Climate Change and the Cost of Capital in Developing Countries

Assessing the impact of climate risks on sovereign borrowing costs

UN environment

Imperial College Business School | Centre for Climate Finance & Investment

SOAS University of London

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Authors

Bob Buhr*
Research Fellow
Imperial College Business School

Charles Donovan
Director
Centre for Climate Finance & Investment Imperial College Business School

Principal Teaching Fellow
Department of Management

Gerhard Kling
Professor of International Business and Management
SOAS University of London

Yuen Lo
Research Consultant
SOAS University of London

Victor Murinde
AXA Professor in Global Finance
SOAS University of London

Natalie Pullin
Research Associate
Imperial College Business School

Ulrich Volz*
Head of the Department of Economics
SOAS University of London

Senior Research Fellow
German Development Institute

* Lead authors.

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Acronyms

ADRF	African Disaster Risk Financing Initiative
COP	Conference of the Parties
CPI	Consumer Price Inflation
CVF	Climate Vulnerable Forum
EbA	Ecosystem-based adaptation
ESG	Environmental, Social and Governance
FAO	The Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
IADB	Inter-American Development Bank
IFC	International Finance Corporation
IMF	International Monetary Fund
IPCC	Intergovernmental Panel Climate Change
ND-GAIN	Notre Dame Global Adaptation Index
NGOs	Non-Governmental Organizations
OECD	Organization for Economic Co-operation and Development
PPP	Purchasing power parity
S&P	Standard & Poor's
UN	United Nations
UN-REDD	United Nations Programme on Reducing Emissions from Deforestation and Forest Degradation
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme (also referred to as UN Environment)
USAID	The United States Agency for International Development
USD	United States (of America) Dollars
V20	Vulnerable 20

Executive summary

This report represents the first systematic effort to assess the relationship between climate vulnerability, sovereign credit profiles, and the cost of capital in developing countries. Climate risks are multi-dimensional, covering a range of geophysical, social, and economic issues. The intensification of these risks and the degree to which they are accurately priced by financial markets are of increasing concern to global economic stability.

Key messages:

– Integrating climate risks into financial decision-making is crucial to long-term economic and financial stability as these risks affect return on investment. Broader recognition of these risks will be necessary for sustainable development.

– For every USD 10 paid in interest by developing countries, an additional dollar will be spent due to climate vulnerability. This financial burden exacerbates the present-day economic challenges of poorer countries. The magnitude of this burden will at least double over the next decade.

– The climate consequences on poorer countries' cost of capital and overall fiscal health need to be addressed. A range of existing policy and market responses can build climate resilience in vulnerable countries and deliver demonstrable financial benefits.

– Investments that enhance the resilience of climate vulnerable countries are crucial to not only helping vulnerable countries deal with the consequences of climate risks, but also bring down their cost of borrowing.

Core research findings:

– Our econometric modeling suggests that climate vulnerability has already raised the average cost of debt in a sample of developing countries by 117 basis points. In absolute terms, this translates into USD 40 billion in additional interest payments over the past 10 years on government debt alone.

– Incorporating higher sovereign borrowing rates into the cost of private external debt, we estimate that climate vulnerability has cost these countries USD 62 billion in higher interest payments across the public and private sectors. We expect the additional interest payments attributable to climate vulnerability to increase to between USD 146 – 168 billion over the next decade.

– Investments in social preparedness can partially mitigate the impacts of climate vulnerability on sovereign borrowing rates by increasing the social and economic resilience of countries.

– Cooperative efforts to measure, monitor, and transfer climate risks provide an opportunity to prevent a deterioration of sovereign borrowing capacity in affected countries. Monitoring the financial indicators used by the major rating agencies is a crucial tool for anticipating impacts on sovereign credit profiles.

Contents

Introduction

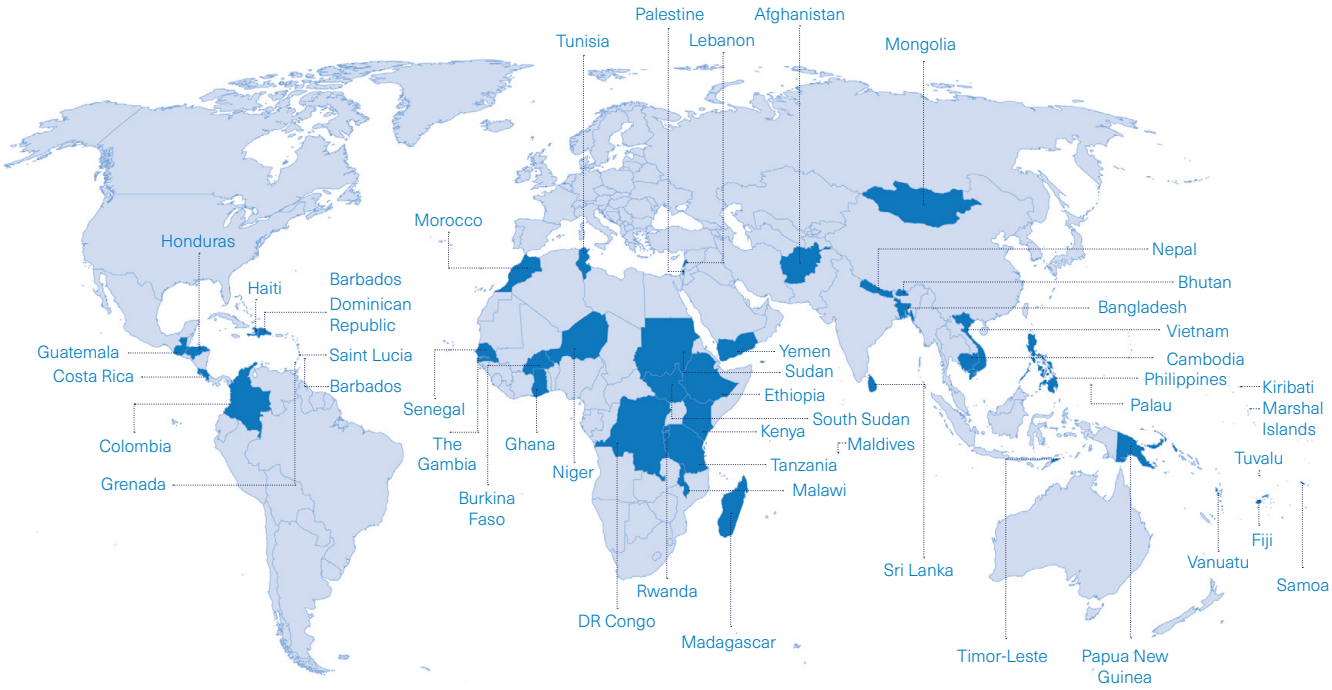
This study investigates whether climate change is impacting on the rate at which countries can borrow from international debt capital markets. We focus on physical climate risks that have the potential to undermine a country's sovereign credit profile. Our analysis considers countries that are members of the Climate Vulnerable Forum (CVF).

The CVF was established in 2009 as an 'international partnership of countries highly vulnerable to a warming planet'.[1] The concept of Vulnerable 20 countries (V20) arose from the Climate Vulnerable Forum's Costa Rica Action Plan in 2015. By March 2018, member nations of the CVF and V20 had risen to total of 48 countries.[2]

V20 countries (as of March 2018)

Afghanistan	Fiji	Maldives	Samoa
Bangladesh	The Gambia	Marshall Islands	Senegal
Barbados	Ghana	Mongolia	South Sudan
Bhutan	Grenada	Morocco	Sri Lanka
Burkina Faso	Guatemala	Nepal	Sudan
Cambodia	Haiti	Niger	Tanzania
Colombia	Honduras	Palau	Timor-Leste
Comoros	Kenya	Palestine	Tunisia
Costa Rica	Kiribati	Papua New Guinea	Tuvalu
Democratic Republic of the Congo	Lebanon	Philippines	Vanuatu
Dominican Republic	Madagascar	Rwanda	Vietnam
Ethiopia	Malawi	Saint Lucia	Yemen

Figure 1. V20 countries



The key aims of the research are:

– First, to analyze the impact of climate change on the cost of debt capital for climate-vulnerable countries, through the analysis of potential impacts on sovereign credit ratings.

– Second, to quantify any change in cost of capital in climate-vulnerable countries and forecast such changes into the future.

– Third, to discuss policy interventions at the national and international scale that could mitigate potential fiscal impacts.

Our study investigates whether physical climate risks currently are incorporated in country-level credit ratings and sovereign bond yields of V20 countries. We employ a mix of quantitative and qualitative methods to explore the mechanisms by which physical climate impacts may impair fiscal health. Our work concludes with a set of case studies that identify the mechanisms by climate change impacts that manifest themselves as financial risks. We consider three physical impacts in five countries:

Flooding – Vietnam and Bangladesh

Drought – Guatemala and Kenya

Severe weather events – Barbados

While there is a substantial body of research on the economic impacts of climate change on developing countries, there has been very little work to date on translating estimates of economic loss into fiscal measures. Our analysis seeks to isolate how climate change may impact the rate of interest demanded by investors on government-issued debt.

Our analysis focuses exclusively on the physical impacts of climate change, such as extreme weather shocks and severe climatic trends, which have the potential to impair country-level credit ratings and increase sovereign bond yields. We do not address broader impacts of climate change, such as carbon pricing, technological disruption, and shifts in consumer demand. While these 'transition risks' will likely have equal, and in some cases greater, impact on the fiscal health of developing countries, the methodologies for quantifying these impacts are only now emerging for country-level analysis. A study by HSBC[3] is a notable example of recent work in this area.

This report discusses three closely related topics. They are climate impacts, climate vulnerability, and climate risks. We define **climate impacts** as the physical manifestations of man-made climate change. They include rising sea levels, increased coastal flooding, and increased incidence of drought. Climate impacts generate economic costs. Climate vulnerability is an aggregate measure of a country's propensity to be affected by climate change. **Climate vulnerability** encompasses the level of sensitivity (as determined by geographic, demographic and economic factors) as well as the capacity to cope and adapt.

Finally, **climate risks** are negative financial outcomes that are attributable to man-made climate change. While it has become commonplace to speak of 'climate risk' as a catch-all phrase in financial markets, the use of the singular term is, in fact, a gross simplification. Climate risks are highly heterogeneous and affect economic sectors in different ways. For example, the loss of oil revenues from a shift to electric vehicles (a transition risk) bears little resemblance to loss of fisheries revenues from ocean acidification (a physical risk). Quantifying climate change as a priced risk factor in financial markets therefore requires specification of unique variables.

In this study, we define climate risk as the marginal increase in the rate of interest on sovereign debt that is attributable to national climate vulnerability.

In the sections that follow, we address the following questions regarding this climate risk in developing countries:

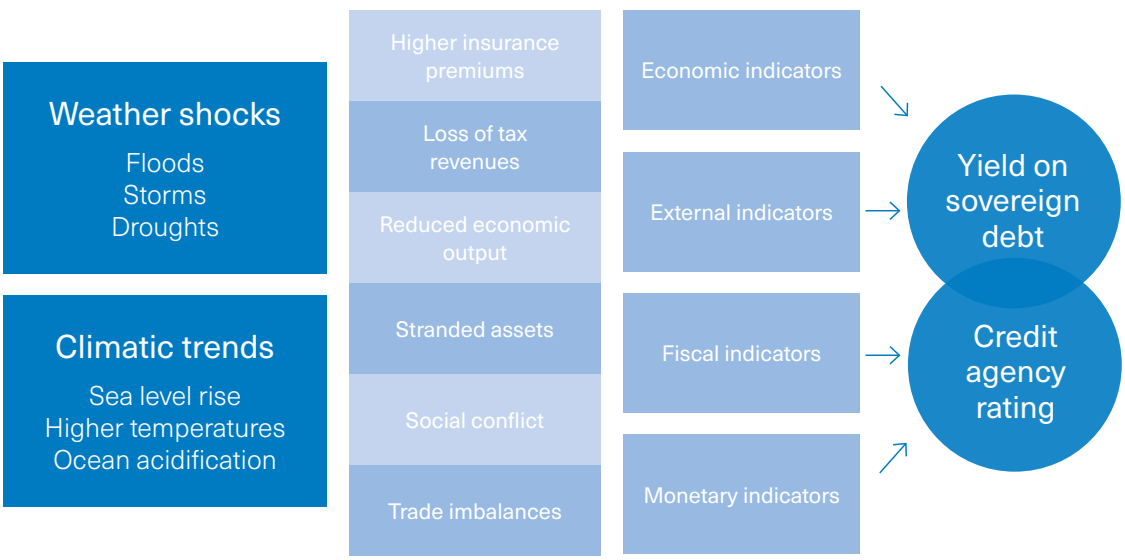
Do credit rating agencies perceive a relationship between climate change and a country's cost of sovereign borrowing?

Can the cost of climate vulnerability be quantified within sovereign borrowing rates?

What policies might alleviate the impact of climate change on the cost of borrowing?

Figure 2. below, provides a simplified schematic of the relationship between physical climate impacts and country-level financial indicators, as explored in this report.

Figure 2. Relationship between physical climate impacts and country-level financial indicators



2. Climate change and sovereign credit ratings

In summary

To date, no downgrade by a major credit rating agency has been attributed to climate risks. As the major rating agencies do not generally itemize climate risks in their published country assessments, sovereign credit ratings are likely to be incorporating these risks in their assessments, but capturing them in other areas. At the sovereign level, climate change is an asymmetrical, downside risk. If climate-related rating actions are taken in the future, as the agencies themselves have indicated is likely, these actions will almost certainly be negative.

Credit ratings are an assessment of the credit risk of a borrower. There is a strong relationship between sovereign credit ratings and the market rate of interest. Understanding how ratings agencies measure (or might measure) climate impacts is vital for understanding real or potential climate change vulnerability in financial markets.

Rating agencies have recently begun to take note of climate change and its potential role in credit assessment. Rating agency comments have suggested that a range of sovereign issuers, particularly emerging market sovereign issuers, are potentially vulnerable to negative rating actions as a result of climate impacts. Rating agencies have also noted that mitigating factors potentially could offset these negative climate trends.

Moody's has neatly summarized the types of climate impacts likely to be felt by countries:

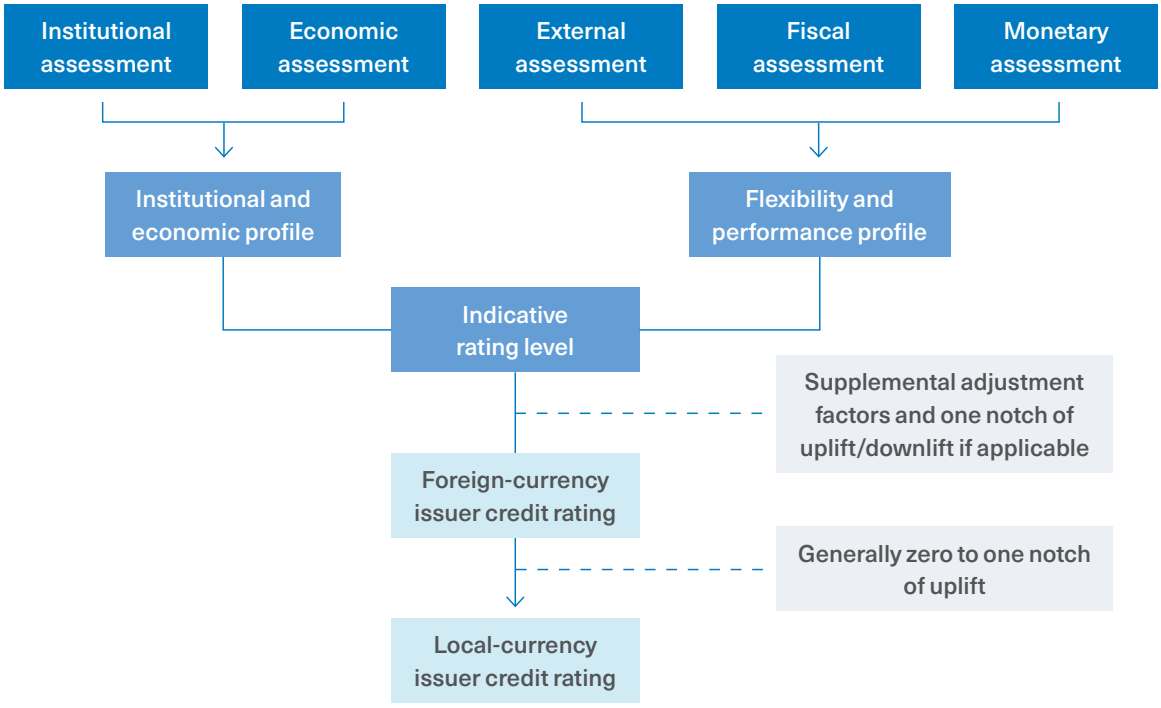
"The physical effects of climate change can be broadly grouped into two categories: climate shocks and climate trends. Climate shocks, in the form of storms, floods, droughts, and other climate-related disasters, are acute, costly and more conspicuous than trends. While climate trends including higher global temperatures and rising sea levels are multi-decade phenomena and less visible from one year to the next, one of the manifestations of climate trends is a higher frequency of shocks."[4]

Rating agencies such as S&P Global Ratings (S&P) and Moody's, whose role in capital markets is to assess the relative likelihood of the ability of borrowers to repay debt obligations, are aware of the potential risks posed by climate change. S&P has noted in a recent report that "climate change, in particular, could have significant implications for sovereign ratings in the decades to come".[5] In addition, both agencies have published occasional research pieces on particular climate topics. For example, Moody's recently published a report on climate risks potentially affecting small island nations.[6] Nonetheless, climate risks have not yet been specifically indicated in Sovereign Ratings Methodologies, the formal criteria published by rating agencies that delineate the factors relevant to credit rating assessment, although S&P includes vulnerability to 'constant natural disasters or adverse weather conditions,' areas where some climate impacts will manifest themselves, in its recently updated methodologies.[7]

More specifically, both Moody's and S&P have published several reports on the potential credit impacts of natural catastrophes,[8] although we note that natural catastrophes and climate impacts are not interchangeable terms. Changes in climate affect both average temperatures and extreme temperatures, and climate change is increasing the risk of natural catastrophes such as extreme weather events, including droughts, flooding and heat waves.[9] However, natural catastrophes such as earthquakes and the incidence of tsunamis are unaffected by climate impacts.

In its studies focused specifically on the impact of climate change on sovereign credit ratings, S&P has indicated that climate change could become a factor in credit profiles at the sovereign level, especially for lower-rated emerging market countries. S&P also noted that the ratings pressure created by climate change factors would be negative.[10] **However, the agency noted that this was not likely to be a near-term event within the current five-year horizon of sovereign credit ratings.** Moody's has made similar comments about the increased vulnerability of lower-rated countries, noting that "In general, sovereign issuers with smaller, less diversified economies and geographies, lower incomes and quality of infrastructure, and lower fiscal flexibility are more susceptible to the credit implications of climate change".[11]

Figure 3. Sovereign issuer credit rating framework
Five key areas to determine a sovereign's creditworthiness



Source: S&P Global Ratings, *Sovereign Rating Methodology,* 18 December 2017

In a recent report, Moody's itemized those areas relevant to sovereign credit profiles where climate impacts might be expected to materialize:

We identify four primary channels by which the effects of physical climate change are transmitted to sovereigns' credit profiles. These are: 1) the potential economic impact (for example, weaker activity due to a loss of agricultural production); 2) damage to infrastructure assets as a direct result of the physical destruction incurred from climate shocks; 3) rising social costs brought about, for example, by a health crisis or food security concerns; and 4) population shifts due to forced displacements resulting from climate change.[12]

Even more recently, Moody's has expanded its list of climate-vulnerable countries, and notes, "A common characteristic among the most susceptible sovereigns is their economic reliance on the agricultural sector, which is typically not irrigated and is thus rain-fed. In addition, undiversified economies are disproportionately affected by the increasing frequency and/or severity of natural disasters impacting growth and causing lasting damage to infrastructure".[13]
As we demonstrate in our case studies, agriculture is particularly vulnerable to climate risks and a corresponding loss of economic resilience, and as a result may also provide the best indicators of evolving climate risks in some countries.

In practice, climate risks are rarely discussed in individual country reports, or in rating actions, although these risks are the subject of numerous general commentaries. When they are, these are almost always situation-specific. For example, Moody's has recently commented that Cape Town's credit profile could come under stress in the event the ongoing drought in South Africa persists.[14] An ongoing Brazilian drought was discussed by S&P in a comment on Brazil's electricity distribution system, in 2016.[15] Bangalore's water issues have been well documented;[16] and, in fact, Moody's discussed India's water and drought issues in general in 2015.[17]

In a joint report from the UN Environment Finance Initiative and the Global Footprint Network in 2012 on integrating ESG issues into sovereign credit analysis,[18] the authors note the paucity of comments from ratings agencies at the time. A second report in 2016 noted that while rating agencies had issued some reports on potential impacts of climate change on credit quality, "Research on the broader economic impacts of long-term environmental degradation is, however, still rare".[19] However, it is now clear that both S&P and Moody's are becoming increasingly vigilant about climate impacts and their possible fiscal and economic consequences.

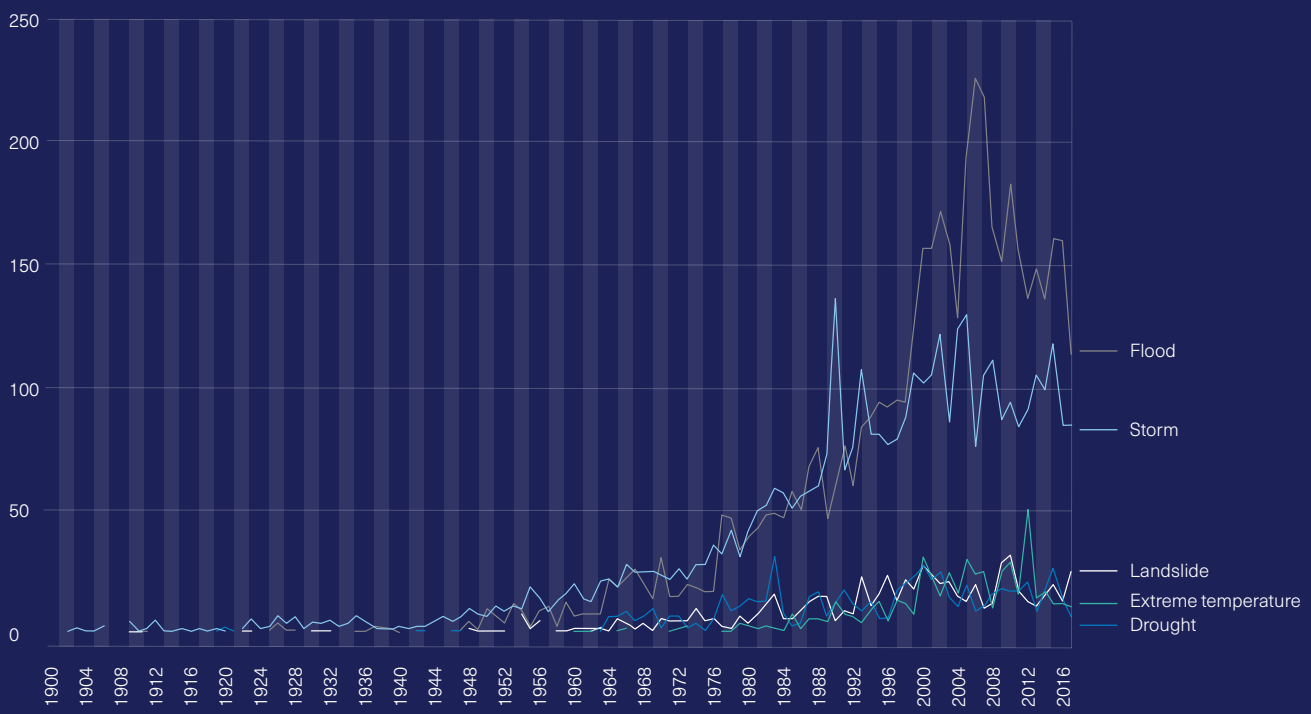
3. Climate vulnerability and the cost of sovereign borrowing

In summary

Our analysis confirms that countries with higher vulnerability to climate change risk bear an incremental cost on government-issued debt. These costs are above and beyond the rates attributable to macroeconomic and fiscal fundamentals. This incremental debt yield carries over into the cost of private debt. Greater social preparedness mitigates this source of risk to developing countries, but only partially. Our findings distinguish between the economic losses V20 countries suffer from climate change, and the fiscal burdens they carry due to their exposure to climate vulnerability. Recognizing climate vulnerability in investment decision-making will help direct financial resources more effectively. Further strengthening of national adaption capacity and resilience is an appropriate response to climate-related fiscal impacts.

The frequency of natural catastrophes has increased significantly over the past 50 years. While the causes of these hazards are complex, there is widespread consensus in the scientific community that anthropogenic climate change has led to an increase in temperatures of oceans and the atmosphere, which have contributed to an increase in the frequency and severity of extreme weather events.[20] Figure 4 shows a pronounced increase in droughts, extreme temperatures, floods, landslides and storms since the 1970s.

Figure 4. Number of weather-related catastrophes, 1900–2017

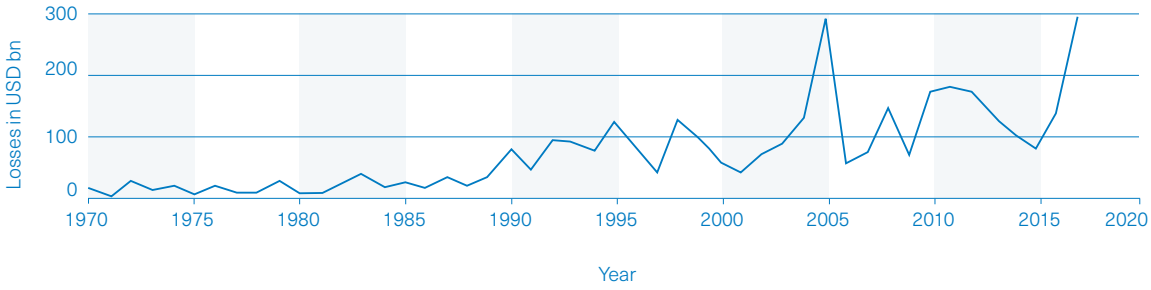


Source: Compiled with data from EM-DAT: The Emergency Events Database – Université Catholique de Louvain (UCL) –CRED, D. Guha-Sapir – www.emdat.be, Brussels, Belgium, 2018.

Note: The count includes events that meet at least one of the following criteria: (i) 10 or more people reported as dead, (ii) 100 people reported as affected, (iii) a declaration of a state of emergency, or (iv) a call for international assistance.

Figure 5 shows the increase in economic losses due to major weather-related events over the last five decades, which also displays a clear trend.[21] As documented in a range of economic studies, future increase in climate-related natural disasters could have large negative effects on economic growth.[22] While natural disasters do not always negatively impact GDP growth, when they do, the negative impacts are larger for developing countries.[23]

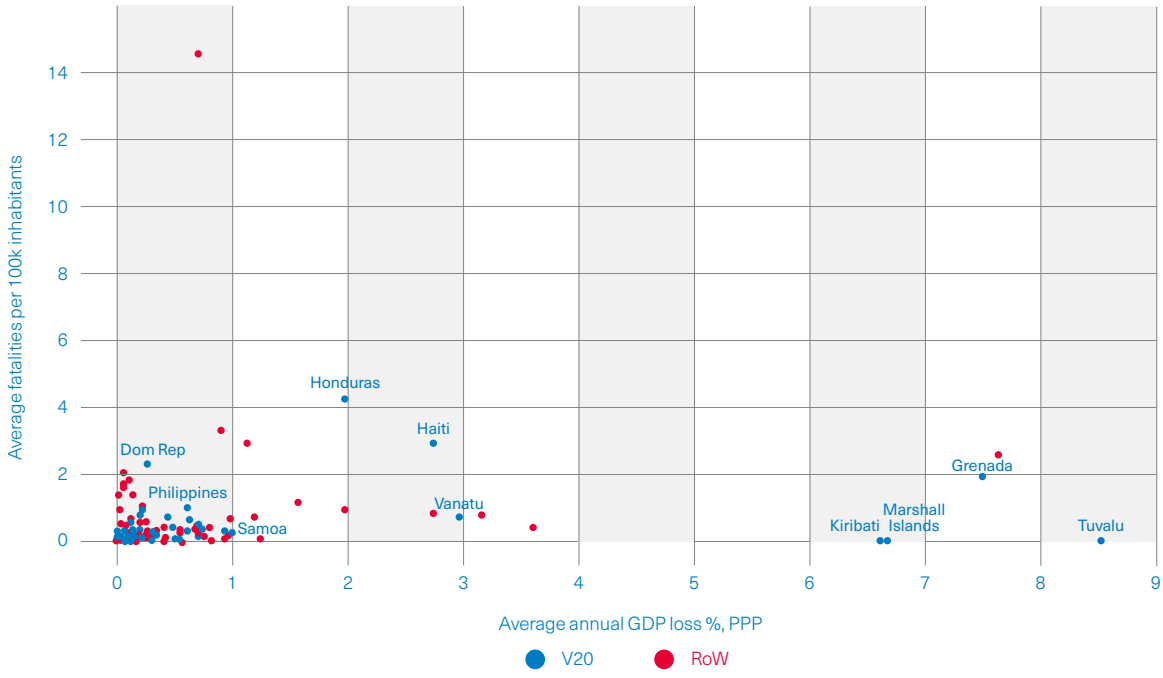
Figure 5. Total economic losses due to major weather-related events (insured and uninsured), USD inflation adjusted, 1970–2017



Source: Compiled with data from Swiss Re.

V20 countries are particularly exposed to the effects of climate change. Between 1997 and 2016, major weather events negatively impacted the national incomes of Tuvalu, Grenada, the Marshall Islands and Kiribati by over 6% a year.[24] Although there are large differences between the highly diverse members, this is not just a matter of economic statistics. Extreme weather events also entail substantial human fatalities. Figure 6 and Table 1 illustrate the burden to selected V20 countries from extreme weather events over the last 20 years.

Figure 6. 20-year average fatalities per 100,000 inhabitants and percentage GDP losses due to major weather events, 1997–2016



Source: Compiled with data from Germanwatch's Global Climate Risk Index database.
Note: V20 countries selected on the basis of available data in 2016.

Table 1. V20 average annual weather-related human fatalities and economic losses, 1997–2016

Country	CRI	Deaths		Deaths per 100k		Losses in USD mil		GDP loss %	
	Score	Avg	Rank	Avg	Rank	Avg	Rank	Avg	Rank
Honduras	12.2	302	14	4.3	2	561.1	31	2.0	12
Haiti	13.5	280	15	3.0	5	418.8	36	2.7	10
Philippines	20.2	860	7	1.0	18	2,893.4	8	0.6	35
Bangladesh	26.5	642	9	0.4	38	2,311.1	10	0.7	32
Vietnam	31.8	313	13	0.4	44	2,029.8	14	0.6	38
Dominican Republic	34.0	211	19	2.3	7	243.5	53	0.3	59
Guatemala	34.3	98	30	0.7	26	402.9	40	0.4	42
Madagascar	37.8	79	36	0.4	39	196.4	61	0.7	26
Fiji	37.8	8	90	1.0	19	119.5	77	2.0	11
Cambodia	38.0	54	44	0.4	41	242.7	54	0.8	24
Grenada	41.0	2	132	1.9	9	78.5	90	7.5	3
Afghanistan	44.2	280	15	1.0	16	100.3	84	0.2	67
Nepal	45.8	228	18	0.9	20	108.6	81	0.2	68
Vanuatu	55.5	2	137	0.7	24	15.9	132	3.0	8
Kenya	56.0	57	40	0.2	76	354.7	44	0.4	50
Sri Lanka	59.3	49	46	0.3	61	315.6	46	0.2	71
Colombia	59.5	107	27	0.3	63	609.1	30	0.1	87
Saint Lucia	61.0	1	144	0.7	28	17.8	130	1.0	18
Mongolia	66.8	8	93	0.3	57	80.2	88	0.3	53
Papua New Guinea	67.7	24	66	0.4	42	36.8	110	0.2	73
Ethiopia	69.7	91	31	0.1	92	180.6	65	0.2	69
The Gambia	75.5	5	105	0.3	49	7.3	146	0.3	52
Samoa	76.3	0	156	0.3	62	8.6	144	1.0	17
Yemen	77.0	41	52	0.2	73	114.0	78	0.1	93
Niger	77.2	15	72	0.1	97	47.0	101	0.4	48
Malawi	78.8	11	76	0.1	111	61.8	95	0.5	40
Sudan	94.0	47	48	0.1	85	82.8	86	0.1	130
Costa Rica	95.0	6	96	0.1	82	50.4	98	0.1	106
Bhutan	95.5	2	137	0.3	60	5.0	154	0.2	81
Burkina Faso	98.0	8	92	0.1	125	40.2	106	0.2	70
Morocco	98.0	17	70	0.1	124	172.1	66	0.1	102
Ghana	103.0	30	62	0.1	84	32.1	114	0.1	137
Tanzania	104.2	25	65	0.1	116	61.7	96	0.1	116
Kiribati	112.0	0	174	0.0	174	10.6	140	6.6	5
Marshall Islands	112.2	0	174	0.0	174	9.0	143	6.7	4
South Sudan	113.5	11	80	0.1	102	16.6	131	0.1	133
Tuvalu	114.2	0	174	0.0	174	2.6	161	8.5	1
Rwanda	118.5	11	78	0.1	91	3.3	157	0.0	147
Comoros	119.3	1	147	0.2	78	0.7	171	0.1	121
Tunisia	122.5	4	115	0.0	145	64.2	94	0.1	118
Senegal	126.7	5	103	0.0	138	15.4	133	0.1	124
Lebanon	127.0	2	129	0.1	122	27.3	117	0.1	136
Congo, Dem. Rep. of	131.0	33	58	0.1	130	5.7	150	0.0	159
Barbados	142.7	0	173	0.0	161	3.7	155	0.1	103
Palau	167.2	0	174	0.0	174	0.1	181	0.0	150
Maldives	169.2	0	174	0.0	174	0.6	173	0.0	160
Timor-Leste	171.5	0	171	0.0	170	0.3	176	0.0	171

Source: Compiled with data from Germanwatch's Global Climate Risk Index (CRI) database.
Note: Countries are ranked out of 182. Losses in USD purchasing power parity.
The lower the CRI score, the higher a country's level of exposure and vulnerability to extreme events.

While a growing literature has investigated the impact of climate change on economic growth and estimated the economic losses associated with extreme weather events,[25] there is a dearth of research that investigates the effect of climate vulnerability on the cost of sovereign debt. The cost at which governments can access finance does not only affect their ability to invest in climate mitigation and adaptation, but also has a range of negative spillover effects. A high cost of capital in the public sector constrains social investments in areas such as infrastructure, education and public health. The governmental cost of borrowing also acts as a proxy for the country risk premium, which has direct ramifications on investments undertaken by the private sector. Empirical evidence has shown that the most critical variable affecting the Weighted Average Cost of Capital – which is a crucial variable for investment appraisal – is the sovereign risk assigned to each country.[26] Understanding the extent to which climate vulnerability impacts the sovereign cost of borrowing is not just vital for helping to develop appropriate policies at the sovereign level, but also to develop appropriate policies and mechanisms for unlocking private finance.

Methodology

To formally investigate the relationship between climate vulnerability, adaption capacity and the cost of sovereign debt, we calculated bond yields for 46 countries. The sample is made up of a selection of V20 countries, the Group of Seven (G7) and a group of middle-to-low income countries not in the V20. Among the V20 countries, our sample includes 17 countries with openly traded debt.[27] It also includes an additional eight V20 member countries whose yields can be tracked using multilateral concessionary bond yield observations from the International Monetary Fund (IMF). The complete group of countries is shown in Table 8. Estimation and testing is conducted within the sample period 1996-2016.

We developed a linear econometric model with a series of macroeconomic control variables, including per capita income (on a purchasing power parity basis), gross government debt to GDP, government revenue as share of GDP, government expenditure as share of GDP, the government's primary balance as share of GDP, consumer price inflation, and foreign direct investment as share of GDP, to gauge the effects of climate vulnerability on sovereign bond yields.[28] Our model employs the Notre Dame Global Adaptation Index (ND-GAIN) to generate our variables for climate vulnerability and social preparedness.[29] It is currently the most comprehensive and granular database for these purposes.

ND-GAIN has three sub-components of interest for this study – they are the Sensitivity index, the Capacity index and the Social Readiness index. The ND-GAIN sensitivity index, which acts as our proxy for climate vulnerability, is based on 12 measures.[30] We combine this statistically with the ND-GAIN capacity index, which is based on a further 12 measures, using principal component analysis.[31] The ND-GAIN Social Readiness index acts as our proxy for country-level climate preparedness. It comprises variables including social inequality, information and communications technology infrastructure, education, and economic innovation. The data for the indices are drawn from the United Nations, the Food and Agriculture Organization, the World Health Organization, the World Bank, and peer-reviewed academic research.[32]

Further details on the methodology and the data are presented in Appendix 1, along with the main estimation results. A technical paper with details of this analysis and a detailed description of all variables used is available online **https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3198093** [33]

Table 2. Empirical model sample countries

Country	Type of debt cost observation		V20 member	Outstanding debt 2016 (V20 only), in USD billions		
	Marketable	Multilateral		External total	Public & guaranteed	Multilateral
Argentina	✓					
Bangladesh	✓		✓	41.1	28.6	26.5
Brazil	✓					
Burkina Faso	✓		✓	2.8	2.5	2.5
Canada	✓					
China	✓					
Colombia	✓		✓	120.3	70.9	6.8
Costa Rica	✓		✓	25.6	11.1	1.2
Dominican Republic	✓		✓	28.0	17.2	1.8
Egypt	✓					
Ethiopia		✓	✓	23.1	21.8	15.8
Fiji		✓	✓	0.9	0.7	0.3
France	✓					
Germany	✓					
Ghana	✓		✓	21.4	17.0	8.7
Guatemala	✓		✓	21.2	8.1	1.3
Honduras		✓	✓	7.6	6.0	3.4
India	✓					
Indonesia	✓					
Italy	✓					
Jamaica	✓					
Japan	✓					
Kenya	✓		✓	22.3	18.3	12.7
Lebanon	✓		✓	32.0	27.2	0.8
Malawi		✓	✓	1.8	1.5	1.5
Maldives		✓	✓	1.2	0.9	0.7
Mexico	✓					
Mongolia	✓		✓	23.9	4.5	2.1
Morocco	✓		✓	46.3	30.1	9.0
Nepal		✓	✓	4.3	3.6	3.6
Nigeria	✓					
Pakistan	✓					
Peru	✓					
Philippines	✓		✓	77.3	33.4	8.4
Papua New Guinea		✓	✓	19.7	1.9	1.2
Rwanda	✓		✓	2.8	2.4	1.9
Senegal	✓		✓	6.6	6.1	4.9
South Africa	✓					
Tanzania	✓		✓	16.5	11.2	9.1
Thailand	✓					
Tunisia	✓		✓	28.1	18.3	5.5
United Kingdom	✓					
United States	✓					
Vanuatu		✓	✓	0.2	0.1	0.1
Venezuela	✓					
Vietnam	✓		✓	87.0	48.0	35.0
Total				661.9	391.7	164.8

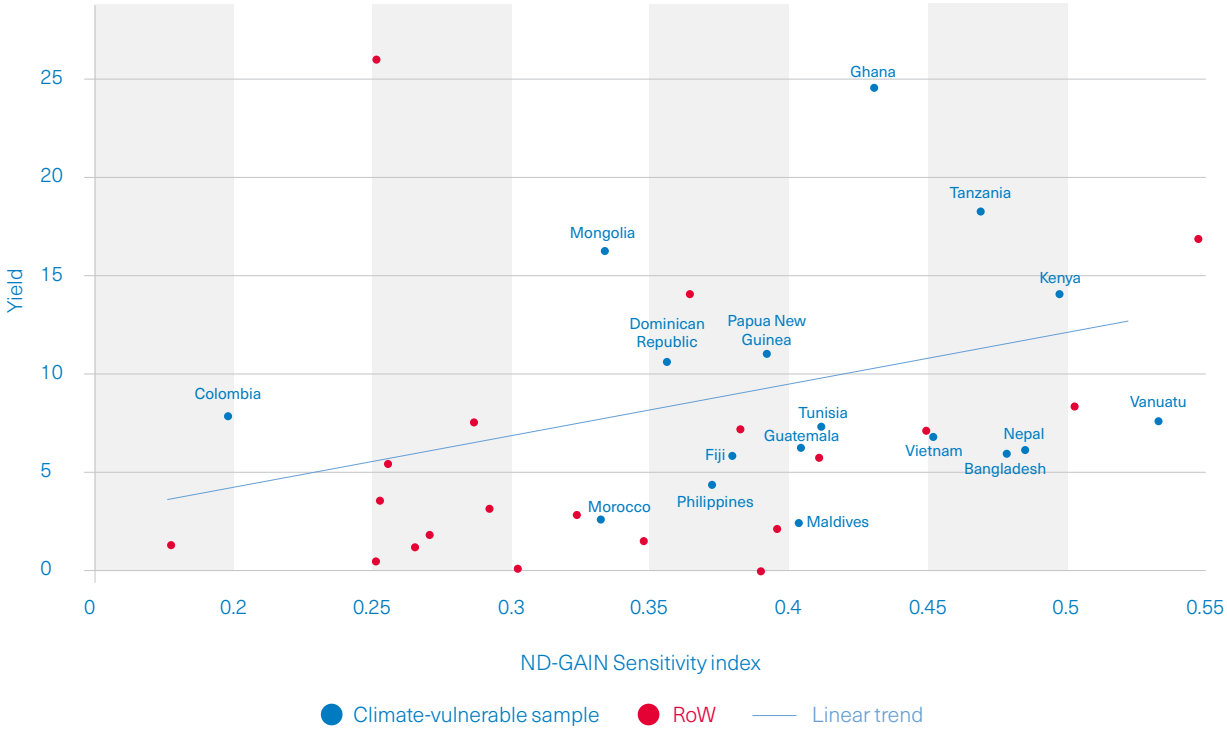
Source: Compiled with data on outstanding debt in 2016 from the World Bank Development Indicators.
Note: External total debt is the sum of public, publicly guaranteed, private non-guaranteed, use of IMF credit and short term debt – that is owed to non-residents.

Results

Our econometric analysis provides evidence regarding the impact of climate vulnerability on the cost of sovereign debt. We estimate a linear model to explain sovereign bond yields using a set of control variables. We link measures of climate vulnerability and social preparedness with cost of debt. Our primary conclusion is that countries with higher degrees of climate vulnerability face higher sovereign borrowing costs. Our econometric analysis finds that climate vulnerability, after controlling for a range of potentially confounding variables, has a positive and significant impact on sovereign yields. We also find that measures of social preparedness have a negative and significant effect on bond yields.

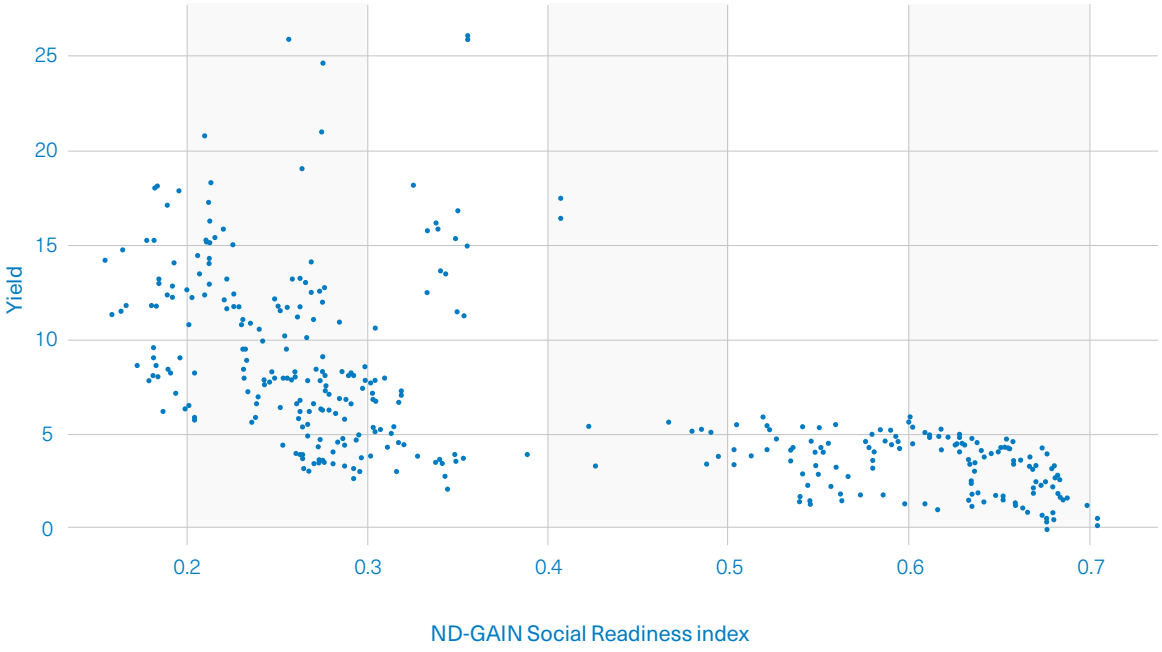
The main findings are illustrated in Figures 7 and 8. Figure 7 shows that countries with greater sensitivity to climate impacts tend to have higher sovereign borrowing costs. Figure 8 shows that countries that are well prepared to deal with the risks of climate change enjoy low borrowing costs; less well-prepared countries are often encumbered by high cost of debt.

Figure 7. Cost of debt and ND-GAIN Sensitivity index, 2016



Source: Compiled with data from Bloomberg and ND-Gain.

Figure 8. Cost of debt and ND-GAIN Social Readiness index, 1996–2016

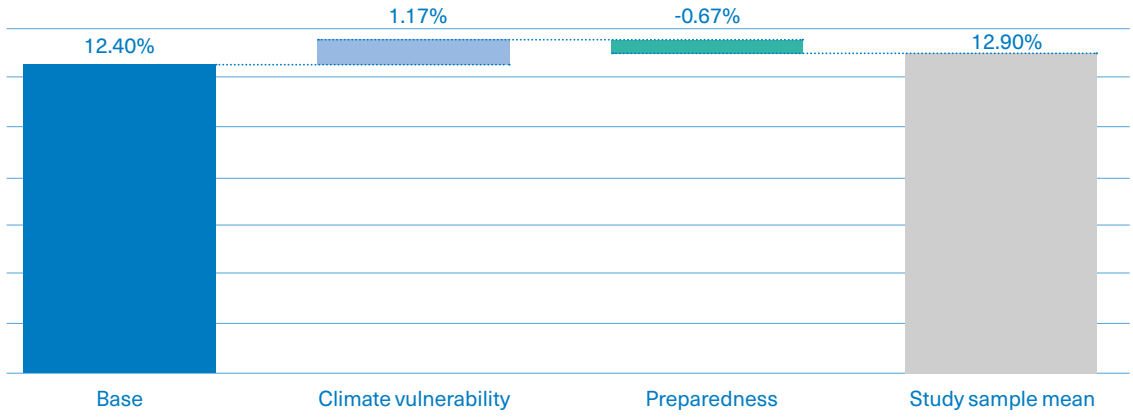


Source: Compiled with data from Bloomberg and ND-GAIN.
Note: Excludes multilateral debt.

Figure 9 shows our base estimate of the expected cost of sovereign debt based on macroeconomic control variables for V20 countries. On average the model predicts a base cost of debt of 12.40%. Climate vulnerability increases the cost of debt, on average, by 117 basis points.[34]

This increase is considerable, representing an uplift of nearly 10% on overall interest costs. Our modeling suggests that investing in social preparedness reduces the cost of debt by 67 basis points, on average.

Figure 9. Estimated impact on cost of debt



Source: Authors' own work, based on own estimations with data compiled from Bloomberg, ND-GAIN, IMF and the UN.

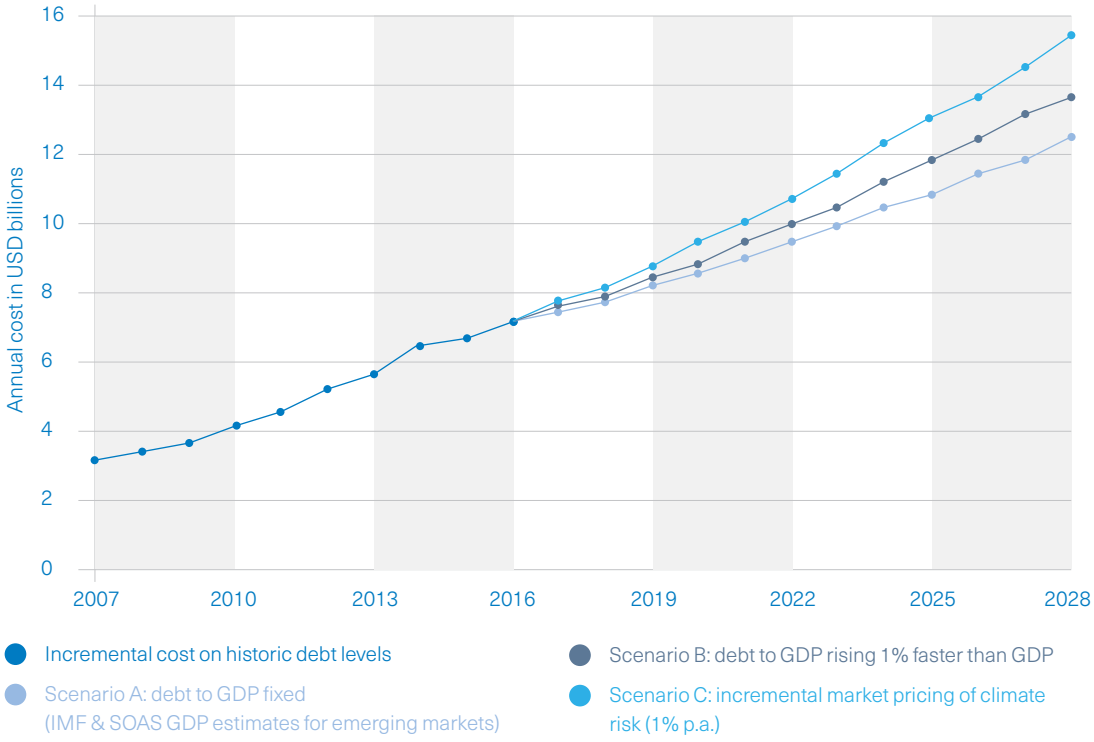
Based on our empirical analysis, we estimate that over the last 10 years, climate vulnerability has cost the V20 countries over USD 62 billion in higher external interest payments. This figure includes more than USD 40 billion in additional interest payments over the past 10 years on government debt alone. Our model estimates this incremental debt cost for the V20 countries was almost USD 9 billion in 2016 alone.

Our estimate of total additional interest payments is gained by multiplying the marginal cost of debt to the stock of external debt outstanding amongst V20 countries. We use the stock of outstanding external public, publicly guaranteed and private debt as reported by the World Bank's World Development Indicators database over the 10-year period 2007 to 2016.[35] Our estimate is a lower bound as many V20 countries face financial exclusion.[36] Moreover, indirect effects of climate on macroeconomic variables are not considered, only direct impact. Furthermore, we use historic debt levels understating current levels of debt, given that we are estimating the cumulative effect over the last 10 years. The 25 V20 countries sampled in our empirical model reflect 86% of the external debt reported by the World Bank for the 48 countries of the V20.

In Figure 10, we chart the historical increase in the cost of debt associated with climate risk as well as three scenarios for how it might develop over the next decade.

The low case Scenario A employs the central forecast for emerging market GDP growth in the IMF's most recent World Economic Outlook. The IMF estimate of GDP growth extends to 2022, after which we have applied a slight deceleration to 2028. We apply a constant marginal cost of debt associated with climate vulnerability (1.17%) and a stable debt to GDP ratio. Scenario B allows total indebtedness to grow 1% faster than GDP. Scenario C assumes that the interest rate premium associated with climate vulnerability grows by 1% each year, thereby increasing in absolute terms by 1.7 basis points per annum. This would be consistent with the rising frequency and severity of catastrophes, and higher volatility in fiscal revenues and expenditures as countries attempt to absorb and address changes in climate. Scenario A implies a 10-year incremental climate risk debt costs of USD 146 billion for the period 2019-2028. The forecast estimates are USD 156 billion for Scenario B and USD 168 billion for Scenario C, respectively.

Figure 10. Forecasted increases in annual interest costs due to climate vulnerability, 2007–2028



Source: Authors' own work, based on own estimations with data compiled from Bloomberg, ND-GAIN, IMF, the UN and the World Bank's World Development Indicators.

The use of macroeconomic and fiscal controls, such as GDP per capita and government primary balance, means that we have adjusted for differences in both wealth and fiscal policies. To test the robustness of the results, we re-ran the analysis using the US Treasury bond yield as a control for the risk-free rate and made a maturity adjustment to examine the impact of variations in bond maturities. The statistical results were largely unchanged. We also used the share of agricultural value added as a percentage of GDP as an alternative measure of climate vulnerability, with the results being very similar. Such a measure is correlated with the development of countries over time as well as the fact that the agricultural sector is particularly vulnerable to climate change. Our findings from the technical analysis are robust to alternative econometric approaches.

4. Country case studies

With a better understanding of the overall financial impact of climate vulnerability on developing countries, we also need to assess how the risks will manifest themselves for individual countries, particularly in terms of not only the physical risks themselves, but also in terms of the financial and economic impacts that may affect sovereign governments' ability to address these risks. This is a necessary condition for determining how these countries will develop policies and programmes, perhaps with international assistance, to reduce the impacts of these risks.

While all countries have some measure of climate vulnerability, some countries' situations are particularly acute. These differences reflect factors such as the country's physical size and population, its overall wealth, its existing infrastructure, and the relative effectiveness of its government. For highly vulnerable countries, there is a clear need to monitor the climate risks that impact upon national credit assessment and market responses by the bond markets. The purpose of this section is to identify specific physical climate risks that have the potential to lead to actions by ratings agencies such as Moody's and S&P, and to suggest potential mitigating actions that may reduce the likelihood of such actions. While rating agencies factor climate risks only generally in their approach to sovereign ratings, we believe they also will factor any positive impacts of adaptation or mitigation activity on relevant economic or fiscal indicators into their credit assessments.

For each country considered in these case studies, we highlight one particular physical climate risk and its potential impacts. We consider economic indicators that can be monitored to evaluate the impact of each risk over time. We take as our model the notion of a 'keystone species' discussed by ecologists in ecosystem analysis: the particular species that either dominates, or exemplifies the health and resilience of, a particular ecosystem. For each of our case studies, we propose a climate impact and a physical indicator that will exemplify that impact, either fiscally or economically. We propose that the relative health of that physical variable can be taken to represent the relative degree of physical resilience underlying a country's social and economic resilience.

Our basic model is shown in Figure 11. While we recognize that most countries face a number of climate risks, we believe this simplified approach to assessing the potential credit impacts of climate risks could prove useful for affected countries. We note that assessing a broader range of risks, a process that would more realistically capture the range of impacts that countries are experiencing, would involve more complex analysis. However, we believe that any such analysis will embody the approach taken here.

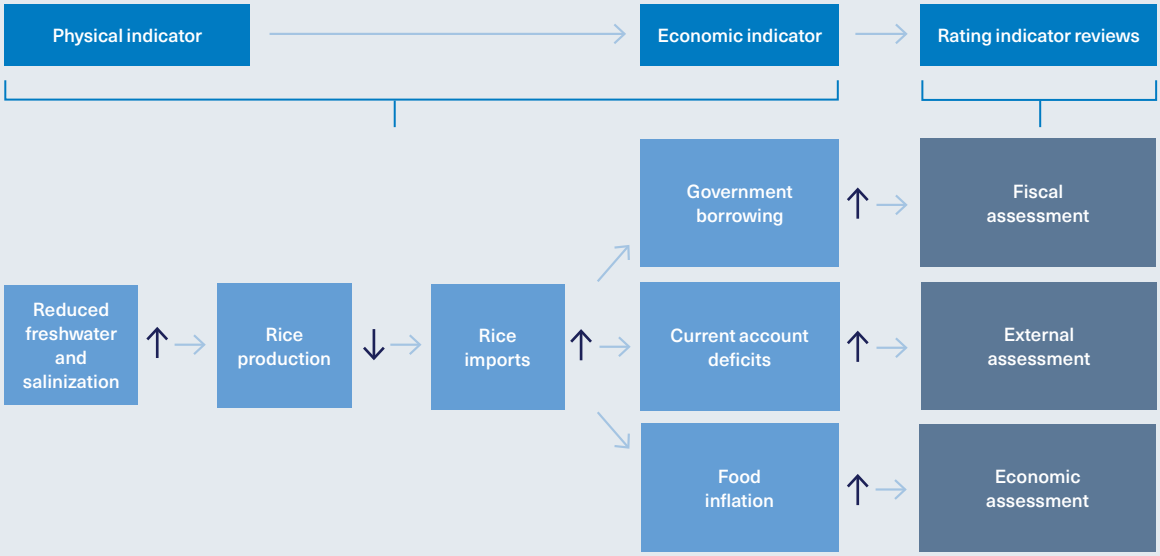
For each country considered in these case studies, we highlight one particular climate risk and its potential impacts. We consider economic indicators that can be monitored to evaluate the impact of each risk over time. Our basic model is shown in Figure 11.

Figure 11

4.1 Bangladesh

In summary

Bangladesh's credit rating is likely to come under pressure in the event of sustained rice production declines from climate change – either from salinization or from increased freshwater flooding. The impact of such declines would negatively affect critical measures of focus for rating agencies, including possible increased government borrowing, increased domestic food inflation, and deteriorating external trade balances. More aggressive efforts to limit rice production declines consequently are crucial to the long-term stability of Bangladesh's credit profile, and its ability to borrow internationally.



Current S&P Ratings assessment: BB- (Foreign long-term rating)/BB- (Domestic long-term ratings)

Climate risk assessed: River flooding

Key near-term indicators:

Rice production levels and yields

River salinization

Food inflation

Longer-term climate issues:

Sea level rise

Increased frequency and severity of tropical storms

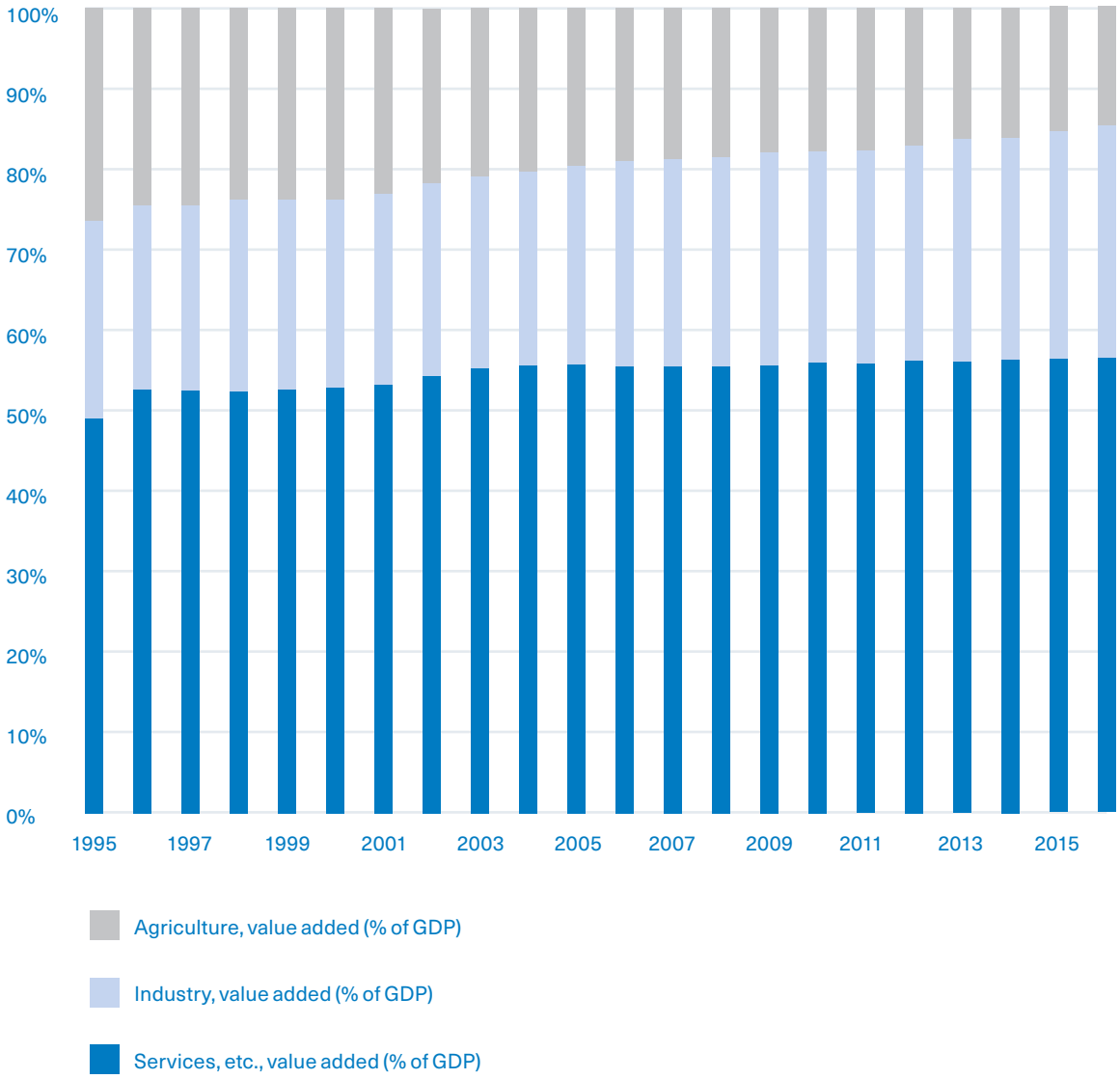
Storm surge severity

Economic vulnerabilities

Bangladesh's economy is beginning to diversify thanks to growth in its service and manufacturing sectors. The garments industry accounted for nearly 85% of total goods exports in US dollar terms in 2016.[37] Agriculture generates 15% of GDP, but its relevance to daily life in Bangladesh is far greater as it provides employment to 42% of the population.[38]

Bangladesh is the world's fourth largest producer of rice at 30 million tons/year, but almost all of it goes on domestic consumption. The country still needs to import rice, alongside other staples such as wheat.[39] The national food staple accounts for 75% of all cropping areas. Similarly, Bangladesh's fisheries sector currently contributes around 4% to GDP, while providing 55% of animal protein intake in Bangladesh.[41]

Figure 12. contribution to GDP by sector in Bangladesh, 1995-2016



Source: Compiled with data from the World Bank.

Government debt to GDP has been steadily declining over the past decade, reducing from 37% in 2008 to about 27% in 2016, suggesting some room for additional debt issuance. However, government interest payments on debt still account for nearly 20% of revenues per year.[42] Bangladesh runs a trade deficit of about 5% of GDP. Any major disruption to agriculture has the potential to create significant social pressures requiring increases in government spending. Domestic inflation remains a concern as well, particularly relating to food prices. Overall inflation hit a high in 2011 of 16%. Food price inflation, which reached over 9% in 2014, has more recently settled at around 7%.

Climate vulnerabilities

Flooding causes considerable economic dislocation, with concomitant impacts on government spending. Bangladesh ranks 160 out of 181 countries in the ND-GAIN Country index,[43] with very low rankings on both vulnerability and readiness. At a rank of 167 for the ND Readiness index, it is the 25th least ready country, and the 37th most vulnerable with a rank of 159 for the ND Vulnerability index. The ND-GAIN ranking has remained unchanged over the past two decades, with a mild improvement in Vulnerability being offset by a decline in readiness, particularly economic readiness, derived from a World Bank indicator measuring openness to external investment. As the World Bank has noted, climate-related risks are likely to depress agricultural activity by about 3% annually through 2050.[44] River flooding is a significant climate risk, largely because Bangladesh contains the second largest river basin in the world. 80% of the country is on floodplains. Equally problematic is the fact that about one third of the land is exposed to tidal incursions, which refers to the mixing of saline and fresh water, and which is expected to expand as tidal zones spread inland from sea level rise.

Overall, climate change could decrease agricultural GDP by 3.1 % each year during 2005–50.[45] That's a cumulative USD 36 billion in lost value-added. According to the World Bank, salinization issues in Bangladesh will most likely lead to significant shortages of drinking water and irrigation problems by 2050 and may result in a decline in rice yield by 15.6 %.[46] A separate analysis suggests Bangladesh may incur a financial impact of about USD 3.2 billion on average annually due to cyclones and floods, about 2.2 % of GDP.[47]

Increased intensity of storms and the potential for greater saltwater intrusion in rivers are likely to disrupt the normal annual salinization cycle. In addition, inland monsoon flooding is likely to become an even greater risk: a 1998 storm inundated[48] over two thirds of Bangladesh and cost 4.8% of GDP.[49] Climate change places an additional 4% of land area at risk from the inundations caused by monsoon flooding.[50]

Adaptation and resilience

In the case of Bangladesh, there are many climate impacts that have the potential to cause economic damage and widespread human suffering. From the narrower perspective of fiscal health, the impact of freshwater flooding on rice production stands out as a key economic indicator. Bangladesh imports rice for domestic consumption to make up for any domestic production shortfalls, even in a normal agricultural year. In the event of significant domestic shortfalls, imports will need to increase, negatively affecting the country's trade deficits. In addition, material increases in food inflation remain a concern.

Based on historical data, natural hazard events in Bangladesh cost more than USD 10 billion in economic losses from 2000 to 2013, but the total funding available, for relief, rehabilitation, and reconstruction for the same period was only USD 2 billion.[51] Many of the initiatives to date are preliminary, such as some of the measures being taken to combat rising salinity levels, and some involve external financing – in February 2018, a total of USD 80 million was approved for climate change adaptation initiatives in Bangladesh, Georgia, and Zambia through the Green Climate Fund, led by UNDP.[52]

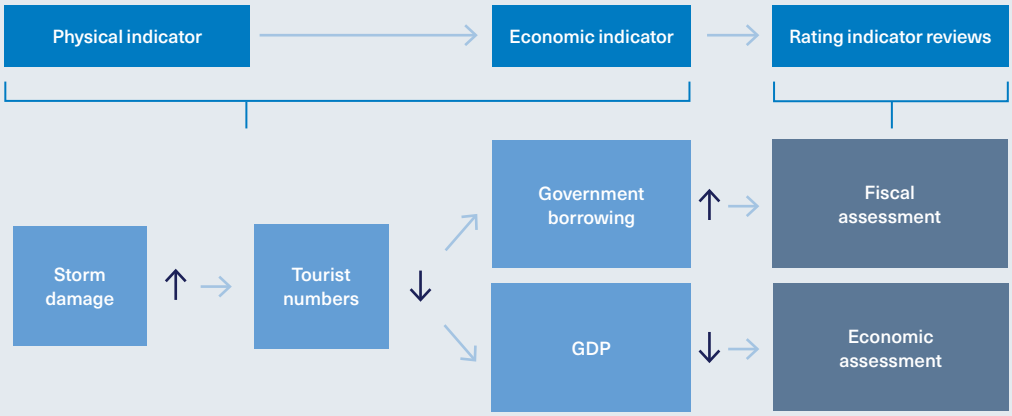
Some of these efforts could be further buttressed by greater utilization of existing natural capital resources to rebuild the natural infrastructure. There is currently a program underway to mitigate some of the current threats to mangrove forests,[53] which range from upstream agricultural practices to industrial development at the periphery of these areas. More broadly, there is now increasing interest in assessing the potential for natural capital factors to contribute to adaptation and mitigation efforts.[54] Work is being done to improve the effectiveness of salt-tolerant rice grains[55] and devise projects to build solar-powered desalination plants.[56]

Currently, three disaster risk finance solutions are considered effective in Bangladesh: sovereign disaster risk contingent credit, parametric sovereign risk insurance, and disaster risk microfinance portfolio insurance. Bangladesh is currently piloting a flood insurance program, with the support of several external agencies and insurers, under the direction of the Swiss Agency for Development and Cooperation.[57]

4.2 Barbados

In summary

Barbados represents a good example of the long-term impacts, and negative rating implications, that a significant one-time economic event can generate. Significant storm damage on the order of that generated by Hurricanes Harvey and Maria elsewhere in the Caribbean in 2017 would have a comparable effect. Developing natural capital approaches to minimizing physical impacts, and broader participation in risk-transfer partnerships, could help ensure more rapid recoveries, which would produce lower impacts on the country's credit profile.



Current S&P Ratings assessment: CCC+ (Negative) (Foreign long-term rating)/CCC (Domestic long-term rating)

Climate risk being assessed: Severe weather events

Key near-term indicators:

Tourist numbers

Major storm damage

Longer-term climate issues:

Increased frequency and severity of tropical storm events

Sea level rise reducing beach area

Economic vulnerabilities

As Moody's discussed in its report on small island nations[58], as well as its separate report on climate risks for Fiji, small island nations are expected to suffer a range of impacts from climate change. In aggregate, these impacts could reduce small islands' GDP by 4% by 2030. In 2016, the value of disaster effects arising from Tropical Cyclone Winston in Fiji, was estimated to amount to F$2 billion (USD 0.9 billion), which is more than 20% of Fiji's current GDP.[59]

Unlike Fiji, Barbados does not have significant natural resources. Rather, Barbados has significant exposure to two industries – tourism and financial services. Following the unfolding of the 2007-2008 financial crisis, GDP growth in 2009 was -4.1%, compared to an average of 2.8% over the period 2002-2007 (5.7% GDP growth rate in 2007.) Barbados has yet to fully recover from the impact of this event. GDP growth was 0% for several years following the crisis, and only in the past two years has GDP growth reached, or raised above, 1%. During this period, Barbados's S&P rating declined from A- in 2008 to CCC (Negative Watch) today. This ratings decline occurred without the physical damage that affected Fiji, or Puerto Rico, the Dominican Republic and other, more northerly Caribbean islands, in 2017. Government debt currently stands at about 154% of GDP, and the country's new government has indicated 'urgent action' is required to deal with the debt problem.[60] Barbados currently is limited in its ability to issue new debt without external assistance.

Climate vulnerabilities

Barbados ranks 54 out of 181 countries in the ND-GAIN Country index of climate vulnerability and its readiness to improve resilience, with relatively modest vulnerability and strong readiness measures.[61] However, this ranking has declined over the past decade, almost entirely due to the weakening economy and declining governance measures, offsetting a mild improvement in vulnerability measures. Barbados benefits from having a relatively low percentage of land within five meters of sea level – about 15%. Still, Moody's assesses Barbados's vulnerability to climate risks as relatively high, although not as high as some other Caribbean nations. However, as the Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC) has pointed out, 60% of resort properties in the Caribbean would be damaged by a one-meter rise in sea level.[62] Insured losses in Barbados over the past several decades have been substantially lower than elsewhere in the Caribbean. But the likelihood of comparable damage will increase as the likelihood of severe storms increases.

Adaptation and resilience

Barbados has undertaken a number of adaptation and mitigation measures to anticipate the impacts of climate change. These include some measures of coastal defense, and a recent initiative to pilot solar and wind power on the island. Given the island's current dependence on imported oil to generate the island's electricity, reducing such dependence would improve Barbados' external balances by removing the potential volatility associated with oil imports. Broader economic and ecological resilience measures may be harder to achieve, given the difficulties in diversifying a small island economy.

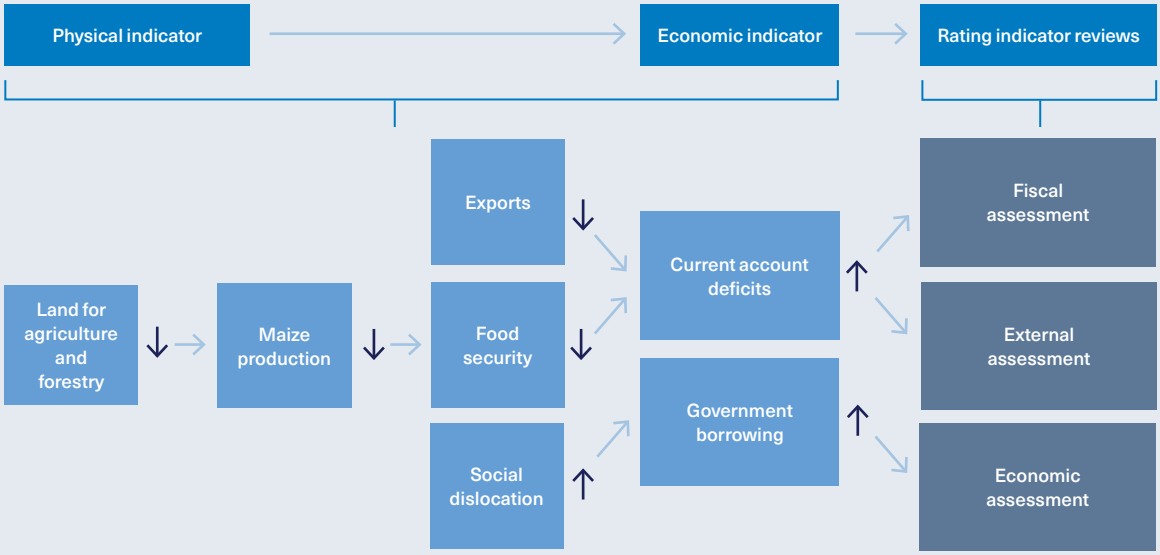
The government's recent initiative to assess the natural capital of Barbados, particularly its marine ecosystems, appears a welcome development. For example, a project being funded by the Inter-American Development Bank (Enhancing Capacity for Coastal Management with Ecosystem Services in Barbados) in conjunction with a number of scientific organizations and NGOs will assess coastal zone management from a natural capital perspective, including the potential for natural infrastructure development. Further initiatives along these lines for the island's full range of ecosystems would facilitate decision-making regarding keeping tourism central to the Barbadian economy and providing some degree of resilience to the island's economy in the event of severe events.

Barbados participates in the Caribbean Catastrophe Risk Insurance Facility. However, as noted earlier, insured and uninsured losses have been low relative to other Caribbean nations.

4.3 Guatemala

In summary

Guatemala's drought exposure has the potential to generate sufficient economic costs that would lead to increased government borrowings and a negative impact on agricultural exports; either event could weaken the country's credit profile and increase borrowing costs. More critically, negative impacts on maize production would result in higher government borrowing for measures to address social dislocation impacts. Minimizing drought impacts through aggressive reforestation efforts should remain a priority for helping to retain credit stability.



Current S&P Ratings aessessment: BB- (Foreign long-term rating)/BB (Domestic long-term rating)

Climate risk being assessed: Drought

Key near-term indicators:

Deforestation rates

Maize production yields

Changes in agricultural and arable land

Longer-term climate issues:

Increased drought frequency and severity, increasing social dislocation and social costs

More severe and frequent droughts, with increased government borrowings to deal with impacts of increased social dislocation

Economic vulnerabilities

Guatemala's GDP growth has been relatively strong in recent years. Much of this growth has been driven by exports of agricultural products (with bananas and sugar cane the leading crop exports) and light manufactured goods. In the latter category, Guatemala competes with other emerging market countries for developed country manufacturing facilities.

Nonetheless, the Guatemalan economy demonstrates some significant vulnerabilities, which have contributed to GDP per capita being about half the Latin American average. The country suffers from significant income inequality and a critical need for infrastructure expansion. The IMF noted in 2017, "At less than 1% of GDP, public infrastructure investment in Guatemala is among the lowest in Latin America and emerging markets. The resulting infrastructure gap constrains Guatemala's future growth and living standards"[63] Sovereign debt to GDP currently stands at about 24%, and has remained relatively constant over the past decade, suggesting some room for additional borrowings.

Climate vulnerabilities

Guatemala ranks 112 out of 181 countries in the ND-GAIN Country index. Despite this ranking improving over the past two decades, it is still the 70th most vulnerable country and the 64th least ready country. It has both a great need for investment and innovations to improve readiness and a great urgency for action[64]. Vulnerability remains high in a number of areas, including exposure to warm periods and natural capital depletion. Situated in the 'dry corridor' of Central America, Guatemala regularly suffers from multi-year droughts. Droughts in this region have a direct impact on agricultural production, which employed over 29% of the country's population in 2016 and into 2017.[65] Droughts can destroy up to 50-90% of the harvest in some areas in the dry corridor and may contribute to growing inequalities between the most vulnerable groups who are hardest hit.[66] Over the past decade, losses in Guatemala linked to all climate-related events amounted to USD 5 billion, according to the official statement made by Guatemala at the UN Disaster Reduction meeting during the COP event in Mexico in May 2017.[67]

Critically, agriculture still represents close to 30% of exports[68], thus constituting an important source of foreign earnings and access to foreign capital. Key indicators of the potential economic impacts of climate-related drought risks will come from this economic sector. An impact of recurring droughts has been increased rates of deforestation. Guatemala has lost more than a quarter of its forests since 1990, with forest cover representing only 33% of total land area in 2015, down from over 44% in 1990.[69] Over the longer term, forest loss is a significant contributor to topsoil loss, so total land productivity tends to trend downwards.

Second, while maize production is not necessarily critical to agricultural exports, it is critical to subsistence farming for much of the population. While production of bananas and sugar cane, each representing USD 1 billion in annual exports, have almost doubled over the last decade, other smaller staples like maize have stagnated relatively, with an 8% decrease in overall yield over this period. Negative impacts on maize production and yields are likely to drive up social dislocation costs.

Third, the total amount of land devoted to agriculture, for both domestic consumption and subsistence and for export, is likely to be negatively affected by increasing drought severity and frequency. While there has been an increase in permanent cropland since 2005, there has also been an overall loss of agricultural and arable land during this same period – from 56% of total land area in 2005 to 43% in 2015.

Adaptation and resilience

Guatemala has a national climate change fund to finance adaptation and mitigation projects, and some 80% of the fund will be mandated to fund risk and vulnerability management issues and adaptation projects.

While some efforts have been ongoing for the past 25 years to replant trees, educating the population to the benefits of keeping forest cover has been one of the biggest challenges, along with lack of funding.[70] This makes reforestation a means to both mitigate and adapt to the effects climate change. This is one of the objectives of the recent National Adaptation Plan,[71] part of an adaptation capacity-building program funded through the Global Environment Fund and implemented by UNDP.[72]

Guatemala has invested over USD 270 million over the past 16 years in reforestation, benefiting an estimated 900,000 people whose livelihoods depend directly on forests.[73] There are also ongoing programs with both multilateral agencies and NGOs to expand these efforts. For instance, Guatemala is one of the first countries to implement the Forest Investment Plan[74], backed directly by international institutions including the World Bank, IADB, and the UN-REDD program. NGOs like the Alliance for International Reforestation have also been present for decades to implement programs that increase the resilience among local populations by finding sustainable alternatives to the illegal forest clearing they often depend on.

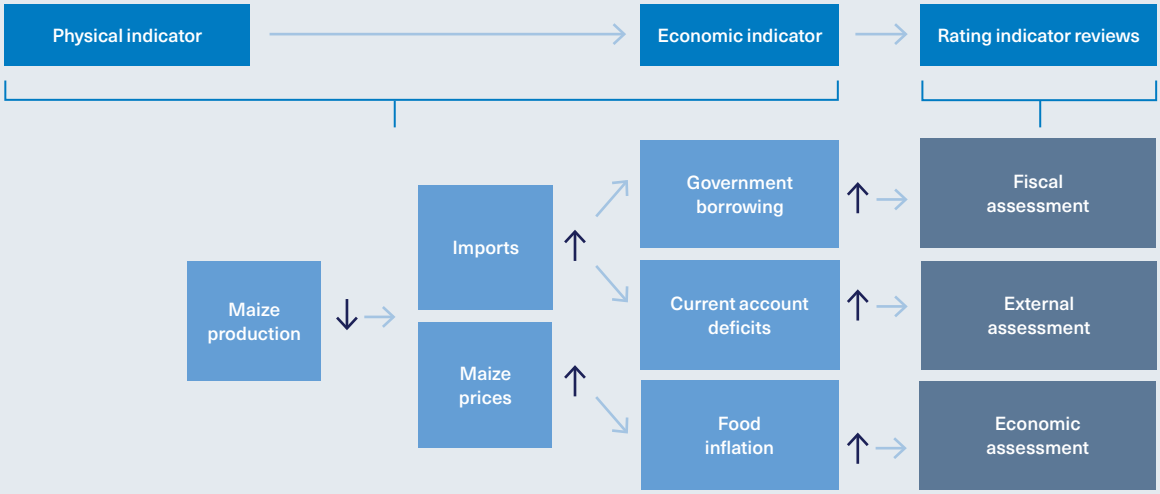
Much of Guatemala's efforts have been devoted to a broader range of climate shocks, not just drought. However, we believe that such an indicator as forest cover and its rate of change may be a useful indicator not only of climate impacts, but also of potential resilience to economic shocks. Guatemala has one of the more advanced efforts at natural capital assessment. Since 2014, the government has been working in conjunction with the World Bank's WAVES program (Wealth Accounting and the Valuation of Ecosystem Services) to update the 2006 Natural Capital assessment.

Guatemala has developed a comprehensive National Strategy for Disaster Risk Reduction, now in its second iteration. In addition, since 2016 microinsurance has been piloted by the Microinsurance Catastrophe Risk Organization (MiCRO), incorporating detailed risk analysis as the basis of payouts to rural farmers in the event of natural catastrophes. This program is similar to a program introduced in Kenya with some success.[75]

4.4 Kenya

In summary

Kenya's vulnerability to drought impacts, particularly in terms of potential food inflation and social dislocation costs, represent a potential risk to Kenya's credit stability through impacts on government borrowing levels, external debt, overall trade balances, and overall inflation. Programs to reduce the impact of drought on these fiscal and economic measures, in part through further risk-transfer programs, will help to prevent ratings deterioration.



Current S&P Ratings assessment: B+ (Foreign long-term rating/B+ (Domestic long-term rating)

Climate risk being assessed: Drought

Key near-term indicators:

Maize production

Maize imports and prices

Longer-term climate issues:

Persistent drought resulting in substantial food shortages

Increased coastal flooding risk, with resultant economic damage

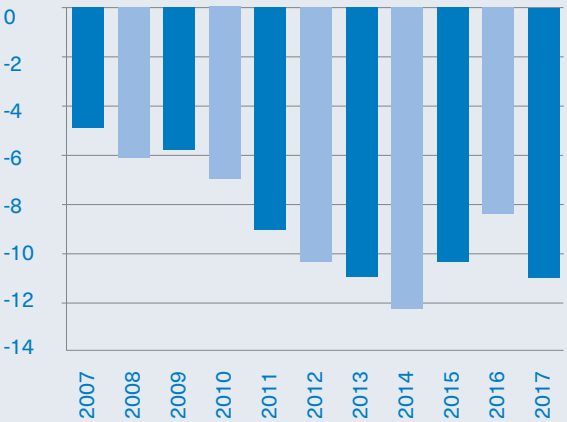
Rising sea levels

Economic vulnerabilities

Kenya has a large rural population (76% as of 2016, according to the World Bank) with 49% of the country's land devoted to agriculture. Agriculture employs about 62% of the population, despite Kenya having a relatively low average level of precipitation.[76]

Kenya also has the largest trade deficit of the countries profiled in our case studies. The average trade deficit was 5.9% of GDP in 2017,[77] reaching as high as 6.2% in February 2018. This increase was driven by a doubling of food imports and higher machinery imports. In addition, exports of agricultural goods were affected by drought. As a result, foreign reserves have been declining.

Figure 13. Kenya's trade deficit



Source: Compiled with data from the World Bank.

However, foreign exchange reserves of USD 7.1 billion (4.7 months of import cover), coupled with arrangements with the IMF of USD 1.5 billion, are seen as some degree of protection against short-term trade deficits. Nonetheless, Kenya remains vulnerable to foreign exchange volatility. Foreign debt continues to rise. S&P has cautioned the country on this issue. Government debt currently stands at about 57%.

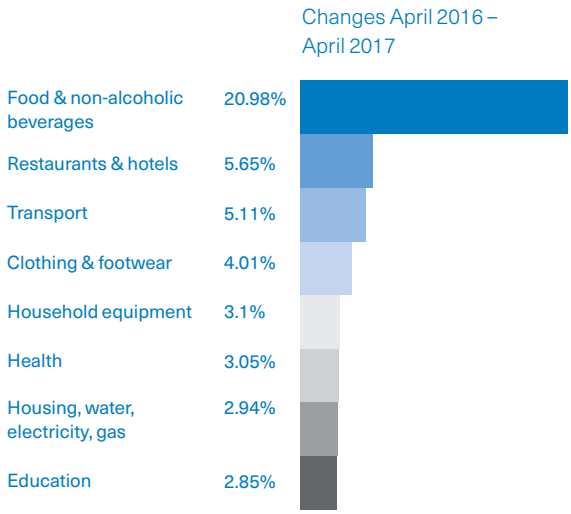
While Kenya's economy has remained a strong performer, with 2017 GDP growth at 4.7%, and CPI down to a manageable 4.5%, millions of vulnerable communities suffered from much higher food inflation during the year that was directly attributable to the persistent drought.

Climate vulnerabilities

Kenya ranks 151 out of 181 countries in the ND-GAIN Country index (in the bottom 20%), a modest decline over the past two decades. While most readiness measures have improved, overall it has a low readiness score and needs to prioritize investment in innovation and education. Kenya's vulnerability measures have deteriorated, particularly those associated with food and ecosystem services[78]. According to the Stockholm Environment Institute, Kenya is exposed to a potential loss of 2.6% of GDP annually through 2030 as a result of the impacts of climate events and trends.[79]

The government declared a drought emergency in February 2017. Climate vulnerability manifests itself in food prices during periods of drought. As the UN Environment ERISC Phase II report suggested, Kenya stands to suffer a 4.4% loss of GDP in the case of a doubling of food prices from drought events. The price of maize and beans (often consumed together) are the most indicative of any drought situation.[80] As shown in Figure 14, Kenya had 21% food price inflation between April 2016 and April 2017.[81]

Figure 14. Soaring food costs pushed inflation rates higher in Kenya



Spikes in food inflation have significant implications for vulnerable populations. Internal migration tends to increase during drought periods, bringing attendant social costs. Drought also is a significant contributor to food insecurity and malnutrition costs, which put a strain on government finances.

Maize imports are a critical measure of drought risk impacts, with higher levels of imports associated with extended periods of drought. Maize prices thus prove to be a key indicator of the impact of drought risk on several credit metrics, particularly food inflation and import requirements. If sufficiently large, these may affect external balances. Outbreaks of fall armyworm, associated with drought, have made a significant impact on yields on maize and wheat. Climate-related pest infestations clearly have an impact on food price inflation.

The impacts of drought are of concern to rating agencies as it impacts government borrowing levels, external debt, overall external balances, and overall inflation. Programs to reduce the impact of drought on these fiscal and economic measures will help to prevent ratings deterioration, with a resulting increase in interest costs. To date, none of these factors has been sufficient to change Kenya's credit profile.

Adaptation and resilience

The Kenyan government has undertaken a number of programs to deal with adaptation issues. USAID is funding a variety of adaptation efforts designed to address river vulnerability issues and natural resource management concerns. Dealing with drought, however, involves multiple levels of resilience preparation. Many of these involve adoption and implementation of the Sustainable Development Goals.

Kenya, unlike Guatemala, is not heavily forested, but deforestation nonetheless has been a trend for a number of years. However, its utility as a drought indicator is more limited because of the low level of forestation in the first place. Still, there are a number of forest preservation programs in place. The International Finance Corporation (IFC) has issued 'forest bonds,' where the proceeds are intended for use for forest conservation in Kenya. In this case, interest is being paid in the form of cash or carbon credits. Even here, though, there was a need for additional external support from BHP, a large mining company, which pays the cash interest. The principal will be paid upon maturity by the IFC.

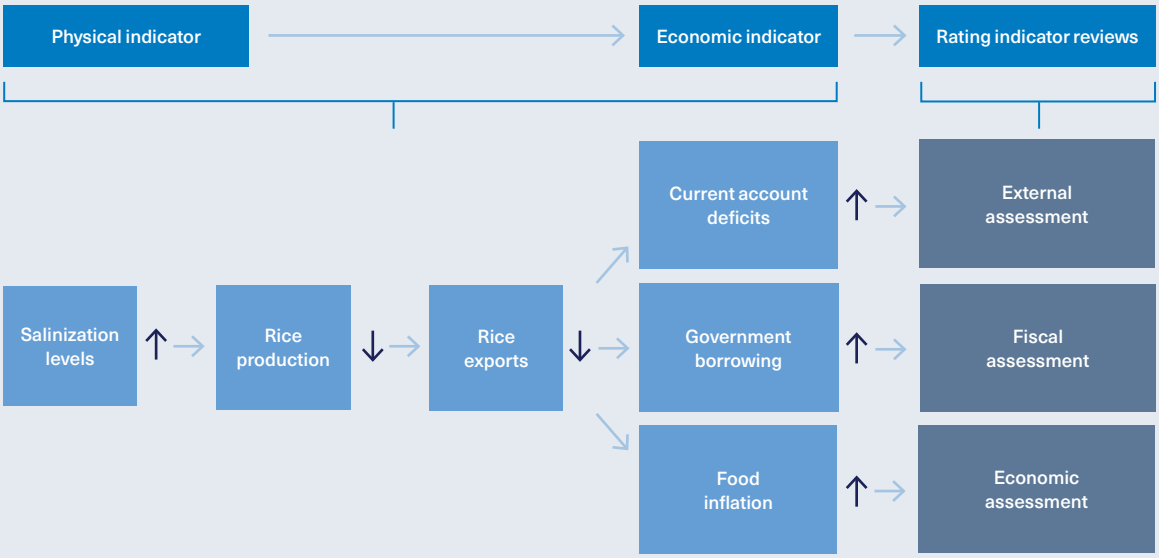
The Kenyan government is involved in several national or pan-East African initiatives to ensure better management of drought emergencies. While these initiatives will have no impact on drought incidence, the government is moving towards a more systematic set of efforts to manage drought emergencies. Other efforts are more targeted, relating to the most recent UN FAO Flash Appeal, which has among its objectives the strengthening of the resilience of drought-affected communities and mitigating the humanitarian impacts of drought emergencies. The overall goal is to reduce 'drought aid dependency'.[82]

There is now a concerted effort to develop local insurance markets, particularly for agriculture. Kenya's Livestock Insurance program[83] currently provides insurance for about 24,000 farmers, but the government plans on expanding the program to include 100,000 farmers by 2020. More financial options are being developed. The FAO's African Disaster Risk Financing Initiative (ADRF) is a notable example.[84]

4.5 Vietnam

In summary

Vietnam's economic profile is likely to be negatively affected by coastal flooding impacts, which will negatively impact rice production, and generate significant social dislocation effects. Current programs in coastal management and salinity infusion need to be aggressively expanded to minimize these economic impacts, which would likely result in credit profile deterioration and increased borrowing costs.



Current S&P Global Ratings assessment: BB- (Foreign long-term rating) /BB- (Domestic long-term rating)

Climate risk being assessed: Coastal flooding

Key near-term indicators:

Increased river salinization from coastal flooding and sea level rise

Rice yields

Loss of land area devoted to agriculture

Longer-term climate and economic concerns:

Changes in agricultural production in response to increased salinization, or reduced land devoted to agriculture

Food price inflation resulting from shortfall in domestic rice production

Increased government borrowing to fund population dislocations

Economic vulnerabilities

Vietnam's GDP has doubled over the past eight years.[85] The country has developed an export markets and implemented government reforms that are creating a transition from a centrally planned economy. A key plank of government reforms were incentives for rice production that would not just meet the needs of the population but create a major export product. Vietnam has been generating trade surpluses since 2012.

Vietnam is now a significant rice exporter to other Asian countries. Rice accounts for 90% of total domestic cereal production. It is the staple food for 95% of the population and an important source of income for 60 million people. Rice farms are generally small in size: only 2% rice farms throughout the country cover more than two hectares land and 47% of farms are smaller than 0.2 hectares.[86] One of the most vital components of Vietnam's economy is based on hundreds of small-scale farms, owned by individual land owners/farmers. The majority of these farms are located in land areas very exposed to coastal flooding and sea level rise risks.

In June 2017 Vietnam was disqualified from further development funding from the World Bank, although it is remains a 'blended borrower' from the Asian Development Bank. However, as rating agency comments have indicated, any increase in external borrowings at present could be problematic for maintaining the country's current ratings. Sovereign debt to GDP currently stands at about 61%, a level that has nearly doubled over the past decade.[87]

Climate vulnerabilities

Vietnam ranks 96 out of 181 countries in the ND-GAIN Country index[88], a ranking that has been improving over the past two decades from an increase in readiness and a decline in vulnerability measures. Nonetheless, two crucial vulnerability measures, projected change in sea level rise impacts, and projected change of flood hazard, remain very high. Investment in dam capacity is required. Despite its recent economic gains, it faces significant vulnerabilities from rising seas, river flooding and the resulting salinization and groundwater issues. Over 15% of all of Vietnam's land is below five meters above sea level. In total, 37% of Vietnam's population – or about 34 million people – live in this area. Coastal flooding risks are expected to increase with the severity of tropical storms, and this may have direct population impacts. Moreover, increased coastal flooding may well affect access to fresh water, with significant impacts on both local populations and local economies.

As with Bangladesh, salinization of rivers and other freshwater sources is significant concern for Vietnam. Salinization has multiple negative impacts for freshwater ecosystems, including the availability of groundwater, its effect on rice yields, and the amount of water available for both human and animal consumption and for irrigation.[89] More than half of Vietnam's rice crop is grown in the Mekong Delta. Forecasts up to 2050 suggest that not only could rice yields decline by an estimated 10-15% as a result of climate trends, but rice prices could increase by as much as one third in that event.[90]

Adaptation and resilience

The Vietnamese government has been monitoring salinity infusion in various river deltas since 1991, and there has been considerable modeling of the extent, and potential effects, of this process. In response, the government has created a Government National Climate Change Committee, to oversee the various National Climate Change Strategies passed by the government over the past 10 years, including a whole range of programs designed for adaptation and mitigation. Many of these programs receive external support from NGPs and foreign government agencies such as USAID. These include coastal zone management programs ranging from full protection; involving strengthening and elevating embankments to withdrawal from potentially affected areas. Given the length of Vietnam's coastline (3,440 kilometres), this is an ambitious program. We note that in conjunction to various agriculture measures described below, the government has introduced various measures directed at reforestation, including mangrove restoration.

In addition, the government has put forward various measures to protect agricultural production, including soil preservation measures, as well as accelerating a shift to more climate-appropriate crops. The government has also begun to implement a variety of water sustainability measures, including upgrading water infrastructure, and adding new infrastructure as appropriate. New for 2018, is a more inclusive approach: ecosystem-based adaptation (EbA)[91]. Traditional flood management structures, such as dikes, which vulnerable communities depend on, can have negative impacts on the environment. Two EbA measures will be implemented in Thua Thien Hue Province jointly with the Disaster Management Centre, the Women's Union and local communities.[92]

All of these measures require financing. The government, in conjunction with the World Bank, has issued a report outlining the various means at its disposal for financing these projects[93], with the majority of expenditures directed at food and water security. We note that development partners have provided about 30% of the funding required for these proposals to date, although whether this level of support will be maintained remains unclear.

Vietnam has begun to undertake broader risk transfer programs. Every year, natural disasters and epidemics have caused significant losses for the Vietnamese agricultural sector and farmers, accounting for 1.5% of the national GDP. Agricultural insurance has become an urgent need. After a pilot during the years 2013-2016, in which 300,000 households gained agriculture insurance worth USD 340m, the state is expected to subsidize insurance fees of up to 20% for farmers and 90% of poor households this year.

5. Conclusions

Vulnerable countries face not just economic losses from climate impacts, but also an increasing fiscal burden. The major credit rating agencies have discussed climate risks as being potentially material to sovereign ratings. Our work indicates that interest rates on V20 government debt are already higher than they would otherwise be, due to climate vulnerability. This effect has a broad impact on national measures of the cost of capital.

We estimate that exposure to climate risks has increased the cost of debt for V20 countries by 117 basis points, on average. In absolute terms, that translated into more than USD 40 billion in additional interest payments over the past 10 years on government debt alone. Incorporating higher sovereign borrowing rates into the cost of private external debt reveals that climate risks have cost debt-issuing V20 countries over USD 62 billion in higher interest payments across the public and private sectors. As we noted in Section 3, these additional costs are projected to balloon to between USD 146 – 168 billion over the next decade.

Vulnerable countries face the unenviable task of managing the financial costs of climate change increase as the physical impacts of climate risks themselves accelerate. National governments need to develop programs that will preserve physical and economic resilience to minimize these costs. Governments wishing to borrow internationally critically need to monitor the fiscal factors that could affect a country's sovereign credit profile. This is particularly true for the large number of climate-vulnerable countries that are not in a position to issue international sovereign debt because they lack an investment grade credit rating or are limited in further issuance by current debt levels.

Improved resilience will not only help safeguard sovereign credit profiles, but also has the potential to increase the rate of return for investment. Overall, we see broad economic, fiscal and social benefits from building greater economic and social resilience to climate change. Our research suggests that investing in social preparedness reduces cost of debt by 67 basis points, on average. In addition to traditional fiscal policies, programs that address social inequality, ICT infrastructure, education and innovation are crucial to strengthening national adaption capacity.

The process of identifying critical indicators that are of interest to rating agencies and bond market participants can be a useful tool for managing climate risks at the country level. In our case studies, we assessed one specific climate impact for each country. In many cases, changes in output in the agriculture sector were identified as having the greatest potential to ultimately lead to actions by rating agencies. In practice, national governments will need to track a much broader range of economic indicators. We hope this report serves as good guide for how that can be done on a bottom-up basis.

Our findings are consistent with other studies that have demonstrated a financial burden to developing countries from climate change.[94] As noted in this report, there are several market and policy initiatives that can play a role in reducing this burden. From a financial perspective, effective climate adaptation initiatives must accomplish at least one of the following three goals: reduce economic costs, improve economic recoveries, and/or transfer financial risks. These goals are not meant to be mutually exclusive. Given that countries will likely face increased costs as climate impacts become more severe, policy responses must be scalable to meet the growing sense of urgency.

Reducing economic losses

In our case studies, we highlighted adaptation programs designed to reduce economic loses from climate events. From a financial perspective, there appears to be a business case for restoring natural capital that acts as climate-resilient infrastructure. While the lag times associated with these investments make cost-benefit analysis difficult, there is a growing opportunity for 'natural climate solutions.'[95] For example, a recent report on flood protection through natural infrastructure noted that the "largest opportunities for funding are in the redirection of post-disaster recovery funds to pre-disaster investments in risk reduction".[96] The authors point to the European Investment Bank's Natural Capital Financing Facility as a model. Investments in adaptation will over the long-term be a more efficient use of expenditures than insurance, which allows for improved speed of economic recoveries but does not act to prevent the occurrence of event-related costs.

As rating agencies repeatedly have commented, the lack of a well-developed physical infrastructure in V20 countries needs to be addressed, not only for greater resilience in dealing with climate impacts, but more generally for reasons of economic development. We note in Section 3 that infrastructure development plays an important role in reducing climate vulnerability. Given the frequent limitations on the ability to borrow, other mechanisms for improving infrastructure need to be considered. In particular, public-private partnerships in areas such as transportation infrastructure may need to be expanded in situations where public borrowing options are limited. In addition to facilitating infrastructure development that reduces economic losses, the inclusion of the private sector may help transfer some of the associated economic risks.

'Green bonds' have been put forward as a possible option to fund not just infrastructure upgrades, but also a wide range of adaptation and mitigation investments. Green bonds are indeed an attractive option for those countries that actually are able to issue international debt. Fiji and Kenya both issued sovereign green bonds in 2017. The majority of countries in the Climate Vulnerable Forum, however, do not have sovereign credit ratings. These countries generally are not able to issue international debt, or, if rated, may be constrained from issuing further amounts. For these countries, such issuance would require external support for the costs incurred through such debt issuance, such as those mentioned below. The International Finance Corporation's 'forest bonds,' discussed previously, could serve as a model for financing structures that employ partial guarantees from higher-credit quality issuers such as multilateral lenders and large corporates.

Improving the speed of economic recoveries

Many initiatives in the V20 countries seek to create the conditions for more rapid recoveries from extreme weather shocks and long-term climatic trends. The development of more sophisticated domestic debt capital markets would help diversify sources of funding and build financial resilience to these external shocks. The recent growth in the number of local currency bond markets in developing countries is an encouraging trend in this direction.[97] However, this option is not available to all V20 countries in the short term. Likewise, GDP-indexed bonds may be useful for V20 countries, but only those that already have access to international capital markets.[98]

Developing markets for local insurance is a necessity for more rapid recoveries from climate shocks and trends. In most V20 countries, insurance is not a realistic option for a broad section of the population. This is a critical issue in countries that regularly experience catastrophic weather events, endure economic losses that are mostly uninsured, and are expecting further increases in the severity/frequency of extreme weather events. In some cases, national governments do provide selected insurance options. Kenya's drought insurance program is one example. Such programs are not widely available across the V20.

Sovereign catastrophe risk pools would enable climate-vulnerable countries to protect public budgets in a disaster situation and to access more rapid financing for disaster response. Catastrophe risk pools allow countries to pool risks in a diversified portfolio; retain some risk through joint reserves/capital; and transfer excess risk to the reinsurance and capital markets.[99] Examples of existing regional risk pools include the aforementioned Caribbean Catastrophe Risk Insurance Facility, the Pacific Disaster Risk Financing and Insurance Program, and the African Risk Capacity.[100] A recent international effort to address this problem is the InsuResilience Global Partnership for Climate and Disaster Risk Finance and Insurance Solutions,[101] which may provide a useful framework for designing risk finance and insurance solutions for V20 countries.

Transferring financial risks

The relatively weak economic situation of V20 countries may require that the costs of climate risks be absorbed more widely. Financial protection can be accomplished most immediately via sovereign risk transfer solutions. Since the 1990s, a number of different mechanisms of sovereign risk transfer have been developed. Insurance-linked securities such as catastrophe bonds, for example, are debt instruments that transfer a specific set of risks (usually natural disaster risks) from an issuer to investors. A recent report from the World Bank reviewed a variety of risk-pooling models of potential use by V20 countries.[102] It is worth noting that these risk-pooling measures do not necessarily reduce economic costs associated with climate shocks, but they do have the potential to transfer a significant amount of the financial costs to other parties.

There is considerable scope for expanding existing risk-transfer solutions. National efforts to preserve sovereign credit profiles will be necessary going forward, given the potential for increased climate-related costs and the need to finance these. Whether these will be sufficient will in part depend on the willingness of the international community to absorb some of the costs of these risks. It may be that the most effective way for the international community to support such initiatives is through measures designed to stabilize and support sovereign credit profiles.

Appendix

Econometric approach

As a baseline specification, a panel ordinary least squares (POLS) model is estimated:

$$Y_t = a + bx_t + yz_t + e_t$$

where the dependent variable y_t denotes country bond yields, b is a $k \times 1$ coefficient vector, x_t is a $k \times 1$ vector of climate-related variables, y is a $p \times 1$ coefficient vector, z_{it} is a $p \times 1$ vector of controls. Although a is a $k \times 1$ vector, all the intercepts are assumed to be identical within this framework. Subscript t is the year. We conduct multiple regressions to test the significance of the set of climate variables and controls.

The model is a linear regression model and hence all the standard assumptions apply (OLS assumptions: linearity, spherical error terms, exogeneity). To obtain the predictions, conditional expected values of the dependent variable are taken considering an average V20 country. Hence, the average of the V20 sub-sample of explanatory variables is used to derive linear predictions of base cost of debt for the average V20 country, climate risk and social preparedness. Mechanically this multiplies the coefficients estimated by the model with the variables themselves. We can then observe the mean, median and standard deviation for members of the V20 group of climate-vulnerable countries. The base effect is the predicted cost of debt minus the partial climate risk and social preparedness effects.

We assume that parameters are constant, i.e. the partial impact of climate risk on cost of debt does not change over time. Furthermore, our model only identifies the direct effect of climate risk on cost of debt; indirect effects through macroeconomic variables are not modeled. This also includes interventions such as IMF support, which is assumed to be exogenous, i.e. independent from climate risk. The results are presented in Table 3.

Table 3. Determinants of yields

	A	B	C	D
SCORE climate risk measure based on ND-GAIN sensitivity and capacity indices	0.146*** (-3.88)	0.176*** (-4.59)	0.135*** (-3.63)	0.081* (-2.07)
ND-GAIN social readiness index	-1.557*** (-5.37)	-1.764*** (-6.06)	-1.541*** (-5.31)	-2.410*** (-6.38)
Per capita gross domestic product	0.000** (-3.3)	0.000*** (-3.74)	0.000** (-3.14)	0.000 (-1.96)
Gross government debt to GDP	-0.010*** (-12.78)	-0.010*** (-12.80)	-0.010*** (-12.83)	-0.010*** (-14.35)
Government revenues to GDP	-0.185*** (-11.34)	-0.171*** (-9.91)	-0.178*** (-10.61)	-0.168*** (-10.21)
Government expenditures to GDP	0.182*** (-12.22)	0.172*** (-11.04)	0.178*** (-11.75)	0.160*** (-10.44)
Primary balance to GDP	0.150*** (-10.88)	0.140*** (-9.77)	0.145*** (-10.40)	0.112*** (-7.22)
Annual change in consumer price	0.006*** (-3.62)	0.006*** (-3.60)	0.006*** (-3.52)	0.006** (-3.02)
Foreign direct investment to GDP	0.024* (-2.20)	0.026* (-2.51)	0.018 (-1.75)	0.019 (-1.90)
IMF multilateral debt dummy		-0.227** (-2.65)	-0.271** (-3.15)	-0.300*** (-3.81)
V20 climate vulnerable forum member dummy			0.197*** (-3.62)	0.162** (-3.12)
G7 advanced economy group member dummy				0.974*** (-5.18)
aic	361.649	357.925	350.024	322.297
bic	400.593	400.763	396.757	372.925
Adjusted R^2	0.739	0.742	0.748	0.767
N	363	363	363	363

Note: Statistics in parentheses. All models refer to POLS using the Huber-White sandwich estimator. * p<0.05, ** p<0.01, *** p<0.001.

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[31] The 12 measures, all equally weighted, are as follows: agriculture capacity (e.g. fertilizer use); child malnutrition; access to reliable drinking water; dam capacity; medical staffs, access to improved sanitation facilities; protected biomes; engagement in international environmental conventions; trade and transport related infrastructure; paved roads; electricity access; disaster preparedness.

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For more information about the research,
please contact:

Dr Charles Donovan
Director, Centre for Climate Finance and Investment
Imperial College Business School
Imperial College London

T: +44 (0)207 589 5111
E: climatefinance@imperial.ac.uk

Dr Ulrich Volz
Head of Department of Economics
SOAS University of London

T: +44 (0)207 898 4721
E: uv1@soas.ac.uk

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