1. Introduction

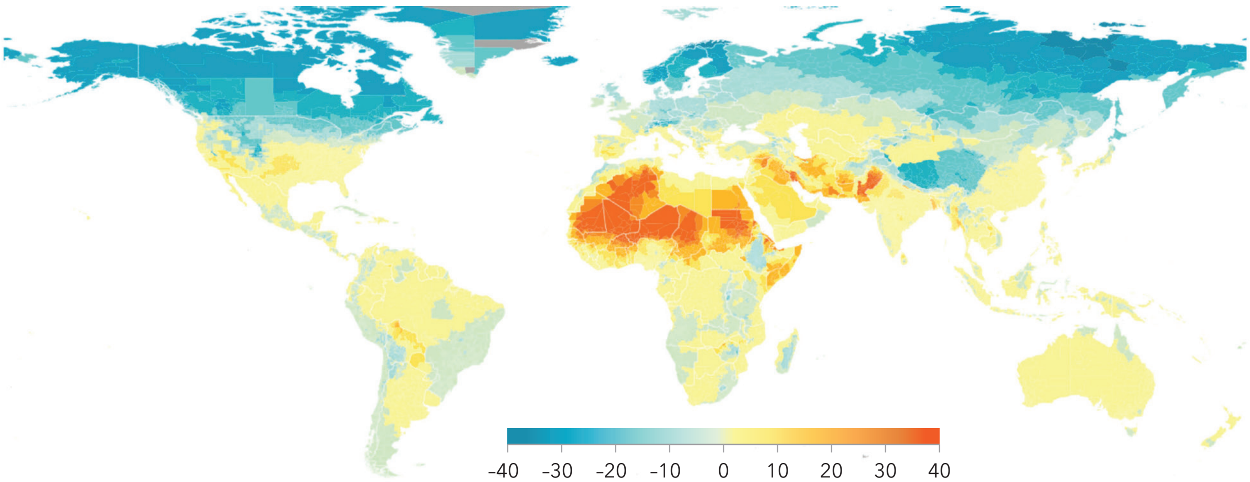
The Middle East and Central Asia (ME&CA) region is a hotspot for climate change due to its geographical setting. Spanning from the northwestern parts of the Sahara Desert across the Arabian Peninsula to the Southern Caucasus and Hindukush mountains, the region hosts a diverse group of countries—in terms of not only socio-economic development, but also geography and climate.[1] Recent climate disasters include droughts in North Africa and Central Asia; epidemics in the Horn of Africa; cyclone Gonu in the Arabian sea; locust infestations in the Horn of Africa, Arabian Peninsula, and the Indian subcontinent; severe winters, riverine floods, and landslides in the CCA; and flash floods in many countries throughout ME&CA. In much of the region, already difficult climate conditions have further harshened in recent decades, and this trend is set to accelerate more than in other regions worldwide. The Global Climate Risk Index ranked three ME&CA countries among the top 20 countries with the highest climate risks in 2019: Afghanistan, Iran, and Pakistan (Eckstein and others 2021). Increasing temperature, erratic rainfalls, and rising sea levels are expected to fuel the frequency and intensity of natural disasters (IPCC 2021b, 2019). They could permanently alter geophysical living conditions, likely to the point of making large parts of MENAP uninhabitable before the end of this century (Lelieveld and others 2016). Even in a moderate emission scenario (RCP 4.5) that limits global warming to 2–3°C by 2100, mortality-related costs—which capture both the monetized change in projected deaths and costs of adaptation to climate change—could surge more in ME&CA than in any other region. They could reach an average of 1.6 percent of GDP per year during 2040–59 (Figure 1).[2]

This paper shows that ME&CA countries have already started to feel the human, physical, and economic impact of climate change over recent decades, often amplified by low climate resilience. Utilizing data spanning more than a century, this paper shows that three interrelated climate stressors have been at play in the region: higher temperatures, more erratic precipitation, and more frequent and powerful climate disasters. Empirical analysis confirms that these changing climate patterns have caused sizable social and economic costs across ME&CA countries over the past three decades. For instance, for countries with an average annual temperature above 19 °C, untempered climate change is found to be particularly detrimental to growth. In addition, climate disasters are found to have had profound macroeconomic impacts, including an immediate real GDP growth decline of, on average, 1–2 percentage points in ME&CA sub-regions, which even translated into a permanent output loss of 5½ percentage points in CCA countries. The consequences of changing climate patterns can undermine economic development, deepen poverty and inequality, which, in turn, can aggravate existing social tensions and spark widespread protests (such as during the 2021 drought in Iran). They can also undermine regional stability through, for example, climate-driven migration and tensions over water access. Going forward, climate models predict that weather anomalies will only intensify in the future, even in moderate-emission scenarios. This is particularly pertinent for countries with low climate resilience, reflecting their dependence on rain-fed agriculture and weak initial conditions (such as poor socioeconomic fundamentals and institutional capacity). These are mainly lower-income EMDEs, particularly fragile and conflict-affected states (FCS).

[1] As shown in Annex 1, ME&CA includes: (1) 23 countries in the Middle East and North Africa (MENA), Afghanistan and Pakistan (MENAP); and (2) eight countries in the Caucasus and Central Asia (CCA). All 31 ME&CA countries are classified as emerging market and developing economies (EMDEs), of which ten are also fragile and conflict-affected states (FCS). Regional peers in the rest of the world (RoW) cover sub-Saharan Africa (SSA), Asia and Pacific (APAC), the Americas (AMER), and Europe (EUR), often excluding advanced economies.

[2] Today's cold locations are predicted to benefit and hot and/or poor locations to suffer. Three ME&CA countries rank among the five most affected countries globally (Djibouti, Pakistan, and Sudan). Their annual costs exceed 7½ percent of GDP each, relative to -0.3 percent of GDP for an average EMDE peer (Climate Impact Lab).

Figure 1. Costs of Excess Mortality from Climate Change, 2040–59
(Annual median costs, percent of projected GDP, moderate emission RCP 4.5 scenario)



Source: Climate Impact Lab.
Note: Based on Carleton and others (2020), mortality-related costs include both projected change in deaths (monetized using income-scaled values of statical life) above the historical average and the change in monetary costs of adaptation to climate change (measured in millions of 2019 US dollars). This work combines (1) comprehensive historical age-specific mortality-temperature relationships (at the subnational level for 55 percent of the global population and modified by the climate and income levels of the affected population); (2) a revealed preference approach (to estimate the total cost of adaptive behaviors and technologies); and (3) 33 high-resolution climate simulations (to capture scientific uncertainty about the degree of future temperature change).

Hence, adaptation is a pressing policy priority for ME&CA and this paper's focus. While progress on mitigation is an important goal for the region,[3,4] climate change will entail significant human and economic costs for the ME&CA region even with a substantial global mitigation effort. Accordingly, this paper focuses on adaptation, which takes climate change as exogenous and instead focuses on policies aimed at reducing its human, physical, and macroeconomic impacts. The paper's central message is that strengthening capacity to adapt to climate change is an urgent priority for ME&CA economies. Timely adaptation will not only help reduce damages from climate change, but also offers the opportunity to generate sustainable jobs in support of economic recovery from the COVID-19 pandemic in the short term (Chapter 4) and to spur a longer-term structural transformation that revitalizes economies, including those dependent on the export of fossil fuels.

Adaptation should be a central part of national climate strategies, also encompassing mitigation and transition risk management. Despite their criticality, adaptation issues in the region have not yet been well explored; this stands in contrast to climate change mitigation, which has been studied at the global level and has well established policy recommendations (IMF 2019c). Both adaptation and mitigation are critical to address climate risks, as highlighted by their inclusion in the UN's Sustainable Development Goals (SDGs) in 2015. Along with reducing GHG emissions with co-benefits for air quality, ecosystems, health, and so forth, mitigation policies—like those for adaptation—can also boost growth. This is especially the case where green investment and technology transfers complement the potential use of carbon pricing policies to foster a green recovery, provide new local jobs, and reduce the dependency on fossil fuel imports (IMF 2019b, 2019c, Krogstrup and Oman 2019).[5] To protect the poor and enhance political acceptability, mitigation policies

[3] Mitigation aims at containing climate change through the reduction of greenhouse gas (GHG) emissions, the leading cause of rapid global warming.

[4] While only contributing about a 10th of global GHG emissions, the ME&CA region hosts three of the world's 20 largest GHG emitters (Iran, Pakistan, and Saudi Arabia) and has some of the largest global emitters on a per capita basis (Bahrain, Kuwait, Qatar, and UAE). See Annex 3.

[5] Adaptation and mitigation efforts can overlap, such as reforestation, which not only captures carbon dioxide but also relieves water stresses, fosters coastal protection, and improves biodiversity.

that rely on carbon pricing or the removal of general subsidies can limit the impact on affected households through targeted support, for example targeted cash transfers (IMF 2020c). At the same time, global mitigation efforts raise transition risks for ME&CA's fossil fuel exporters (due to falling demand and prices). In response, they need to rebuild financial buffers and diversify production and exports to preserve their fiscal sustainability and macroeconomic stability (Callen and others 2014, IMF 2019c, Mirzoev and others 2020, Cherif, Hasanov, and Pande 2017).

The rest of the paper is organized as follows. Chapter 2 focuses on how climate change manifests itself in the ME&CA region. It (1) documents the past and predicted worsening of the region's main three climate stressors; and (2) provides new insights on the role of a country's resilience in driving the human damages of climate disasters. Chapter 3 presents novel empirical evidence on the macroeconomic impact of climate change in the ME&CA region. This prepares the ground for Chapter 4, which sets out common principles for effective climate-adaptation policies to strengthen the region's climate resilience and coping mechanisms. Chapter 5 discusses the financing needs and options of these policies, at the domestic and external levels. Chapter 6 offers main takeaways and policy implications, including related to IMF engagement.

2. Climate Change Challenges

ME&CA's already extreme climate conditions have harshened in recent decades, in turn increasing the frequency of associated disasters. The resulting human and material damages have been particularly large in countries with low resilience, which mainly reflects dependency on rain-fed agriculture and underlying structural vulnerabilities. Global climate change is set to further intensify current climate stresses.

A. Manifestation of Climate Change

ME&CA countries are already suffering from the ramifications of global climate change. Much of the region resides in vegetation-sparse drylands (Box 1), where climate conditions have harshened to an unprecedented extent in recent decades with higher temperatures, more erratic precipitation, and more frequent and severe disasters. In many ways, these interconnected climate stresses have been more pronounced than in other regions worldwide, with important differences across geographic locations and seasons[1]:

- *Higher temperatures*. Annual temperatures have increased by about 1½° C on average in ME&CA over the past three decades (Figure 2, panel 1). This is more than double the global increase of 0.7° C, which already significantly surpasses precedents from any comparable period during the last 10,000 years (Marcott and others 2013).
- *More erratic precipitation*. Annual precipitation has become more unpredictable in ME&CA than elsewhere (Figure 2, panel 2), with volumes on a strongly declining trend in MENAP (especially Jordan, Kuwait, Oman) and the opposite in CCA (especially Kyrgyz Republic, Tajikistan, Uzbekistan). In addition, within-year rainfall has become more volatile across the ME&CA region (especially Armenia, Georgia, Lebanon).
- *Higher frequency and severity of climate disasters*. Over the past two decades, discrete impactful events caused by a climate hazard have increased in two ways[2]:
  - *Frequency*. The occurrence of climate hazards has risen the fastest in ME&CA relative to worldwide EMDEs over the past two decades (Figure 3, panel 1). Extreme temperature phenomena have become more numerous and changing rain patterns have resulted in both more droughts (most notably in the CCA) and more frequent excessive rain events (especially in MENAP). Recent decades have seen numerous flash floods in MENAP's arid/semi-arid zones (Egypt, Iraq, Morocco, Tunisia), cyclones in the Horn of Africa, and riverine flooding and landslides after heavy rain and snowmelt in the mountainous CCA (especially Georgia, Kyrgyz Republic, Tajikistan).
  - *Severity*. Climate hazards have also become more intense in ME&CA countries over the past two decades (Figure 3, panel 2), often more than in other emerging market and developing economies (EMDEs). For instance, warm spells have increased the most in MENAP (on average by almost 19 days relative to the previous two decades) and cold spells have decreased the least in CCA countries (by only 3 days). Examples of these extreme temperature spells include the summer of 2017 in Iran, Iraq, and Kuwait and the 2008 winter in Tajikistan. ME&CA countries currently account for almost half of the 50 countries most prone to extreme heat events (Climate Impact Lab data), with populations in

[1] See for example, Lelieveld and others (2016), World Bank (2011, 2018a, 2020), and Islam, Hove and Parry (2011) on MENAP; and Prange, Wilke, and Wessenlingh (2020), Lioubimtseva and Henebry (2009), Shatberashvili and others (2015), and USAID (2018a) on the CCA. Other aspects of climate change—including ocean acidification and loss of biodiversity—are not discussed in this paper.

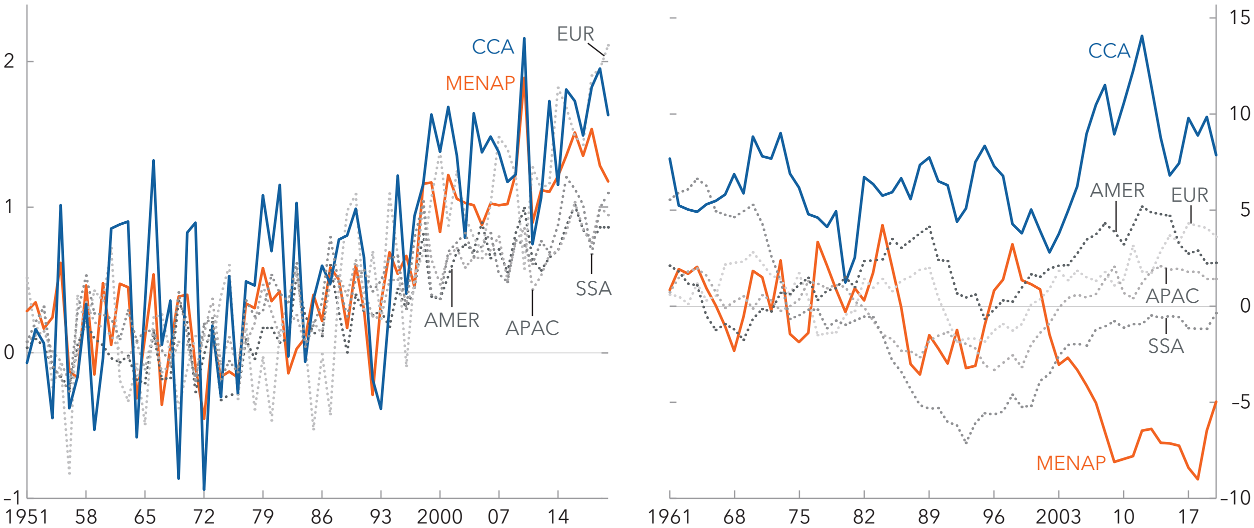
[2] A climate hazard is the physical impact from a climate event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources (IPCC 2014).

Figure 2. Climate Trends, 1951–2019

(Mean deviation of countries' annual weather averages from their respective 1901–50 averages)

1. Temperature
(Degree celsius)

2. Precipitation
(10-year rolling average deviation, percent)



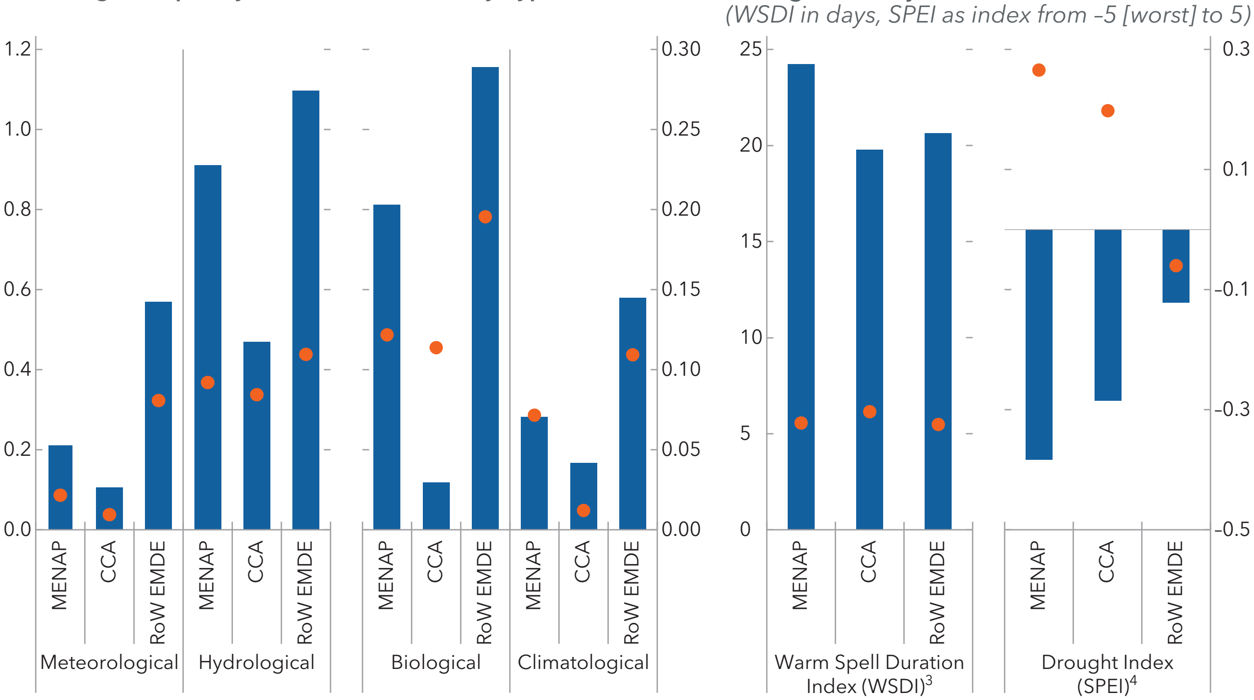
Sources: World Bank; and IMF staff calculations.

Figure 3. Pattern of Climate Hazards, 1980–2020

■ 2000–20 ● 1980–99

1. Average Frequency of Climate Hazards by Type[1,2]

2. Average Intensity of Extreme Climate Hazards
(WSDI in days, SPEI as index from –5 [worst] to 5)



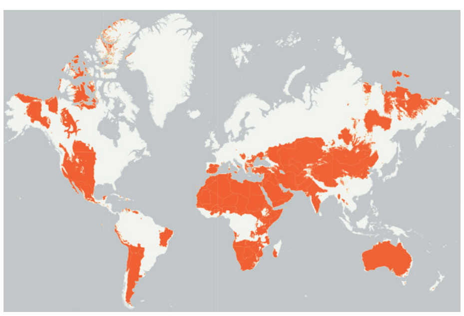
Sources: EM-DAT; WB WDI; World Bank; IMF WEO; and IMF staff calculations.
[1]Annex 4, section A explains the data, variables, and typology of hazards.
[2]Reference period for CCA countries is the 1990s.
[3]The WSDI captures the average number of days per year over a climatological interval that are part of a sequence of six or more days in which the projected daily maximum temperature exceeds the 90th percentile of daily maximum temperatures found in the reference period.
[4]The SPEI (Standardized Precipitation-Evapotranspiration Index) for a 12-month period uses the daily difference between precipitation and potential evapotranspiration to determine droughts.

two-thirds of ME&CA countries exposed to over 20 days of extreme heat per year and 10 countries to more than 100 days of extreme heat per year (Bahrain, Mauritania, Sudan). In addition, drought severity has increased throughout ME&CA, to a much larger extent than in the rest of the world. For instance, Afghanistan just experienced the second severe drought in just four years in 2021, damaging 40 percent of the wheat crop.

The further intensification of the region's already extreme climate conditions has aggravated its people's challenges. Throughout history, people have learned to adapt to the region's extreme climatic conditions. This is, for instance, evidenced by the location of human settlements and agriculture near water resources, widespread nomadic herding, and choice of more climate-resilient crops and underground water storage solutions. However, global warming and its regional ramifications increasingly overstrain people's traditional adaptation skills and infrastructure, as they reinforce three major challenges in ME&CA countries: land degradation (especially desertification and salinization), water stress, and rising sea levels (Box 1). These regional climate change challenges erode arable land size and fertility, surface and underground waters (which sustain farming, fishing, and hydropower), and coastal habitats, in turn leading to fundamental economic disruptions and endangered water and food security. Unfortunately, these regional climate change challenges are not only driven by accelerating climate stress, but also by several mutually reinforcing trends in the ME&CA region: high population growth, progressing urbanization, and substantial ecosystem changes (related to environmental pollution and overexploitation of agricultural land). Together, they cause additional distress, as they increase the demand for, but decrease the supply of water and food.

Box 1. Climate Conditions and Challenges across the ME&CA Region

Box Figure 1.1. Map of the World's Drylands, 2021



Source: European Commission (2021).
Note: Drylands are arid, semi-arid, and sub-humid areas with an Aridity Index of less than 0.65. Aridity is a measure of "dryness" of the climate expressed as the ratio of precipitation to evapotranspiration; the lower the ratio the drier the climate.

The ME&CA region has always posed special adaptation challenges for its people's lives and livelihoods. It generally hosts drylands with harsh and volatile climate conditions (Box Figure 1.1), but with some differences across its subregions[1]:

- *Middle East, North Africa, Afghanistan, and Pakistan (MENAP)*: (1) high temperatures, low rainfall, and dry soils in the Middle East and North Africa's (MENA) coastal arid/semiarid climate; and (2) hot summers, cold winters, and little rainfall in Afghanistan's generally continental climate and Pakistan's arid climate, with distinct differences across the vast plains of the Indus Valley, coastlines, and snowy Hindukush and Himalaya mountains.

- *Caucasus and Central Asia (CCA)*: (1) sharp temperature contrasts between summer and winters, and varying precipitation in the Caucasus' arid subtropical lowlands, alpine mountains, humid subtropical Black Sea coast and arid Caspian Sea coast areas; and (2) hot, cloudless, dry summers and moist, relatively warm winters in the south, and cold winters with severe frost in the north in Central Asia's continental arid/semiarid zones.

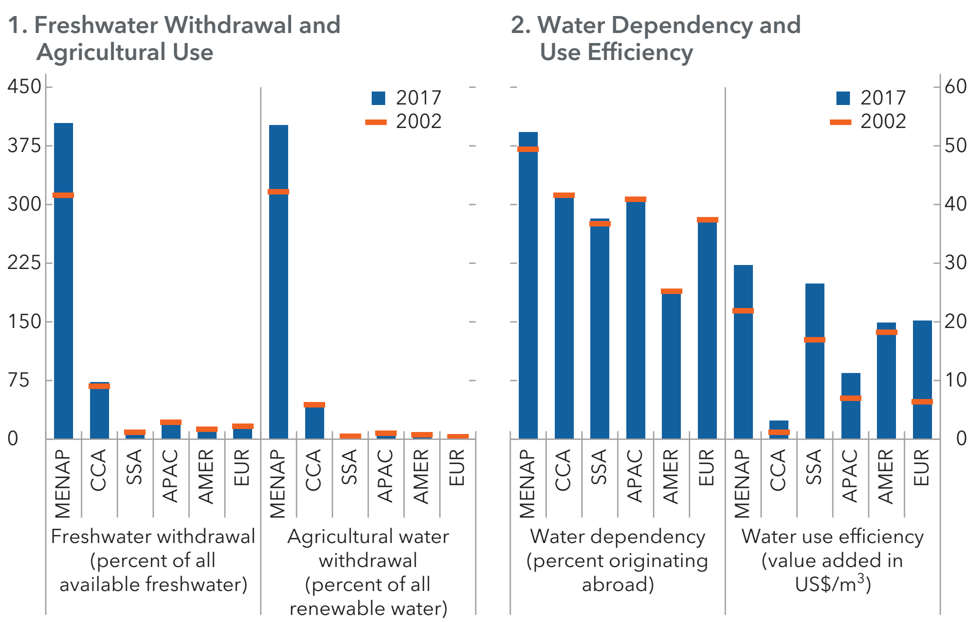
1 See Lelieveld and others (2016), USAID (2018a), UNDP (2021b, 2021c), Blood (1994), Lioubimtseva and Henebry (2009), and Zoi (2011).

Box 1. Climate Conditions and Challenges across the ME&CA Region *(continued)*

Climate change has increased these adaptation challenges for ME&CA populations. Further propelled by high population growth, urbanization, and environmental pollution, key concerns for the region are:

- *Land degradation, especially desertification, and salinization*. About a quarter of the MENAP population was already living on degraded agricultural land in 2000 (UNCCD 2017). Droughts—mainly aggravated by resource intense agriculture and mining[2]—have since accelerated the pace of turning arable drylands into desert (Mirzabaev and others 2019) and salinized grounds (Langenberg and others 2021). This trend has contributed to an erosion of soils and biodiversity, disruption of the water and carbon cycle, and loss of land fertility, which in turn has reinforced shifting human and animal habitats. It also amplifies the impact of natural hazards and disasters (including pandemics).
- *Water stress*. Eighteen ME&CA countries (plus Israel) head the list of the most water-stressed countries globally (FAO 2021). This attests to their low ability to meet their demand for water due to scarcity, quality, and accessibility constraints (Box Figure 1.2, World Bank 2017b, Sieghart and Betre 2018, and Taheripour and others 2020).
  - *High freshwater withdrawal and water dependency*. MENAP countries' freshwater usage has exceeded 400 percent of their available freshwater resources on average (driven by Gulf Cooperation Council [GCC] countries, particularly Kuwait and United Arab Emirates) and reached 75 percent in CCA, both far exceeding the average levels seen in other regions. Water-dependent agriculture is the biggest driver, especially in MENAP. Within-border freshwater availability is shrinking, currently mitigated by water desalination (GCC countries) and inflows from abroad. Water dependency has further increased in recent years. For MENAP countries, on

Box Figure 1.2. Water Stress Factors, 2002 and 2017



Sources: FAO; and IMF staff calculations.

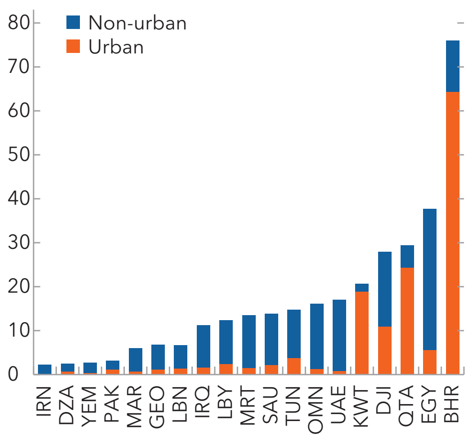
[2] Deliberate clearing of forested land has been less of an issue in the typically forest-scarce ME&CA region (except for in Somalia).

Box 1. Climate Conditions and Challenges across the ME&CA Region *(continued)*

average, more than 50 percent of total renewable water resources originates outside of country borders (headed by Bahrain, Egypt, and Kuwait with more than 97 percent) and 40 percent outside CCA countries (led by Turkmenistan with more than 95 percent). This is significantly above other regions and amplifies the risks of regional water disputes and refugee flows, especially in times of droughts.

- *Low water efficiency and high agricultural use*. At the same time, water is generally used inefficiently across ME&CA, except for GCC countries that have successfully invested in high water efficiency. In most other ME&CA countries, water efficiency has even deteriorated in recent decades (especially in Kyrgyz Republic, Somalia, and Tajikistan). Efficiency is typically lowest in the agricultural sector, which is also the sector with the highest water withdrawal (Damania and others 2017).

Box Figure 1.3. MENAP: Population in Low-Elevation Coastal Zones, 2000
(Percent of population)



Sources: Neumann and others (2015); and IMF staff calculations.
Note: Low-elevation coastal zones are those ranging from 1 to 20 meters of elevation above the mean sea level.

- *Rising sea levels*. Global sea levels have been rising over the past century, and at an accelerating rate in recent decades. They have increased by about 20 centimeters since 1900, of which more than one-third occurred between 1990 and 2015 alone, mainly driven by melting ice and the expansion of water when it warms (NOAA 2021, Dangendorf and others 2019). Permanent flooding threatens ME&CA's highly populated coastal regions—in both rural areas (particularly in Djibouti, Egypt, and United Arab Emirates) and cities (such as Manama, Doha, Kuwait City, and Alexandria). In 2000, 10–30 percent of the MENAP population already lived in low-elevation coastal areas 1–20 meters above the mean sea level (Box Figure 1.3), with even higher population shares in Bahrain and Egypt. These numbers have since likely risen substantially, considering recent population growth and urbanization trends.[3] Coastal habitats are crucial to maintaining ecological balance and they host vital freshwater resources, especially in MENAP (Abumoghli and Goncalves 20120). They also support large parts of economic activity and jobs in many countries, including economic infrastructure and tourism activity zones, for example in Bahrain, Georgia, and Tunisia. In addition, almost 8 percent of the ME&CA population lived 5 meters below sea level in 2010, with an increasing trend in urban areas and the opposite in rural areas.

[3] Certain country-specific estimates are a multiple of the presented estimates: for example, Tunisia, where an estimated two-thirds of the population will be impacted by rising sea levels by the end of the century (Annex 2, section C).

B. Climate Damages and Resilience

Harsh climate conditions have caused vast material and human losses in the ME&CA region. Since the turn of the century, the region has suffered about 10 percent of all global climate disasters (broadly similar to population share), entailing: (1) 2 percent of global material damages (with $40 billion in damages to property, crops, and livestock); (2) 4 percent of global affected people (with 147 million people requiring assistance with food, water, shelter, sanitation, and medical care); and (3) 9 percent of global fatalities (with 56,000 people deceased or missing). However, these aggregates mask several noteworthy subregional patterns:

- *Material damages have trended down in the region, but human damages rose in MENAP* (Figure 4). Encouragingly, material damages have declined in ME&CA over the past two decades, much more than in other regions. For human damages, the trends in MENAP and CCA go in opposite directions: while human damages have generally been on the rise in MENAP, they have come down from their 2008 peak in the CCA, when cold winters adversely affected large swaths of the population in several countries in the subregion.

- *Years with severe human damages ("disruptive years")*[3] *have become more frequent*. ME&CA countries have experienced on average three disruptive years per decade since 2000 (Table 1), up from two during 1980–99. Disruptive years have come with substantial damages, often exceeding those in other regions.

Figure 4. Damages over Time, 1990-2020[1]
(10-year rolling average)

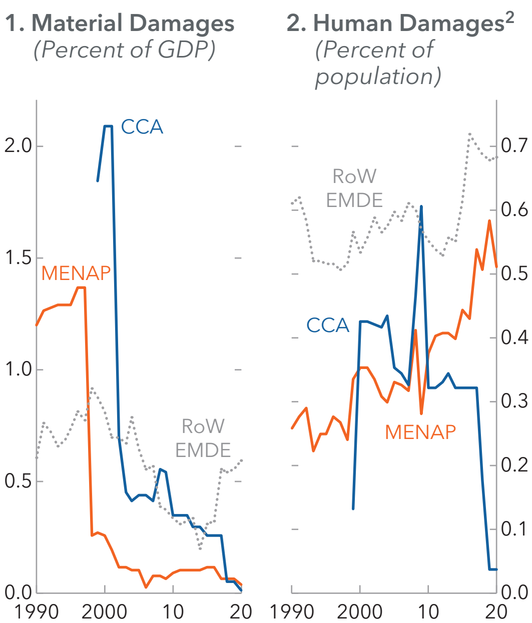


Table 1. Damages by Region, 2000-20[1]
(Annual average)

	MENAP	CCA	RoW EMDE All	SSA	APAC	AMER	EUR
Frequency of							
disasters	1.40	0.65	2.10	1.66	3.51	1.74	1.45
disaster years[3]	0.52	0.43	0.64	0.68	0.60	0.64	0.60
disruptive years[3]	0.29	0.29	0.47	0.49	0.52	0.50	0.27
(unconditional on an event)							
Material damage (percent of GDP)	0.07	0.29	0.47	0.07	0.44	1.24	0.12
Affected people (percent of pop.)	1.44	1.03	2.09	2.22	2.88	1.83	0.73
Deaths (permille of pop.)	0.006	0.001	0.008	0.009	0.010	0.009	0.003
(conditional on a disruptive year[3])							
Material damage (percent of GDP)	0.22	0.98	0.97	0.14	0.82	2.41	0.38
Affected people (percent of pop.)	4.96	3.58	4.40	4.52	5.52	3.63	2.66
Deaths (permille of pop.)	0.020	0.001	0.017	0.017	0.018	0.018	0.008

Sources: EM-DAT; WB WDI; IMF WEO; and IMF staff calculations.
[1]Note that the sharp decline in the 10-year rolling average of material damages reflects the impact of some particularly costly events in the 1990s in both subregions. Annex 4, section A explains the data, variables, typology of natural hazards, and disaster types.
[2]Following Fomby, Ikeda, and Loayza (2009), human damages are defined as annual deaths plus 0.3 times the affected persons.
[3]A "disaster year" saw at least one disaster event; and a "disruptive year" human damages exceeding 0.01 percent of population (Fomby, Ikeda, and Loayza 2009).

[3] The terms in quotation marks are defined in the footnotes in the referenced figures. The concept of disruptive years—rather than events—allows to simultaneously capture the annual cumulative impact of both an observed increasing trend in event frequency and number of people affected. Also, this paper focuses on human rather than physical damages (for example, Noy 2009) as human damages give a better reflection of the dominant disaster types and available data for the ME&CA region. Annex 4, aection A discusses the main data caveats.

MENAP countries on average incurred the largest death toll (with 2 deaths per 100,000 people) and the second largest number of people affected (with almost 5 percent of the population). CCA countries suffered on average the second largest material damage (with almost 1 percent of GDP).

- *Some climate hazards have triggered more damages than others* (Figure 5).[4] Over the past two decades, the lion's share of material damages in MENAP and death toll in the CCA originated in hydrological hazards (which were also the most frequent hazard type in both regions). At the same time, the largest driver of human damages (both affected people and casualties) in MENAP and of material damages and the number of affected people in the CCA were climatological hazards. Notably, 95 percent of drought-related fatalities worldwide have occurred in the ME&CA region.

At the same time, climate-related losses have generally been higher in less developed ME&CA countries, especially on the human aspects (Figure 6). This reflects both high numbers of people affected (Mauritania, Somalia, and Djibouti) and death tolls (Somalia, Afghanistan, and Sudan)—driven by numerous events (Afghanistan and Pakistan) (Figure 5, panel 1) and some very severe events (Table 2). The latter includes, for instance, the 2017 drought in Mauritania (that affected 91 percent of the population) or the 2010 drought in Somalia (that killed 0.2 percent of the population). In the CCA, Tajikistan stands out with large human and material damages, primarily due to severe winters, droughts, and rain-fueled riverine floods (Annex 2, section B). GCC countries have generally been spared large damages, except for Oman on the material side (such as from the 2007 Cyclone Gonu that caused material damage of more than 9 percent of GDP).

A closer look at past climate disasters reveals that natural hazards have caused larger damages in ME&CA countries with low climate resilience, particularly the FCS among the lower-income EMDEs. This points to a weak capacity of their social, economic, and environmental systems to cope with the physical impact of a hazardous climate event or trend, by responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation (IPCC 2014). Low ability to withstand and recover quickly from a given climate shock encompasses two key dimensions[5]:

- *High exposure*. This captures a large presence of people livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected. In ME&CA, exposure is generally high and particularly elevated in coastal and land-degraded areas or close to rivers and snowmelt water flows (Box 1). In many countries, exposure is reinforced by their economic dependence on rain-fed agriculture (for example, Afghanistan, Tajikistan, and Uzbekistan; Figure 7),[6] tourism (for example, Egypt and Tunisia [Annex 2, section C]), and hydropower (for example, Pakistan). It has also grown in many places in the region over the past decades, because of not only climate change, but also socioeconomic trends. The latter includes strong urbanization, which often pushes unplanned urban settlements into flood- and landslide-prone areas. Two-thirds of the ME&CA population live in cities today (especially in Algeria, Iran, and Oman), which is likely to further increase with continued strong population growth that reflects both high birth rates and migration, including refugee flows from conflict-affected countries.[7]

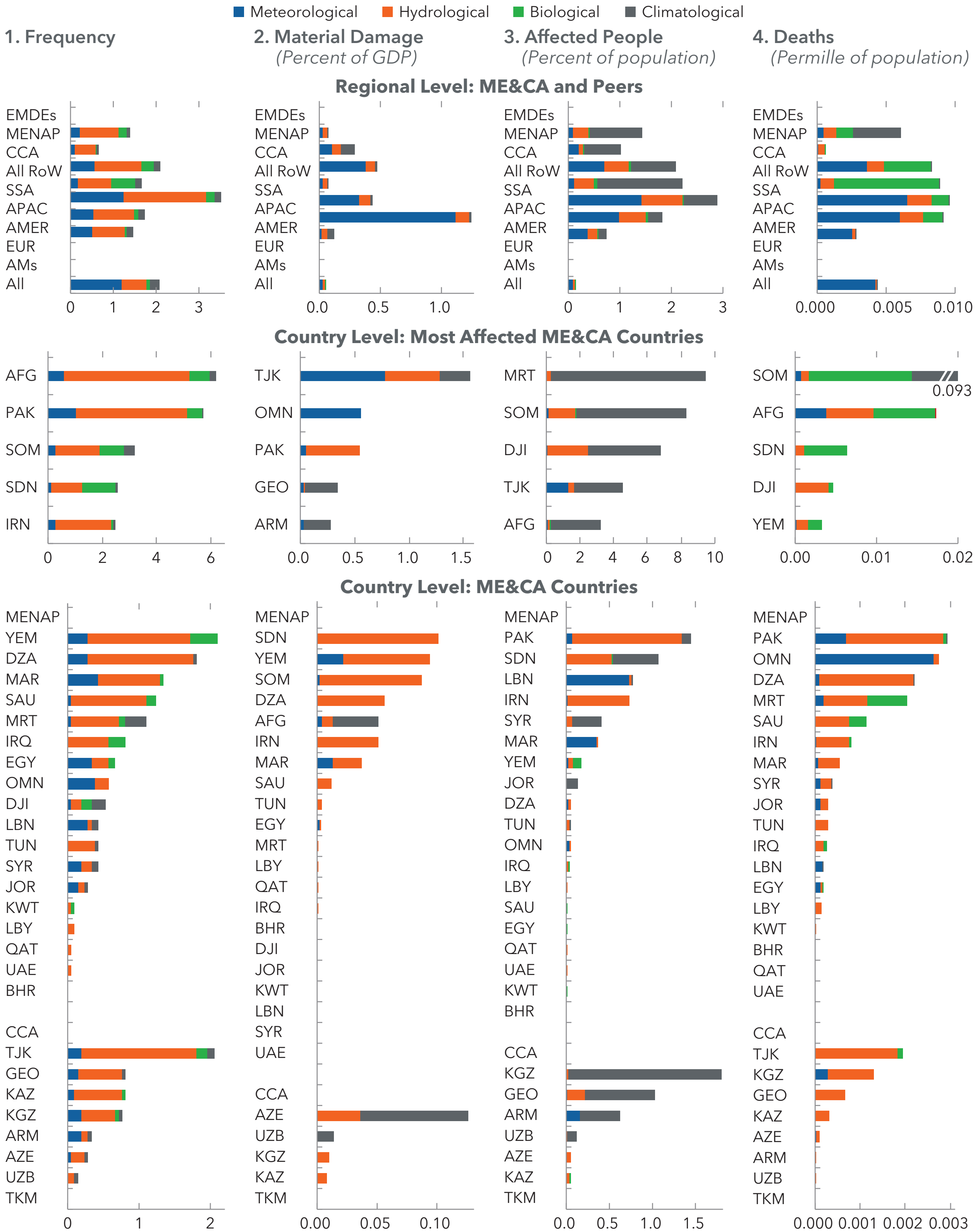
4 Also note that material and human damages show little co-movement with each other, except for a subset of episodes (that is, in CCA countries and the most severe events). The same is true for the correlation between frequency and annual damages.

5 For definitions, see IPCC (2014) and for international evidence, for example, Acevedo and Noah (2021), UNDRR (2019), Peduzzi and others (2009), Cardona and others (2012), Hill, Skoufias, and Maher (2019), Milan and Creutzig (2015), Batten, Sowerbutts, and Tanaka (2020, 2016), Cœuré (2018), or Gencer (2013).

6 Only about a 10th of agricultural land is irrigated in ME&CA, with stark differences across countries. This ranges from 43 and 30 percent in Bahrain and Azerbaijan to 0.1 and 0.8 percent in Mauretania and Kazakhstan (World Bank WDI).

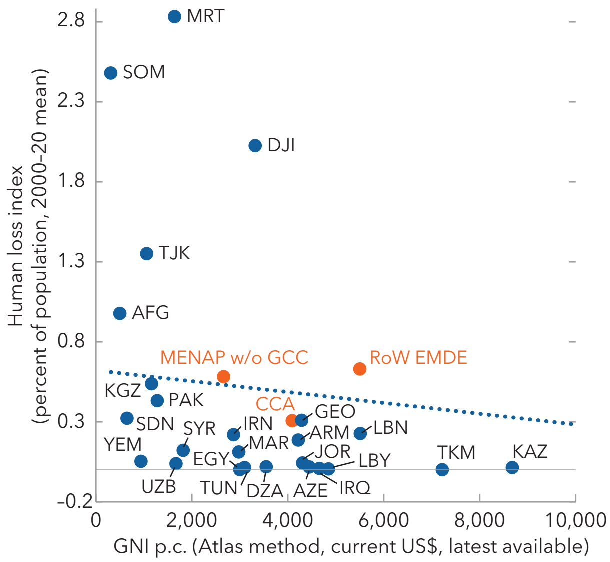
7 ME&CA countries' populations have grown on average by 2.3 percent per year over the past three decades (led by the GCC countries, Jordan, and Afghanistan), which is almost 1 percentage point above the RoW EMDE average.

Figure 5. ME&CA: Country Patterns of Climate Hazards, 2000–20
(Annual average)



Sources: EM-DAT, WB WDI, IMF WEO, and IMF staff calculations.
Note: For a typology of hazards and disaster types, see Annex Table 4.1.

Figure 6. GNI p.c. and Human Loss Index
(Units and vintages as displayed on axis)

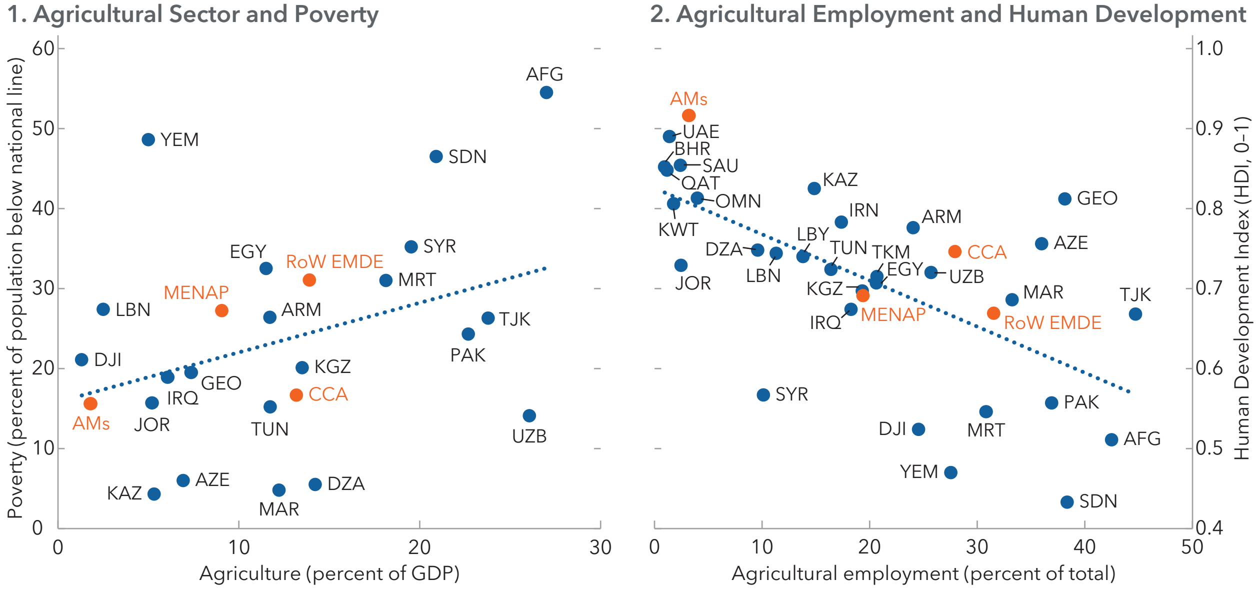


Sources: EM-DAT, WB WDI; and IMF staff calculations.
Note: The human loss index is defined as 0.3 times people affected plus deaths as a share of population (Fomby, Ikeda, and Loayza 2009).

- *High vulnerability*. This relates to a high propensity or predisposition to be adversely affected by climate hazards. In most ME&CA countries, this reflects a pronounced sensitivity to harm and lack of capacity to cope and adapt, which arises from a combination of underlying structural factors. These include: (1) low, jobless growth and weak macroeconomic stability; (2) low socioeconomic and financial development (with for example, low per capita incomes and human capital, widespread poverty, poor living conditions, and lack of financial inclusion); (3) inadequate infrastructure and investment (including at the public level for adequate social safety nets, health care, and education); (4) weak institutional frameworks, capacity, and regulation (including for disaster prevention and response management; or appropriate zoning codes and standards for building, waste, and water management); and (5) violent conflict and migration. Also, production technologies matter, including the availability of water irrigation systems and adequacy of crops for given climatic conditions (Amare and others 2018). Addressing these vulnerabilities takes time and often complex structural reforms. A notable achievement is the improvement in disaster preparedness and response capacity (for example, better early warning systems and emergency protocols), which helps explain the observed reduction in disaster damages

Figure 7. ME&CA: Agricultural Dependence and Socioeconomic Development
(2020 or latest available)

1. Agricultural Sector and Poverty **2. Agricultural Employment and Human Development**



Sources: ILO; UNDP HDI; World Bank WDI; and IMF staff calculations.

Table 2. ME&CA: Most Severe Climate Disasters, 2000–20

(Along three damage dimensions: material damage, people affected, and deaths)

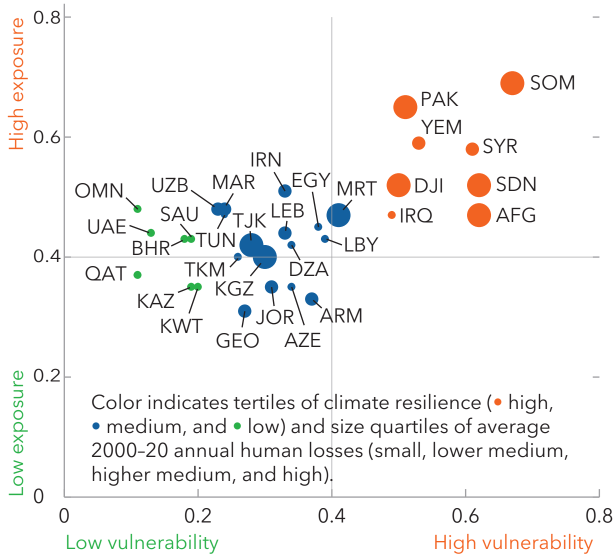
	MENAP					CCA				
	Material damage (percent of GDP)		People (of population): affected (percent)	People (of population): dead (permille)	Hazard type (subtype, duration)	Material damage (percent of GDP)		People (of population): affected (percent)	People (of population): dead (permille)	Hazard type (subtype, duration)
Loss dimension I: material damage (to property, crops, and livestock)										
1	OMN (2007)	9.3	0.8	0.029	meteo. (tropical cyclone, 5 days)	TJK (2008)	16.4	27.7	n.a.	meteo. (severe winter, 2 months)
2	PAK (2010)	5.4	11.3	0.011	hydro. (flash flood, 10 days)	GEO (2000)	6.4	17.1	n.a.	climat. (drought, >1 year)
3	OMN (2010)	1.8	n.a.	0.005	meteo. (tropical cyclone, 1 day)	TJK (2000)	5.8	48.3	n.a.	climat. (drought, >1 year)
4	SOM (2018)	1.7	4.7	0.000	hydro. (riverine flood, 2 months)	ARM (2000)	5.2	9.7	n.a.	climat. (drought, >1 year)
5	YEM (2008)	1.5	0.1	0.004	hydro. (flash flood, 2 days)	TJK (2010)	3.6	0.1	0.013	hydro. (riverine flood, 5 days)
Loss dimension II: affected people (requiring assistance with food, water, shelter, sanitation, and immediate medical care)										
1	MRT (2017)	n.a.	91.0	n.a.	climat. (drought, 4 months)	TJK (2000)	5.8	48.3	n.a.	climat. (drought, >1 year)
2	DJI (2008)	n.a.	41.6	n.a.	climat. (drought, >6 months)	KGZ (2009)	5.2	37.2	n.a.	climat. (drought, n.a.)
3	SOM (2015)	n.a.	34.1	n.a.	climat. (drought, ≈2 years)	TJK (2008)	16.4	27.7	n.a.	meteo. (severe winter, 2 months)
4	MRT (2001)	n.a.	37.1	n.a.	climat. (drought, ≈2 years)	GEO (2000)	6.4	17.1	n.a.	climat. (drought, >1 year)
5	AFG (2018)	n.a.	36.3	n.a.	climat. (drought, 15 months)	ARM (2000)	5.2	9.7	n.a.	climat. (drought, >1 year)
Loss dimension III: deaths (dead or missing)										
1	SOM (2010)	n.a.	33.2	1.662	climat. (drought, ≈19 months)	TJK (2010)	3.6	0.1	0.013	hydro. (riverine flood, 5 days)
2	AFG (2002)	n.a.	0.0	0.128	biol. (epidemic, 1 day)	GEO (2015)	0.2	0.3	0.011	hydro. (flash flood, 2 weeks)
3	SOM (2007)	n.a.	0.1	0.105	hydro. (riverine flood, 1 month)	KGZ (2003)	n.a.	0.0	0.008	hydro. (landslide, 1 day)
4	SOM (2000)	n.a.	2.5	0.078	biol. (epidemic, several months)	KGZ (2017)	n.a.	0.0	0.004	hydro. (landslide, 1 day)
5	DJI (2004)	n.a.	13.0	0.066	hydro. (flash flood, 5 days)	TJK (2007)	n.a.	0.0	0.003	hydro. (flood, 1 day)

Sources: EM-DAT, WB WDI, IMF WEO, and IMF staff calculations.

Note: See Annex 4, section A for a description of the data and hazards. Empty fields indicate missing values or non-reported information.

Figure 8. ME&CA Countries and EMDE RoW Peers: Climate Resilience and Human Losses

(Latest available vulnerability and exposure indices from 0 [best] to 1; average 2000–20 human losses in percent of population)



Sources: EM-DAT; FAO; INFORM Risk Index 2022; World Bank; IMF WEO; and IMF staff calculations.

Note: See Annex 4, section B for the methodology of the resilience clustering and construction of the underlying vulnerability and exposure indices. The color and size of the circles reflects quantiles of a lack of resilience and human losses, respectively (with the latter defined as 0.3 times the number of people affected plus deaths as a share of population; Fomby, Ikeda, and Loayza 2009).

relative to the past around the world, including in ME&CA (Figure 4, panel 1). In a similar vein, the socioeconomic improvements in the CCA help explain the lower occurrence of biological hazards (mainly diseases) over the past two decades (Figure 3, panel 1).

A clustering exercise highlights two main takeaways: (1) countries with lower levels of resilience—captured by exposure and vulnerability to climate disasters—have broadly suffered larger human damages over the past two decades; and (2) resilience varies widely across ME&CA countries (Figure 8). The countries with low resilience are mainly the region's fragile and conflict affected states (FCS) (such as Somalia, Sudan, and Afghanistan), followed by the region's lower-income EMDEs. These FCS also host nearly half of the region's people below the poverty line (World Bank WDI). They are mostly located in degraded drylands, where their people live off rain dependent subsistence farming and severely suffer from many of the vulnerabilities discussed above. FCS' human losses have been on the higher end of the spectrum, but likely even then understate the true losses because of administrative weaknesses and political considerations.[8] The larger human losses observed in low and medium climate-resilient countries additionally mirror the past impact of particularly severe hazards (which are not depicted in Figure 8).[9] In contrast, despite similarly harsh climate conditions, GCC countries have generally experienced lower human damages, amid both lower exposure and vulnerabilities.[10] Besides better institutional capacity, this reflects fewer climate-dependent economic structures (including smaller agricultural sectors and employment), better climate adapted infrastructure, and higher levels of socioeconomic and human development.[11] These findings underscore that climate damages are a function of two factors: the severity of a climate hazard and a country's degree of resilience (captured by exposure and vulnerability). They also have important policy implications: investment in climate adaptative infrastructure and institutions (Chapter 4) increases climate resilience and thereby helps contain damages from exogenous climate hazards.

C. Climate-Change Outlook

Global climate change is set to further intensify ME&CA's current climate stress trends.

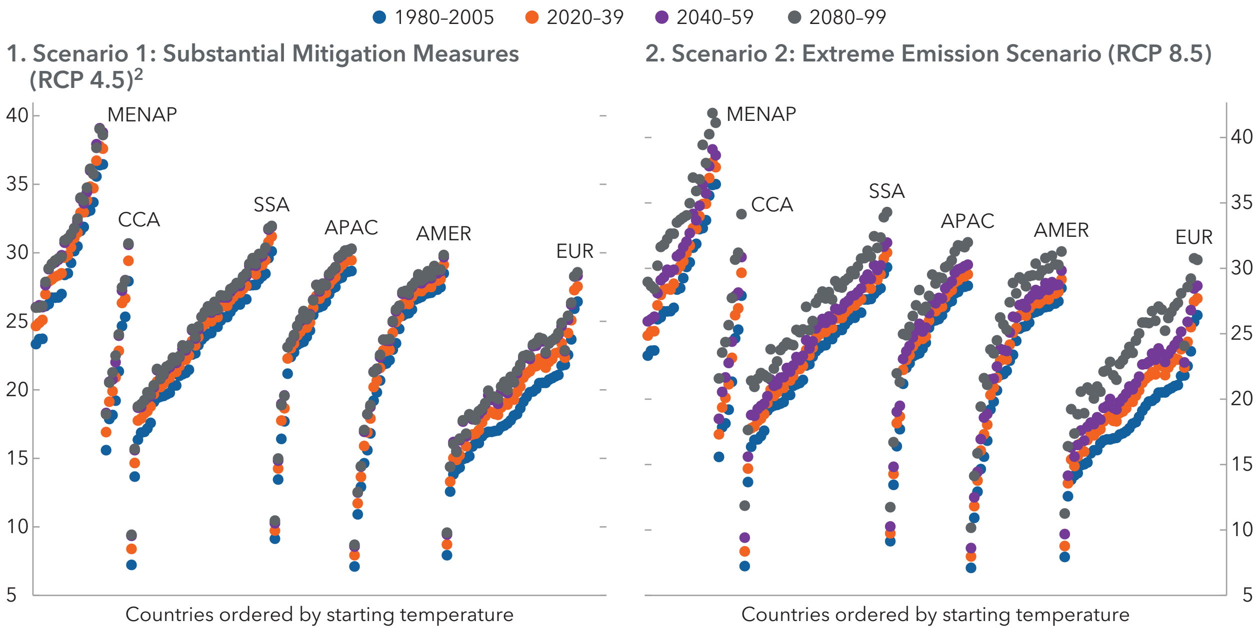
[8] Note that the quality and completeness of self-reported EM-DAT disaster data can depend on a country's economic and political conditions (for example, Hsiang and Jina 2014, Kahn 2005, Strömberg 2007, Noy 2009).

[9] Note that no cross-country data are available for the region on the strength of a hazard and the observed material and human damages.

[10] However, like other fossil fuel exporters, GCC countries can be adversely affected going forward by the transition to a low-carbon economy.

[11] Carleton and others (2020) find a U-shaped link between very cold and hot temperatures on the one hand and mortality (especially for the elderly) on the other hand, which is flattened by both higher incomes and adaptation to local climate for example, robust heating systems in cold climates and cooling systems in hot climates).

Figure 9. Average Summer Temperatures by Country and Region, 1980–2099[1]



Sources: Climate Impact Lab; and IMF staff calculations.
[1]Each dot corresponds to average summer temperatures for a given country in the regional grouping in one time period from the median output of an ensemble of 30 of the most advanced climate models (CMI P5). Within each region, countries are ordered along the *x*-axis according to their temperature in the earliest period, from lowest to highest.
[2]There is no visible difference between the summer temperatures in the last two time periods.

- *Higher temperatures*. Many ME&CA countries are likely to see temperatures rise more than in their peers elsewhere, especially during summers, according to multi-model climate projections (Figure 9). Given ME&CA countries' warmer starting conditions, average temperatures could exceed 30° C in half of the region's countries by 2050, even in a scenario with sharply dropping global GHG emissions. Higher temperatures, aggravated by lower and more irregular rainfall, will worsen existing geographic challenges. They are set to deplete soil moisture (in turn reducing evaporative cooling) and increase evaporation, thereby drying out rivers and lakes (for example, the Caspian Sea). They will also accelerate desertification in North Africa and the Arabian Peninsula, aridity in the CCA (particularly in the western parts of Kazakhstan, Turkmenistan, and Uzbekistan), and glacier retreat (with pressures on river systems) in the Caucasus and Pakistan.

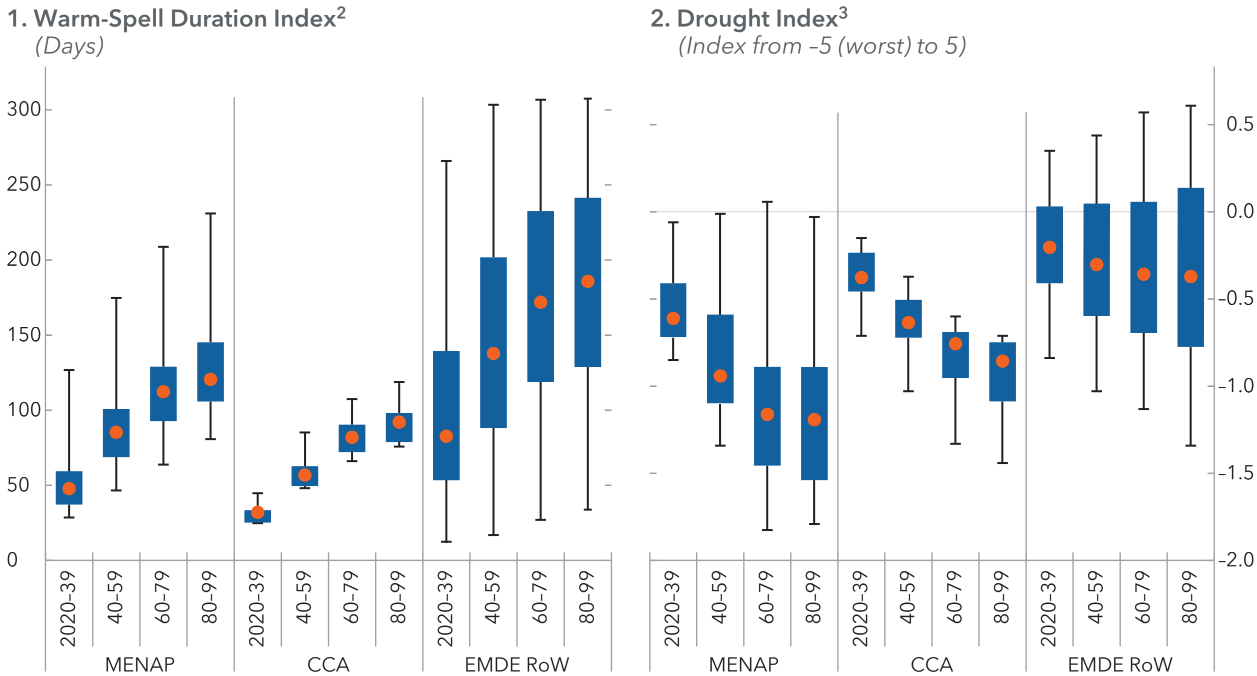
- *More erratic precipitation*. Projections point to drier seasons in MENA and higher precipitation variability in the CCA and Pakistan. This would worsen the ME&CA region's already severe water stress (on account of scarcity, quality, and accessibility constraints, Box 1); endanger large swaths of the economy (from agriculture, to industry, tourism and even transport through rivers); and lead to more accentuated boom/bust cycles and potential socio-political tensions (Chapter 3).

- *More frequent and powerful climate disasters*.[12] Higher global surface temperatures are set to magnify climate anomalies, including hotter and drier weathers. This will exacerbate extreme hazards, such as warm spells and drought severity in the region (Figure 10). For instance, the median MENAP country is predicted to experience almost 50 more warm-spell days per year within 2020–39 in the moderate-emission scenario, relative to eight days over 1986–2005 and at much higher temperatures (Figure 10, panel 1).[13] Alongside, accelerating atmospheric water evaporation is projected to fuel desertification and more

[12] See for example, IPCC (2018, 2014), Waha and others (2017), USGS (2021a, 2021b), Sneed (2021), Zhao and others (2021), and NASA (2005).

[13] Absent effective mitigation, temperature increases (to as high as 50° C) and prolonged warm spells (for more than 200 days a year) could make large parts of MENAP uninhabitable by the end of this century (Lelieveld and others 2016).

Figure 10. Predicted Median Intensification of Weather Anomalies, 2020–99[1]
(Absolute change relative to the reference period 1986–2005, RCP 4.5 scenario)



Sources: World Bank; and IMF staff calculations.
[1]The orange dot shows the averages of the median changes across each region, the blue box the 10 and 90 percentiles, and the whiskers the minimum and maximum.
[2]Captures the average number of days per year over a climatological interval that are part of a sequence of six or more days in which the projected daily maximum temperature exceeds the 90th percentile of daily maximum temperatures found in the reference period.
[3]The Standardized Precipitation-Evapotranspiration Index (SPEI) for a 12-month period uses the daily difference between precipitation and potential evapotranspiration to determine droughts.

powerful storms, amplifying cyclones and flash floods. Together, they will also feed mosquito borne infectious diseases—including malaria and dengue fever. Melting ice caps and glaciers will swell sea levels along the shores, worsening coastal flooding and storms. They will bring devastation around mountainous areas through avalanches, landslides, and floods; and change the pressures acting on the earth's crust, possibly triggering volcanic eruptions and tsunamis in the region.[14]

The intensification of climate stresses would markedly worsen human and material damages. It would also further aggravate the ME&CA region's perennial challenges of land degradation (especially desertification and salinization), water stress, and rising sea levels (Box 1). Global sea levels, for instance, are projected to rise by at least 0.3 meters above 2000 levels by 2100 in a low emission scenario and 2.5 meters in a worst-case scenario (NOAA 2021). Indeed, the effects of climate change—and its damaging impacts—are predicted to be higher in the absence of ambitious mitigation (Annex 3) and swift transformational adaptation (Chapter 4). Damages could even increase in a nonlinear way, for instance, when physical thresholds are surpassed (for example, making water-constrained countries full-fledged water-short) or vicious cycles occur (for example, mutually reinforcing climate hazards and low resilience, leaving a country with higher vulnerability than before the shock on account of not-fully-addressed impacts).[15]

[14] The Middle East and Indian Ocean host 56 Holocene volcanoes, mostly in Saudi Arabia, Syria, and Yemen (Brown and others 2015). In the CCA, the lesser Caucasus Mountains are also largely of volcanic origin (Philip and others 1989).

[15] For instance, climate shocks can weaken nutrition and health outcomes as well as soil fertility and water availability, which undermines peoples' resilience to disease. Also, deforestation-induced erosion and uncontrolled building can make flash floods and landslides more impactful, in turn leaving behind an even more damaged ecosystem.

3. Macroeconomic Impact of Climate Change

Climate change is a major amplifier of existing macroeconomic challenges and vulnerabilities in ME&CA countries, threatening inclusive growth as well as macro-financial and socio-political stability. Importantly, the region's key climate stressors have already shown short- and longer-term impacts. Changing temperature and precipitation patterns have already eroded per capita incomes and shifted the sectoral composition of output and employment. MENAP countries have been harder hit than their CCA peers, given their hotter and drier starting conditions. Climate disasters have adversely affected growth, fiscal, and external sector dynamics, mainly within the two years following the events but with permanent output and tax revenue losses in CCA countries.

A. Impact of Main Climate Stresses

Climate change is macro-critical in ME&CA countries, not only because of the direct human and material damages (Chapter 2, section B) but also its impact on economic performance. This follows from this paper's empirical analysis of how the region's main climate stresses—higher temperatures, more erratic precipitation, and intensified disasters (Chapter 2, section A)—have affected key macroeconomic variables in ME&CA's subregions during 1970–2020 (Table 3).[1] The results are broadly in line with the emerging literature for other country groups and share the same caveats[2]: capturing average impacts from past climate stresses, the results (1) mask substantial country heterogeneity in underlying climate stresses (Box 1), resilience (Chapter 2, section B), and post-disaster policy responses (often held back by capacity and financing constraints); (2) reflect measurement errors and data constraints (especially for precipitation and countries with weak administrative capacity); and (3) do not incorporate any acceleration of future climate change, tail risks, and irreversible impacts from climate change (Chapter 2, section C).

Changing Temperature and Precipitation Patterns

ME&CA countries have seen climate variations erode per capita incomes and shift sectoral output and employment. This arises from both past (1) temperature shocks, defined as a 1° C increase in annual mean temperatures; and (2) precipitation shocks, defined as a 100-millimeter increase in annual precipitation levels (in each case relative to their respective 20-year moving historical average). Some interesting results—summarized in Table 3—arise across subregions.

Growth

Higher temperatures harm growth in already hot countries or when the temperature increase is high. The impact of a 1° C increase in temperatures on real per capita growth depends on a country's starting temperature (Figure 11, panel 1): it is beneficial in countries with low average annual temperatures of up to 19° C (CCA countries, Afghanistan) and detrimental in hotter countries,[3] particularly those with average annual temperatures above 26° C (some MENAP countries, including the GCC, Mauritania, and Somalia).[4] In addition, abnormally large temperature deviations within one year have also reduced GDP per capita (independently of the initial annual temperature level), and more so with larger temperature deviations.[5] Temperature shocks can even affect growth over longer periods (Figure 11, panel 2). Colder CCA countries

[1] See Annex 4 for data sources and issues, empirical approaches, and some robustness tests of the results.

[2] These are also reflected in typically wide error bands around the estimated mean responses (indicated by dotted lines in the figures in this chapter).

[3] This result is in line with previous results for a global sample (IMF 2017a, 2020).

[4] This result is robust to the use of annual average summer temperatures.

[5] Temperature increases would generally be beneficial to real GDP p.c. growth in years with below-norm temperatures, but detrimental above an anomaly of 0.8° C or more. The detrimental growth effect increases with higher abnormal temperatures (Annex Table 4.3).

Table 3. ME&CA: Key Macroeconomic Impacts of the Region's Main Climate Stressors, 1970-2020

	Real GDP p.c. growth		Sectoral GDP		Sectoral employment	
	MENAP	CCA	MENAP	CCA	MENAP	CCA
Temperature shock	-	+	(-) for agriculture + for tourism until a turning point + for construction		- total employment + total employment (-) for agriculture* + for services no impact for industry - for youth employment	
Precipitation shock	+ for countries with below-average rains, otherwise (-)	+ for countries with below-average rains, otherwise (-)	+ for agriculture - on hotels, restaurants, trade	- for agriculture - for financial and real-estate activities	- total, male and female employment, youth employment	
	Real GDP p.c. growth		**Public debt**		**Current account balance**	
	MENAP	**CCA**	**MENAP**	**CCA**	**MENAP**	**CCA**
Disruptive disaster year	-	-	+	+	(inclonclusive)	-

Sources: IMF staff calculations.

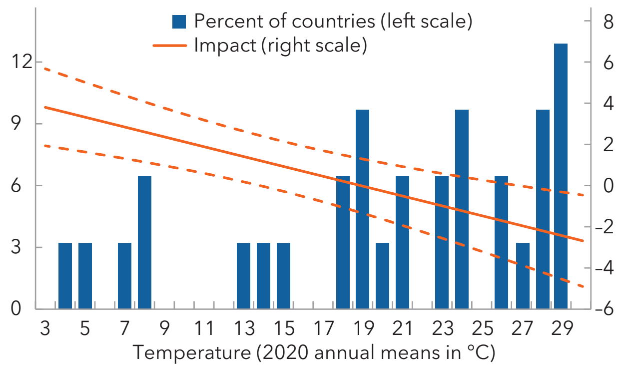
Note: + means positive impact, - negative impact, while () indicates imprecisely estimated effects.

* The impact of temperature shock on agricultural employment in the CCA is statistically significant over a short time period.

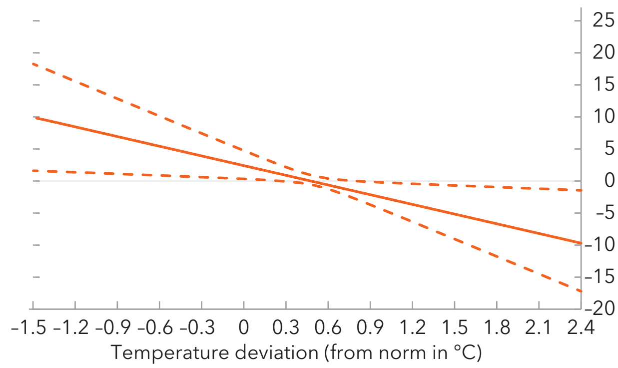
Figure 11. ME&CA: Impacts of Temperature and Precipitation Shocks on Economic Growth[1]
(Growth in percentage points, temperature in °C and precipitation in 100 millimeters)

1. Immediate Impact on Real GDP p.c. Growth

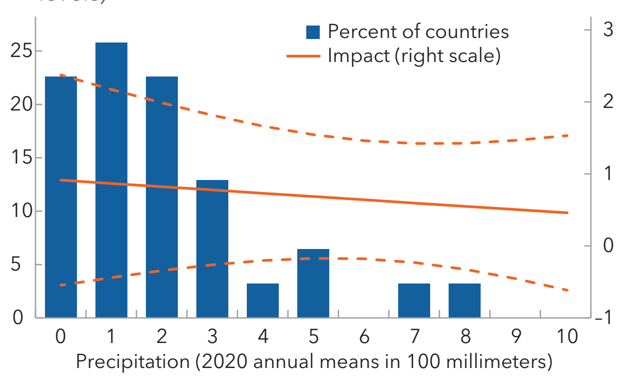
a. 1°C Temperature Increase
(Along the distribution of 2020 annual mean temperatures)



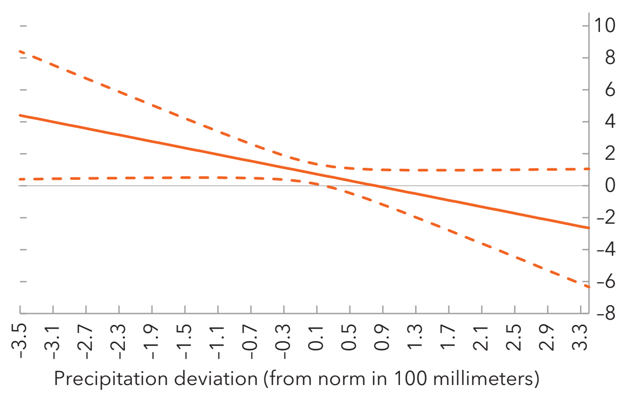
b. Temperature Deviation
(Along the distribution of deviations from norm)[3]



c. 100-Millimeter Precipitation Increase
(Along the distribution of 2020 annual precipitation levels)

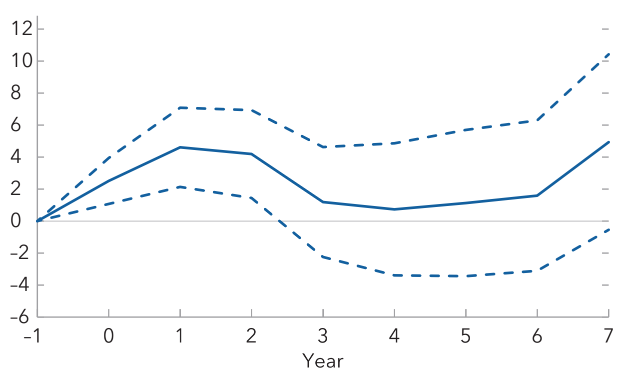


d. Precipitation Deviation
(Along the distribution of deviations from the norm)[3]

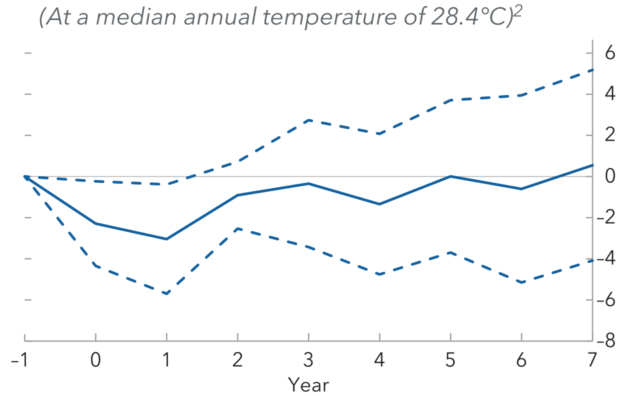


2. Medium-Term Impact on Real GDP p.c. Growth

a. Temperature Increase in CCA Countries
(At a median annual 2020 temperature of 8.4°C)



b. Temperature Increase in the Five Hottest MENAP Countries
(At a median annual temperature of 28.4°C)[2]



Sources: WB; IMF WEO; and IMF staff calculations.
[1]See Annex 4 for data and methodology. Dashed lines show 90 percent confidence.
[2]Includes UAE, DJI, QTR, MRT, and BHR.
[3]The norm is defined as the 20-year moving average.

have experienced higher growth for about three years, while hotter MENAP countries have incurred lower growth for two years. With average temperatures predicted to increase sharply in most ME&CA countries over the next decades (Figure 9), climate change is poised to undermine growth in an ever increasing number of ME&CA countries.

Higher precipitation seems to boost growth only in years with below-average rainfall. A precipitation increase has generally, but weakly, boosted real GDP per capita in ME&CA countries (Figure 11, panel 1). At the same time, higher precipitation has unequivocally raised growth for ME&CA countries in below-average rainfall years, whereas the opposite was observed in ME&CA countries in above-average rainfall years.[6] This highlights the risk of flooding and other adverse consequences (especially where within-year rain variability is high), which are predicted to worsen in the future with continued climate change (Chapter 2, section C).

Sectoral GDP Composition

At the same time, weather patterns affect some sectors more than others (Table 4).

- *Agriculture*. A temperature increase has negatively affected agricultural output in the ME&CA region (as also observed in other regions).[7] This effect has been especially pronounced in MENAP countries with very hot climates but was imprecisely estimated for average MENAP and CCA countries. In contrast, a precipitation increase can go both ways: it can either temporarily support rain-fed agriculture in dry climates, or damage crops and livestock in flood areas (see above). While MENAP countries have generally experienced the first in the past, they need to be prepared for the second effect in view of the predicted higher volatility of within-year rainfalls (Chapter 2, section C). CCA countries' agriculture did not benefit from precipitation increases. This heterogeneity across subregions is not uncommon and was observed in other regions as well, attesting to the caveats pointed out in the beginning of this subsection.

- *Services*. Temperature shocks have benefited tourism activity in MENAP countries in the short term. However, the impact tends to turn negative after three years, suggesting the existence of a tipping point of too hot temperatures (Rutty and Scott 2010, Hambira and Mbaiwa 2020), which in the future could be exacerbated by rising sea levels along MENAP's tourist coasts (Olsen 2009). At the same time, higher precipitation has dampened hospitality sector activity and boosted that of the finance and real estate sector. The latter points again to increased insurance activity following weather events. CCA countries have also experienced negative trade effects in the short term, likely from disrupted transportation and consumer behavior following weather events.

- *Industry and construction*. Weather shocks have negatively affected ME&CA's industrial sectors, driven by lower water and electricity supply. This likely mirrors the effect of droughts on hydropower production and damages to power infrastructure from flooding and high winds (such as flooding electricity stations, breaking damns, and falling trees on power lines).[8] Interestingly, temperature shocks appear to have boosted construction throughout the ME&CA region over the medium term. This boost could mirror increased activity for heat-resisting infrastructure (such as water, air conditioning, and insulation), which, for now, seems to dominate the dampening effect of higher temperatures on worker's health and productivity (Park and others 2018, Deryugina and Hsiang 2014).

[6] These results match IMF (2017a) and Kahn and others (2021) for world data. They are also in line with World Bank (2017b) that finds that MENAP countries could see the highest economic losses from climate-change induced water scarcity worldwide, estimated at 6–14 percent of GDP by 2050. In contrast, Central Asian countries could face an impact between –11 and 11 percent of GDP, reflecting their specific precipitation trends.

[7] The negative impact of temperature shocks on agriculture is in line with the literature, which finds average agricultural output to be robust to temperature deviations when they happen independently of precipitation shocks (Dell and others 2012, Burke, Hsiang, and Miguel 2015b, Carleton and Hsiang 2016, IMF 2017a).

[8] See also Webster (2014). Dry weather is an issue in countries that rely heavily on hydropower (such as Kyrgyz and Tajikistan, with a share of more than 90 percent in electricity generation). Electricity/water data for these two countries are unavailable, which could bias the regional results.

Table 4. ME&CA: Sectoral Impact of Climate Change
(Percentage points)

	Temperature shock				Precipitation shock			
	Contemporanous		After 3 years		Contemporanous		After 3 years	
	MENAP	CCA	MENAP	CCA	MENAP	CCA	MENAP	CCA
Agriculture	–0.3	–0.7	–0.15	–0.1	0.45**	–0.13	0.07	–0.1**
Industry	–0.50	0.14	–0.75	0.48	–0.07	0.22	–0.20	-1.00
Water and electricity	0.00	–0.01	–0.1	0.02	0.0	–0.09***	0.0	–0.2**
Services and trade	1.1*	0.86	1.09	0.28	–0.07	–0.11	0.47	0.11
Hotels and restaurants	0.02	0.01	–0.12	0.06	–0.07***	–0.02	–0.08*	–0.05*
Tourism	0.6**	0.04	-1.45	0.87	0.69	–0.07	0.04	–0.32
Finance and real estate	0.49	0.29	–0.39	0.37	0.23	–0.03	0.66*	0.55*
Trade	–0.16	0.09	–0.42	–0.34	–0.14	–0.33**	–0.41*	–0.03
Construction	0.02	0.18	0.7*	0.6**	0.01	–0.25	–0.09	–0.32

Source: Country authorities; WB WDI; World Travel & Tourism Council; and IMF staff calculations.
Notes: See Annex 4 for data and methodology. * significant at 10 percent, ** significant at 5 percent, *** significant at 1 percent. 3-year coefficients are shown as significant if at least one of the coefficients from year 1 to 3 following the shock is significant. If more than one year is significant, average over significances is used.

Employment

The impact on total employment largely mirrors output effects. Higher temperatures have eliminated jobs in MENAP countries but created jobs in CCA countries (Figure 12, panel 1).[9] Higher precipitation, however, has increased unemployment throughout ME&CA, particularly in the CCA.

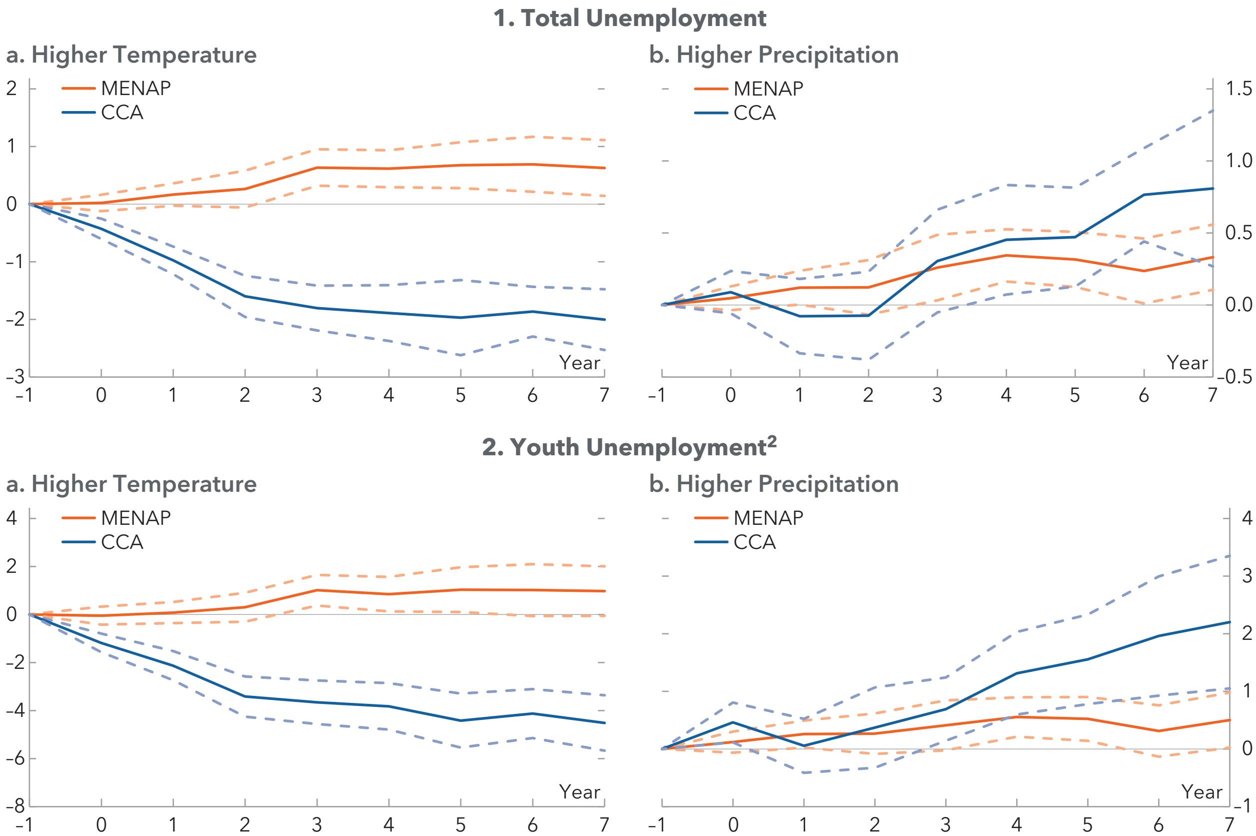
Employment effects across labor force groups and productive sectors are more heterogenous. Weather shocks can affect some productive sectors more than others, resulting in a re-composition of output shares across sectors, with ripple effects on sectoral employment.[10]

- *Labor force groups* (Figure 12, panel 2). Temperature increases beyond annual averages have increased medium-term youth unemployment in MENAP but reduced it in CCA countries. Higher precipitation has increased youth unemployment in both subregions, with the effect being stronger in CCA countries. This is not surprising as the young tend to be the first to lose or gain jobs following changes in weather patterns and other shocks with an economic impact (as also seen during the COVID-19 pandemic) due to both limited job security and skill sets. The impact on male and female unemployment follows that of youth unemployment in both regions (see Annex 4, section C for details).

- *Productive sectors* (Figure 13). Temperature increases tend to have weighed negatively and persistently on agricultural employment throughout ME&CA, an effect that would likely have been even stronger if the employment of informal workers could be included. This contrasts the positive effect on employment in the service sector (and the discernible effect on industry), which suggests that climate change will amplify the shift out of agriculture and into the service sector going forward. The impact on tourism employment is consistent with that on output, turning negative in the medium term in MENAP while remaining positive in the CCA. Tourism, therefore, does not seem to benefit from temperature increases in already hot climates over time.

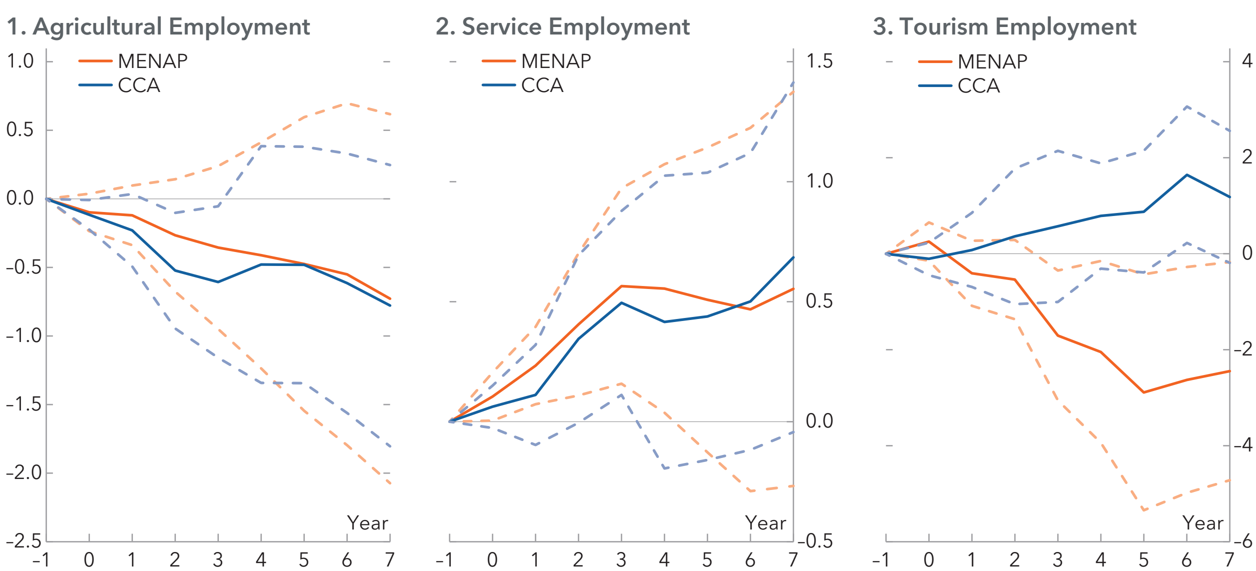
[9] Sectoral employment results are not shown as they are generally found to be insignificant.
[10] Further ripple effects are, for instance, a shift in the composition of trade and credit.

Figure 12. ME&CA: Impact of Weather Patterns on Unemployment
(Percentage points)[1]



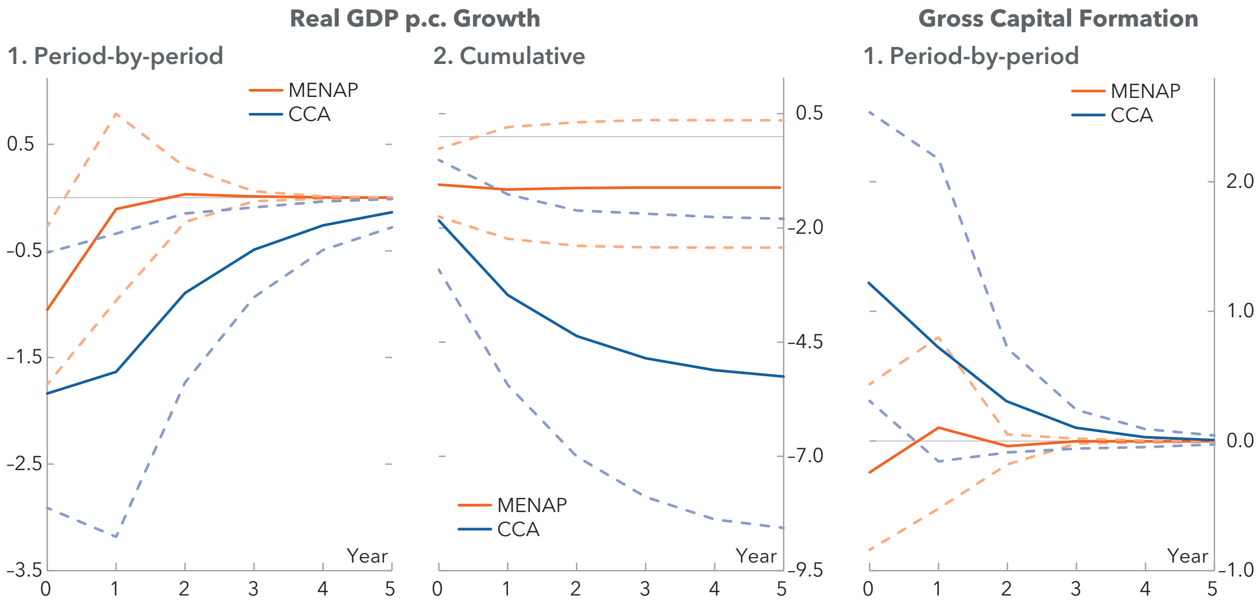
Sources: ILO; WB; World Travel and Tourism Council; IMF WEO; and IMF staff estimates.
[1]See Annex 4 for data and methodology. Dashed lines represent 90 percent confidence bands.
[2]Youth unemployment in percent of total labor force, ages 15–24.

Figure 13. ME&CA: Impact of Temperature on Sectoral Employment
(Percentage points)



Sources: ILO; WB; World Travel and Tourism Council; IMF WEO; and IMF staff estimates.
Note: See Annex 4 for data and methodology. Dashed lines represent 90 percent confidence bands.

Figure 14. ME&CA: Growth and Investment Response to Disruptive Climate Disaster Years[1]
(Percentage points of GDP, dashed lines represent 90 percent confidence bands)



Sources: EM-DAT; WB WDI; IMF WEO; IMF staff reports; and IMF staff calculations.
[1]The impulse-response reaction functions (IRFs) show the multiyear fiscal response to the shock of a disruptive year, that is, when the annual deaths plus 0.3 times affected persons exceed 0.01 percent of the population (Fomby, Ikeda, and Loayza 2009). The IRFs capture quite heterogenous post-disaster outcomes and policies, as evidenced by the width of the confidence bands. The number of included years and countries varies with data availability. Also see Annex 4 for data and methodology.

Climate Disasters

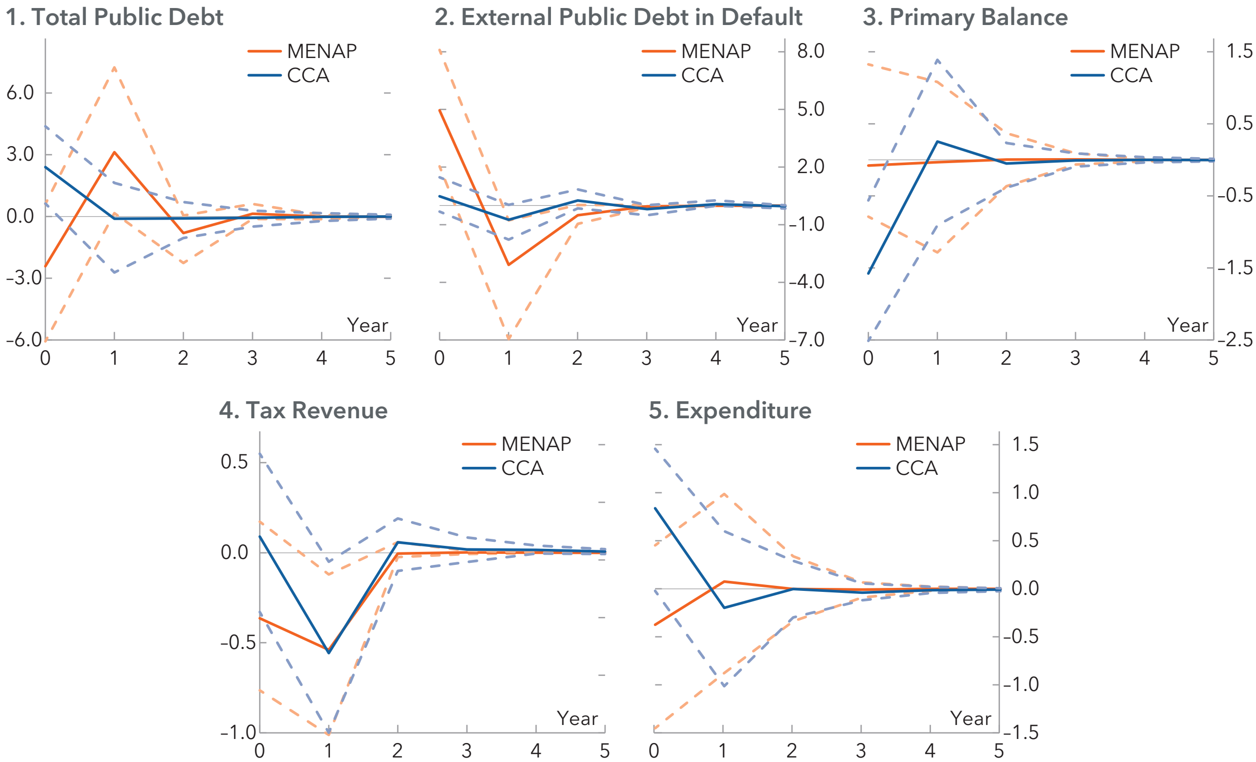
ME&CA countries have experienced climate disasters which adversely hit their economic performance in the short term, with some effects persisting through the medium term. Some effects stand out in disruptive disaster years, that is, when climate events have caused particularly high annual human damages (Chapter 2, section B).[11]

Climate disasters trigger an immediate, at times even permanent, decline in output (Figure 14). In disruptive disaster years, real per capita growth tended to decline by 1.1 percentage points in MENAP but bounced back within a year without permanent scarring. The impact was found to be both larger and more persistent in CCA countries, where growth initially declines by 1.7 percentage points and recovers slowly over the medium term, resulting in a permanent output loss of almost 5½ percentage points of GDP. These effects would have been even more pronounced in the absence of both a policy response to support lives and livelihoods and investment to repair the damaged capital stock and thereby restore potential output. In fact, the latter played an important role in CCA, where investment initially tended to jump by over 1 percentage point of GDP in a disruptive year, permanently increasing the investment ratio by about 2 percentage points of GDP.

Climate disasters increase public debt, but not always fiscal deficits (Figure 15). In disruptive years, public debt tended to surge by 2½ percent of GDP in ME&CA countries. The same-year increase in CCA countries mainly reflects an immediate budget and growth deterioration, whereas the deferred increase in MENAP countries point to debt stock-flow adjustments (including the realization of contingent liabilities). Tax revenues tended to take a deferred hit in both subregions (even resulting in a permanent decline in the tax ratio of 1 percent of GDP), whereas the mobilization of grants generally remained insignificant. Spending only saw

[11] This paper's focus on the human (rather than material) loss dimension generally reflects both a better match with the disasters seen in the ME&CA region and data availability.

Figure 15. ME&CA: Period-by-Period Fiscal Response to Disruptive Climate Disaster Years[1]
(Percentage points of GDP, dashed lines represent 90 percent confidence bands)



Sources: EM-DAT; WB WDI; IMF WEO; IMF staff reports; and IMF staff calculations.
[1]The impulse reaction functions (IRFs) show the multiyear macro response to the shock of a disruptive year, that is, when the annual deaths plus 0.3 times affected persons exceed 0.01 percent of the population (Fomby, Ikeda, and Loayza 2009). The IRFs capture quite heterogenous post-disaster outcomes and policies, as evidenced by the width of the confidence bands. The number of included years and countries varies with data availability. Also see Annex 4 for data and methodology.

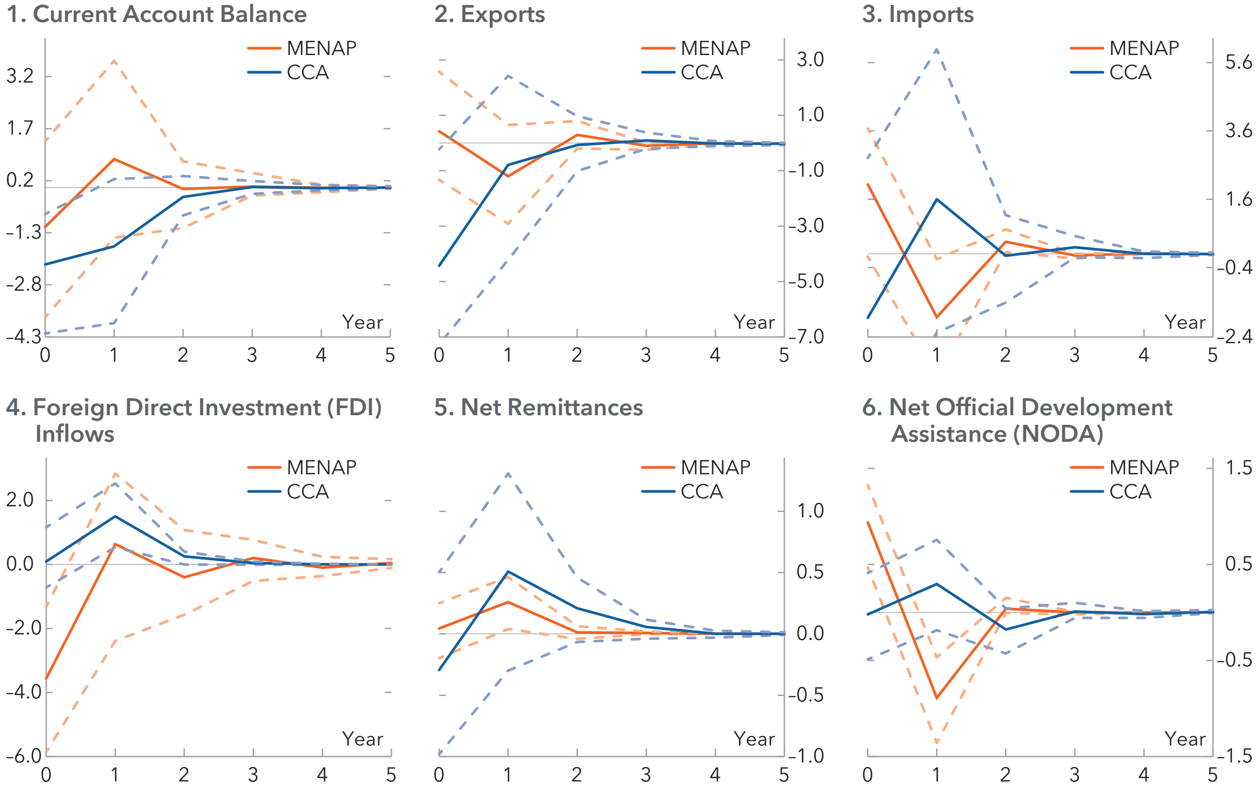
a real increase in the CCA. While this widened the CCA's primary deficit substantially, MENAP's remained broadly stable. This reflects more binding financing constraints, rigid budget processes, and deliberate policy choices.[12] These constraints forced a recourse to fiscal containment polices (mainly spending reprioritization),[13] debt deferral (particularly external default, Figure 15, panel 2), and reliance on the private sector. Throughout the region, the private response was helped by fresh financing thanks to remittances and aid (Figure 16, panels 4 and 5), but not much by private credit (given weak financial inclusion and rigid lending rules).

Climate disasters deteriorate current account dynamics (Figure 16). During disaster years in CCA countries, the current account immediately deteriorated, which persisted over the medium term and resulted in a permanently higher current account deficit of about 4 percentage points of GDP. Exports declined too, while FDI increased in the post-disruptive year. In contrast, MENAP countries' current account response was heterogenous, notably on the export side. This mirrors some countries' stable fossil fuel exports and/or narrow non-oil export bases, and others' collapse of climate-affected agricultural exports. MENAP imports,

[12] Those include (Gerling 2017): (1) limited fiscal policy flexibility in many ME&CA countries due to insufficient fiscal space, weak capacity, or rigid budget procedures; (2) normative case for public intervention out of countercyclical or distributional concerns (with the first being stronger in CCA because of the sharper and permanent growth decline); (3) extent of direct public sector damages, which in ME&CA is typically only a fraction of those of the private sector; and (4) adequacy of the private sector response, which often substantially substitutes for that of the public sector.

[13] Expenditure rebalancing (in the disruptive year to current and the next year to capital spending) was only observed in the CCA, whereas MENAP saw a spending freeze, followed by an increase in both current and capital spending.

Figure 16. ME&CA: Period-by-Period External Sector Response to Disruptive Climate Disaster Years[1]
(Percentage points of GDP, dashed lines represent 90 percent confidence bands)



Sources: EM-DAT; WB WDI; IMF WEO; IMF staff reports; and IMF staff calculations.
[1]The impulse reaction functions (IRFs) show the multi-year macro response to the shock of a disruptive year, i.e., when the annual deaths plus 0.3 times affected persons exceed 0.01 percent of the population (Fomby et al. 2009). The IRFs capture quite heterogenous postdisaster outcomes and policies, as evidenced by the width of the confidence bands. The number of included years and countries varies with data availability. Also see Annex 3 for data and methodology.

however, immediately increased (predominantly for food, medical supplies, and construction materials), facilitated initially by more aid and later remittances. The latter helped prop up private demand and rebuilding efforts, even as FDI dropped sharply.

B. Emerging Policy Challenges

Climate change poses widely shared macroeconomic policy challenges in ME&CA countries. The past economic impact of the region's key climate stressors—lower growth, shifting GDP and employment shares, as well as larger fiscal and external imbalances (Chapter 3, section A)—will likely deepen with the predicted intensification of the region's climate stressors (Chapter 2, section C), especially where current weaknesses in climate resilience persist (Chapter 2, section B). Policymakers in the region thus need to recognize that without adequate adaptation strategies (Chapter 4), even in a moderate global warming scenario with ambitious global mitigation efforts, climate change will weigh on:

- *Inclusive growth and per capita incomes.*[14] Climate change can result in lower and more volatile economic growth, as it damages human capital (by increasing mortality and morbidity) and physical infrastructure (including business assets, transport ways, industrial structures, and crops). Productivity declines and

[14] See Burke, Hsiang, and Miguel (2015b), Carleton and Hsiang (2016), Dell, Jones, and Olken (2012, 2014), IMF (2017, 2020a), Garcia-Verdu and others (2019), Hsiang, Meng, and Cane (2011), Kahn and others (2021), and Volz and Ahmed (2020) for results on broader country samples.

jobs are lost, at times resulting in worker displacement and conflict (Box 2). Moreover, climate change increases risks and uncertainty, dampening investment. Unaddressed physical and human damages can weigh on potential growth. Changing weather patterns typically first impact agricultural and hydropower production in the rural areas, with ripple effects on manufacturing, trade, and tourism via demand- and supply-side shocks.[15] Discrete climate disasters can hit anywhere, including in urban areas where manufacturing is generally most affected, with ripple effects on trade and services.

- *Macroeconomic stability*. Climate impacts can undermine government finances and debt sustainability (1) directly, through fiscal accounts (lower tax revenues, current spending pressures to save lives and livelihoods, capital expenditure pressures for new public infrastructure, etc.) and/or public debt (such as from a larger fiscal deficit, the triggering of debt guarantees for loss-making state-owned enterprises, or a shock to foreign currency debt from a depreciating currency); and (2) indirectly, from lower growth, including from socio-political turmoil (Volz and others 2020). Besides, numerous climate induced demand and supply shocks can fuel inflation (for example, if food shortages create price spikes). These shocks can also reshape import needs and export potential (particularly of agricultural products, services such as tourism, and hydropower), which in turn can weigh on external sustainability, erode reserves, and put pressure on the currency.

- *Financial stability*. Climate effects can erode the soundness of financial institutions, including insurance companies. Channels include a deterioration of balance sheets, deposit withdrawals, nonperforming loans, and reevaluation of stranded assets used as collateral or asset (IMF 2020b). Climate disasters could result in large losses for banks, insurers, and investment funds and could trigger outflows from financial institutions that have high physical exposure—potentially leading to fire sales and macro-financial spillovers. Disasters can also damage the infrastructure of payment systems.

- *Socioeconomic development, inequality, and political stability*. Climate impacts can cause new, and aggravate existing, social disparities with adverse effects on migration and conflict (Box 2). This is more likely to occur where past climate damages were not fully addressed and where prevailing intrinsic vulnerabilities as well as institutional and policy gaps disproportionally affect low-income households (Chapter 2, section B), the youth and women or seasonal and outdoor workers, including due to a proliferation of diseases.[16]

[15] These impacts vary widely across regions; however, Dupressoir and others (2007) find a mixed picture even across the European Union, where employment impacts on agriculture and tourism could be positive, that on many other economic activities negative, but northern Europe is likely to benefit more than the south. Muritala, Muyideen, and Olurotimi (2013) also point out that in the short to medium term, employment shifts will occur from carbon-intensive to low-carbon and construction sectors, with the net effect dependent on each country and the strength of climate policy.

[16] Also see for example, Olsen (2009), Rosemberg (2010), and International Labour Organization (2021).

Box 2. Climate Change, Human Security, and Political Stability

Climate change and environmental collapse often hit populations that already live in protracted crisis, in turn threatening human security and political stability. Throughout the region, climate change reinforces a vicious cycle of eroding water and food security (Box 1), amplifying pre-existing socio-political tensions. Evidence suggests that deviations from both moderate temperature and precipitation patterns can indeed systematically raise the risk of political instability, conflict, and migration, including from sub Saharan Africa (Missirian and Schlenker 2017; Sakaguchi, Varughese, and Auld 2017; Hsiang, Meng, and Cane 2011; Dell, Jones, and Olken 2012; Hendrix and Salehyan 2012). For instance, Mach and others (2019) find that up to 20 percent of organized armed conflict was influenced by climate variability over the past century; and Burke, Hsiang, and Miguel (2015a) that an increase in temperatures by one standard deviation contemporaneously raises intergroup conflict by more than 11 percent.

Examples from the region are manifold. The 2010 Arab Spring was preceded by a drought that caused food price spikes in Tunisia in an already tense socio-political environment (Perez and Wire 2013). Even today, Tunisia's economic base in its less developed regions largely remains a vulnerable export-oriented agricultural monoculture (mainly olives). This, combined with high poverty, unemployment (particular among the youth and women), and constraints to private sector initiative and investment, provides fertile ground for dashed hopes and radicalization (Young and Lazard 2020). Another example is the uniquely long drought in Syria during 2007–10, which particularly hit the government-promoted water-intensive wheat and cotton production. This fueled an unprecedented rural exodus into already cramped cities and a disintegration of livelihoods. Social unrest increased, leading to conflict, which pushed people into neighboring countries and Europe (Gleick 2014; Kelley and others 2015; Young and Lazard 2020). The case of West Bank and Gaza also highlights the detrimental impact of conflict on vulnerability (most obviously security buffer zones restricting the use of arable land and exacerbating access to water, in turn threatening food and water security) and adaptation efforts (most obviously through import restrictions on critical equipment; see Agha 2019, Weir 2018, State of Palestine Environment Quality Authority 2016).

4. Climate Adaptation Policy

To contain the predicted human and macroeconomic impact of climate change in the ME&CA region, countries will have to shore up their climate resilience. As with other policies, adaptation strategies are inherently country specific, but some common principles apply. First, comprehensive climate strategies—consisting of risk assessments, along with measures to adapt, mitigate, and manage transition risks—need to be fully embedded in countries' medium-term inclusive growth and development agendas. Above all, this means mainstreaming adaptation into all existing policy frameworks and accelerating relevant structural reforms, including those aimed at strengthening governance and institutions. In parallel, no-regret measures could help boost climate resilience. Regional priorities are to step up high-quality spending on social protection, health, and education, as well as to invest in water resource management, irrigation schemes, and early warning systems. Moreover, ensuring adequate private sector participation, with support from the financial sector and better data disclosure are key. In the near term, climate policies in support of demand and adaptation initiatives offer the chance to "green" the recovery from the COVID-19 pandemic.

A. Adaptation Strategies

Climate change necessitates urgent and decisive adaptation action. As noted earlier, the objective of adaptation is to reduce the impact of climate change on the economic variables discussed in Chapters 2 and 3. Without adaptation, the adverse humanitarian, social, and macroeconomic costs of exacerbating climate stresses discussed in this paper will continue to increase—potentially even at an accelerating pace, amplified by a cycle of worsening climate hazards and waning resilience. While potential returns to adaptation (benefit-cost ratios) can range as high as 100–1,000 percent—possibly avoiding up to 50–80 percent of climate damages—reaping the full benefits requires time, capacity building, and funding (IMF 2021b; Hallegatte, Rentschler, and Rozenberg 2019). Against this backdrop, the UN added "Taking urgent action to combat climate change and its impacts" as the 13th Sustainable Development Goal (SDG) in 2015.[1] Although actual policies will need to reflect individual country circumstances and challenges, adaption efforts could be guided by some common principles applicable for the entire ME&CA region.

Policy Priorities

As a general principle, climate change impacts and adaptation policies need to be mainstreamed into all national economic strategies. As the climate will continue to change, adaptation should be designed as a dynamic process that takes the risks of climate stress and related disasters as given. On that basis, policymakers should (1) develop macroeconomic frameworks that fully reflect these risks and pursue macro-financial policies that build adequate domestic and external buffers and fiscal contingencies, (2) devise interventions that address those risks, and (3) secure financing sources that are adequate and robust. Although adaptation will be a long-term continuous process in ME&CA countries, it should start now. Near-term macroeconomic forecasting and budget planning should incorporate adequate shock scenarios, post-disaster financing needs, and risk reduction strategies based on current climate risks and trends in the region. At longer horizons, adaptation planning should rely on robust scenario analyses grounded in climate science that also update the baseline impact of mitigation.

Specific adaptation policy priorities arise from the empirical analysis of the macroeconomic impact of climate change and climate disasters in the ME&CA region:

[1] The SDGs define three concrete targets: (1) strengthening resilience and adaptative capacity to climate-related hazards and natural disasters in all countries; (2) integrating climate change measures into national policies, strategies, and planning; and (3) improving education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction, and early warning.

- *Boosting public investment in resilient infrastructur*e. In ME&CA countries, the public sector is typically the main investor in infrastructure but has historically used *ex post* measures for disaster relief, recovery, and reconstruction rather than *proactive* investments.[2] Policymakers should reverse this focus and prioritize investments in adaptation that have positive externalities to help contain the significant human and material damages which result from climate change as well as the detrimental impact on growth, employment, debt, and current accounts. Investing in preemptive resilient infrastructure promises to reduce the adverse impact of climate change on growth and employment, limit the need for stimulative fiscal policy, and improve debt dynamics.[3] A simulation for Morocco, for example, suggests that infrastructure investment that targets higher climate resilience entails more growth benefits than the standard investment plans, before and after climate disasters (Box 3). Even though adaptation investment is associated with higher fiscal costs, it brings down the public debt that would otherwise have to be used to fund post-disaster relief measures.

- *Increasing the role of the private sector*. Given the urgency and potential payoffs of investments in resilient infrastructure, policymakers should encourage increased participation in adaptation investment by the private sector. They should remove market imperfections and policies that make private adaptation both insufficient and inefficient. To this end, policymakers should review regulations,[4] step up mandatory climate risk disclosure, disseminate business relevant information on impending climate risks, and devise appropriate fiscal policies, such as through tax breaks and subsidies, financing incentives, or public private partnerships.[5]

- *Designing prudent, efficient, and fair macroeconomic policies*. Public policies should aim at minimizing climate risks efficiently while preserving macroeconomic stability. When it is too costly to eliminate all risks, fiscal, external, and financial sector policies should prepare for and address residual risks by (1) building adequate buffers and preparing contingency plans and (2) when needed, implementing sustainable support programs that balance equity and efficiency, including through redistributing resources and compensations (IMF 2021b). Thus, policymakers need to carefully weigh the strategic interactions between available self-protection, public investment, and market insurance (Kahn and Lall 2021, Ehrlich and Becker 2007) as well as distributional impacts.[6]

- *Adjusting inclusive growth and development agendas*. Policymakers need to factor in up-to-date expectations about current and future climate risks and direct more efforts to unleashing higher job-rich growth and protecting the most vulnerable population groups.[7] Low resilience, among other factors, stemming from prevailing structural bottlenecks, amplifies the impact of climate change in most ME&CA countries (Chapter 2, sections B and C). For instance, large swaths of the population are highly vulnerable to climate change as their livelihoods depend on rain-fed agriculture or tourism. Similarly, the employment

[2] A role for the government arises from the inefficiency of adaptation amid market imperfections, such as those pertaining to the public goods nature of many adaptation goods (for example, infrastructure, know-how, information), market inefficiencies (for example, distortionary subsidies in water and private insurance), moral hazard (for example, when building flood-prone areas), barriers to trade, or imperfect credit markets (IMF 2021b).

[3] Several other studies have also highlighted the potential benefits of preemptive resilience relative to ex post disaster response (Forni, Catalano, and Pezzolla 2019; Dabla-Norris and others 2021). Such investment not only limits human and material damages from climate change, but also helps contain capital depreciation, stabilize public debt, and increase output (Forni, Catalano, and Pezzolla 2019).

[4] Specifically, using hazard maps that consider climate change to improve urban planning by adapting climate- and disaster-resilient regulation on zoning, building codes, and land use can help foster resilience (Hallegatte and others 2020), particularly in the face of expanding urbanization (Chapter 2, section B), and promote the construction of energy-efficient and environmentally-responsible structures (for example, Saudi Arabia's and Bahrain's Green Building Codes). Public incentives or support schemes for vulnerable groups can encourage compliance, especially where enforcement and governance are weak (Bhattacharya and others 2021).

[5] An example of a public-private partnership in this area are the planned desalination and waste management plants in Tunisia.

[6] Hallegatte (2021) highlights how better accounting for distributional and poverty impacts can improve cost-benefit ratios of investments through spatial and sectoral prioritization of interventions.

[7] Given large SDG challenges and needs in many ME&CA countries, adaptation efforts should be additional: adaptation investment should not crowd out more productive investments toward other development objectives (IMF 2021b).

of youth and women in the region is already low and could further be disproportionately affected by climate change. Against this backdrop, some cross cutting priority reforms arise on the structural side in ME&CA countries:

- *Strengthening social spending*. Higher and better targeted social spending—especially for education, health, and social programs—is important not only to provide adequate social protection for the poor, but also to improve peoples' skills and health and hence, productivity. Protecting human capital accumulation from the impact of climate change and disasters additionally warrants making social spending responsive to such shocks and transitions. Options comprise well-targeted social systems that include climate-dependent social transfers (kicking in when climate conditions exceed pre-defined thresholds), adequately indexed cash transfers (neutralizing the effects of food price spikes after adverse climate events),[8] or subsidized insurance against natural hazards (either through government or donors). Moreover, anticipative active labor market policies (notably through specific [re-]training programs) can help people transition to more climate-sustainable jobs and address climate-induced inequality, especially if geared toward those people most at risk of losing their jobs within the labor force (notably lower-skilled women and youth), sectors (notably rain-fed agriculture and tourism), and regions (for example, flood-prone areas).
- *Generating opportunities for all*. This requires removing impediments to increasing productivity, developing a vibrant private sector, and creating high-quality jobs for a rapidly growing labor force with due consideration of the sectoral and regional policies need to account for impeding adaptation needs. These needs warrant, for instance, efforts to reduce the climate impact on jobs and livelihoods in coastal regions and on sectors (notably agriculture, tourism, and energy) that could suffer with changing climate conditions, sea level rise, and global low carbon transition. In addition, policymakers should focus on boosting the business and investment climate, mainly through legal and regulatory reforms that improve product and labor market flexibility, governance, and access to finance—both specifically targeted at marginalized groups like youth, women, refugees, and rural populations (Purfield and others 2018). Micro enterprises and smallholder farmers could benefit from improving their capacity through training programs, weather information, and access to climate-resistant production technologies and financial services.
- *Improving water and hydromet value chains*. Given the ME&CA region's perennial water challenges, including the dry climate and low efficiency of water use (Box 1), a key focus of resilient infrastructure policy lies on investing in water management (mainly better irrigation, desalination, and wastewater treatment systems), water pricing, and hydromet services. The latter includes the monitoring and forecasting of hydrological and meteorological ("hydromet") hazards, which is a crucial input in early warning and response systems. It helps protect lives and livelihoods as well as provide wider economic, environmental, and social co-benefits at both national and regional levels.

Some preconditions to help achieve these adaptation priorities include:

- *Prioritizing high-value, no-regret investments*. Efficient prioritization of public policies is critical to exploit complementarities and adequately handle trade-offs. The analysis presented in Chapter 3 suggests MENAP countries are particularly susceptible to higher temperatures, and so may want to focus adaptation spending in this area, while CCA countries are particularly hard-hit by precipitation events and climate disasters. So-called "no-regret" measures could be prioritized, which aim at addressing current climate variability while building adaptative capacity for future climate change (Noble and others 2014).[9]

[8] There is evidence that households receiving cash assistance after natural disasters recover faster than their peers without such assistance (Mansur, Doyle, and Ivaschenko 2018).

[9] Such no-regret measures can even be initiated without any capacity for climate data generation and analysis as they would be beneficial even in the absence of climate change. Also see "adaptation" measures in the glossary, including in contrast to low- and high-regret measures.

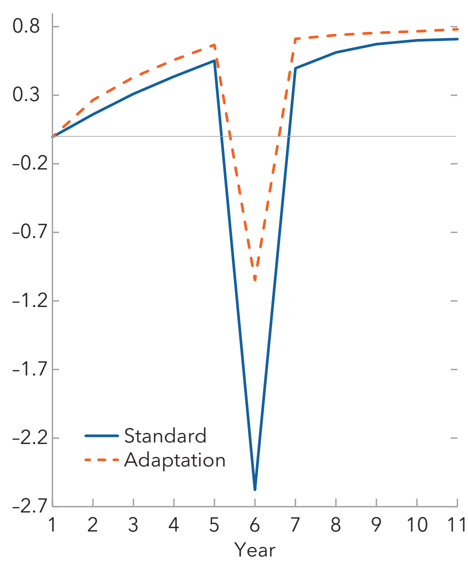
Box 3. Modeling the Macroeconomic Effects of Adaptation Investment in Morocco[1]

Morocco's agricultural output is highly sensitive to droughts and would benefit from investments in climate resilient water infrastructure. The agricultural sector employed more than 30 percent of the labor force and contributed about 12 percent of GDP in 2020. With only 10 percent of the arable land equipped with irrigation systems, frequent droughts have caused GDP losses in the range of 1.2–7.6 percent in the past three decades (Verner and others 2018). Climate change is worsening the intensity and frequency of these events, causing concerns for food security and livestock survival. As a result, Morocco has invested in scaling up its water infrastructure in recent decades. Water infrastructure investments, notably in hydro-agriculture development (that is, dams and irrigation systems), can help reduce the impact of droughts on macroeconomic performance.

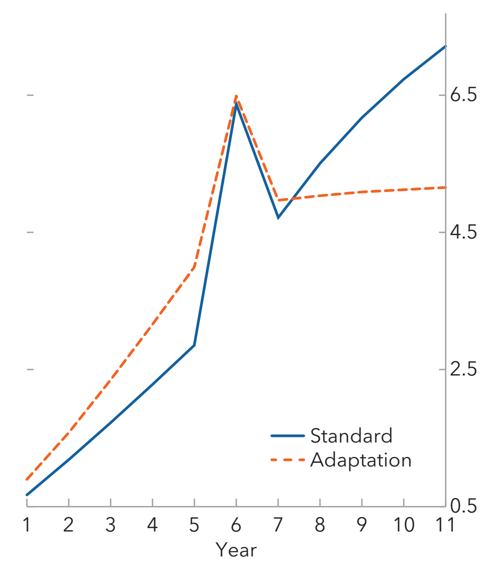
To understand the effects of water infrastructure investment, this paper simulates the macro-fiscal implications of two investment regimes of equal size: a standard infrastructure investment plan and an adaptation investment plan with enhanced resilience. Both plans start in year 1 with a gradual increase equivalent to 1 percent of GDP each year until a drought strikes. Compared with the standard plan, the adaptation plan comes with higher fiscal cost for each unit of investment put in place, which translates into higher debt accumulation.

The adaptation investment plan delivers higher economic returns, even before a drought materializes, than the standard investment mix. Although both types of public capital increase the productivity of the private sector, resilient irrigation projects (such as dams and canals) yield higher GDP dividends, as they deliver higher economic returns in drought-prone countries than standard investments, even before a drought strikes (World Bank 2005).

Box Figure 3.1. Real GDP
(Deviation form steady state, percent)



Box Figure 3.2. Public Debt
(Deviation form steady state, percent of GDP)



Source: IMF staff calculations.
Note: Based on a calibration of a Debt-Investment-Growth-and-Natural-Disasters (DIGNAD) model of Marto, Papageorgiou, and Klyuev (2017) to the economy of Morocco. Also see Annex 4, section D for details on the methodology.

[1] Prepared by Zamid Aligishiev, Chen Chen, Giovanni Melina, and Kubi Johnson.

Box 3. Modeling the Macroeconomic Effects of Adaptation Investment in Morocco *(continued)*

Investment in climate adaptation improves the resilience of the Moroccan economy to drought events. In the model, output falls in line with historical average drought-related GDP losses of about 3.2 percent from the peak following the five-year accumulative standard investment. In comparison, adaptation investment in resilient irrigation infrastructure could reduce these GDP losses by almost 60 percent, bringing them down to about 1 percent. The enhanced water and irrigation capacity would help address the gap of water demand and supply in the agriculture sector, enabling it to remain productive to a large extent also during drought occurrences. The more muted decline in GDP would also be beneficial for the debt-to-GDP ratio trajectory in the aftermath of the events.

Early investment in adaptation would be more efficient than post-disaster measures. After drought events, higher government spending is needed to fund social safeguard measures for urban and rural populations, as well as to support increased food imports. At times, the gap between increased needs for food imports and reduced fiscal space can be exacerbated by volatile global food prices. For example, the compounded effects of the 2007 global food price crisis and the 2007 Moroccan drought more than tripled food import expenditures relative to 2006 (Food and Agriculture Organization 2021b). With increasing drought risks, proactive adaptation investment is thus crucial to reduce both the depth of drought impacts and the fiscal needs associated with government responses.

Examples from the region include the upgrade of the national water management system in Jordan, wider use of drip irrigation schemes in Maghreb countries, cross-border early warning systems for natural disasters in Tajikistan and Uzbekistan, and upgrade of social safety nets in Pakistan.

- *Strengthening administrative capacity*. ME&CA countries face many constraints that could limit climate-related spending, including low administrative and institutional capacity, weak governance, and tight fiscal space. It would help to ensure that fiscal risks are properly managed before gradually incorporating climate considerations in public financial management (PFM) tools and institutions,[10] and before significantly scaling up adaptation investment or entering PPPs. Concretely, this mainly means strengthening public investment management (PIM) in terms of project planning, selection and appraisal; public procurement and PPP frameworks; and central oversight in the Ministry of Finance (IMF 2021b, Gerling 2017).[11]

- *Upgrading the financial sector*. Managing climate risks requires financial sector reforms aimed most importantly at ensuring financial stability, pooling climate-related risks, and facilitating adaptative and clean investments (IMF 2016). This requires efforts on multiple fronts including strengthening prudential regulation for climate change (particularly for the insurance sector), regulatory oversight and stress testing to ensure sound and resilient institutions, and well-functioning financial markets to provide adequate instruments. Besides promoting green financial instruments, catastrophe bonds and similar hedging instruments can transfer climate damage risks to those who are better able to bear them. Analyses of how firms' asset values could be impacted by climate stresses and de-carbonization are needed to efficiently allocate investments across sectors.

[10] This could include incorporating requirements for climate-risk evaluations, better energy efficiency standards, or better protection against natural disasters for public-funded projects. See Gonguet and others (2021) for key principles of climate-sensitive management of public finances.

[11] Besides, budget processes need flexibility, for instance by incorporating some escape clauses for natural disasters in budget laws and fiscal rules or streamlining the process for preparing and passing a revised budget.

- *Stepping up standards for climate data and disclosure*. Understanding the potential economic payoffs of adaptation policies requires high-quality, reliable, and comparable data on physical risks faced by households, firms, and financial institutions. This is often lacking in many ME&CA countries (Ferreira and others 2021), mainly reflecting gaps in forward looking, granular, and verifiable data (for example, on efforts to move to sustainable business models) and disclosure standards.[12] Closing these gaps would help facilitate investment decision-making and contribute to improving the allocation of capital and credit (with dividends for productivity, growth, and employment), financial supervision, and calibration of public interventions. Supported by regional and global partners (such as the Network for Greening the Financial Systems), policymakers should promote the disclosure of physical risks by making the process mandatory. This would require harmonizing existing assessment methodologies and standardizing disclosure regimes as well as supervisory frameworks.

Policy Framework

Adaptation policy priorities should be embedded within a guiding framework, while considering each country's specific climate risks and capacity. The National Adaptation Plan (NAP) under the United Nations Framework Convention on Climate Change (UNFCCC) framework helps countries refine and update national initiatives and incorporate them in a cohesive climate adaptation plan, integrate climate change into national decision-making, and guide implementation and regular review (Box 4).[13] To help accelerate adaptation, the NAP Global Network helps EMDEs accelerate their NAP efforts, mobilizes financial and technical donor support, offers opportunities for peer learning, and increasingly looks at how to engage the private sector in the NAP process.

Although ME&CA countries are at an early stage of drawing up national adaptation plans, their initial work indicates the focus of their adaptation strategies. As of mid-February 2022, only four ME&CA countries have published a NAP under the UNFCCC process (Armenia, Kuwait, Sudan, and West Bank and Gaza), while a total of 34 NAPs have been finalized worldwide. Most of the other ME&CA countries have started identifying adaptation needs and costs while making progress toward at least one part of the UNFCCC process, and some are more advanced (Figure 17): for instance, Jordan finalized its draft NAP in April 2021 and Afghanistan, Azerbaijan, and Mauritania have made progress on three out of the four required elements. Some countries have instead formulated climate strategies outside of the NAP process. The UAE, for example, launched its National Climate Change Adaptation Program in 2017 and Saudi Arabia introduced its "Green Initiative" in 2021 and refers to its specific adaptation strategy within its mitigation commitments under the UNFCCC. Furthermore, some countries are using their Nationally Determined Contributions (NDCs) reports to lay out not only their mitigation efforts (Annex 3), but also major adaptation projects (for example, Pakistan and Tunisia). Despite many country-level specificities, existing adaptation strategies not only share some common themes and challenges but also provide a broad view of what adaptation polices should focus on (Box 5).

Domestic consultation and cross-county cooperation can facilitate adaptation policies.

- *Domestic consultation and compensation*. Adaptation policies affect a wide range of stakeholders, including local communities, national suppliers, and neighboring countries. "Procedural" and "distributive" justice is therefore important (Lager and others 2021). This implies the need to (1) include all stakeholders in the decision process to help ensure diverse views and impacts are considered and (2) consider the distributional impact of climate risks and resilience building efforts in policy design. Redistributional wealth effects and political economy sensitivities require careful design of adaptation policies and possible compensating measures to ensure broad societal and political support.

---

[12] For example, out of the 700 companies and organizations supporting the Task Force on Climate-Related Financial Disclosures (TCFD) in 2020, only 2 percent were from the Middle East and Africa (TCFD 2020 Status Report).

[13] In addition, some international financial institutions offer guiding principles for adaptation (for example, Hallegatte and others 2020) or frameworks for building structural, financial, and post-disaster resilience (for example, IMF 2019a), which could be incorporated into NAPs. The IPCC has outlined response options for adaptation, including by sector (IPCC 2014, World Bank 2015).

Box 4. What are National Adaptation Plans (NAPs)?[1]

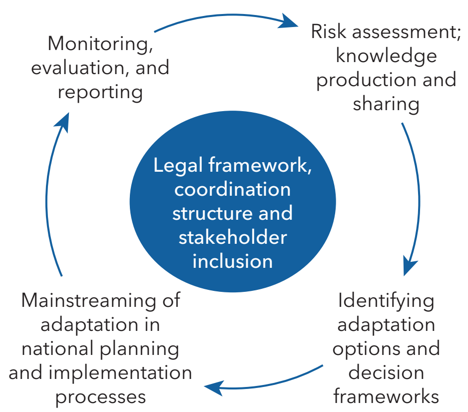
As the adverse effects of climate change become clear, it has become increasingly important for countries to draft plans to adapt to changing climate conditions. These plans are tailored to a country's circumstances and have been formed independently over the last few decades starting with many advanced economies.

Established under the Cancun Adaptation Framework agreed in 2010, the NAP process has two objectives: (1) to reduce vulnerability to climate change by increasing adaptative capacity and resilience; and (2) to facilitate the integration of adaptation into new and existing policies, programs, and activities within all relevant sectors (UNFCCC 2012a, b). To address those principles effectively, the UNFCCC advises coverage of four key elements:

- *Lay the groundwork and identify gaps in information and administration*. This includes taking stock of available data on climate change impacts, identifying capacity gaps and weaknesses in terms of planning for adaptation, and finding synergies between development and adaptation goals.
- *Strategic orientation and preparation*. This involves analyzing current and future climate scenarios; assessing climate vulnerabilities and identifying potential solutions that coincide with national development plans, including their costs; and communicating these plans to the public.
- *Implementation strategies*. This involves mainstreaming climate adaptation into national planning; enhancing the capacity for adaptation planning and implementation across all levels of governments and sectors of the economy; and developing a long-term national adaptation plan that includes potential financing measures.
- *Report, monitor, and review*. Continually monitoring progress made, reevaluating the adaptation plan, and regularly updating it are essential elements of creating an effective NAP.

The guidelines for the four elements are broad to allow NAP customization to countries' specific national implementation processes, national goals, economic structure, and heterogeneous climate change challenges.

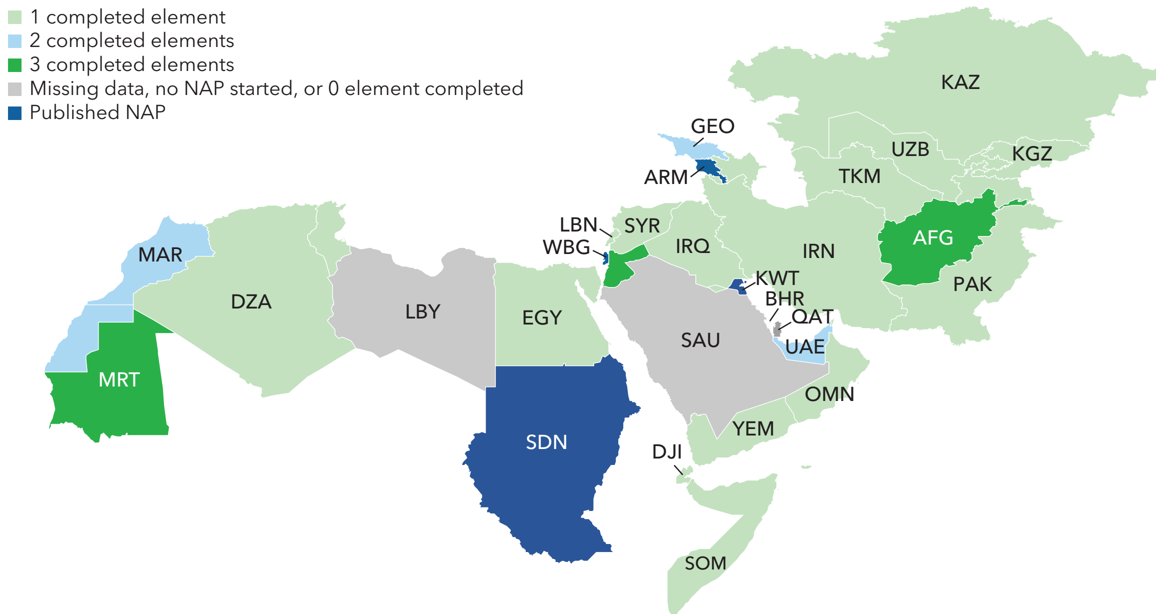
Box Figure 4.1. Adaptation Management



Source: IMF (2021b).

[1] With inputs from Joey Kilpatrick and Matthieu Bellon.

Figure 17. ME&CA: Progress Toward NAPs
(Number of completed elements)



Sources: FAD database on adaptation (forthcoming); UNFCCC (2019); and IMF staff analysis.
Note: Colors indicate the number of completed elements. An element is considered fulfilled if at least one measure in that element is fulfilled. In total, there are four elements (Box 4): (1) laying the groundwork and addressing gaps; (2) preparatory elements; (3) implementation strategies; and (4) reporting, monitoring, and review.

- *International cooperation*. Its importance arises from the transboundary impacts of climate change,[14] the political challenge of making required action an urgent priority, and the capacity and financing constraints faced by many countries, including in ME&CA.
  - *Regional level*. Coordinating adaptation policies across borders offers numerous benefits. It can help improve efficiency by sharing knowledge and the cost of public goods; provide an anchor for reform and address negative spillovers from one country's policy on others. Hence, countries should cover the regional dimension of climate change and adaptation in the NAPs and seek opportunities to leverage comparative strengths across borders. Many G20 countries and multilateral organizations are also fostering regional cooperation to adapt to climate change in ME&CA, such as the EU Association Agreements (for example, with Georgia), the Green Central Asia Transboundary Dialogue supported by Germany, the Blue Peace water arrangement for the Middle East supported by Switzerland and Sweden,[15] or afforestation and reforestation efforts across the Middle East sponsored by Saudi Arabia (Middle East Green Initiative).
  - *Global level*. Most ME&CA countries need capacity development (technical assistance and training of country officials) and technology transfer to achieve their adaptation and mitigation targets (Annex 3). In some cases, climate targets are conditional on this support, even if they are not contingent on receiving international financing (for example, some GCC countries). The 1992 UNFCCC is the primary framework for international climate change cooperation, and many multilateral and bilateral institutions have ramped up technical cooperation and financing for adaptation strategies.

[14] On physical and biological systems, socioeconomic dynamics, and financial flows (Benzie and others 2018).

[15] Blue Peace is a proposal for a comprehensive, integrated, and collaborative management of all water resources in a circle of countries in MENA (Strategic Foresight Group 2011).

Box 5. Review of Key Emerging Adaptation Strategies in ME&CA

Despite many country-level specificities, existing adaptation strategies share some common themes and challenges. Reviewing experience to date along the UNFCCC's principles (Box 4) suggests:

- *Important information and administrative gaps exist*. The published NAPs in the ME&CA region highlight data constraints and institutional capacity weaknesses as limitations to climate change assessments. They stress the importance of scaling up data collection and adaptation-focused research programs to better understand the challenges, calibrate appropriate policies, and guide cooperation to close know-how and technology gaps. Some NAPs identify broader challenges in collaborating between different parts of government (such as Kuwait).

- *Strategic orientation and preparation need focus*. Although NAPs are a work-in-progress for many countries in the region, several have pre-existing national climate strategies. National climate strategies respond to specific country challenges and highlight the capacity and investment requirements to overcome them in a tiered and prioritized manner. They also often specify how different areas of government can cooperate in the planning process to achieve long-term goals (for example, Tajikistan's 2017 National Climate Change Adaptation Strategy, Annex 2, section B). They typically include risk assessments for key sectors, including in the private sector, to identify relevant adaptation measures (for example, health, infrastructure, environment, and energy in the UAE's 2017 National Climate Change Adaptation Program). Often strategic goals are also linked to climate change mitigation, adaptation, and disaster resilience in a holistic manner, coordinating initiatives such as water management, reforestation, marine protection, urban planning, early warning systems, and energy efficiency (for example, Saudi Arabia's 2021 Circular Carbon Economy National Program (Annex 2, section A) or Pakistan's plan to plant 10 billion trees throughout the country by 2023). At the same time, an abundance of climate strategies can lead to a fragmented approach, and NAPs may serve a useful purpose in connecting separate initiatives. Overall, ME&CA countries' strategies show a dedicated focus on responding to the region's key climate change challenges (Chapter 2), but the challenge will be to follow through decisively and urgently with actions on the ground. Some key achievements and ongoing efforts include:

  - *Extreme heat*. To mitigate the impact of extreme heat events on health and productivity, Kuwait plans to increase public awareness on how to respond to heat waves, establish national health alerts, and explore adjusting working hours. Over the medium term, countries should also look to enhance the resilience of buildings and key infrastructure to extreme heat.

  - *Increasing water stress*. Saudi Arabia, for instance, focuses on integrated water management, aiming at harnessing new sources of freshwater by constructing dams (with 11 additional dams added in 2019, reaching a total of 521 dams), collecting water, and recharging aquifers. The UAE aims to reduce water consumption by 20 percent and increase the reuse of treated water to 95 percent by 2036. Desalination and irrigation projects need acceleration, especially where people depend on rain-fed agriculture (for example, rural Tunisia).

  - *Rising sea levels*. To protect its shoreline, Bahrain has planted palm trees and seasonal flowers and is now focusing on reclamation, ground levelling, automatic irrigation networks, reservoirs, and stations for irrigation pumps. Affected countries must also shore up plans for building seawalls and levees, evacuating people, and managing the loss of vast agricultural lands and freshwater resources.

Box 5. Review of Key Emerging Adaptation Strategies in ME&CA *(continued)*

- *More frequent and severe climate disasters*. For example, the "Recharge Pakistan" project envisages reducing flood risk and enhancing water recharge at six sites in the Indus Basin, building resilience for 10 million people, as well as strengthening vulnerable ecosystems (Government of Pakistan 2021). Tunisia has developed an SMS-based early warning system to alert people to major disasters, including floods. Similarly, Somalia has also set up a Drought Operations Coordination Center which informs communities about severe drought and flood risks. Undertaking contingency planning and strengthening emergency and recovery response strategies are additional disaster management policies countries should pursue.

- *Implementation strategies need operationalization*. ME&CA NAPs provide a useful framework for guiding policy sequencing and identifying capacity, investment, and financing needs, mostly through a clear prioritization of projects along with cost estimates. Implementation strategies vary in how they assess priority adaptation measures. Some use a sectoral approach (for example, Armenia, Kuwait and West Bank and Gaza), while others focus on the state level (for example, Sudan). Some countries have tasked specific implementation agencies to oversee and coordinate adaptation initiatives, such as the Environment Public Authority in Kuwait. However, those strategies still require full embedding in medium-term macroeconomic frameworks and development agendas in ME&CA countries as well as implementation of related structural and regulatory reforms. The identified large financing estimates require funding efforts (Chapter 4). In general, it is important that implementation is supported by effective governance to drive progress, ensure accountability, coordinate decision-making processes, and maintain political will at all levels.

- *Regular reporting, monitoring, and review is key*. Most NAPs, such as West Bank and Gaza's, propose revisiting the identification and prioritization of vulnerabilities and adaptation options each time their NAP is updated. Other countries are leveraging technology to develop tools to help continuously analyze environmental data and raise public awareness about adaptation, such as the electronic environmental Monitoring Information System of Kuwait and the electric vehicles in public transportation in Armenia. In any case, strengthening reporting, monitoring, and review remains key to ensuring that adaptation policies are well-targeted and effective.

B. Economic Policies for Near-Term "Green" Recovery

ME&CA countries can boost their recovery from the pandemic by steering their economies toward becoming more climate resilient and less carbon intensive. At the current juncture, policymakers are thinking about how to accelerate recovery from the pandemic. Hence, as countries transition from the acute phase of the pandemic toward the recovery stage, they can design stimulus measures and recovery initiatives to both support aggregate demand and promote a green recovery. The immediate policy responses should involve both adaptation and mitigation aspects of climate change. Where adaptation planning is still underway, adaptation should focus on "no-regret" measures. Governments in ME&CA countries can also accelerate their mitigation efforts and set more ambitious targets for reducing GHG emissions (Annex 3).

The economic circumstances of countries in the region vary, but some principles can guide the design of fiscal policies for the recovery (IMF 2020a). Support measures could include:

- *Adaptative investment*, especially low-regret options in countries where climate risks are not yet well identified and/or effective ad (Chapter 4, section A). They should be assessed for their climate impact, whether it is positive or negative, and reported in the budget where possible to encourage "green budgeting."

Public investment projects, public works programs, and debt guarantees in support of the recovery could be targeted toward "green," rather than "brown," initiatives. For example, investment could focus on projects which strengthen climate resilience through increased flood protection, better irrigation, and improved building infrastructure.

- *Mitigation*. Gradually eliminating generalized energy subsidies—which are common in the region (Purfield and others 2018)—and replacing them with targeted measures to compensate those with lower ability to pay, adjusting energy prices, expanding renewable energy production, introducing carbon taxation—while ensuring adequate protection for vulnerable groups—and reforestation are all options to deliver a reduction of GHG emissions through encouraging lower energy consumption and pivoting toward greener sources of energy production. In addition, these policies, the exact combination of which should be tailored to country circumstances, constraints, and characteristics (IMF 2020c, Black and others 2021), would create fiscal space for adaptation investment (Chapter 5, section B) and can also help countries pursue a cleaner, more sustainable economic development path

Investments in adaptation can be job-rich and have significant net benefits. Recent studies have found that investments in adaptation can have high benefit-cost ratios, by providing a "triple-dividend" from avoided losses, economic benefits, and social and environmental benefits (Global Commission on Adaptation 2020). Investing in climate-resilient infrastructure can have large multipliers and significant employment effects, depending on the nature of the construction sector in an economy. For example, for every $1 million spent on construction in G20 countries, estimates suggest output may increase by $2.5 to $5 million and between 13 to 647 jobs could be created, depending on the country (ILO 2018, Ernst and Sarabia 2015).[16] Government incentives that target adaptation measures, for example through tax breaks or guarantees, can also play an important role in encouraging private sector participation in adaptation initiatives (World Bank and the Global Facility for Disaster Reduction and Recovery 2021).

Some ME&CA countries have already started to green their economic recoveries, through adaptation and mitigation efforts alike. Egypt's sovereign green bond issuance in 2020 is supporting climate initiatives in a range of areas, including renewable energy, clean transportation, and water sustainability. Pakistan has launched an ambitious reforestation initiative and a National Electric Vehicle Policy. Both aim at reducing emissions and support job-rich growth (IMF 2021d).

[16] Generally, investments in times of heightened uncertainty, such as at present, could benefit from larger fiscal multipliers and a stronger impact on employment, potentially through signaling a government's commitment to achieving stability (IMF 2020a).

5. Climate Adaptation Financing

Adaptation will require significant additional spending and hence financing. Current cost estimates vary, reflecting methodological issues, and cover public infrastructure investment needs in a moderate-emission scenario only. Such costs could amount to up to 3.3 percent of GDP per year for individual ME&CA countries over the next 10 years (IMF 2020c), not including other needs, such as for public social spending and private adaptation measures. In any case, taking action will be challenging for many ME&CA countries, where urgent and large spending needs meet tight fiscal space, particularly in the aftermath of the COVID 19 pandemic. These countries need to create fiscal space through a mix of domestic policy reforms and more international support, leveraging various multilateral and bilateral financing options available under international agreements dedicated to climate change. Finally, public policies need to help catalyze crucial private investment in adaptation to complement that of the public sector. Socially and environmentally responsible investment broadly aligns with the principles of Islamic Finance.

A. Financing Needs

Responding to climate change requires additional spending and hence financing. Fiscal envelopes need to accommodate adaptation goals and include adequate buffers to respond to climate shocks whilst preserving debt sustainability. While advanced economies have typically relied on contingency reserves and tax collections to fund post disaster outlays, EMDEs—including in ME&CA—have heavily depended on emergency loans or grants (Mechler, Mochizuki, and Hochrainer-Stigler 2016). However, ramping up adaptative investment (Chapter 4) triggers additional financing needs, which poses a challenge for many fiscally constrained ME&CA countries. Their susceptibility to climate change and low resilience can adversely affect sovereign creditworthiness and borrowing costs (Cevik and Jalles 2020), in turn limiting investments in adaptation projects (Volz 2020), and so setting off a vicious cycle.

Adaptation costs are estimated to be very large. However, reflecting methodological difficulties, current approximations only cover investment needs for adaptation, thus abstracting from indirect costs and additional spending on increasing climate resilience (Chapter 2, section B). They also crucially depend on the underlying assumptions, especially the assumed climate change scenario, treatment of cost savings, and accounting of eventual positive spillovers. This gives rise to likely understated and widely ranging cost estimates.[1] For instance, the (UNEP 2020) projects that developing countries' annual investment needs for adaptation amount to up to $300 billion in 2030 and up to $500 billion in 2050. The annual public share of that cost could be around a few tenths of a percent of world GDP by mid-century (IMF 2021b). This, however, masks much larger needs relative to GDP in poor, small, and vulnerable countries. The World Bank (2010) assesses that annual investment needs in the MENA region could range between $2.9 and 4.1 billion in 2005 prices over 40 years (2010–50) (or 0.2–0.3 percent of regional 2005 GDP). These amounts would cover costs in moderate-emission scenarios only and abstract from additional needs (like, for instance, social spending aimed at shoring up much-needed resilience, Chapter 2, section B; or responding to worse-than-predicted climate hazards, Chapter 2, section C). Meanwhile, the IMF (2020c) estimates that annual investment needs for individual ME&CA countries could vary between 0.1 percent of GDP (Bahrain, Jordan, Saudi Arabia,) and 3.3 percent of GDP (Tajikistan) for the next 10 years. Their bottom-up approach only incorporates three specific risks (floods, storms, and sea level rise) and does not incorporate drought or extreme heat that can

[1] Estimating adaptation costs raises difficult methodological issues. Two approaches exist: (1) top-down, relating expected climate change to climate impacts and sectoral costs and (2) bottom-up, aggregating detailed cost estimates of specific adaptation strategies. Challenges include an incomplete coverage of climate change risks, underestimated implementation costs, and limits to adaptation strategies. At the same time, some cost-dampening factors are not yet accounted for, such as the co-benefits of adaptation strategies (UNEP 2021), which include for example, health benefits arising from improved urban design and planning.

be particularly relevant to the ME&CA region (Chapter 2). The investment needs refer to the costs of: (1) upgrading existing infrastructure to improve climate resilience, (2) upgrading projected investment, and (3) building coastal protection infrastructure.

B. Financing Sources

These potentially large financing needs will require tapping both domestic and external sources. On the domestic front, there may be scope to (1) redirect some of the existing spending (for example, from fossil fuel subsidies) to either directly cover adaptation outlays or to provide tax breaks for adaptation investment or (2) raise additional revenues from general taxation or green taxes (for example, a carbon tax whereby a price is set that emitters must pay for their greenhouse gas emissions). From the perspective of policy coordination and sequencing, where large energy subsidies are still in place, reducing those would be a priority before embarking on carbon taxation. On the external front, options include (1) tapping multilateral and bilateral financing available under international agreements dedicated to climate change; and (2) issuing green financing instruments. This can be accompanied by efforts to make frameworks more conducive for attracting private investment in adaptation.

Domestic Financing Sources

Significant sources of adaptation financing exist on the domestic front. This includes fiscal policy adjustments (such as the reorientation of spending away from less productive spending, widening tax bases and making them more equitable, tackling waste and corruption, and reforming loss making state-owned enterprises, Rigo and others 2021) that are warranted irrespective of climate policy. Two broad areas to focus on are:

- *Redirecting resources from energy (and other) subsidies*. Fuel subsidies currently in place are rather generous throughout the region and, in some countries, even after some initial energy price reform steps (Figure 18), especially in Algeria, Saudi Arabia, and Tajikistan.[2,3,4] The removal of explicit subsidies would thus be sufficient to cover the substantial adaptation costs estimated in IMF (2020a) in most of the 25 ME&CA countries included in the study.[5] Such a removal should be part of broader energy sector reform that entails having well-targeted social transfer systems put in place first. Also, general—and thus mostly regressive—electricity and water subsidies could be scaled back in some countries (such as in Pakistan and Tunisia), accompanied by well targeted cash transfers for the most vulnerable.

- *Mobilizing domestic revenue*. Mobilizing domestic (non-oil) revenues, particularly in areas where the region still lags comparators, is a key way of increasing fiscal space to raise adaptative investment for greater resilience. Boosting the efficiency of tax collection systems, streamlining exemptions, raising income tax rates, and introducing new taxes (for example, property taxes) would support this objective. Depending on country circumstances, carbon taxation could be considered to generate additional revenue. If pursued, taxing the production and uses of fossil fuels can raise significant revenue in many countries in the region (Figure 19), depending on the tax rate applied, volume of domestic carbon emission, and capacity of the tax administration. For instance, a tax of $25 per ton of carbon could collect almost 4 percent of GDP in fiscal revenues in Iran and 3 percent in Turkmenistan and Uzbekistan—and double those amounts with a tax of $75. This additional revenue would open fiscal space for a range of purposes (Marron and Morris

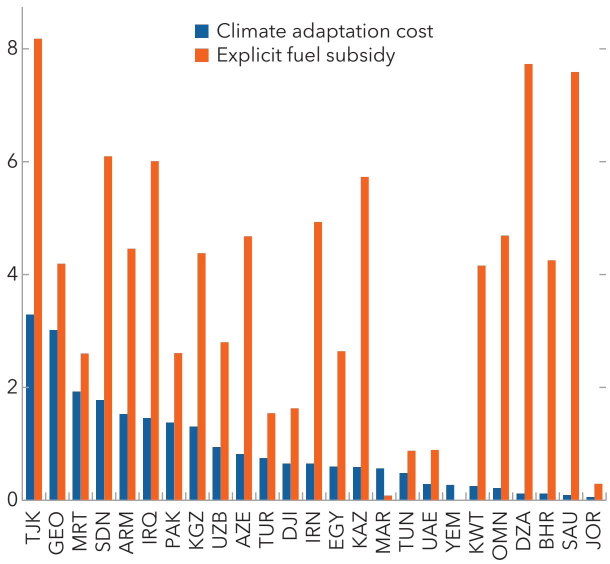
[2] These subsidies are not necessarily annual budget allocations only, but also recapitalizations of loss-making SOEs.

[3] There are many other ME&CA countries with large fuel subsidies. For example, in Iran, despite embarking on an ambitious subsidy reform program in 2010, gasoline prices—at about $0.05 per liter—remain among the lowest in the world.

[4] The estimation of explicit subsidies includes subsidies for petroleum, natural gas, coal, and electricity.

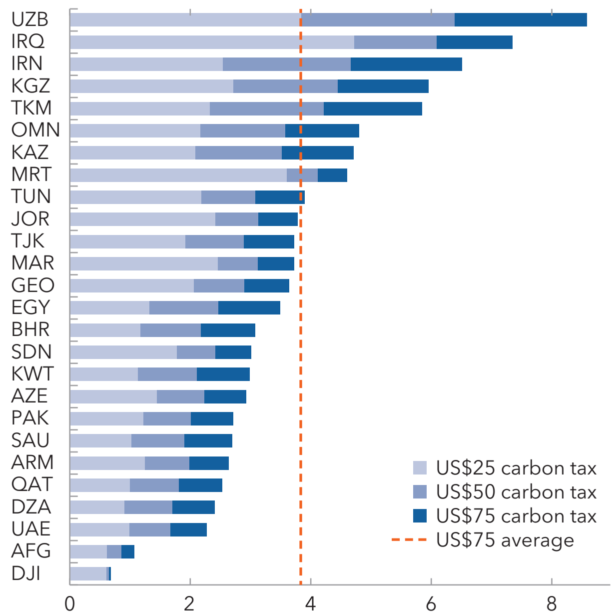
[5] The estimation of explicit subsidies reflects the difference between the price consumers pay for the use of energy including of fuel or electricity (retail price) and the cost of supplying it (supply cost). The supply cost is assumed to be equal to the export parity price, which is expected to be higher than the production cost.

Figure 18. ME&CA: Adaptation Costs and Explicit Fuel Subsidies, 2020
(Percent of GDP)



Sources: Parry, Black, and Vernon (2021); IMF (2020a); IMF WEO; and IMF staff calculations.
Note: Six countries miss data for adaptation costs, subsidies and/or GDP (Afghanistan, Lebanon, Libya, Qatar, Somalia, and Syria). The data do not reflect subsequent subsidy reforms, including in Saudi Arabia. Climate adaptation costs cover floods, storms, and sea level rise and do not capture investments needed to protect against other risks, including droughts and heatwaves.

Figure 19. ME&CA: Potential Carbon Tax Revenue, 2030
(Percent of GDP)



Sources: Country authorities; and IMF staff calculations.
Note: Estimations are based on a model calculation from the IMF Fiscal Affairs Department's Carbon Pricing Assessment Tool.

2016), including for compensating those vulnerable to the consequences of both the use of fossil fuels and policy measures to encourage a reduction in the use of fossil fuels (for example, carbon taxation or cap-and-trade mechanisms).

To make a dent, private adaptation efforts require public support. The private sector—households and companies alike— can sometimes take adaptation actions much more efficiently than the public sector. However, private sectors also face constraints: the availability of financing per se (due to both a lack of spare funds and access to credit) and for adaptation more specifically. Three key factors weigh on the latter (Tall and others 2021): (1) a lack of data on country-level climate risks and vulnerabilities to guide investment decision making, (2) limited clarity on government investment gaps to achieve adaptation goals, and (3) low perceived or actual returns on investment. This is a particular challenge in ME&CA's low-income countries, where communities largely depend on humanitarian funds to cope with climate risks. Thus, countries need to recognize the criticality of climate resilience (UNDP 2018b) and better gear public policies and finance toward catalyzing private investment, also with financial and capacity development support from the international community by:

- *Reducing costs and improving the risk-return profile*. Potential measures include the deployment of various financial instruments and mechanisms (such as blended finance, guarantees, subsidization, and credit enhancement), and other actions that prepare bankable projects to further reduce costs and improve the risk-return profile for private funding.

- *Creating an enabling environment*. Better planning and coordination between different stakeholders within a country is important to provide better data (notably on costs and benefits of various adaptation measures elaborated by sectoral and geographic needs) and public policies (building standards, incorporating climate change into planning for public infrastructure, etc.). In addition, countries could help strengthen price signals to better steer investment (notably by full cost accounting for water and energy, and removing government incentives in the form of subsidies, transfers, and administered prices), leverage public finance to accelerate R&D and technology diffusion, and deepen financial inclusion to improve market efficiency. Authorities facing a challenging economic environment, such as in Iran, should strive to balance measures aimed at reducing energy subsidies with targeted transfers to the most vulnerable, thereby mitigating the welfare impact of such policies and reducing public resistance against them.

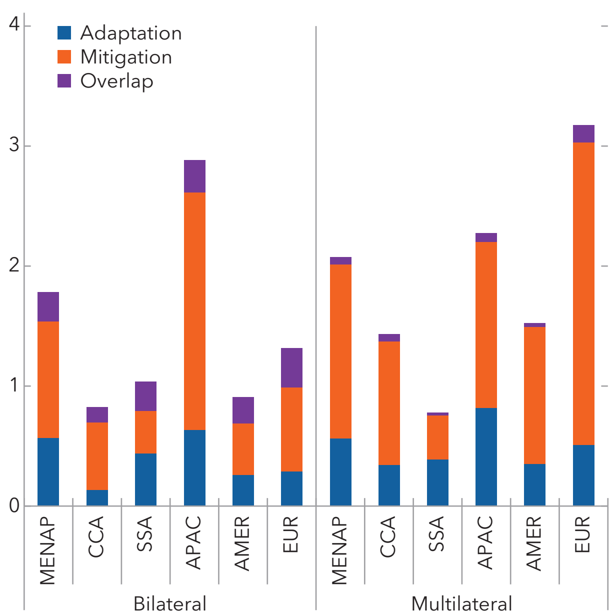
- *Sharing risks*. This requires developing insurance sectors, including for climate risks. Moreover, risk sharing arrangements can offer countries in a region with similar levels of disaster risks (such as droughts) to make contributions to a common pool. Payouts will then be triggered when risks materialize (for example, droughts of specific lengths or intensities). Those payouts could be used to finance further adaptation measures (including by recovery from disasters). Such arrangements, though, are rare around the world. Some notable examples include the African Union's African Risk Capacity, which provides insurance against droughts, and the Caribbean Catastrophe Risk Insurance Facility, which is the world's first regional fund that utilizes parametric insurance offering insurance against climate disasters such as cyclones and excess rainfall.[6] Both initiatives are also supported by the InsuResilience Global Partnership for Climate and Disaster Risk Finance and Insurance.[7]

External Financing Sources

Official Flows

The international community provides adaptation financing through multilateral and bilateral sources in a complex architecture. Watson and Schalatek (2021) show that funds for climate financing essentially flow from contributors (broadly G7 economies, Scandinavian countries) via bilateral (for example, KfW, Agence Française de Développement [AFD], DFID) and multilateral institutions to recipients (Box 6), which can include regional and national implementing entities. Between 2009–19, ME&CA countries received a total of about $70 billion in climate financing (Figure 20), which was substantially less than their EMDE peers in sub-Saharan Africa and in Asia and Pacific. Bilateral sources account for about 57 percent of total climate financing received by ME&CA countries. A similar proportion holds for adaptation financing.

Figure 20. EMDEs: Average Climate Financing by Region, 2009–19
(Billions of 2019 US$)



Sources: OECD; and IMF staff calculations.

Multilaterals' adaptation-related development financing has specific traits in ME&CA:

- *Terms are predominantly non-concessional.* Multilateral institutions have provided a total of $34 billion to ME&CA countries during 2009–19, of which 60 percent was on non-concessional terms and almost exclusively in debt instruments

[6] Parametric insurance as opposed to traditional insurance determines payouts based on triggering events in a predetermined scheme rather than according to the actual losses incurred.

[7] Launched at in 2017 as a joint G7, G20, and V20 initiative, the InsuResilience partnership connects countries, civil society, international organizations, the private sector, and academia. It seeks to strengthen EMDEs' resilience and protect the lives and livelihoods of the poor and vulnerable against the impacts of disasters and other climate risks.

Box 6. Important Sources of Official Financing for Adaptation in EMDEs

Multilateral sources:

- Green Climate Fund (GCF). Established by 194 countries party to the UNFCC in 2010, the GCF is a critical element of the historic Paris Agreement. It is the world's largest climate fund, mandated to support EMDEs in achieving low-emissions and climate-resilient pathways. The UN SDG 13 on Climate Action includes a target to "implement the commitment undertaken by developed-country parties to the UNFCCC to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the GCF through its capitalization as soon as possible."

- Global Environment Facility (GEF). Established in 1994 and administered by the World Bank for 183 member countries, the GEF provides grants and concessional financing to help protect the global environment and promote sustainable development. It funds projects related to mitigation, adaptation, biodiversity, and land degradation. Through the end of March 2021, the GEF has disbursed about $20 billion, with a quarter dedicated to climate change and almost a third to multi-focal areas (World Bank and the GEF 2021).

- Adaptation Fund (AF). Launched in December 2007, it finances adaptation projects and programs in developing countries that were parties to the Kyoto Protocol. The AF has pioneered a direct access model, which allows national entities to access funding without going through international intermediaries (Adaptation Fund 2018) as is the case, for example, for the GCF. Through the end of March 2021, the AF has disbursed $820 million (World Bank 2021b).

- Climate Investment Funds (CIF). Founded in 2008, the CIF is an $8 billion multi-donor trust fund that seeks to empower transformations in clean technology, energy access, climate resilience, and sustainable forests. It provides EMDEs with grants, concessional loans, risk mitigation instruments, and equity that leverage financing mainly from the private sector and multilateral development banks (MDBs). It is the only multilateral climate fund to work exclusively with MDBs and the International Finance Cooperation (IFC) as implementing agencies. Programs include the Clean Technology Fund ($5.8 billion), Pilot Program for Climate Resilience ($1.2 billion), Forest Investment Program ($1 billion), Scaling Up Renewable Energy in LICs ($0.6 billion), or the Climate-Smart Urbanization Program (Climate Investment Funds 2021).

- Other multilateral sources. Those include specific climate facilities offered by almost all multilateral development banks, that is, the World Bank Group (also including the IFC) and regional MDBs (that is, the African Development Bank (AfDB), Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD), and Interamerican Development Bank (IDB)).

Bilateral sources. Advanced economies are typically the main contributors of climate finance, both through the multilateral venues described above and their individual institutions. While the UK has established a climate-specific agency (International Climate Finance), most others operate via broad-based development agencies (for example, France's [AFD], Germany's German Agency for International Cooperation [GIZ], or Japan's International Cooperation Agency [JICA]). Funds often come with technical assistance on the ground. Examples of their work in the ME&CA region include: (1) GIZ's support for the water sector (with the Arab Ministerial Water Council) or resilient low-carbon economy in Algeria, the GCC, Iran, Jordan, Morocco, and Tunisia; (2) JICA's support for water supply and solid waste management systems in urban areas or disaster management in Pakistan, air pollution

Box 6. Important Sources of Official Financing for Adaptation in EMDEs *(continued)*

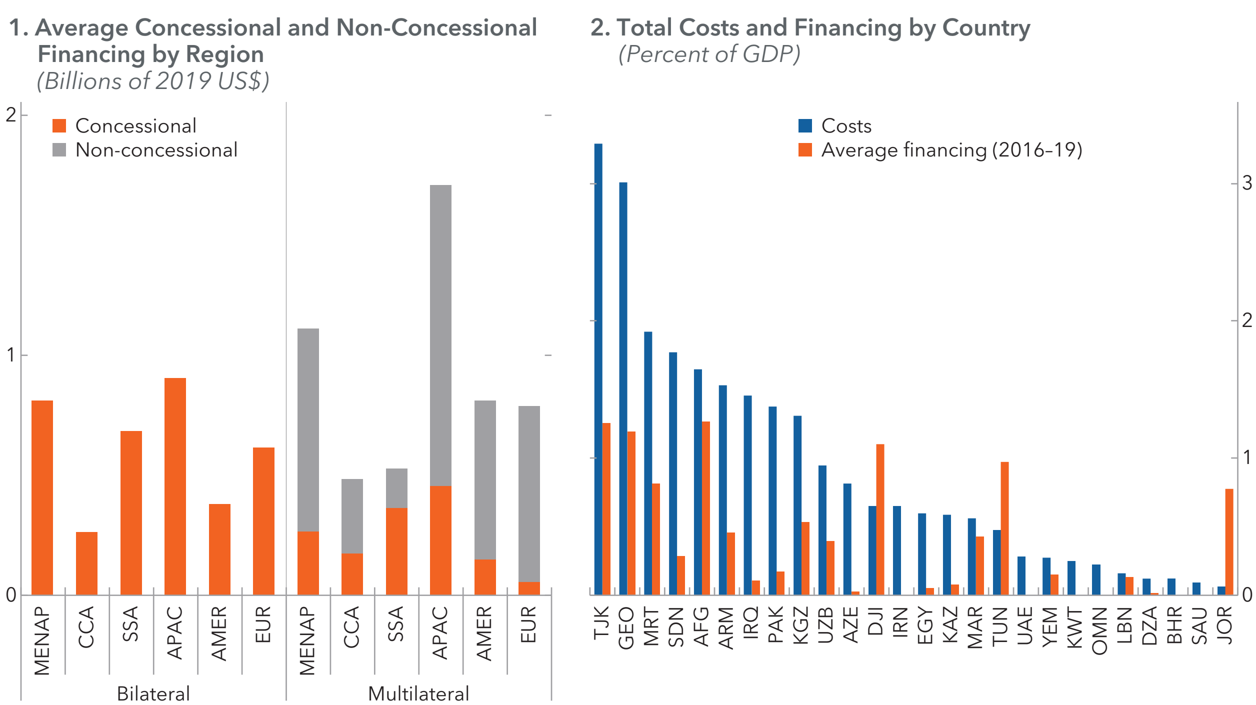
reduction and ecosystem conservation in Iran, and sustainable rural water supply in Tajikistan; and (3) AFD's support for the livestock and hydropower sectors in Uzbekistan and depollution of the Mediterranean in Tunisia.

Debt-for-climate swaps. International creditors offer debt relief in exchange for accelerated action on mitigation and adaptation projects. Instead of making external debt payments in hard currency, the debtor country makes payments in local currency to finance climate mitigation and adaptation projects on terms agreed upon between debtors and creditors. These swaps build on the model of debt-for-nature swaps, first pioneered by Bolivia in 1987 and were recently used by Antigua and Barbuda (with Brazil) and the Seychelles (with the Paris Club and South African creditors) (IGSD 2020).

(Figure 21, panel 1). The share of non-concessional loans was higher than what multilaterals use in other EMDEs, especially in sub-Saharan Africa and Asia-Pacific. It also is a stark contrast to the completely concessional nature of bilateral financing sources.

- *Complex access rules require strong institutional capacity.* The multilateral finance flow is rather limited in the ME&CA region, as the multilateral adaptation assistance appears less related to country vulnerability per se than to other factors, notably institutional capacity to apply, implement, and manage projects (Doshi and Garschagen 2020). The GCF is a good example in this respect. Its complex project selection criteria require specialized expertise to put forward viable projects. Besides, GCF project implementation requires cooperation with accredited entities, which must meet GCF standards for financial reporting,

Figure 21. EMDEs: Climate Adaptation Costs and Related Development Financing, 2009–19



Sources: IMF (2020a); OECD; and IMF staff calculations.
Note: Climate adaptation costs cover floods, storms, and sea-level rise and do not capture investments needed to protect against other risks, including droughts and heatwaves.

environmental and social safeguards, and gender. Hence, only countries with sufficiently high institutional capacity can request accreditation of a domestic agency (for example, Ministry of Environment) to access GCF financing directly.[8] Other countries can only access GCF financing indirectly through an accredited non-domestic entity (for example, all MDBs are accredited).

- *Mitigation is still prioritized over adaptation*. Although the ME&CA region accounts for only a 10th of global greenhouse gas emissions (Annex 3), climate-related development financing has largely supported mitigation projects (60 percent of total). This disproportionate allocation risks leaving climate adaptation efforts underfunded in a region where climate adaptation related costs can exceed 3 percent of GDP per year (Chapter 5, section A). The shortfall in adaptation financing becomes more urgent in a region where most countries fail to cover its estimated average costs (Figure 21, panel 2), especially in Iran, Iraq, and Pakistan.

More concessional financing for adaptation is crucial, given tight fiscal space particularly after the COVID-19 pandemic. Fiscal deficits, gross financing needs, and public debt levels were already high in many ME&CA countries before COVID-19. They have taken another hit since then from the additional COVID-related spending and tax revenue losses. Debt sustainability concerns thus limit countries' ability to take out more debt to finance spending on climate adaptation (October 2020 Regional Economic Outlook: Middle East and Central Asia). Against this backdrop, multilateral institutions could reconsider their financing strategy for climate adaptation to bring it closer to their engagement in sub-Saharan Africa and the bilateral partners' approach—in terms of volumes and concessionality. Well-targeted multilateral support for adaptation can also have a catalytic effect in crowding-in private sector investment, including FDI (United Nations Environment Programme 2020).

Private Flows

Green bonds can help attract resources for climate change goals. Unlike traditional corporate and municipal bonds,[9] green bonds (including green sukuks in Islamic countries) are earmarked for specific climate and environmental projects.[10] Before the COVID-19 pandemic, the green bond market had grown to more than $257 billion worldwide since the first issuance in 2007. Almost 500 green bond issuers, spread across 51 jurisdictions around the world, are invested in renewable energy, building efficiency, transport, water and waste management, and so forth (Climate Bonds Initiative 2020). Until 2020, eight ME&CA countries had issued green bonds (Table 5; IFC 2019, 2020, 2021). Issuers include financial sector institutions (for instance, in Armenia and Kazakhstan) and nonfinancial firms (for instance the Saudi Electricity Company). In 2020, Egypt became the first ME&CA country to issue a sovereign green bond, helping the government to diversify the investor base for its sovereign debt. The latest ME&CA country to issue a green bond is Pakistan, having sought $500 million in 2021 to increase the share of hydropower in the national power generation mix (Mangi 2021).

However, adaptation remains largely underrepresented among the active green bonds currently in the market. Globally, only 3–5 percent of the green bond proceeds can be traced to fund climate change adaptation, as well as resilience (which is almost exchangeable in the green bond market, Climate Bonds Initiative 2018). The challenge of defining "adaptation and resilience" projects has contributed to the underrepresentation. On the one hand, investors want to know that projects align with certain adaptation goals. On the other hand, adaptation is regarded as notoriously difficult to measure, track, and evaluate, compounding

[8] Few ME&CA government entities are accredited, for example, the Moroccan Agency for Agricultural Development.

[9] Traditional bonds allow the issuer to exert discretion in using the bond proceeds.

[10] Although not suitable to finance ex ante adaptation, catastrophe bonds (similar to reinsurance providers) can help ex post-disaster efforts by "building-back better" and thereby make infrastructure more resilient to climate change. It is, however, uncertain if such instruments would be viable as climate disasters become more frequent and severe (Chapter 2, section A). In essence, those instruments are usually issued by insurance companies with the proviso that should a large disaster strike, the principal of the bond could be used to cover claims arising from the disaster. In the absence of a disaster, the repayment includes the principal and higher interest payments.

Table 5. Green Bond Issuances
(Millions of US dollars)

	Before 2018	2019	2020
Morocco	356	–	–
Lebanon	60	–	–
UAE	587	1,270	97
Egypt	–	–	750
Saudi Arabia	–	–	1,300
Kazakhstan	–	–	0.5
Armenia	–	–	50
Georgia	–	–	250

Sources: IFC Emerging Market Green Bond Report; and IMF staff research.

the challenges involved in adequately pricing climate risks.[11] The Climate Resilience Principles—launched by the Climate Bonds Initiative (Climate Bonds Initiative, Climate Resilience Consulting, and World Resources Institute 2019)—set out to remove the definition barrier with the aim of giving investors clearer ideas on what they are investing in. In the ME&CA region, it has not been a common practice to include adaptation in the issuers' reference framework, with notable exceptions such as the First Abu Dhabi Bank's fourth green bond and Egypt's sovereign bond issuance that include explicitly a category of climate change adaptation.

Green investment in the region largely aligns with the principles of Islamic Finance. An important principle of Islamic Finance is the promotion of equality, social justice and inclusion, and economic prosperity (CFA Institute and PRI Initiative 2019). The total assets that comply with the principles are estimated at about $2 trillion in 2019, which provides big potential to support climate-related activities and to tap a wider base of investors (Suruhanjaya Sekuriti and World Bank Group 2019). Like typical green investments, Islamic finance is also restricted by the lack of standards and guidelines while considering investing in climate-related activities. Addressing these constraints could be catalytic to expand the potential for green investment.

[11] Some countries, notably outside the region, have included climate change considerations in a broader framework for the achievement of SDGs and issued SDG bonds, which in part finance also climate change adaptation. Subsuming climate change adaptation in a broader set of measurable SDG goals could help EMDEs, especially given their limited institutional capacity.

6. Takeaways and Policy Implications

This paper is the first to analyze the enormous adaptation challenges that climate change poses for ME&CA countries. Exploiting comprehensive regional data and employing macro-financial empirical analysis, the paper highlights:

- *Worsening climate stressors*. Climate change is already widely felt throughout ME&CA and set to further intensify the region's key climate stresses: temperature extremes, precipitation anomalies, and more frequent and severe disasters.

- *Increasing damages, amplified by low climate resilience*. Human and material damages are set to rise, reflecting the interplay between worsening natural hazards (especially droughts, storms, and floods) and low climate resilience, which in turn reflects countries' (1) high exposure (especially of people and specific sectors, such as rain-fed agriculture, tourism, and hydropower); and (2) elevated vulnerability (mainly reflecting weak macro buffers, socioeconomic development, and institutions). Population growth, urbanization, and environmental degradation further heighten the region's vulnerability.

- Economic and social development under threat. Changing climate conditions threaten the region's prosperity, socioeconomic development, and stability. They have, for instance, already shown to dampen growth and trigger sectoral and employment shifts, notably within the agricultural sector. MENAP countries were harder hit than their CCA peers, given their hotter and drier climates at the outset. Climate disasters have often been followed by a substantial and immediate growth decline and large macro-fiscal effects across ME&CA, particularly in CCA countries that experienced permanent output losses and fiscal effects.

Given the urgency and extent of the fallout from climate change, ME&CA countries need to move from good intentions to robust action. While policy priorities differ across countries depending on their specific set of climate hazards, resilience, and capacity, some common adaptation policy priorities arise:

- *Across the region*: Most importantly, all ME&CA countries need to: (1) mainstream adaptation into existing policy frameworks and accelerate relevant structural reforms, notably those that strengthen governance and institutions (including disaster preparedness and management capacities); (2) focus on no-regret measures to shore up much-needed climate resilience, which include upgrading social safety nets and social spending (health, and education) and adapting crucial infrastructure to intensifying climate stresses (notably water resource management, irrigation schemes, and early warning systems); (3) ensure adequate participation of the private sector (which is a crucial complement to that of the public sector); and (4) enhance the role of the financial sector.

- *Across country groups*, depending on their level of climate resilience and available fiscal space:

  - Higher- and middle-income ME&CA countries with high resilience and fiscal space, that is, mainly hydrocarbon-rich GCC and some CCA countries. Relative to their regional peers, they are less exposed thanks to smaller, less rain dependent agricultural sectors and less vulnerable thanks to a higher level of socioeconomic development. The quality of their adaptation strategy would benefit from strengthening administrative capacity to ensure a holistic and well-prioritized approach. Bolstering international cooperation would also allow their strategy to exploit latest technologies and know how, which could even help transition to a more sustainable and resilient low-carbon growth model. This would be particularly important for the many hydrocarbon exporters in the ME&CA region that need to respond to the transition risks from a global low-carbon future with measures to diversify their economies away from, and reduce the dependency of government revenues on, hydrocarbons.

- *Middle-income ME&CA countries with medium resilience but without fiscal space*, that is, mainly hydrocarbon-poor MENAP and some CCA countries. In terms of climate resilience, they fall in the middle of the region's range, reflecting significant exposure (with their large, mostly rain-fed agricultural sector) and vulnerability (due to high poverty, low human development, inadequate social safety nets, and weak public infrastructure and institutions). To make space for adaptation spending while preserving debt sustainability, these countries need to focus on both: (i) enhancing domestic revenue mobilization and expenditure efficiency and (ii) tapping more into international assistance. They should also improve the quality of public services (especially in education and health care) and better target social safety nets, while—where administrative capacity allows—introducing state-dependent social transfers (for example, activated when precipitation drops below a certain level) and indexation of cash transfers (for example, to food prices that typically rise during a drought). In addition, these countries should strengthen financial inclusion and insurance (possibly subsidized) against natural hazards, particularly for farmers, and leverage PPPs (with appropriate PPP related risk management safeguards) for infrastructure development.

- *Lower-income, fragile and conflict-affected ME&CA countries with low resilience*, mainly in MENAP. They lack their peers' fiscal space but additionally have particularly low climate resilience and institutional capacity. Their immediate focus needs to be on strengthening disaster preparedness and coping capacities, while trying to build broader institutional capacity and social resilience. To gradually upgrade social spending and infrastructure, these countries need international support for financing (ideally on concessional terms) and capacity development. Domestic revenue mobilization will help sustain spending needs without becoming dependent on external support and assuming too much debt that could threaten their debt sustainability.

In the near term, all countries could leverage green policies for a sustained recovery from the COVID-19 crisis. Green investment and policies (mitigation and adaptation) can serve that purpose while dealing with the problems that existed before COVID-19: (i) mitigation to help minimize the intensification of global warming and thus climate hazards and (ii) adaptation by investing in climate-resilient infrastructure and addressing vulnerabilities.

Limited adaptation progress so far underscores the need for domestic consultation and international cooperation. Given the re-distributional impact of climate policies within and across countries, policymakers need to acknowledge political economy sensitivities. This means consulting stakeholders and designing compensation mechanisms to galvanize broad societal support for climate policies. Furthermore, while cross-country cooperation can support the effectiveness of a country's adaptation policy, international cooperation is crucial to address often binding capacity and funding bottlenecks.

To live up to its mandate and assist its members with addressing these climate challenges, the IMF is strategically and systematically integrating climate change into its core activities (IMF 2021b). In this context, this paper is the first regional contribution for ME&CA. Next steps will include (i) translating the paper into a more granular and tailored analysis of climate risks and adaptation challenges at the country level; and (ii) advancing the thematic focus from adaptation to other climate-related issues important for the region (notably mitigation and transition management). At the same time, the IMF continues to adapt its core activities to meet its members' needs:

- *Surveillance.* Given the IMF's mandate, it focuses on helping members assess the macroeconomic impact of climate change and building financial and institutional resilience to natural disasters and extreme weather events through appropriate economic and financial policies. The IMF is ramping up policy and analytical work to lay the foundation to comprehensively incorporate climate change in its surveillance. This notably includes accounting for the macroeconomic effects of climate change and adaptation measures in medium-term macroeconomic frameworks (for example, potential growth estimations), incorporating climate shocks into standard cross-country analytical tools (for example, debt sustainability analysis, financial sector assessments, and external balance assessments), and deriving customized policy advice (for example, on how to build adequate macroeconomic buffers and identify crucial structural reforms) that takes into account each country's particular circumstances and capacity.

- *Financial support*. The IMF can provide financial support to member countries hit by adverse climate effects through three types of facilities: (i) existing standard facilities to address balance of payments (BOP) needs that arise from certain climate adaptation measures; (ii) emergency financing instruments to help countries address BOP needs arising from severe climate-related shocks; and (iii) the Catastrophe Containment and Relief Trust (CCRT) to provide debt service relief for the poorest and most vulnerable countries hit by catastrophic natural disasters or public health disasters. In addition, the recently proposed Resilience and Sustainability Trust (RST) can help support member countries address risks to prospective BOP stability stemming from selected long-term structural challenges. Moreover, IMF program design could focus on adaptation, for example, through quantitative and structural conditionality (for example, floor on adaptation spending and subsidy reforms) or fiscal adjustment (through revenue and expenditure measures) to strengthen fiscal buffers and reallocate spending to adaptation.

- *Capacity development*. Technical assistance and training, particularly in the fiscal and financial realm, will help IMF member countries upgrade climate-related skills. The IMF can also help identify and cost adaptation gaps across sectors and risks, for instance by supporting countries in the production of Disaster Resilience Strategies. In addition, the IMF is participating in global efforts to narrow data gaps for climate indicators. IMF capacity development can also help support stronger institutions and frameworks for climate-related spending (for example, green public financial management).

Annex 1. Country Sample

Annex Table 1.1. Country Sample

	190 IMF Members	154 Emerging Market and Developing Economies (EMDEs)		36 Advanced Markets (AMs)
		83 Emerging Markets (EMs)	71 Low-Income Countries (LICs)	
31 Middle East and Central Asia (ME & CA)	23 **Middle East and North Africa** (MENA), **Afghanistan and Pakistan** (MENAP)	16 **MENA:** Algeria (DZA), Bahrain (BHR), Egypt (EGY), Iran (IRN), Iraq (IRQ)*, Jordan (JOR), Kuwait (KWT), Lebanon (LBN)*, Libya (LBY)*, Morocco (MAR), Oman (OMN), Qatar (QAT), Saudi Arabia (SAU), Syria (SYR)*, Tunisia (TUN), United Arab Emirates (UAE) 1: Pakistan (PAK)	5 **MENA:** Djibouti (DJI)*, Mauritania (MRT), Somalia (SOM)*, Sudan (SDN)*, Yemen (YEM)* 1: Afghanistan (AFG)*	
	8 **Caucasus and Central Asia** (CCA)	5: Armenia (ARM), Azerbaijan (AZE), Georgia (GEO), Kazakhstan (KAZ), Turkmenistan (TKM)	3: Kyrgyz Republic (KGZ), Tajikistan (TJK)*, Uzbekistan (UZB)	
159 Rest of the world (RoW)	45 **Sub- Saharan Africa** (SSA)	10: Angola (AGO), Botswana (BWA), Equatorial Guinea (GNQ), Eswatini (SWZ), Gabon (GAB), Mauritius(MUS),Namibia(NAM),Nigeria(NGA), Seychelles (SYC), South Africa (ZAF)	35: Benin (BEN), Burkina Faso (BFA), Burundi (BDI)*, Cabo Verde (CPV), Cameroon (CMR), Central African Republic (CAF)*, Chad (TCD)*, Comoros (COM)*, Rep. of Congo (COG)*, CÔte d'Ivo ire (CIV)*, Dem. Rep. of the Congo (COD)*, Eritrea (ERI)*, Ethiopia (ETH), The Gambia (GMB)*, Ghana (GHA), Guinea (GIN)*, Guinea-Bissau (GNB)*, Kenya (KEN), Lesotho (LSO), Liberia (LBR)*, Madagascar (MDG)*, Malawi (MWI)*, Mali (MLI)*, Mozambique (MOZ), Niger (NER), Rwanda (RWA), São Tomé and PrÍncipe (STP)*, Senegal (SEN), Sierra Leone (SLE)*, South Sudan (SSD)*, Tanzania (TZA), Togo (TGO)*, Uganda (UGA), Zambia (ZMB), Zimbabwe (ZWE)*	
	35 **Asia and Pacific** (APAC)	12: Brunei Darussalam (BRN), China (CHN), Fiji (FJI), India (IND), Indonesia (IDN), Malaysia (MYS), Mongolia (MNG), Palau (PLW), Philippines (PHL), Sri Lanka (LKA), Thailand (THA), Vietnam (VNM)	18: Bangladesh (BGD), Bhutan (BTN), Cambodia (KHM), Kiribati (KIR)*, Lao P.D.R. (LAO), Maldives (MDV)*, Marshall Islands (MHL)*, Fed. States of Micronesia (FSM)*, Myanmar (MMR)*, Nauru (NRU), Nepal (NPL), Papua New Guinea (PNG)*, Samoa (WSM), Solomon Islands (SLB)*, Dem. Rep. of Timor-Leste (TMP)*, Tonga (TON), Tuvalu (TUV)*, Vanuatu (VUT)	5: Australia (AUS), Japan (JPN), Korea (KOR), New Zealand (NZL), Singapore (SGP)

190 IMF Members	154 Emerging Market and Developing Economies (EMDEs)		36 Advanced Markets (AMs)
	83 Emerging Markets (EMs)	71 Low-Income Countries (LICs)	
34 **Americas** (AMER)	24: Antigua and Barbuda (ATG), Argentina (ARG), Bahamas, The (BHS), Barbados (BRB), Belize (BLZ), Bolivia (BOL), Brazil (BRA), Chile (CHL), Colombia (COL), Costa Rica (CRI), Dominican Republic (DOM), Ecuador (ECU), El Salvador (SLV), Guatemala (GTM), Jamaica (JAM), Mexico (MEX), Panama (PAN), Paraguay (PRY), Peru (PER), St. Kitts and Nevis (KNA), Suriname (SUR), Trinidad and Tobago (TTO), Uruguay (URY) Venezuela (VEN)	8: Dominica (DMA), Grenada (GRD), Guyana (GUY), Haiti (HTI)*, Honduras (HND), Nicaragua (NIC), St Lucia (LCA), St. Vincent and the Grenadines (VCT)	2: Canada (CAN), United States (USA)
45 **Europe** (EUR)	15: Albania (ALB), Belarus (BLR), Bosnia and Herzegovina (BIH), Bulgaria (BGR), Croatia (HRV), Hungary (HUN), Kosovo (KOS)*, Montenegro, Rep. of (MNE), North Macedonia (MKD), Poland (POL), Romania (ROM), Russia (RUS), Serbia (SRB), Turkey (TUR), Ukraine (UKR)	Maldova (MDA)	29: Andorra (AND), Austria (AUT), Belgium (BEL), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Iceland (ISL), Ireland (IRL), Israel (ISR), Italy (ITA), Latvia (LVA), Lithuania (LTU), Luxembourg (LUX), Malta (MLT), Netherlands (NLD), Norway (NOR), Portugal (PRT), San Marino (SMR), Slovak Republic (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), Switzerland (CHE), United Kingdom (GBR)

Note: AMs as per the IMF WEO; LICs as the group of countries eligible to access the IMF's Poverty Reduction and Growth Trust (PRGT). * denotes fragile and conflict-affected states (FCS) as defined in IMF (2022, 2017b).

Annex 2. Country Case Studies: Adapting to Climate Change

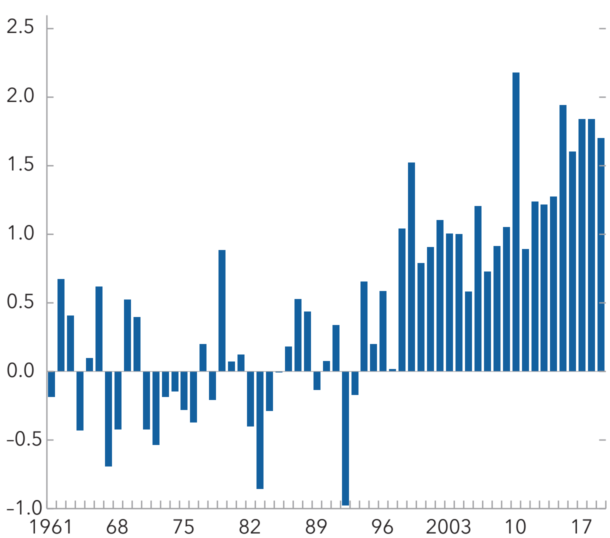
A. Saudi Arabia[1]

Saudi Arabia's ecosystem is highly vulnerable to climate change. Moreover, the economy's dependency on oil—the main source of fiscal and external revenue—makes it vulnerable to global mitigation actions. Climate stressors have significant impact on water, the environment, and health. Global mitigation actions will pose a serious challenge for the demand of oil over the medium to long term. The government has implemented a range of actions to adapt to climate change and build economic resilience. Further interagency coordination of adaptation initiatives under the Circular Carbon Economy National Program is needed to harness existing efforts and reduce climate vulnerabilities.

Background

Saudi Arabia exhibits significant vulnerabilities to climate change. The Arabian Desert spans approximately 70 percent of the Arabian Peninsula (3.2 million km^2). Current climatic conditions range from semi- to hyper-aridity, with extremely low rainfall, lack of perennial rivers or permanent water sources, and high evaporation of water. The average summer temperature ranges from 26° C–40° C (and can reach 50° C). Climate change has already become apparent: the annual average temperature has seen an increase beyond its historical average since the turn of the millennium (Annex Figure 2.1). Water stress is severe and Saudi Arabia is the world's third-most water stressed country, where freshwater withdrawals amounted to 883 percent of available freshwater resources after taking into account environmental water requirements (Annex Figure 2.2). Desertification has also increased the severity of sandstorms.

Annex Figure 2.1. Saudi Arabia: Annual Mean Temperature Change, 1961-2019
(Change in degree Celsius from 1951–80 baseline)



Sources: FAO; and IMF staff calculations.

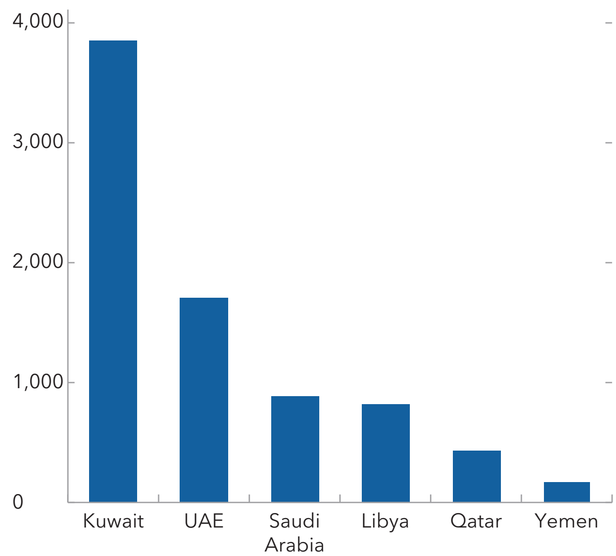
Oil, the country's main source of export and fiscal revenue, is sensitive to global mitigation actions. Saudi Arabia is endowed with significant oil reserves (258,600 million barrels, or about 17 percent of the world's proven petroleum reserves). The economy relies heavily on the oil sector—oil accounts for about 77 percent of total budget revenues, about 26 percent of GDP, and 79 percent of total exports on average over the period 2010–20. Global mitigation efforts will pose a serious challenge for the demand of oil over the medium to long term, as the world progressively shifts away from fossil fuels. Without proactive policy measures, this would have a profound macroeconomic impact, especially on fiscal and external sustainability and intergenerational equity.

[1] Prepared by Abdullah AlHassan.

Climate stressors have a significant impact on water, environment, and health.

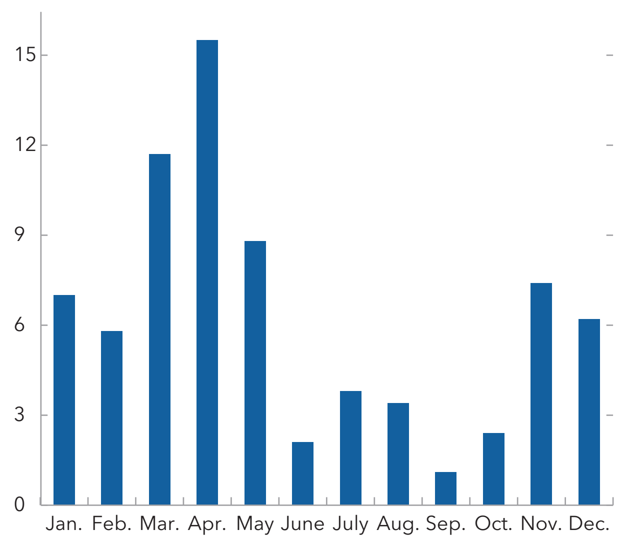
- *Water*. Resources have already been under stress from aridity and low reserves in underground aquifers. Groundwater—the most reliable source of water—provides over 84 percent of the country's water needs. Along with global warming, rapid population growth, insufficient recharge of freshwater, water consumption by agriculture (82 percent of total water consumption), followed by industry (13 percent) and municipal (5 percent), have increased the pressure on nonrenewable natural water sources and the threat to food security. Low rainfall—precipitation averaged only 75.2 mm annually during 1991–2020 (Annex Figure 2.3)—has resulted in limited renewable resources of surface water. The Saudi Third National Communication's (UNFCCC 2016) estimates of climatic parameters show that Saudi Arabia may suffer from increased insufficiency of water in the future and thereby droughts, more communicable diseases, and less production of agricultural food.

Annex Figure 2.2. Most Water-Stressed Countries, 2017
(Freshwater withdrawn as a share of renewable freshwater in percent)



Sources: FAO; and IMF staff calculations.

Annex Figure 2.3. Saudi Arabia: Monthly Precipitation, 1991–2020
(Millimeters)



Sources: World Bank; and IMF staff calculations.

- *Environment*.
    - *Agriculture*. Climate change will have a direct effect on agricultural production. With only about 30 percent of cultivation originating from greenhouse farming, the remaining 70 percent is in open fields and would be adversely affected by increased temperatures, reduced precipitation, higher evapotranspiration, and lower water reserves (UNFCCC 2016). In addition, an increased frequency of droughts and floods have negatively affected crop yields and livestock.
    - *Coral reefs*. Along the country's extensive coastlines, coral reefs are at risk of disappearance due to climate change (ocean acidification and seawater warming) and human activities (fishing, dredging, and marine pollution). While coral reefs in the southern part of the Red Sea have experienced bleaching events, the ones in the northern part are considered coral reef refugia.
    - *Desertification*. The expansion of the desert may become irreversible if environment dryness intensifies and the soil becomes further degraded (UNFCCC 2016), leading to more evaporation of water and less productive lands to support rural communities. This would generate more impactful heatwaves and

sandstorms, adversely affecting trade and services.

- *Health impact*. Air pollution from greenhouse gases is estimated to have shortened life expectancy by 1.5 years according to the announced Saudi Green Initiative. Dust storms and humidity were among several environmental risk factors associated with the prevalence of asthma (UNFCCC 2016). Heat waves can cause heat illnesses and aggravate pre existing heat-sensitive medical conditions, leading to death. Further, hydrological hazards were the most frequent and costliest in terms of material and human damages in recent years. Since 2000, Saudi Arabia has experienced three events and two disruptive years, which have caused $1.3 billion in material damages, affected more than 28,000 people and 595 fatalities (EM-DAT 2021). Relative to the MENAP region, this corresponds to 4 percent of all events and 1 percent of disruptive years and 3 percent of material damages, and close to 0 percent of the people affected and fatalities. Intensity of hazards is mitigated by the high quality of infrastructure and institutional capacity.

Adaptation Strategies and Progress

Saudi Arabia adopted a Circular Carbon Economy National Program in 2021. It focuses on reducing (renewables, energy efficiency), recycling (CO2 to materials), reusing (carbon utilization), and removing (natural sinks, carbon capture and storage) emissions by consolidating and accelerating adaptation and mitigation initiatives toward climate sustainability in a holistic manner (especially water management, reforestation, marine protection, urban planning, early warning systems, energy efficiency). Saudi Arabia has committed to net zero emission by 2060. Besides the emissions reduction target in the Nationally Determined Contribution (NDC), Saudi Arabia aims—as a member of the Global Methane Pledge—to collaborate with other members to reduce global methane emissions by 30 percent by 2030 relative to 2020 levels.[2]

Specifically, a range of adaptation initiatives have been implemented to address climate change and foster resilience. Some adaptation measures have mitigation co-benefits:

- *Water management*. Integrated water management actions aim at harnessing new sources of freshwater by constructing dams to collect water and recharge aquifers. To facilitate the storage of surface runoff water and to prevent flash floods, 11 additional dams have been constructed in 2019 (reaching 521 dams). Saudi Arabia is also the largest producer of desalinated water, accounting for about 70 percent of domestic water supply and 30 percent of the global capacity. Further, waste-water management actions have promoted the reduction, recycling, and reuse of water, while reducing energy consumption and water desalination. In 2019, the government launched the Qatrah program to rationalize water usage with the target of reducing daily per capita consumption by 43 percent by 2030 and adding around 30 new seawater plants by 2030.

- *Land degradation*. A range of actions have been implemented to: (1) reduce desertification and stabilize sand movements through using green belts as barriers; and (2) improve land management practices especially for agriculture and forestry. Vegetation cover increased by 40 percent since 2016. At the global level and during the Saudi's G20 Presidency in 2020, G20 Leaders agreed to launch "the Global Initiative on Reducing Land Degradation and Enhancing Conservation of Terrestrial Habitats to Prevent, Halt, and Reverse Land Degradation." At the national level, the government launched the Saudi Green Initiative in October 2021 that aims to plant 10 billion trees in the upcoming decades (equivalent to rehabilitating about 40 million hectares of degraded lands) and raise the percentage of protected areas to more than 30 percent of its surface.[3] At the local level, Green Riyadh is one of urban greening initiatives to plant 7.5 million trees around the city by 2030.

---

2 The first NDC was submitted in November 2015 and an updated NDC in October 2021. It provides a mix of mitigation and adaptation actions that have co-benefits in the form of GHG emission avoidances. The updated NDC aims to achieve mitigation co-benefits ambitions of up to 278 million tons of CO2eq avoided by 2030 annually relative to 2019 levels, while contributing to economic diversification and adaptation.

3 Due to water scarcity, recycled water from an irrigation network will be used for this purpose.

- *Marine protection*. Coastal management measures have been undertaken to protect biodiversity of seas, reduce coastal erosion, and increase the sinks for blue carbon. Actions have included planting mangrove seedlings and restoring coral reefs along its coasts (for example, Aramco has been developing a mangrove eco-park to protect 63 square km of mangrove forest, salt marsh and sea grass habitats). Saudi Arabia increased natural reserves from 4 percent to 20 percent and aims to scale up the Special Forces for Environmental Security from 1,100 to 10,000 by 2025. Also, G20 Leaders during their 2020 Riyadh Summit agreed to launch "the Global Coral Reef R&D Accelerator Platform" to conserve coral reefs that would be housed at King Abdullah University of Science and Technology.
- *Urban planning*. Ongoing measures have included expansion of metro systems to promote the use of intercity public mass transport system (in the east, north, and west regions) and within urban areas (the metro system in Riyadh). Also, the Saudi Green Building Council encourages the adoption of green building concept with the view to promoting the construction of energy efficient, resource efficient, and environmentally responsible buildings.
- *Carbon capture, utilization, and storage (CCUS)*. As an enabler to the circular carbon economy, which was endorsed by the G20 Leaders to address GHGs through the reducing, reusing, recycling, and removing (4Rs) GHG. The CCUS has been used by Aramco and SABIC to either store carbon emissions deep underground or turn them into marketable industrial and commercial products.
- *Energy efficiency*. The Saudi Energy Efficiency Center, established in 2010, focuses on the industry, building, and land transportation sectors that collectively account for over 90 percent of the energy demand. The target is to reduce the consumption of these sectors by 20 percent in 2030. Further, energy and water price reforms have been implemented since 2017 to reduce subsidies and improve energy efficiency.
- *Waste management*. Saudi Arabia established the National Center for Waste Management in 2019 to promote waste reduction, recycle, and convert the waste into energy through the principle of circular economy, and contribute to achieving the Sustainable Development Goals.
- *Health and early warning systems (EWS)*. As an important pillar of Vision 2030, the Quality-of-Life Program aims at raising environmental quality through reducing all types of pollution (for example, air, sound, water, soil) and establishing a central unit to monitor air quality and emissions. The development of EWS aims at reducing vulnerability due to extreme weather events such as rainstorms, floods, and dust storms by increasing resilience of infrastructure.
- *Economic diversification*. To manage the transition risks of the world shifting to cleaner energy sources, Vision 2030 strives to diversify Saudi Arabia's economic base and fiscal revenue away from the oil sector by increasing the share of other productive sectors in the economy.

Adaptation Financing

Government entities have stepped up green financing to boost green investment and accelerate the transition to a low-carbon economy. The Saudi Industrial Development Fund launched a credit facility program of $28 billion (1.4 percent of non-oil GDP) in September 2019 to support Saudi companies investing in renewable energy. The Saudi Electricity Company has issued $1.3 billion green sukuk in September 2020 to finance its green projects. The Red Sea Development Company has raised a $3.77 billion 'green' loan in April 2021 from domestic banks for 16 new hotels, powered by renewable energy. Going forward, Saudi Arabia's government aims to issue its first green bond in 2022 that considers environmental, social, and governance factors.

Strong coordination of adaptation initiatives is needed to catalyze adaptation financing. Though the implementation of the INDC is not contingent on receiving international financial support, technology cooperation and capacity building are key factors for INDC implementation. The establishment of the Circular Carbon Economy National Program in 2020 is a welcome step to consolidate and accelerate the current momentum toward climate sustainability in a holistic manner. Further coordination among government entities and research institutions would harness existing efforts to reduce climate vulnerabilities. Both public and private sectors could help support further R&D to scaling the potential of nature-based solutions. This would enhance decision making in designing and implementing adaptation measures.

B. Tajikistan[4]

Tajikistan faces fundamental adaptation challenges, given its high susceptibility to climate hazards, exposure of its agricultural sector as the main contributor to GDP, and vulnerability of its people that depend on remittances. Tajikistan's National Adaptation Plan, which has garnered wide support, focuses on four areas: energy, agriculture, water management, and transportation. Going forward, Tajikistan should focus on capitalizing on intersectoral and multi-stakeholder collaborations, strengthening institutional capacity, and fostering economic diversification and regional cooperation.

Background

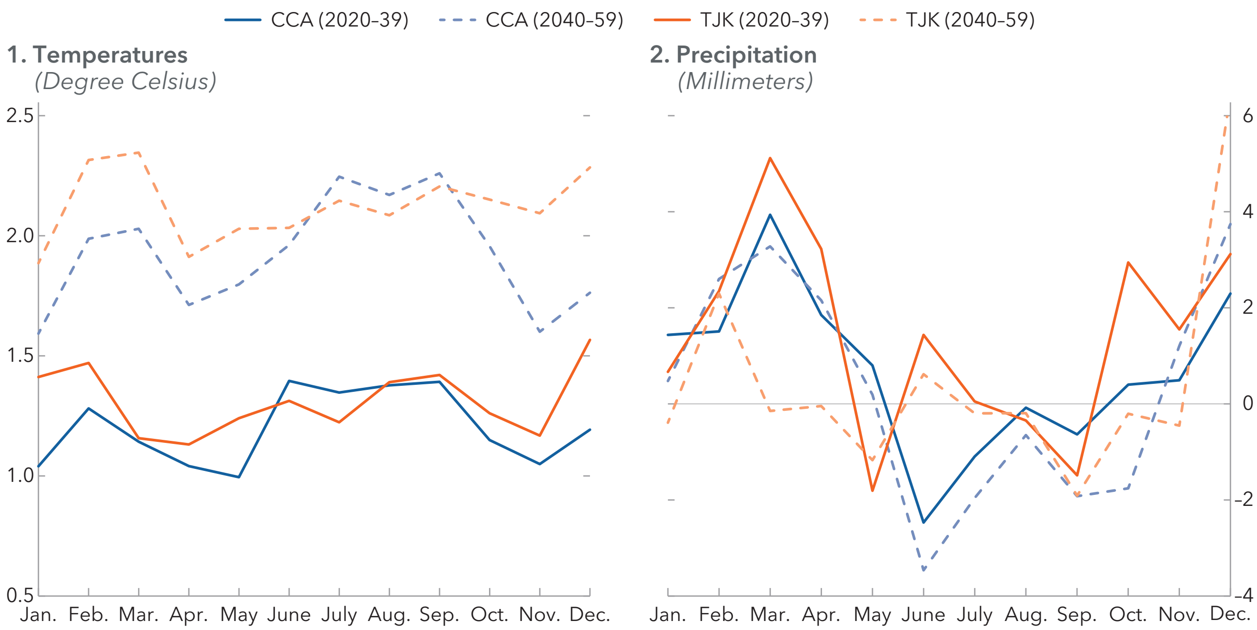
Tajikistan has a diverse climate.[5] Landlocked in the mountainous part of Central Asia, the country comprises continental, subtropical, and semiarid zones (with some deserts), largely depending on elevation. Glaciers occupy about 6 percent of the total area, which fulfill the important functions of retaining water, controlling flows, and regulating the climate. While precipitation is generally higher than in other CCA countries and occurs mainly in winter and spring, glaciers and permafrost provide the main source of water, recharging the Aral Sea river basins. Mountains shield the lowlands (including the Fergana Valley) from Arctic air masses, where temperatures still drop below freezing for more than 100 days a year.

Weather conditions are impactful.

- *Past experience*. Tajikistan has seen an increasing trend of temperatures, fluctuating levels of precipitation, and extreme climate disasters with sizable damages since the turn of the millennium: 43 events and 17 disruptive disaster years[6] have caused $1.2 billion in material damages (mainly from crop losses) and left more than 6.3 million people affected and 301 killed (EM-DAT 2021). Relative to the CCA total, this corresponds to 40 percent of all events and more than one-third of disruptive years, almost 60 percent of material damages and people affected, and almost half of all fatalities. These damages mainly reflect the impact of climatological, meteorological and hydrological hazards (Figure 5) and extreme climate events, such as: (1) extreme cold winters, for instance, in 2007–08, which was the coldest since 1969 and the costliest in the entire CCA region, with a material damage of 16.4 percent of GDP (Table 2) and increased electricity demand that—coupled with high prices for food and fuel—led to the so-called 2008 Central Asia energy crisis (UNDP 2009); (2) flooding, including the 2020 floods in Khuroson District and the severe floods regularly impacting the capital, Dushanbe, and Varzob District; and (3) droughts during main agricultural seasons (UNFCC 2008a). Furthermore, glacial retreat is on the rise, with a volume loss of 2.5 percent during the 20th century already (UNDP 2021a).
- *Outlook*. Climate change will intensify adverse weather patterns (Annex Figure 2.4): temperatures are set to further increase sharply by 1.8–2.9° C by 2050 (UNFCCC 2014), combined with large variations in precipitations (Zoi 2020). At the same time, climate disasters would become even more frequent and severe, particularly winter avalanches, spring floods, and summer dust storms. Absent adaption, their economic cost could reach 20 percent of GDP (WFP 2017).

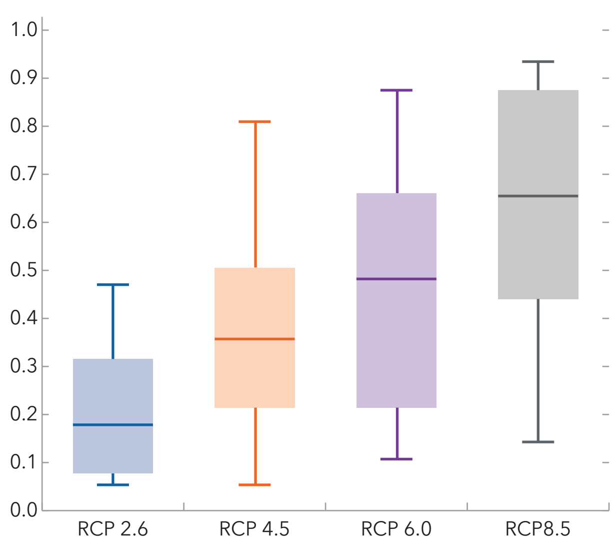
[4] Prepared by Faten Saliba.
[5] See for example, Atkin (1997), Zoi (2020), and UNDP (2021c).
[6] Years when the sum of affected and 0.3 times deceased people exceeds 0.01 percent of the population (see Chapter 3).

Annex Figure 2.4. Tajikistan: Projected Change in Weather Patterns, 2020-59
(Median change in RCP 4.5 models relative to 1986–2005 mean)



Sources: World Bank; and IMF staff calculations.

Annex Figure 2.5. Severe Droughts, 2080-2099
(Annual probability in percent)



Sources: World Bank Climate Change Knowledge Portal; and IMF staff calculations.

Higher drought frequency and intensity caused by climate change pose significant threats to Tajikistan Currently, the likelihood that Tajikistan will suffer a severe drought in any given year is 3 percent.[7] However, severe droughts, which were rare occurrences in the past, are becoming more common as they are occurring every 15 years. Looking ahead, the World Bank Climate Change Knowledge Portal model indicates a significant rise in the probability of climate-induced droughts, suggesting a rise from the current 3 percent per year to more than 30 percent by 2080–99 under the mid-low emission scenario (RCP 4.5).

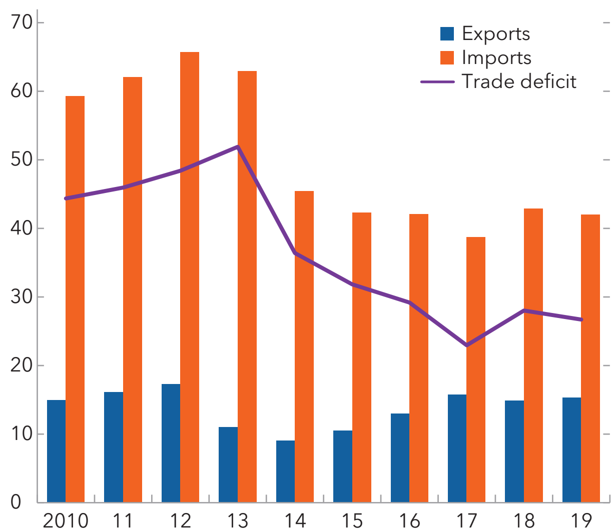
Agriculture, the country's main employer and source of food, is especially exposed to climate-related risks. More than 75 percent of the Tajik population resides in rural regions, with agriculture as the main provider of jobs (about 75 percent of women and 42 percent of men work in agriculture). Agriculture and agricultural products account for approximately 22 percent of Tajikistan's GDP over 2001–15. At the same time, 97 percent of the land surface is prone to degradation (Khakimov and others 2020, WFP 2017). Water-intensive wheat and cotton cultivation, inefficient water management, and fragile land rights all exacerbate the vulnerability of the agricultural sector to erosion, deforestation, swamping, and salination (ADB 2014). Climate change will

[7] Climate Change Knowledge Portal (World Bank 2020). Climate Data: Projections.

hit Tajik agriculture hard owing to considerable variations in precipitation, increasing water scarcity, and heat stress on vegetation. Considering current climate trends, water needs for agriculture are estimated to rise by 20–30 percent (FAO 2019), which will endanger food supply. Likewise, climate-related shocks are estimated to potentially reduce crop yields by 5–30 percent by 2050 (WFP 2017), further exacerbating food insecurity and dependence on food imports (which already corresponds to 50 percent of the population's needs).[8]

High vulnerability compounds the effect of climate hazards and exposure. Tajikistan is the poorest country in Central Asia. It ranks 105 out of 137 for financial market development, 99 out of 137 for infrastructure, and the top disincentivizing factors are foreign currency regulations, inflation, taxation, and access to financing (WEF 2018). There are currently 6385 stateless individuals, 5588 refugees, and 408 asylum seekers in the country (UNCHR 2020). Border tensions have been recently escalating between Tajikistan and Kyrgyz, threatening to evolve into a conflict (USIP 2021).

Annex Figure 2.6. Tajikistan: Exports, Imports and Trade Deficit, 2010–19
(Percent of GDP)



Sources: IMF WEO; and IMF staff calculations.

- *Weak macro buffers*. Tajikistan's economy was seriously hit by the civil war from 1992–97 and has since made a slow recovery. The main economic sectors are non-ferrous metallurgy (lead, zinc, and aluminum), light industry and agriculture, with cotton being its most important export commodity (Renaud 2020, OEC 2019). Macro imbalances remain substantial though and thus provide no adequate buffer to respond to a disaster or invest in increasing resilience to climate change: chronic twin deficits have increased government public debt to 50 percent of fiscal year GDP and external debt to 76 percent of GDP in national currency. The quality of infrastructure is low (World Bank 2018a). Public investment is low. A chronically high trade deficit (Annex Figure 2.6) weighs on the current account and remains financed by high remittance inflows (peaking at 48 percent of GDP in 2013), leaving it susceptible to shocks, notably from fluctuations in global market sentiment, exchange rates, and international commodity prices (particularly food). The country's economy is further impacted by regional economic crises, notably those affecting Russia (WFP 2017).

- *Low socioeconomic and structural development*. According to data from the ADB, poverty is prevalent with 26.3 percent of individuals living below the national poverty line in 2019, albeit already reflecting a decline from 2009 (47 percent) and 1999 (47 percent). Tajikistan is considered a low-income country; over two-thirds of the population lives on less than $2.15 a day (Margulis and Narain 2010). Nevertheless, rural areas remain most heavily poverty stricken. Tajikistan's 2019 Human Development Index (HDI) is 0.67 which makes it below average (0.79) for countries in Central Asia and Europe. Climate change risks will disproportionately impact the poorest groups in Tajikistan. Poorer farmers and communities are least able to afford and access technologies for adaptation. Access to basic utilities remains a challenge, with approximately 70 percent of the Tajik people suffering from extensive shortages of electricity during the winter and still low access to electricity in rural areas.[9]

[8] Wheat ranks high on the imports' list and constitutes a staple in Tajik diets.

[9] Rural communities often still use forest wood for cooking and heating, which increases GHG emissions and erosion, and adversely affects biodiversity (Fields and others 2013).

- *Weak institutions and governance*. In general, Tajikistan is suffering from deteriorating education and healthcare systems. It is also characterized by weak economic, financial, and banking institutions. Weak governance and legal frameworks, lack of accountability, and low wages further constitute an obstacle to good governance. They also translate into corruption which, in turn, weakens preparedness and response capacity to climate disasters. The poor quality of services and unequal public spending have widened socioeconomic divides. Efforts should be made to improve transparency and accountability which can provide a better allocation of resources toward climate change adaptation policies. Therefore, Tajikistan must strive to strengthen its institutional, organizational, and human resources capacities (ADB 2014).

Adaptation Strategies and Progress

Tajikistan has consistently committed to combat climate change. In 2002, it launched the Initial National Communication aimed at reviewing climate change evolution, greenhouse gas emissions, Tajikistan's vulnerability to climate change as well as sectoral solutions. A year later, it established the National Action Plan for Climate Change Mitigation which investigates challenges and determines climate priorities. In 2003, a National Action Plan for Climate Resilience was developed to assess climate change and its associated risks. It serves to facilitate disaster risk reduction and incorporates adaptation measures. More recently, the Third National Communication under the United Nations Framework Convention on Climate Change 2014 (UNFCCC 2014) reassessed climate change and its impact on resources in Tajikistan. It is also more in line with UNFCCC stipulations. It was followed by the 2015 Intended Nationally Determined Contribution (INDC) aligned with the UNFCCC. The INDC emphasizes greenhouse gas emission reductions, combating weather fluctuations, and streamlining climate resilience into various Tajik sectors. These include agriculture, engineering, transportation, disaster risk reduction, glacier preservation, and protecting vulnerable populations.

In 2017, Tajikistan has launched a National Climate Change Adaptation Strategy targeting energy, agriculture, water management, and transportation. The strategy emphasizes cooperation between the Committee on Environmental Protection, ministries, departments, and localities to implement the strategy by 2030. The government noted its climate vulnerability, ranking first among European countries and Central Asian countries on the "settlement simplified vulnerability index to climate change" (WFP 2017). It also noted the urgency for livelihood diversification to increase rural resilience and reduce food insecurity. The strategy also defined intersectoral fields woven into the four main priority areas. Prior to this, Tajikistan had ratified the Paris Agreement and launched national plans for climate mitigation and resilience. It had additionally tried to align its policies with the UNFCCC.

In 2019, Tajikistan adopted the National Strategy for Adaptation to Climate Change (NSACC 2030) strategically outlining actions to implement the Paris Agreement. It emphasizes risk assessment and prioritizes "energy, water, transport, and agriculture" (UNFCCC 2021a). In 2021, Tajikistan adopted the Medium-Term Development Program building on the NSACC to expand climate adaptation measures. The program includes a gender-sensitive lens deemed important for climate adaptation measures.

Going forward, Tajikistan plans to implement its 2020 Readiness and Preparatory Report for Adaptation Planning jointly with the UNDP. The proposal focuses on three main outcomes: (1) strengthening governance and institutions; (2) mainstreaming adaptation within main priority sectors; and (3) solidifying foundations and the increase of subnational abilities for implementing the National Adaptation Plan. It calls for the inclusion of the private sector in development efforts. The government requested technical support from UNDP Green Climate Fund (GCF) corresponding to almost

$3 million for a period of 36 months (GCF 2020) (Annex Table 2.1). It also emphasizes monitoring and reporting through inter-ministerial coordination. This includes the development of proper monitoring and evaluation strategies and a "financing mechanism" for the National Adaptation Plan. Recently, Tajikistan estimated that an annual investment of $1 billion is needed by 2030 to finance climate adaptation measures (UNFCCC 2021b). This funding is divided across different sectors: energy (20 percent), transport (20 percent),

Annex Table 2.1. Tajikistan: Green Climate Fund: Disbursement Schedule
(Millions of US dollars)

Description	GCF project funds
Total	2.7
For Year 1 activities	0.5
For Year 2 activities	1.1
For Year 3 activities	1.1

Source: 2020 GCF Readiness and Preparatory Support.

agriculture (20 percent), water irrigation (15 percent), disaster-readiness and biodiversity (15 percent), and water and sewage (10 percent).

Tajikistan continues to face economic, social, and environmental challenges despite progress in developing the economy, reducing poverty, and designing adaptation plans to reduce climate change risks. Tajikistan should continue to capitalize on intersectoral and multi-stakeholder collaborations, while further localizing its adaptation financing and improving monitoring and evaluation processes. It should also focus on strengthening institutional capacity (particularly on disaster prevention and response abilities) and reducing red tape (particularly to facilitate investment, including in adaptation). In addition, fostering economic diversification would increase resilience in the face of climate change and other adversities, and regional cooperation would support both trade expansion and energy security.

Adaptation Financing

Several multilateral partners are ramping up support for adaptation financing:

- *Green Climate Fund (GCF)*. It currently finances five projects in Tajikistan for a total of $85 million. The GFC also approved three readiness activities with $4 million, of which it already disbursed $1.2 million (GCF 2021). Tajikistan is currently working on institutionally developing its hydrometeorology agency and on scaling up its hydropower sector to become more climate resilient. It is also emphasizing livelihood diversification and capacity building to combat food insecurity and reduce community vulnerabilities.

- *World Food Program (WFP)*. Tajikistan signed an MoU with WFP to improve government capacity for climate change adaption in April 2021. The focus was on forestry management, tree selection training, preservation, and other bilateral avenues for cooperation to increase food security. WFP supported 27,000 cash-for-work initiatives during the COVID-19 pandemic in the GBAO province and Rasht Valley (WFP 2021).

- *World Bank*. Its programs include the "Climate Adaptation and Mitigation Program for the Aral Sea Basin with IBRD and the Global Climate Fund (GCF)" and the "Strengthening Critical Infrastructure against Natural Hazards."

- *Private sector partners*. Tajikistan is considering a "multilateral development fund" that would include private sector partners to finance technologies for climate adaptation. It is also calling for international support to mitigate climate change impacts and to equitably channelize finances. Likewise, it is asking for partners' help in tracking funds invested towards climate change adaptation measures. The aim is to capitalize on the GCF efforts to develop monitoring and evaluation mechanisms incorporating capacities and technologies (Government of Tajikistan 2021).

- *Others*. Another notable program is "Scaling Up Hydropower Sector Climate Resilience" by the EBRD, Tajikistan Ministry of Finance, and GCF. Lastly, WFP and GCF also have a joint program titled "Building Climate Resilience of Vulnerable and Food Insecure Communities Through Capacity Strengthening and Livelihood Diversification in Mountainous Regions of Tajikistan". Past programs include "Strengthening of Livelihoods through Climate Change Adaptation in Kyrgyzstan and Tajikistan" by BMZ and GIZ as well as the UNDP/Global Environment Facility (GEF) "Small Grants Programme" which ran between 2010 and 2019. The latter provided local communities with grants for projects related to climate change, forestry, biodiversity, and land degradation (UNDP 2018a).

C. Tunisia[10]

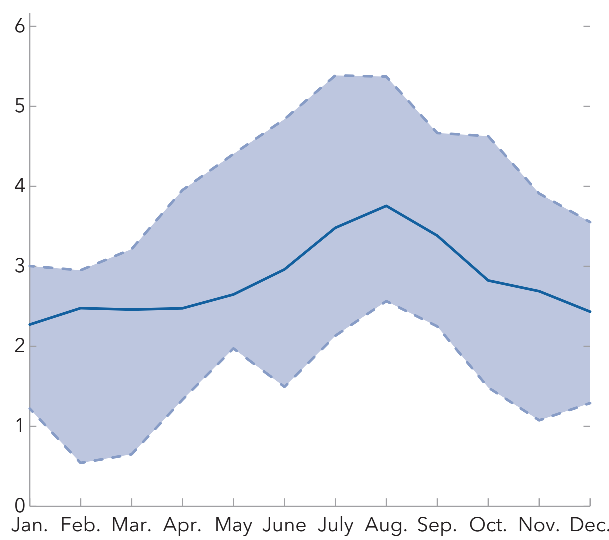
Tunisia is one of the most susceptible countries to the effects of climate change in the Mediterranean. Increasing temperatures and more erratic rains are predicted to reinforce water scarcity, desertification, and rising sea levels. This threatens lives and livelihoods, particularly through a loss of safe water and other infrastructure and reduced agricultural output as well as tourism activity. Although challenges are severe, adaptation efforts have been limited and uncoordinated thus far, although the updated 2021 NDCs set an ambitious agenda for the next decade. Preparing Tunisia for a more challenging climate environment requires strong coordination among public, civil society, and research institutions to deliver both more effective adaptation policies and financing.

Background

Within the Mediterranean, Tunisia is among the countries most vulnerable to the effects of climate change. It has about 1,300 km of continental coastline in the north and east and is bordered by the Sahara Desert in the south. The climate is thus Mediterranean along coasts, with mild, rainy winters and hot, sunny summers, while its inland areas are semi desert or desert (USAID 2018b). Temperatures are expected to increase around 0.7° C to 2.6° C by 2050, coinciding with a reduction of precipitation in the range of 4.1 to 6.7 percent (USAID 2018b). Between 2080 and 2099, this temperature increase could be up to 6° C in the summer months, or even higher if worldwide emissions increase beyond expectations (Annex Figure 2.7). Rising sea levels of 30–50 cm by 2050 (and up to 61 cm by the end of this century) threaten a significant part of Tunisia's population along the Mediterranean coasts. Besides, droughts are expected to become more frequent and longer lasting, and extreme weather events and flooding similarly more likely.

Climate stress is building, even if Tunisia has so far been spared many severe climate disasters. Over the past two decades, Tunisia has only recorded nine climate disasters, which gave rise to four disruptive years.[11] These disasters have caused $36 million in material damages, affected more than 105,000 people, and killed 64 (EM-DAT 2021).[12] Hydrological hazards (particularly droughts) were the most frequent and costliest in terms of material and human damages (Figure 5). However, mounting climate stress—especially higher temperatures and more erratic rains—have already intensified several climate-adaptation challenges:

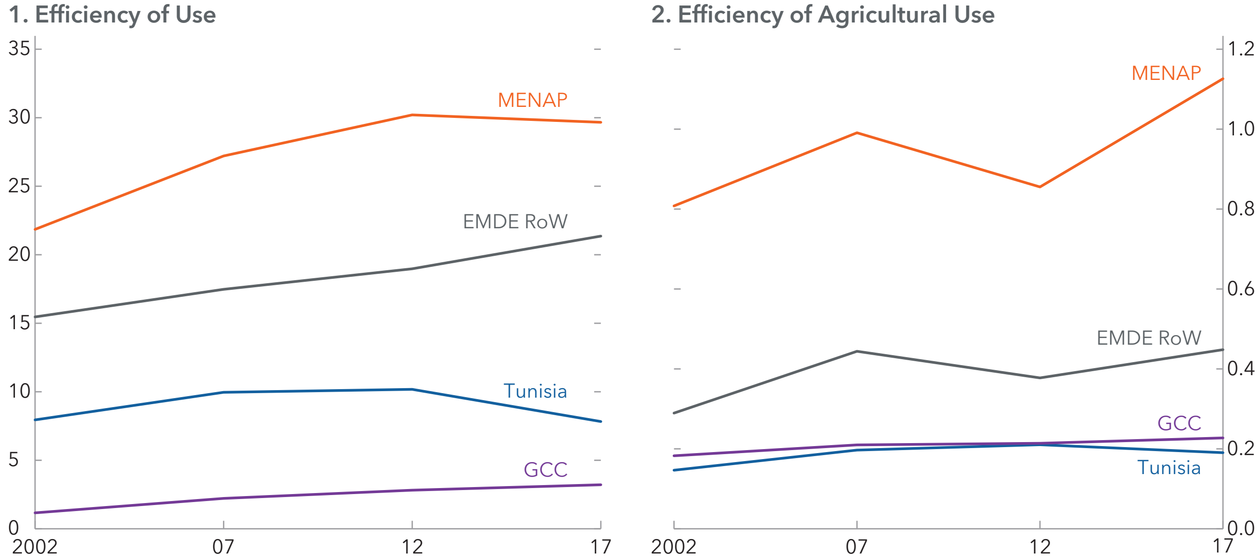
Annex Figure 2.7. Tunisia: Projected Change in Monthly Temperature, 2080–99
(Degree Celsius, medium-high emission scenario)



Source: World Bank Climate Change Knowledge Portal.

[10] Prepared by Anja Baum.
[11] Years when the sum of 0.3 times affected and deceased people exceeds 0.01 percent of the population (see Chapter 3).
[12] See Annex 4, section A for an explanation of disaster data.

Annex Figure 2.8. Tunisia and Peers: Water Efficiency, 2002–17
(Value added per unit of water used, expressed in US dollars per cubic meter)



Sources: FAO; and IMF staff calculations.
Note: RoW = rest of world.

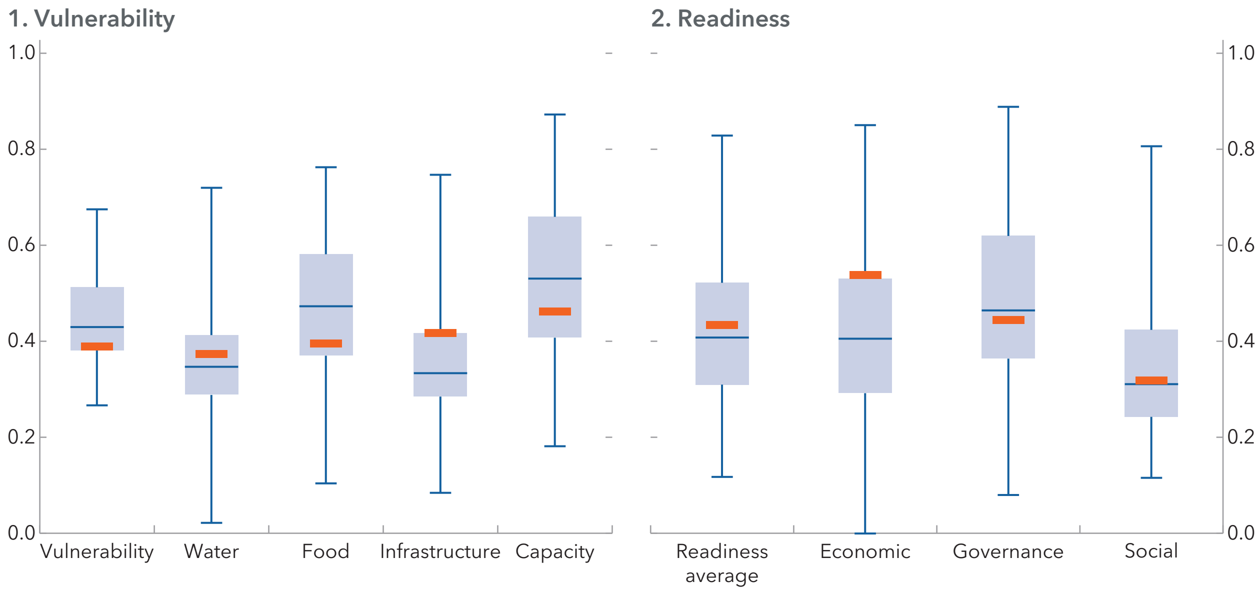
- *Water scarcity*. While access to safe drinking water in Tunisia remains above MENAP and world averages, water stress is rising, and water use efficiency is well below world and MENAP averages (Annex Figure 2.8). Low efficiency is driven by inefficiencies in water use in the agricultural sector, which has the largest consumptive water use and withdrawal in the economy.[13] Irrigation constraints are related to the overuse of irrigation water, inefficient irrigation water distribution networks, degradation of groundwater quantity and quality due to overexploitation, restrictions on access to the resource, and inadequate water valorization (Ministère de l'Agriculture 2017). Water issues are tightly tied to Tunisia's reliance on agriculture, which accounts for 10 to 14 percent of the country's GDP and provides about 16 percent of the country's employment (USAID 2018b).

- *Loss of coasts and ecosystems*. Tunisia has already lost more than 90 km of beaches due to erosion or the construction of artificial defense structures (UNFCCC 2019b). Of the 570 km of existing beaches, 190 km are in a degraded state and may disappear. This puts the tourism industry at risk, of which 90 percent is located along Tunisia's coasts, accounting for 6.5 percent of GDP and directly supporting 6 percent of the country's workforce (USAID 2018b). While some limited stretch of coastline is being fortified against erosion, new problems have emerged—such as the disfigurement of the landscape, accumulation of algae, eutrophication of water in closed creeks, sedimentary imbalances, aggressive erosion in adjoining areas, among others.[14] Sustainability of fishing is equally threatened by sea level rise.

Climate change will intensify Tunisia's key climate hazards, in turn aggravating environmental and socioeconomic vulnerabilities. Future climate developments will likely have dire effects on Tunisia's water supply, with lower precipitation and saltwater intrusion reducing water availability and quality (Fanack 2020). While vulnerability to climate change overall is still below international averages (Annex Figure 2.9), water and infrastructure vulnerabilities are already high and set to increase further.

[13] FAO data indicate agricultural water withdrawal of close to 80 percent of total water withdrawal in 2017.
[14] For example, the ongoing Tunisian Coastal Protection Program aims to protect 27 km of coastline against erosion and marine submersion for the sites of Kerkennah, Rafraf, Sousse North, Soliman, Tabarka, and Hammamet (UNFCCC 2019b).

Annex Figure 2.9. Tunisia and ME&CA Peers: Climate Change, 2018
(Index from 0–1 [worst])

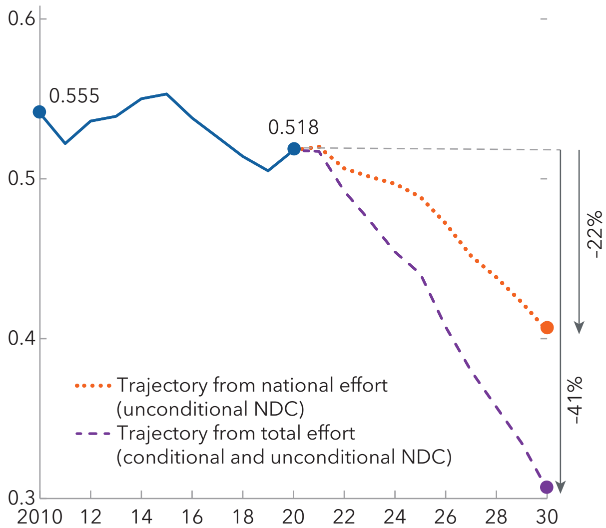


Sources: University of Notre Dame ND-GAIN; and IMF staff calculations.
Note: Each box shows the median and the 25th and 75th percentiles, and the whiskers the maximum and minimum values. Orange lines mark Tunisia.

At the same time, Tunisia's climate resilience remains an issue, with significant exposure and vulnerability levels (Annex Figure 2.9). This mainly reflects limited preparedness compared to international averages, with governance and social indicators at or below the world median. A few main risks stand out. The agricultural sector, accounting for 15 percent of Tunisia's exports in 2020 and located predominantly along the vulnerable coast lines, would see decreased yields and increased food prices, and food shortages could ensue (Lhomme, Mougou, and Mansour 2009; Mougou and others 2011; USAID 2018b). Farmer households' income would suffer, and employment in agriculture (currently at 13 percent of total employment) could decline more rapidly (Chapter 3, section B), increasing poverty if Tunisia's economy proves unable to absorb climate-induced migration and employment shifts. With unemployment currently at almost 18 percent and a large inefficient SOE sector that still dominates Tunisia's economy, private sector transformation needed to adjust to climate change could prove insufficient. Tunisia's infrastructure, particularly transport and tourism infrastructure, which are predominant along the coasts, could be increasingly damaged by sea-level rise and flooding. Finally, increased heat waves, loss of clean water, and increased undernutrition will likely impact general health and increase the spread of diseases.

Tunisia has committed to ambitious mitigation and adaptation targets. Tunisia signed the Paris Climate Agreement in December 2015 and submitted its NDC in September 2015 and an updated NDC in 2021. In the latter, the country promises to lower its carbon intensity by 45 percent by 2030 (relative to 2010) and to step up adaptation efforts, with an estimated cost of $20 billion between 2021 and 2030. NDC adaptation goals are ambitious, providing analysis of links across different sectors as well as social targets. In term of mitigation, Tunisia committed to reducing its carbon intensity by 27 percent through its own efforts (up from 13 percent in the 2015 NDC), while another 18 percent would rely on the support of the international community through funding of investment needs, capacity building, and technology transfer (Annex Figure 2.10). According to the updated 2021 NDC, total funding needs to cover mitigation spending would be about $14.4 billion. Tunisia's own efforts toward mitigation center on the energy sector, through increased energy efficiency, improved electricity infrastructure, and additional investments in renewable energy. To that end, the authorities plan to increase the share of renewables in energy production to 30 percent by 2030 (from

Annex Figure 2.10. Tunisia: NDC Trajectory, 2020–30
($teCO_2$ per 1,000 decitonnes)



Sources: United Nations; and Ministry of Environment and Sustainable Development, Tunisia.
Note: $teCO_2$ = trade in embodied CO_2.

currently about 3 percent). Adaptation costs in the 2021 NDCs are estimated at $4.3 billion until 2030. $0.7 billion are planned for capacity building.

Adaptation Strategies and Progress

Progress toward meeting climate change objectives has remained slow and relatively uncoordinated. Tunisia was one of the first countries to integrate climate change in its Constitution in 2014 but has yet to officially designate an institution to coordinate climate change policies.[15] The authorities adopted a new national strategy (Stratégie Nationale de Maîtrise de l'Énergie) in 2014 and created a Fonds de Transition Énergétique to support initiatives in this area. A decree from March 2018 established a unit dedicated to climate action within the Ministry of Environment, and several development partners are supporting the authorities in finding solutions for water (adaptation), energy (mitigation), and other sectors. However, addressing climate issues has been challenging because of resistance to reform, competing priorities, as well as political instability and turnover. While the country has many sectoral and short-term plans, it has lacked a clear overarching strategy that ensures effective coordination between different policies. In addition, Tunisia's National Adaptation Strategy has been in development since 2018 without a clear deadline or progress. Consequently, climate action remains fragmented across line ministries and civil society. Capacity for change at the national and local government level, as well as governance in the large SOE sector are insufficient. In addition, adaptation initiatives are limited in marginalized, rural arears of the country. An integrated and well-coordinated approach to climate change adaptation urgently needs to be developed and implemented to advance the adaptation agenda.

Tunisia's 2021 adaptation plans focus on coastal management and urban planning, water, agriculture, health, tourism, and ecosystems.

- *Water*. In view of the water challenges (see above), Tunisia has prioritized desalination and wastewater management as means to combat current and future water scarcity and use inefficiency, and there is additional opportunity through integrated water management plans and increased investment into innovative techniques.[16] While some of these efforts are already underway, they should be accelerated and broadened (Taheripour and others 2020) to ensure water security.

- *Agriculture*. Planned actions focus on conservation agriculture, capacity building and institutional development measures, for instance by adapting irrigated crops in the central region or adapting mixed farming-livestock production to climate change in vulnerable areas, and by increasing digitalization and information sharing. While research into agricultural adaptation is vast, the implementation of advocated actions and recommendations remains limited.

[15] Tunisia's 2014 Constitution includes a reference to fighting climate change, noting that the State shall "provide the means necessary to guarantee a healthy and balanced environment and contribute to the climate's integrity."

[16] A study is also underway to transfer part of the surplus water of the north to the center of the country (UNFCCC 2019b) but would require significant water infrastructure development.

- *Coasts and tourism*. Deepened and coordinated planning stands at the core of the updated NDC agenda, especially for coastal protection. Although seen as a priority, so far, adaptation responses to rising sea levels and hotter temperatures, and their impact on the tourism sector have been largely limited to planning. Diversifying tourism and limiting Tunisia's coastline deterioration will be essential to protect the sector and livelihoods going forward.

Improvement in transportation infrastructure will be needed to dampen the effects of climate change. One national highway connects the less-developed interior regions to the north, where most transport, agriculture and tourism-related infrastructure is located. In addition, roads are used to transport about 80 percent of goods in Tunisia. Any damage to these main infrastructure arteries (for example, from sea level rise or flooding) would not only be detrimental to the economy but would also further increase the already large socioeconomic gap between regions.

Investment management reforms will be key. Public investment should be allocated to activities that improve the use of existing resources. Reform priorities include better planning, selecting, and prioritizing of investment projects for adaptation. For example, priority should be given to rehabilitating and modernizing existing water infrastructure, distribution networks (also for energy), and treatment plants. Maintenance should also be improved to keep existing structures running. Increased private sector participation and competition would also incentivize efficiency improvements in SOEs over time. A new pricing policy that aims to recover water and sanitation service costs from all users, implemented gradually and combined with direct transfers to users for social and economic reasons could be established. Finally, Tunisia's energy and water SOEs (STEG, STIR, SONEDE) are poorly managed, regularly run high deficits, and depend on public transfers. Energy price reform to adjust tariffs to cost-recovery levels, while retargeting subsidies to support the most vulnerable, and SOE governance reforms are urgently needed (IMF 2021e).

Adaptation Financing

Funding needs for adaptation efforts to climate change are large. They could amount to about $4 billion over 2021–30, with most funds needed for coastal management, agriculture, and water conservation and reuse (Annex Table 2.2). However, given increasing water stress and other climate change challenges, this estimate likely understates the adaptation needs over the next few decades.

Funding plans rely heavily on contributions from the international community. This raises concerns about adequate ownership of the adaptation response, and about prospects for success. Until 2019, international commitments for adaptation have reached $1.3 billion, according to the OECD's climate financing data (Annex Table 2.3). Given insufficient adaptation progress with these commitments, more will be needed to further Tunisia's adaptation agenda.

Annex Table 2.2. Tunisia: Estimated Adaptation Costs for Sectoral Conditional Actions, 2021–30
(Millions of US dollars)

	National contribution	International contribution	Total
Urban planning and coastal management	734.4	373.3	**1,107.7**
Agriculture	160.6	438.8	**599.4**
Water	143.9	510.8	**654.8**
Tourism and economic planning	57.8	142.0	**199.8**
Ecosystem and biodiversity	32.0	53.5	**85.5**
Natural disasters	80.0	120.0	**200.0**
Other	0.2	4.7	**4.9**
Sum	1,208.9	1,643.2	**2,852.1**

Source: NDC Partnership (2021).
Note: Estimates are based on a sectoral analysis. The UN top-down analysis sees annual needs at around $400 million.

Annex Table 2.3. Tunisia: Adaptation Financing
(Millions of 2019 US dollars)

	2015	2016	2017	2018	2019	Total
Total	**128**	**233**	**481**	**246**	**233**	**1,321**
Germany	102	140	21	172	57	**492**
France	0	59	70	0	94	**223**
Japan	1	0	338	0	0	**339**
African Development Bank	19	24	37	12	28	**120**
World Bank	–	–	15	60	–	**75**
International Fund for Agricultural Development	–	10	–	–	15	**25**
European Bank for Reconstruction and Development	6	–	–	–	17	**23**
Netherlands	–	–	–	–	15	**15**
Other	1	0	1	1	8	**11**

Sources: OECD, IMF staff calculations.
Notes: Excludes financing targeted at mitigation. Excludes European Investment Bank.

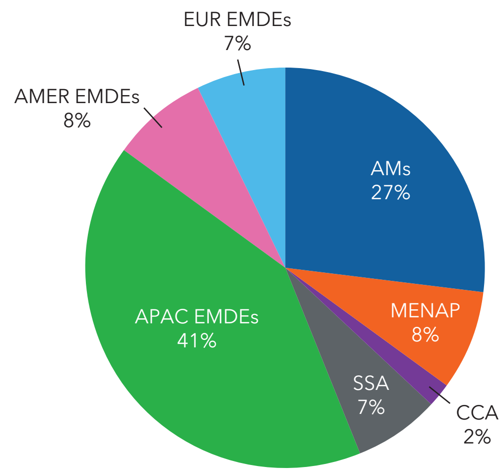
Annex 3. Mitigation Efforts[1]

The ME&CA region is a relatively small emitter of greenhouse gases (GHG) both in absolute terms and on the average-country level, but the largest in per capita terms. Mitigation ambitions vary across the region and generous energy subsidies remain widespread. However, many countries see a key role for developing renewable energy sources.

A. Background

The ME&CA region is a relatively small GHG emitter. In 2018, the region collectively emitted 4.7 billion tons of GHGs, thus contributing 10 percent to the world's total (Annex Figure 3.1), with 11 percent of the world's population and 4 percent of the world's output.[2] Relative to peers, the average CCA country was the second-smallest GHG emitter (topped by SSA peers) and the average MENAP country the fourth smallest (additionally topped by AMER EMDEs, Annex Figure 3.2, panel 1). In line with the global average, three-quarters of ME&CA's GHG emissions came from the energy sector (Annex Figure 3.2, panel 2), which is a key sector in many of the region's oil- and gas-rich countries that predominately source their energy from oil, natural gas, and coal. The global top 20 of GHG emitters features three countries from the region (Iran, Pakistan, and Saudi Arabia), contributing roughly half of MENAP's GHG emissions. Since 1990, GHG emissions have remained broadly stable in CCA countries, but almost tripled in MENAP countries. The growth of emissions in the MENAP region have thus far exceeded the world and other EMDEs that have seen their emissions grow by one-half and three-quarters, respectively.

Annex Figure 3.1. GHG Emissions, 2018
(Percentage shares of total)



Sources: CAIT; and IMF staff calculations.

However, some ME&CA countries are among the largest global polluters on a per capita basis. Within the MENAP region one-third of countries are currently emitting above the global average per person (Annex Figure 3.2, panel 1). Four of them even rank among the top six per capita polluters worldwide (Qatar, Bahrain, UAE, and Kuwait). Among CCA countries, only two are currently emitting above the global average (Kazakhstan and Turkmenistan). Also, as their economies grow, some emerging market economies in the region have the potential to become large emitters if they do not invest in mitigation.

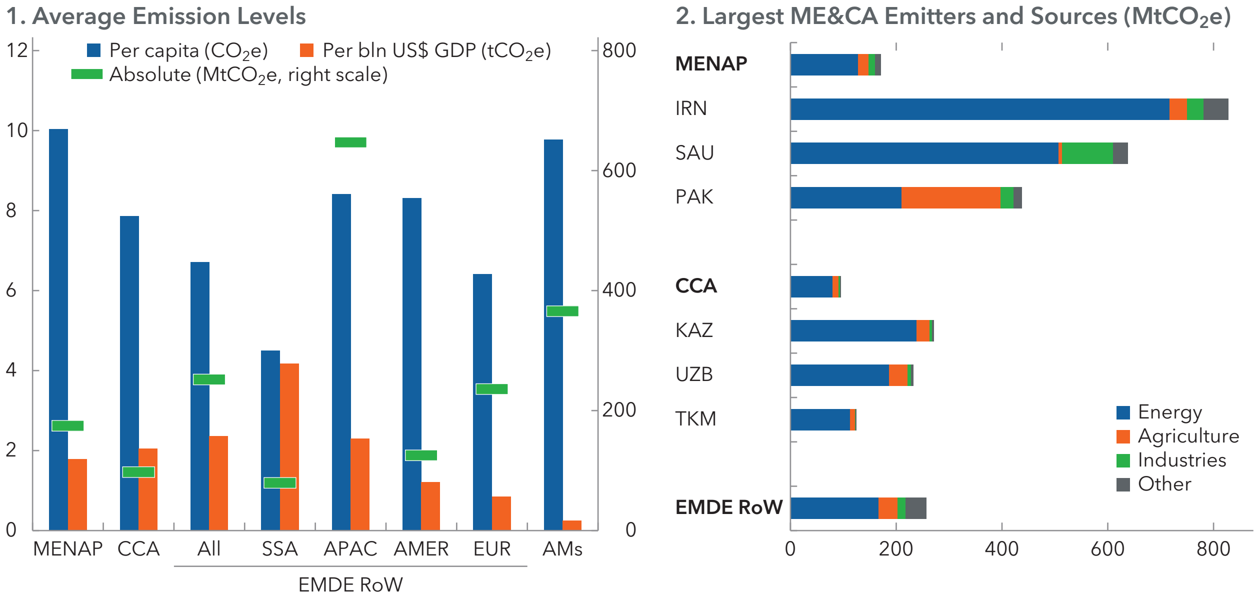
B. NDCs and Policy Actions

Comparing emissions targets across countries is difficult. The mitigation ambitions detailed in countries' Nationally Determined Contributions (NDCs) differ in the way they are reported. Some countries do not have explicit targets for emissions reductions. For those that do, some report targets as a reduction from

[1] Prepared by Gareth Anderson and Kerstin Gerling.

[2] GHG emissions produced by humans—comprising the four Kyoto gases methane (CH_4), carbon dioxide (CO_2), nitrous oxide (N_2O), and fluorinated gases (F-gases)—are widely acknowledged as the primary driver of climate change (Cook and others 2016). In 2018, about half of global GHG emissions came from four countries alone (China, India, Russia, and United States) and three-quarters from 20 countries. About 5 percent came from the 120 smallest emitters.

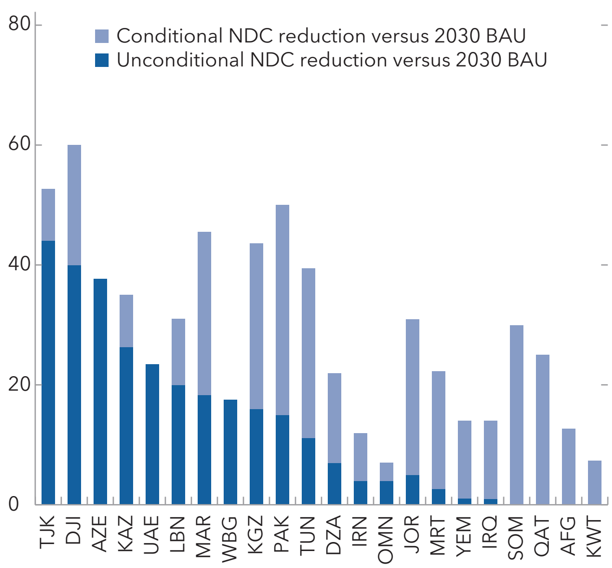
Annex Figure 3.2. GHG Emissions, 2018



Sources: CAIT; WB WDI; IMF WEO; and IMF staff calculations.

a business as usual (BAU) scenario, while others report reductions relative to a baseline period, and some report an absolute emissions target. Comparing the ambition of mitigation targets across countries therefore requires a benchmarking exercise to derive a 2030 NDC implied target level of emissions based on information in the country NDC reports.[3] Countries also distinguish between (1) "unconditional contributions," which they aim to achieve using their own resources without any conditions; and (2) "conditional contributions," for which they rely on international support or other conditions.

Annex Figure 3.3. Envisaged NDC Reduction in 2030 GHG Emissions
(Percent)



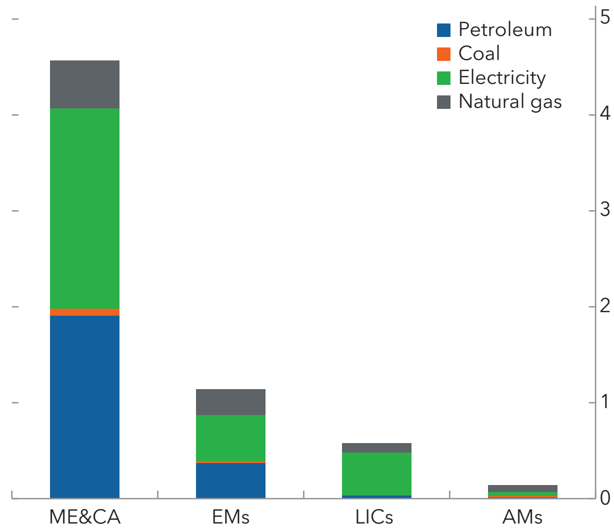
Sources: Country NDC reports (as publicly available on October 25, 2021); and IMF calculations for select countries.

The emissions targets in countries' NDCs vary across the region but are often low. The benchmarking exercise to compare NDC emission reduction targets for 2030 across countries, where data are available, reveals that ambitions differ significantly across the ME&CA (Annex Figure 3.3): some with relatively high reduction targets (for example, Djibouti and Tajikistan) but a long tail of countries with more modest ones. In addition, for several countries, the unconditional targets in their NDCs are significantly less ambitious than the conditional targets because of binding financing constraints, underscoring the dependence of mitigation efforts on external support. Beyond the NDC targets for 2030, some countries in the

[3] As laid out in, for example, IMF (2019b, 2019c), for each country, an expected level of emissions in 2030 is calculated under a business-as-usual scenario using a model known as the Carbon Pricing Assessment Tool. Where possible, the emissions targets reported in each country's NDC are then converted to an implied target level of emissions.

region have also stated longer-term mitigation targets and signed-up to other global initiatives. Kazakhstan and the UAE have pledged to reach net zero carbon emissions by 2050, while Bahrain and Saudi Arabia are targeting net zero by 2060. Several countries from the region, though not all, have joined the Global Methane Pledge, aiming to cut methane emissions by 30 percent by 2030.

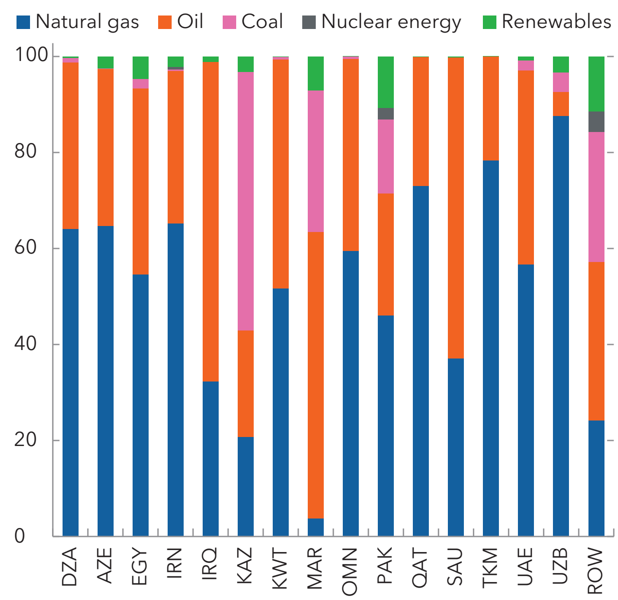
Annex Figure 3.4. Explicit Subsidy by Energy Product, 2020
(Percent of GDP)



Sources: Parry, Black, and Vernon (2021); and IMF calculations.

Mitigation efforts are hindered by generous energy subsidies which remain common in the ME&CA region, particularly in MENAP countries. In 2020, overall explicit energy subsidies in the ME&CA region were around 4.6 percent of GDP, significantly higher than the average for emerging market economies, low-income countries, and advanced economies (Annex Figure 3.4). Explicit subsidies for petroleum products and energy (electricity and natural gas) were particularly high in 2020, at about 2.4 percent and 1.5 percent of GDP, respectively. Within the region, subsidies were largest in Iran and Saudi Arabia. These subsidies significantly reduce the incentives for investment in and the adoption of renewable sources of energy. Total subsidies, which also capture the implicit subsidies relating to environmental costs as well as explicit subsidies, are estimated to be significantly higher at around 18.2 percent of GDP. Many countries have tried to remove energy subsidies, but progress has been limited, and in some cases energy subsidies were expanded in response to the COVID-19 pandemic (IMF 2020a). Egypt has successfully introduced a fuel subsidy reform which lowered the fiscal burden of fuel subsidies from 3.3 percent of GDP in FY 2016/17 to 0.3 percent in FY 2019/20, while Saudi Arabia has reduced fossil fuel subsidies by about 60 percent between 2012–19.

Annex Figure 3.5. Primary Energy Consumption by Fuel, 2019[1]
(Percentage shares)



Sources: BP Statistical Review of World Energy 2020; and IMF staff calculations.
[1]Renewables include hydroelectric.

Many countries in the region have, however, recognized a key role for renewable energy in mitigating emissions. Renewable energy, at present, accounts for a small share of energy in the region (Annex Figure 3.5). Primary energy consumption from natural gas and oil is much larger than in the rest of the world. For the countries in the region where data are available, renewables account for only 2 percent of primary energy consumption, compared with a global average of 11 percent. Pakistan has the highest renewables share in the region at just under 11 percent. Nevertheless, several countries have included targets relating to renewable energy in their NDCs. A recent study found that of the 15 NDCs submitted in the MENA region by the end of November 2019, all of them mentioned renewables and two-thirds had quantified renewable power targets (IRENA 2019). In many oil-producing countries, increasing the share of renewables is also motivated by meeting increasing domestic energy demands and pursuing diversification projects. Saudi Arabia is targeting 50 percent of electricity generation from renewables by 2030. In contrast, UAE's National Energy Strategy 2050 seeks to increase the share of clean energy to 50 percent of the installed power capacity mix and reduce final energy demand by 40 percent by 2050.

Annex 4. Data and Empirical Approaches[1]

This Annex gives details on data and models used in the empirical analysis throughout this paper.

A. Data

Natural Disaster Data

This paper relies on the Emergency Events Database (EM-DAT) maintained by the Centre for Research on the Epidemiology of Disasters. It includes all events since 1900 that meet at least one of the following criteria: (1) 10 fatalities or more, (2) 100 people affected or more, and (3) a declaration of an emergency state and/or call for international assistance. Along six disaster hazards, EM-DAT reports disaster frequency (that is, number of event occurrences) and three loss measures—one material and two human ones (Guha-Sapir, Below, and Hoyois 2015): (1) value of damaged property, crops, and livestock (valued at the moment of the event in US dollars); (2) number of affected people (that is, those requiring immediate assistance during a period of emergency, including for basic survival needs such as food, water, shelter, sanitation and immediate medical assistance); and (3) number of fatalities (that is, people deceased or missing). Although frequency data has likely improved over time and actual losses have likely remained under-reported, the data are widely considered as adequate and comparable thanks to similar reporting standards applied since the 1980s.[2] Six natural hazards are considered as climate related (Annex Table 4.1): (1) meteorological (for example, heat waves and storms); (2) hydrological (for example, floods); (3) biological (for example, epidemics and insect infestations); and (4) climatological (for example, droughts and wildfire).

Annex Table 4.1. Typology of Climate Disasters[1]

Hazards	**Definition:** A hazard cause by . . .	**Disaster type** (and subtype example)
Meteorological	. . . short-lived, micro- to meso-scale extreme weather and atmospheric conditions that last from minutes to days.	• ***extreme temperature:*** cold or heat wave, severe winter • ***landslide:*** avalanche, mudslide, rockfall, subsidence • ***fog*** • ***storm:*** storm (convective, extra-tropical, tropical); cyclone
Hydrological	. . . the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater.	• ***flood:*** coastal, flash, and riverine flood • ***landslide:*** avalanche, mudslide, rockfall, subsidence
Biological[2]	. . . the exposure to living organisms and their toxic substances (for example, venom, mold) or vector-borne diseases that they may carry.	• ***epidemic:*** bacterial, parasitic, or viral disease • ***insect infestation:*** grasshoppers, locusts • ***other:*** venomous wildlife and insects, and poisonous plants
Climatological	. . . long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability.	• ***drought*** • ***wildfire:*** forest and land fire (brush, bush, pasture)

Sources: Guha-Sapir, Below, and Hoyois (2015) ; Below, Wirtz, and Guha-Sapir (2009) ; Kron and others (2012); and IMF staff analysis.
[1]Non-climate-related disasters are geological and extra-terrestrial disasters.
[2]Biological disasters are generally classified as climate-related perils, as they are often triggered by climate hazards (such as insect infestation).

[1] Prepared by Anja Baum, Chen Chen, Kerstin Gerling, and Sahra Sakha.
[2] Note that the quality and completeness of self-reported EM-DAT disaster data can depend on a country's economic and political conditions (for example, Hsiang and Jina 2014, Kahn 2005, Strömberg 2007, Noy 2009).

Macroeconomic Data

Time series come from the April 2020 IMF World Economic Outlook (WEO), the IMF International Financial Statistics (IFS), and the World Bank World Development Indicators (WDI). Where data availability was an issue, series were complemented through splicing series across those sources, further enhanced through splicing with older IMF WEO vintages and staff reports.[3] The GDP sectoral data was obtained from country authorities, and the climate-related development financing data from the OECD.

Other Data

Historical climate data (temperatures and precipitation) come directly from the World Bank and projected monthly changes from its Climate Knowledge Portal.[4] Projected mortality costs and average summer temperatures data are sourced from the Climate Impact Lab. Besides, data on water use and stress comes from the FAO, industry, and services data from the World Bank WDI, employment data from the ILO and World Travel and Tourism Council, and sectoral GDP data from country authorities.

B. Modeling of Clustering

To group countries along similarities in terms of various dimensions of climate resilience (Chapter 2, section B), this paper uses a clustering technique, which is a non-parametric basic machine learning exercise.

Variables

This paper amends the European Commission's INFORM Risk Index 2022. This is a global, open-source composite indicator that identifies countries at risk of climate disasters and humanitarian crisis by tracking three risk dimensions: (1) exposure, (2) vulnerability, and (3) lack of coping mechanisms. Each dimension comprises several variables that this paper modifies as follows for the 31 ME&CA countries in the sample (Annex 1)[5]:

- *Exposure*. To isolate the exposure dimension from the INFORM RISK Index, this paper: (1) drops variables related to hazard exposure and the climate-related number of affected people and (2) includes another exposure variable on irrigated agricultural land (in percent of total agricultural land) from the World Bank WDI. This leaves seven variables to capture exposure: population density; population living in urban areas; household size; and the probability of experiencing floods, tsunamis, cyclones, or droughts.
- *Vulnerability*. To capture the level of self-protection mechanisms, while keeping the dimensionality of the vector of observables as small as possible (given the small number of countries to classify), this paper merges the two INFORM RISK dimensions of lack of vulnerability and coping mechanism. The vulnerability dimension represents a country's economic, political, and social characteristics that can be destabilized in case of a hazardous event. It is, therefore, closely related to the level of self-protection mechanisms (for example, Gini index, Human Development Index, and health. In addition, this paper includes four indicators: (1) violent conflict probability from INFORM RISK exposure dimension, (2) a dummy for fragile LICs, (3) water stress, and (4) water dependency from FAO's AQUASTAT and the World Bank WDI.

[3] When splicing, several decisions rules and robustness checks help minimize time series inconsistencies.

[4] Note that precipitation data has typically much larger measurement errors than temperatures (for example, NCAR 2021, Dahri and others 2018).

[5] All additional variables follow the same methodology as the INFORM Risk, including imputation of missing values, normalization, and aggregation. For a methodological and data overview, see for example, Marin-Ferrer, Vernaccini, and Poljansek (2017).

Empirical Methodology

A basic clustering algorithm (called K-means) helps classify ME&CA countries according to their vulnerability and hazard/exposure level. The K-means algorithm starts with a first group of randomly selected centroids (that is, the middle of the cluster, which is a vector that contains one number for each variable, where each number is the mean of a variable for the observations in that cluster). These are used as the beginning points for every cluster; the algorithm then performs iterative (repetitive) calculations to optimize the positions of the centroids. Thereby, the K-means clustering method minimizes the mean sum of the squared Euclidean distance from the estimated center of each group to each country in the group with the objective of classifying ME&CA countries in K=2, 3… groups. The standard practice to select the optimal K is to find the Elbow where additional K does not substantially decrease the sum of square errors to centers.

C. Modeling of Macroeconomic Impact of Weather Shocks

To quantify the macroeconomic impact of the ME&CA region's key climate stressors (Chapter 3, section B), this paper uses a battery of empirical models and robustness tests. However, while largely in line with the literature (where available), the observed mean effects for the for 31 ME&CA countries in the sample (Annex 1) during 1970–2020 often mask substantial heterogeneity in climate stresses, resilience, and policy responses across studied countries. Besides, data quality and availability are uneven, possibly adding a bias to the results. Together, these issues help explain why some effects have wide error bands around the estimated mean response and remained insignificant at this stage. Going forward, this could change, though, mainly with better data coverage and quality, an intensification of hazards (Chapter 2, section C), especially with delays in decisive resilience-enhancing adaptation policies (Chapter 4).[6]

Temperature and Precipitation Shocks

A range of empirical models helps ascertain the effect of weather shocks on growth, output composition, and employment (Chapter 3, section B). As a starting point, this paper replicates the WEO 2020 approach to measure the impact of climate change on capita incomes in ME&CA countries. It traces the impulse response functions of real GDP per capita growth to a weather shock, using the approach of Dell, Jones, and Olken (2012) and Burke, Hsiang, and Miguel (2015b), as well as Jordà's (2005) local projection. Climate patterns are derived from average annual temperature and precipitation. For the impact of climate on real GDP per capita, a squared term is included to account for a possible nonlinear relationship between temperature and economic development.

Baseline Methodology

Variables. Weather variables are average annual temperature and precipitation. Economic activity is specified either in log changes of GDP per capita, or in changes of sectoral GDP. Sectoral GDP series have been collected directly from country specific data sources and are based on IMF staff estimates, except for tourism activity, which comes from the World Travel & Tourism Council. Employment variables are specified as (1) the unemployment rate in percent of total labor force (ILO), as well as (2) employment in agriculture, industries, services (all WDI), and tourism (World Travel & Tourism Council) specified in percent of total employment.

Baseline methodology. Following Burke, Hsiang, and Miguel (2015b), this paper estimates a quadratic specification in the weather variables, where applicable. The analysis employs Jordà's (2005) local projection method to trace out the impulse response functions of various outcomes to weather shocks. Regressions for each forecast horizon are estimated separately according to the following equation:

$$y_{i,t+n} - y_{i,t-1} = \alpha_1^n w_{i,t} + a_2^n w_{i,t}^2 + \beta_1^n w_{i,t-1} + \beta_2^n w_{i,t-1}^2 + \sum_{j=1}^{n-1} \gamma_1^n w_{i,t+n-j} + \sum_{j=1}^{n-1} \gamma_2^n w_{i,t+n-j}^2 + \delta_1^n \Delta y_{i,t-1} + \zeta_i^n + \theta_t^n + \varepsilon_{i,t}^n \quad (1)$$

[6] Such heterogeneity is the main driver of the observed wide 90 percent confidence bands.

in which y takes the form of either log GDP per capita, sectoral GDP or employment, and w includes average annual temperature and precipitation. i indexes the country index, t years, and n the length of the forecast horizon. The regressions control for one lag of the dependent and weather variables, as well as for forwards of the weather variables, as suggested by Teulings and Zubanov (2014). Squared terms on the weather variables allows to capture nonlinearities in the response to a shock: for countries with colder climates an increase in temperature could be beneficial, while for countries that are already hot a further increase in temperature could be detrimental. Finally, ζ and θ are country and time fixed effects, and ε clustered robust standard errors. To avoid overfitting and the excessive loss of degrees of freedom, other controls are not included.[7]

Specific Modification 1: Growth

Specification. Quadratic terms are kept as significant, and the estimation follows equation above. Taking the first derivative of equation (1) with respect to temperature provides estimates of the effect of a 1° C increase in temperature at horizon n for any given annual temperature T:

$$\frac{\partial(y_{i,t+n} - y_{i,t-1})}{\partial T_{i,t}} = \beta_1^n + 2 * \beta_2^n T_{i,T} \quad (2)$$

Setting equation (2) to zero gives the threshold temperature at which the effect on the outcome variable turns from positive to negative. Equation (2) also helps evaluate a 100-millimeter increase in precipitation for any given precipitation level.

Results. The results confirm the nonlinear relationship between temperature and per capita GDP (also uncovered by Burke, Hsiang, and Miguel 2015b) and suggest highly uneven effects of warming across the globe (Figure 11, panel 1). In countries with cooler climates, a temperature increase boosts economic output; while in countries with higher average temperatures, a rise in temperature suppresses economic growth. However, consistent with the literature, precipitation coefficients might be imprecisely estimated, possibly due to measurement error relative to temperatures (Dahri and others 2018).

Robustness. Kahn and others (2021) point out that temperature data are upward trending for almost all countries in the world. Inclusions of temperature data in levels would thus induce a linear trend in equilibrium log per capita output growth, which could bias the estimates.[8] Therefore, this paper alternatively specifies temperature and precipitation as deviations of 20-year moving averages to be used in the baseline specification. This yields a nonlinear impact for both weather variables (Annex Table 4.2, panel 1, column 2; and main text Figure 11), although the impact of the squared term on precipitation is just shy of being significant. These results are consistent with a recent paper by De Bandt, Jacolin, and Lemaire (2021), who apply the baseline methodology presented here, but specify temperature variables as deviations from historical norms (defined as averages from 1900–50). In addition, this paper applies a variant of the Kahn and others (2021) methodology to check for overall robustness of the empirical strategy. The following fixed effects panel ARDL model is estimated:

$$\Delta y_{it} = \zeta_i + \sum_{j=1}^{n} \delta_1 \Delta y_{i,t-n} + \sum_{j=0}^{n} \beta_1' w_{i,t-n}^{MA} + \theta_t + \varepsilon_{it}\ , \quad (3)$$

in which, as before, y is the log of real GDP per capita, ζ and θ country and time fixed effects, and ε clustered robust standard errors. $w^{MA} = (W_{it} - W_{i,t-1}^*)$, with $W_{it} = (T_{it}, P_{it})'$ and $W_{i,t-1}^* = (T_{i,t-1}^*, P_{i,t-1}^*)'$. T_{it} and P_{it} are average annual temperature and precipitation of country i in year t, and $T_{i,t-1}^*$ and $P_{i,t-1}^*$ the historical norms of climate variables, in this case 20-year moving averages. The average long-term effects, θ, are calculated from the fixed effects estimates of the short-term coefficients of equation (3):

$$\theta = \phi^{-1} \sum_{j=0}^{n} \beta_j \ with \ \phi = 1 - \sum_{j=1}^{n} \delta_j \quad (4)$$

[7] Usual determinants of growth and employment (for example, institutional quality or policies) are themselves impacted by weather shocks (IMF 2017a), which is an additional reason for excluding them from the estimation.

[8] For a more complete technical discussion, see Kahn and others (2021).

Annex Table 4.2. Effect of Weather Shocks on Real GDP Per Capita and Sectoral GDP

	1. Real GDP (p.c. growth)		2. Sectoral GDP (percent of GDP)								
	Baseline[1]	20-year MA[2]	Agriculture	Industries	Services	Electricity and water	Hotels and restaurants	Tourism	Finance and real estate	Trade	Construction
Temperature	0.047***	0.025*									
	(0.013)	(0.013)									
Temperature^2	-0.001**	-0.025*									
	(0.000)	(0.012)									
Precipitation	0.009	0.008**									
	(0.008)	(0.003)									
Precipitation^2	-0.000	-0.005									
	(0.000)	(0.003)									
Temperature MENAP			-0.308	-0.498	1.114*	-0.001	0.022	0.624**	0.489	-0.164	0.015
			(0.327)	(0.494)	(0.634)	(0.065)	(0.054)	(0.295)	(0.325)	(0.133)	(0.114)
Temperature CCA			-0.705	0.135	0.860	-0.011	0.013	0.037	0.293	0.089	0.177
			(0.507)	(0.752)	(0.667)	(0.056)	(0.030)	(0.220)	(0.208)	(0.117)	(0.156)
Precipitation MENAP			0.448**	-0.079	-0.073	0.017	-0.067***	0.686	0.225	-0.143	0.007
			(0.190)	(0.311)	(0.303)	(0.034)	(0.021)	(0.508)	(0.156)	(0.146)	(0.106)
Precipitation CCA			-0.125	0.215	-0.110	-0.092***	-0.022	-0.071	-0.029	-0.333**	-0.253
			(0.602)	(0.358)	(0.599)	(0.020)	(0.030)	(0.096)	(0.159)	(0.129)	(0.189)
R^2	0.11	0.11	0.11	0.2	0.19	0.34	0.27	0.08	0.28	0.12	0.18
Countries	31	31	31	31	28	24	18	26	27	19	26
Observations	1,500	1,500	989	948	853	490	355	572	552	384	574

Source: IMF staff calculations.

Note: Panels 1 and 2 report the estimated coefficients on the weather variables for horizon 0. Year Fixed Effects are included in all regressions. All regressions use clustered standard errors.
[1]Baseline estimation follows Burke, Hsiang, and Miguel (2015b).

[2]Temperature and rain specified in deviations from 20-year moving averages. Panel 2 only reports baseline estimation (that is, results for weather variables specified as deviations from 20-year moving average are not presented).

Annex Table 4.3. Impact of Weather Shocks on Real GDP p.c. Growth
(Kahn et al. (2021) methodology)

	Specification 1	Specification 2
θ ΔT MENAP	0.0074	
	(0.0159)	
θ ΔT CCA	0.0742***	
	(0.0144)	
θ ΔP MENAP	0.0742	
	(0.0144)	
θ ΔP CCA	0.0030	
	(0.0337)	
θ ΔT+		0.0149
		(0.0163)
θ ΔT–		0.0768**
		(0.0397)
θ ΔP+		0.0002
		(0.0210)
θ ΔP–		0.0170
		(0.0241)
ϕ	0.8768***	0.8814***
	(0.1373)	(0.1391)
Observations	1,404	1,404
Countries	31	31

Source: IMF staff calculations.
Note: Temperature and rain specified in deviations from 20-year moving averages. Year fixed effects are included in all regressions. All regressions use clustered standard errors.

Following Kahn and others (2021), 4 lags are used for all variables and countries to avoid data mining.

Results of the estimated long-term impacts of changes in the climate variables are reported for two different specifications (Annex Table 4.3). The first splits temperatures and precipitation changes along MENAP and CCA countries, and the second follows the Kahn and others (2021) specification, splitting deviations into positive and negative deviations to analyze possible non linearities in the direction of the shock. The results of Specification 1 are consistent with the above presented baseline results. Temperature shocks are found to be insignificant in MENAP countries in the long term but are positive in CCA countries, while precipitation shocks are found to be insignificant. When splitting weather deviations from historical norms into positive and negative values (Specification 2), the only significant impact is found following negative deviations from the historical norm. The estimate suggests that a 0.01° C annual decrease in temperature below its historical norm increases real GDP per capita growth by 0.08 percentage points per year. This result conflicts with

Kahn's and others (2021), who show a negative impact following both positive and negative deviations. The difference might come from the different country sample, with most ME&CA countries having far above world temperatures.

Specific Modification 2: Sectoral GDP Composition

Specification. The analysis focuses on the impact of temperature and precipitation changes on three main economic sectors (that is, agriculture, industry, and services), and zooms into subsectors that expose a large exposure to climate shocks (that is, water and electricity, tourism, construction, real estate, finance, and trade). The dependent variable is specified as a ratio to GDP and used in first differences.[9] The square terms of equation (1) are omitted as they are on average found to be insignificant and the sample is usually too small to interpret this type of nonlinearity reliably. Instead, the sample is split into CCA and MENAP countries (Annex Table 4.2, panel 2, for horizon 0).

Results. Climate shocks impact some economic sectors more than others, making their impact uneven across countries depending on their respective sectoral composition.[10] Specifically, this paper finds the following for ME&CA countries[11]:

- *Changing weather patterns affect sectors differently, including across ME&CA subregions*. Temperature increases seem to have a net positive impact on service sector output, while the impact on agriculture is insignificant in both regions.[12] The negative, albeit statistically insignificant, impact of temperature shocks on agriculture is in line with the literature, which finds average agricultural output to be robust to temperature deviations when they happen independently of precipitation shocks (Dell, Jones, and Olken 2012; Burke, Hsiang, and Miguel 2015b; Carleton and Hsiang 2016; IMF 2017a). In hot years, food prices might rise and thus somewhat balance overall agricultural output loss. Indeed, papers studying agricultural yield only (such as Schlenker and Roberts 2009) show that there are critical temperature thresholds beyond which temperatures become harmful to production. A shock to precipitation (that is, an increase), on the other hand, has the potential to either support agriculture temporarily in dry climates, or damage crops and livestock significantly if they materialize in form of floods. In the past, MENAP countries experienced a positive immediate impact, which could, however, change going forward as within year rainfalls are becoming more volatile. CCA countries do not benefit from further precipitation increases.

- *Weather patterns affect some industries and services more than others* (Table 4). Higher precipitation weighs on all sectors in the short and in the medium term across sectors in CCA countries, except for financial and real estate activities. The latter likely picks up increased insurance activity after weather events. The impact of temperature shocks is more muted across sectors and regions, with a contemporaneous positive impact only found on tourism activity in MENAP countries. The negative impact of precipitation increases on water and electricity might seem surprising, but flooding and high winds can severely threaten a country's power supply. Finally, the impact of precipitation shocks on trade is negative in both regions.

9 Results are comparable if sectoral variables are specified in first differences of nominal GDP.

10 This is largely robust to using weather variables specified as deviations from 20-year moving averages.

11 Results should be seen as an indication of direction of impact rather than exact percentages, due to the use of different data sources and a relatively short data horizon in most of the sub-sectors based on IMF country data.

12 Note that these are average effects across MENAP countries. The negative impact found on GDP p.c. was only significant for MENAP countries with very hot climates, not the average MENAP country. By and large, the shifts across different sectors, when ignoring significances, could be seen as cancelling out. However, data availability varies across sectors, and general statements of this kind cannot be made.

Specific Modification 3: Employment

Specification. Using a similar methodology as for sectoral GDP composition, this paper analyzes the impact of temperature and precipitation changes on the unemployment rate, as well as on employment in agriculture, industries, and services, particularly tourism. In addition, the effects of weather shocks on male, female and youth unemployment are studied. The square terms of equation (1) are omitted as they are generally found to be insignificant.

Results. Employment shifts follow climate-induced sectoral shifts. Temperature and precipitation shocks affect total unemployment (Figure 15) and unemployment in agriculture, industries, services, and particularly tourism. The results suggest an employment shift from agriculture to services following temperature increases, and unemployment increases following precipitation shocks in both regions. Temperature and precipitation shocks also increase male, female, and youth unemployment in MENAP countries. In contrast, temperature shocks reduce all unemployment categories in CCA countries, while shocks to precipitation increase unemployment across the board (Annex Figure 4.1). The effects are overall strongest for youth unemployment in both regions, and weakest for female unemployment in MENAP countries.

Macroeconomic Impact of Climate Disasters

A fixed-effects, unbalanced panel vector autoregressive model with exogenous shocks (panel-VARX) helps simulate the impulse response functions (IRFs) of key macroeconomic variables (including real GDP growth and fiscal aggregates) to a disruptive climate disaster (Chapter 3, section B).

Variables

- *Annualized, scaled losses caused by climate disasters*. The focus lies on studying the impact of experiencing a disruptive year (rather than event) to capture both the effect of rare large-scale events and frequent smaller-scale events. Data on disaster losses come from the CRED EM-DAT (see above) and needs two steps of manipulation: (1) aggregation across the four climate hazards (Annex Table 4.1) and (2) scaling to allow comparability across time and countries (notably human losses by population).
- *Shock variable. A "disruptive year" dummy is constructed for human losses*. More specifically, this dummy takes a value of 1 when a country's annual death toll plus 0.3 times the number of affected people exceeds 0.01 percent of its population. This follows the literature à la Fomby, Ikeda, and Loayza (2009) in studying the impact of a disruptive year, regardless of its actual intensity above a chosen threshold level to help identify a disaster shock in its effect.

Empirical Methodology

The panel-VARX specification assumes that climate disasters are exogenous shocks in t0 with a contemporaneous macro-fiscal impact.[13] The model includes four endogenous variables (including for example, real GDP per capita growth, primary balance, tax revenues, exports, gross capital formation)[14] and a disruptive year dummy. Macroeconomic variables are expressed as a share of GDP and first-differenced to ensure stationarity.[15] Remaining data constraints keep the panel unbalanced. They also require minimizing the number of parameters (only allowing for one lag structure) and dropping countries in some specifications.

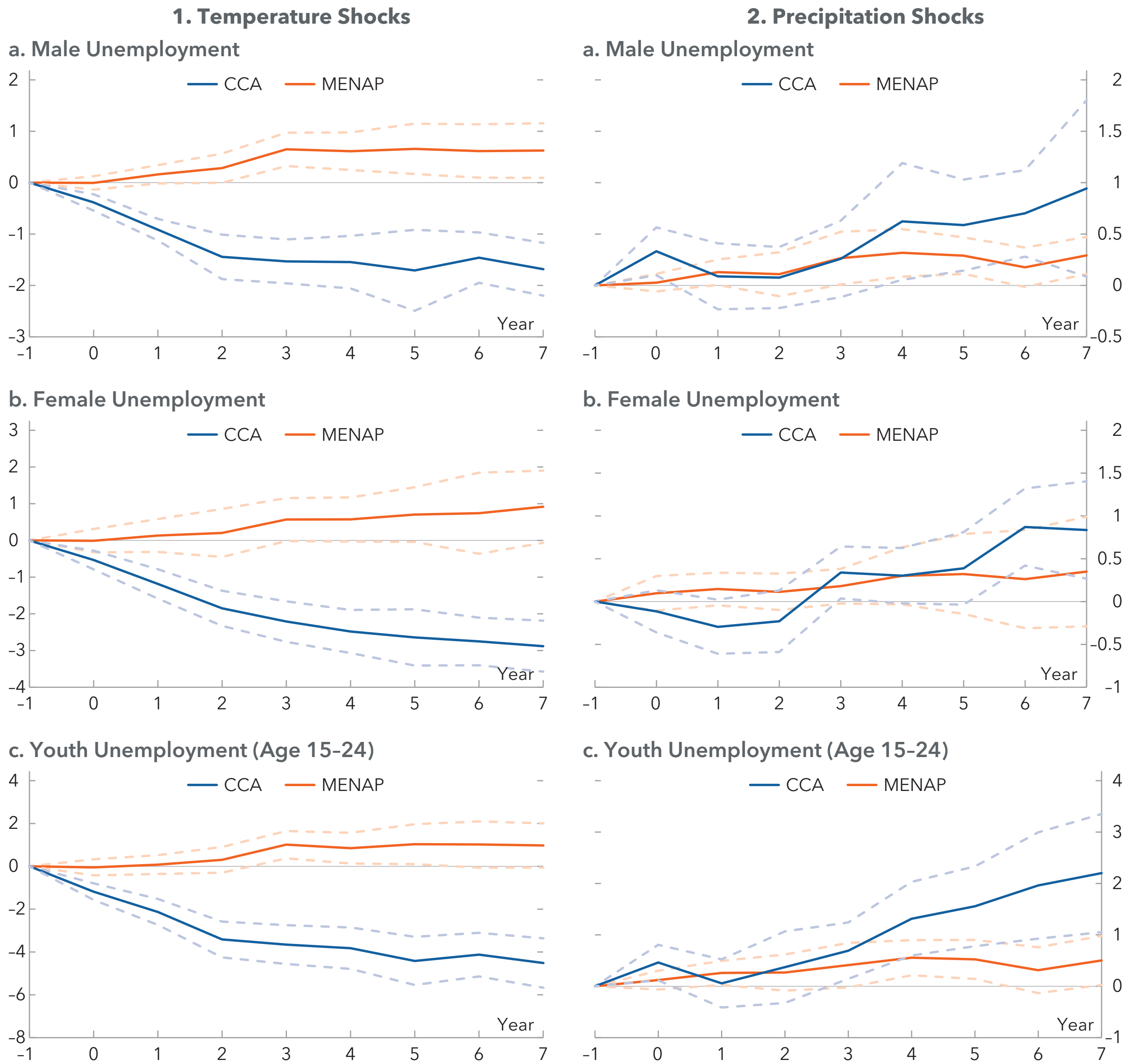
[13] Following IMF (2008), natural disasters are treated as conditionally exogenous variables, since they are not determined by economic choices, at least not in the short term.

[14] The empirical results are broadly robust to the inclusion of other variables (for example, inflation or oil price) or shocks.

[15] While both the Fisher-type and Im-Pesaran-Shin panel data unit root tests allow rejecting the null hypothesis of the growth and overall

[b]alance-to-GDP series containing a unit root, they do not allow doing so for the tax revenue- and expenditure-to-GDP ratio. This is only possible after first differencing the latter two.

Annex Figure 4.1. The Impact of Weather Shocks on Unemployment by Labor Force Groups
(Percent of respective labor force)



Sources: WB WDI; and IMF staff calculations.
Note: Dashed lines represent 90 percent confidence bands.

$$Y_{i,t} = \alpha_{j,i} + \beta_{j,1} Y_{i,t-1} + \gamma_{j,0} X_{j,i,t} + \gamma_{j,1} X_{j,i,t-1} + \varepsilon_{j,i,t}$$

with

$$Y_{i,t} = \begin{bmatrix} \textit{real GDP p.c. growth}_{i,t} \\ \Delta \textit{ overall fiscal balance} - \textit{to} - \textit{GDP ratio}_{i,t} \\ \Delta \textit{ tax revenue} - \textit{to} - \textit{GDP ratio}_{i,t} \\ \Delta \textit{ total government revenue} - \textit{to} - \textit{GDP ratio}_{i,t} \end{bmatrix},$$

in which i = {1, 2,..., N} is the country index; t = {1, 2,..., Ti} the time index for each country i; j = {1, 2,...,M} the index for the disaster damage dimension used to identify the disruptive years (which here is one only, based on the human loss index à la Fomby and others 2009); $\alpha_{j,i}$ a fixed effect coefficient (capturing the unobserved (time-invariant) heterogeneity); $\varepsilon_{j,i,t}$ a vector of errors; $Y_{i,t}$ a vector including the four endogenous variables; and $X_{j,i,t}$ the severe disaster year dummy along the loss dimension j (as defined above). The panel-VARX is run with 300 bootstraps.

D. Modeling of Macroeconomic Effects of Adaptation in Morocco

To understand the effectiveness of adaptation investment (Box 3), this paper calibrates a Debt-Investment-Growth-and-Natural-Disasters (DIGNAD) model of Marto, Papageorgiou, and Klyuev (2017) to the economy of Morocco.

Model Assumptions

DIGNAD extends the Debt-Investment-Growth (DIG) model of Buffie and others (2012) and provides a general equilibrium framework to evaluate macro-fiscal implications of alternative investment programs. To capture the case of Morocco, production in the economy is assumed to be carried out by firms in the agricultural and non-agricultural sectors, using private and public capital, besides labor. In the model, droughts affect the economy by reducing productivity in the agricultural sector. Public capital can be of two different types, based on how it affects economic resilience to climate disasters: standard and adaptation capital. A five-year period is assumed to allow either capital to accumulate.

Empirical Methodology

Calibrations and simulations capture the macroeconomic implications of two alternative investment scenarios: (1) a standard public investment plan of 1 percent of GDP per year for five consecutive years in projects that are not—mirroring historical experience—geared at enhancing the country's economic resilience to droughts; and (2) an adaptation investment plan of the same size and duration in infrastructure projects meant to equip the agricultural sector with more robust irrigation systems that continue to operate also during drought occurrences. For simplicity, both infrastructure plans are assumed to be completed right before the realization of a drought shock that takes place in year six.

Annex Table 4.4. Parameters for Model Calibration

Parameter	Value
Initial return on standard infrastructure investment	30.0
Initial return on adaptation infrastructure investment	68.0
Public standard investment to GDP ratio	4.6
Public adaptation investment to GDP ratio	0
Grants to GDP ratio	0.6
Consumption tax (VAT) rate	20.0
Public debt to GDP ratio	82.5
Private external debt to GDP ratio	6.4
Real interest rate on public domestic debt	4.4
Real interest rate on public external debt	2.8
Remittances to GDP ratio	6.1
Imports to GDP ratio	42.0

Sources: Moroccan authorities; and IMF staff calculations.

Model Calibration

The DIGNAD model is calibrated at an annual frequency, using recent data capturing salient features of the Moroccan economy. Further parameters and their values (Annex Table 4.4) are used to pin down the initial steady state. The share of financially constrained consumers is set at 71.4 percent, as proxied by the fraction of Moroccans without accounts at financial institutions (Statista 2021). The unavailable parameters are calibrated using averages for emerging market economies are reported below:

- Initial return on standard infrastructure investment: set at 30 percent as in the seminal DIGNAD paper of Marto, Papageorgiou, and Klyuev (2017).
- *Initial return on adaptation infrastructure investment*: set at 68 percent, in line with reports on hydro-infrastructure investments (World Bank 2005)
- *Adaptation investment*: assumed to be 25 percent more costly for the government (Cantelmo, Melina, and Papageorgiou 2019).
- *Efficiency of both types of public investment*: set at 60 percent in line with Melina and Santoro (2021).
- *All other parameters*: follow Marto, Papageorgiou, and Klyuev (2017).