconstruction in addition to participating in the Caribbean Catastrophe Risk Insurance Facility (CCRIF).[16] Staff simulations based on a stochastic model indicate that an insurance coverage of 15-30 percent of GDP for Caribbean countries could cover 99 percent of the fiscal cost of natural disasters (Guerson, 2020). Accordingly, countries should expand the insurance coverage by: (i) establishing a government savings fund of 2-5 percent of GDP with annual inflows for ½ percent of GDP during non-disaster years; (ii) introducing a mandatory natural disaster insurance for all private residential and commercial properties with premiums adjusted according to the quality of buildings (iii) issuing state-contingent bonds to provide debt service relief for extreme events; and (iv) raising access to parametric insurance under the CCRIF against less frequent but larger natural disasters.

Nature-based solutions are essential in the fight against climate change and could also contribute to the development of ecotourism. There is growing recognition that climate change is causing biodiversity loss across the world, while nature has a fundamental role in climate change mitigation and adaptation (IPBES, 2019). In view of these interlinkages, nature-based solutions—designed to protect, sustainably manage and restore natural ecosystems—can become highly effective in providing economic well-being as well as greater biodiversity benefits. In particular, nature-based solutions can be applied to address a range of climate risks, including coastal hazards, floods and soil erosion, and rising temperatures and drought (Kapos and others, 2019). Another important advantage of nature-based solutions for adaptation is the cost, which tends to be significantly less than traditional infrastructure for addressing climate hazards (Narayan and others, 2016; Reguero and others, 2020) and generate substantial economic benefits (Menéndez and others, 2020). When well-designed and implemented, they have the potential to generate larger returns in broad socioeconomic terms in addition to reducing climate risks (Rizvi, 2014; Seddon and others 2020). Additional advantages include environmental benefits such as carbon sequestration and storage and biodiversity conservation and socioeconomic benefits such as the provision of food, marketable products, jobs and livelihoods,

[16] The CCRIF, established in 2007 with 23 members, is the first multi-country risk pool in the world. The CCRIF develops parametric insurance policies—designed for tropical cyclones, earthquakes, excess rainfall and the fisheries sector—to limit the financial impact of natural hazard events in the Caribbean.

improved health, and support for cultural and religious values.[17] Nature-based solutions could also provide a much-needed additional stream of revenue if Caribbean countries choose to utilize carbon credit schemes for environmental protection.[18]

VI. ACCESS TO GREEN FINANCING

Financing climate change mitigation and adaptation efforts will require mobilizing additional resources and reforming public financial management. Small island states will need alternative sources of financing for critical investments to strengthen climate resiliency. Adapting to climate change is not cheap, and it will require substantial amount of additional upfront resources to invest in physical infrastructure and other key areas to increase resilience and lessen the macro-financial impact of climate change. With an average public debt ratio already standing above 100 percent of GDP, most Caribbean countries do not have adequate fiscal space to finance climate adaptation needs.

Green financing has grown at a remarkable pace over the past decade and provided valuable resources for sustainable investment projects. Small island states in the Caribbean and beyond can access a rapidly-growing stream of international financing for climate change-related investment projects. The sustainability-linked debt market has reached US$2.5 trillion with net new issuance of US$660 billion in 2020, of which 2.5 percent or US$19 billion was issued by countries in Latin America and the Caribbean. The most significant component of this market in terms of size and environmental impact is green bonds that are used to finance projects to facilitate climate change adaptation and mitigation. Green bonds are growing rapidly in Latin America and the Caribbean, with the region accounting for US$7.9 billion of US$290 billion in global issuance in 2020.[19] Despite its rapid growth, however, sovereign green bonds remain small—about 1 percent—compared to traditional debt instruments issued by governments. Climate vulnerable countries with significant investment needs must improve the institutional framework, including robust and transparent public financial management systems and processes, to gain full access to the global flow of green financing (Fouad et al., 2021; Mejía-Escobar, González-Ruiz, and Franco-Sepúlveda).

[17] For example, Jamaica used a nature-based approach to protect and restore the marine ecosystem in the White River fish sanctuary and achieved an increase of 147 percent in coral coverage and 1,700 percent in fish biomass within the protected area.

[18] Carbon credits are basically a cap-and-trade system that allows emitters to trade carbon permits on an international financial platform. A carbon credit, also called a carbon offset, is a credit for carbon emissions reduced or removed from the atmosphere by an emission reduction project, which can be used by governments and/or companies to compensate for the emissions they generate elsewhere. REDD+ (Reducing Emissions from Deforestation and Forest Degradation), a United Nations-backed framework, is the most prominent international financial mechanism currently being practiced for conserving tropical forests and reducing CO_2 emissions from forestry and land use in the tropics.

[19] On a cumulative basis, the outstanding amount of green bonds in Latin America and the Caribbean reached US$30.2 billion as of June 2021 out of over US$1 trillion globally (CBI, 2021).

VII. CONCLUSION

Climate change is largely not the fault of Caribbean countries, although the region's economic development model has been carbon-intensive. At the precipice of climate change, however, the Caribbean is one of the most exposed and vulnerable regions across the world because of its geography and economic composition. The latest projections show that without immediate and comprehensive action, the frequency and intensity of extreme weather events will only get worse and inflict greater harm on the environment, lives, and livelihoods, especially in small island states in the Caribbean.

A well-designed set of policies and reforms would help the Caribbean to reduce CO_2 emissions and diversify the energy matrix. To guard against threats associated with climate change, countries need to proceed on two fronts: (i) climate mitigation, which refers to policies that help reduce CO_2 emissions and (ii) climate adaptation, which refers to efforts to adapt to the effects of climate change including through minimizing damages from climate-related disasters as well as to adapt to the effects of economic transformations. The empirical analysis presented in this paper indicates that increasing energy efficiency and reducing the use of fossil fuel in electricity generation could lead to a significant reduction in energy-related CO_2 emissions. From a risk-reward perspective, the benefits of reducing the risks of climate change and the health benefits from higher environmental quality clearly outweigh the potential cost of mitigation policies in the short run. Environmental taxes, including a carbon tax on fossil fuels, could raise considerable revenues, which can support domestic revenue mobilization efforts and provide additional funding to compensate the most vulnerable households, build a multilayered safety net, and strengthen structural resilience.

Caribbean countries also need to mainstream adaptation into development plans to strengthen resilience against climate change. Long-term climate risks cannot be completely eliminated, and thus governments must take decisive action to strengthen physical, financial, institutional and social resilience. A variety of adaptation measures have been introduced to enhance resilience to climate change in the Caribbean, but there are still significant gaps that keep the region vulnerable to threats associated with climate change. Enhancing structural resilience requires infrastructure and other ex-ante investments to limit the impact of disasters, while building financial resilience involves creating fiscal buffers and using prearranged financial instruments to protect fiscal sustainability and manage recovery costs. These measures will have upfront fiscal costs, but the lack of inaction on the climate front would have even a greater cost for generations. Furthermore, strengthening physical and financial resilience would reduce damages from natural disasters and increase expected returns to private investment and output. With well-designed policies and reforms, economic recovery could be stronger and faster, and the adverse impact on public finances would be significantly lower after a climate-related shocks.

Investing in mitigation and adaptation could be complementary elements of a broader strategy to respond to climate change. An important illustration of mitigation-adaptation interlinkages in the Caribbean is energy supply and consumption, which is determined to a great extent by tourism-related activities. Balancing mitigation and adaptation strategies would in turn provide diverse ecological, economic and social benefits and opportunities.

Appendix Table A1. Summary Statistics

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
CO_2 emissions per capita	896	3.8	6.0	0.02	49.3
Energy efficiency	465	3.8	1.5	0.5	7.7
Real GDP per capita	859	8,529	7,618	666	32,237
Trade openness	625	100.2	35.0	31.1	275.0
Population	744	1,384,490	2,738,837	40,259	11,000,000
Urbanization	744	44.9	16.7	15.6	83.2

Source: EIA; IMF; World Bank; author's calculations.

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