The climate cost to the Commonwealth

An assessment of the economic threat climate change poses to Commonwealth nations

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Contents

Cover: A family tries to escape floods in north western Pakistan.

Photo by Abdul Majeed Goraya / IRIN

Foreword

By Vanessa Nakate, Ugandan climate activist

The Commonwealth is a bloc of nations with a dark past. Many argue it is an irrelevant throwback to an age of British imperialism. But, it is still a unique mix of countries – one that doesn't fall neatly into any other group, that goes beyond geographical proximity and that spans every populated continent on earth.

The Commonwealth, as a group of nations, captures the severe inequality of climate change. Within its ranks are some of the world's biggest polluters per capita – Australia with its coal industry, Canada with its tar sands. The average citizen of those countries is responsible for as much carbon as 100 people from my country, Uganda.

Some parts of the Commonwealth are truly on the front lines of the climate crisis. Whether it's floods in Pakistan, Nigeria and Bangladesh, drought in India, Kenya and Uganda or storms in Mozambique, Jamaica and Vanuatu, the climate crisis is destroying lives and livelihoods across the Commonwealth. Meanwhile, this crisis is also being disproportionately driven by the Bloc's richest, most polluting members.

This paper outlines that this injustice is only set to get worse, as those countries already suffering the most will face severe economic harm because of climate change over the coming years.

Nowhere should the case for action to drastically cut emissions and increase financial support be more clear than among this group of nations. The leaders of Australia, Canada, New Zealand and the UK like to speak warm words about their Commonwealth 'family', but so far their action to address the climate crisis has fallen tragically short. Climate finance being sent to vulnerable countries for mitigation and adaptation still remains woefully low. The Loss and Damage Fund agreed at COP27, designed to help frontline communities rebuild after climate disasters, still sits empty.

It need not be this way. The Commonwealth is a group of countries that can demonstrate what true climate cooperation can look like. As it enters a new era under the leadership of King Charles, its existence is questioned by more and more people as it seeks to find its purpose and relevance in a modern world. Climate action, something that is dear to the heart of King Charles, is the perfect issue where the Commonwealth can lead the world and be a model for others to follow. Genuine solidarity between historic polluters and the climate vulnerable would be a powerful message to the rest of the world and would forge much stronger and more relevant ties than a collection of countries bound by the shadow of colonialism.

Introduction

King Charles III, a long time environmentalist, is the UK's first 'Eco King'. He has written a Ladybird book on climate change with scientist Emily Shuckburgh and campaigner Tony Juniper. King Charles gave his first speech about the environment in 1970 at the age of 22 – five years before the term 'global warming' was coined by geoscientist Wallace Broecker.

When he looks at the Commonwealth, of which he is now the head, King Charles will be greatly troubled by its relationship with climate change. Despite the warm words from UK leaders about the close 'Commonwealth family', no bloc of nations better exemplifies the stark inequality of the climate crisis.

Within the membership are some of the most polluting countries on the planet. They sit alongside some of most vulnerable countries to the impacts of climate change which have done among the least to cause the crisis.

This report examines the impact that climate change will have on the GDP of Commonwealth nations over the coming decades. The results show the clear injustice and the severe harm climate change is causing to the economies of the climate vulnerable which are already much less well off than their polluting Commonwealth neighbours.

If the Commonwealth is going to live up to its claim to be 'a family', then this injustice must be addressed. Rich polluting members, Australia, Canada, New Zealand and UK need to act to cut their emissions which are causing climate misery in many parts of the Commonwealth. It also shows why they must contribute to the Loss and Damage Fund recently agreed at COP27 to financially support the most vulnerable communities.

Charles III on climate change

5 quotes from the climate campaigner King

1970 – Countryside Steering Committee for Wales

“We are faced at this moment with the horrifying effects of pollution in all its cancerous forms. There is the growing menace of oil pollution at sea, which almost destroys beaches and certainly destroys tens of thousands of seabirds. There is chemical pollution discharged into rivers from factories and chemical plants, which clogs up the rivers with toxic substances and adds to the filth in the seas. There is air pollution from smoke and fumes discharged by factories and from gases pumped out by endless cars and aeroplanes.”

1989 – Saving the Ozone Layer World Conference

“Since the Industrial Revolution, human beings have been upsetting that balance [of nature], persistently choosing short-term options and to hell with the long-term repercussions.”

2009 – Copenhagen climate conference

“As our planet's life-support system begins to fail and our very survival as a species is brought into question, remember that our children and grandchildren will ask not what our generation said, but what it did. Let us give an answer, then, of which we can be proud.”

2012 – Rio+20 Summit

“Like a sleepwalker, we seem unable to wake up to the fact that so many of the catastrophic consequences of carrying on with 'business-as-usual' are bearing down on us faster than we think.

“Already dragging many millions more people into poverty and dangerously weakening global food, water and energy security for the future. One thing is clear. We need to be much more informed about the actual state of the planet.”

2023 – The King's Commonwealth Day Message

“Whether on climate change and biodiversity loss, youth opportunity and education, global health, or economic co-operation, the Commonwealth can play an indispensable role in the most pressing issues of our time. Ours is an association not just of shared values, but of common purpose and joint action.”

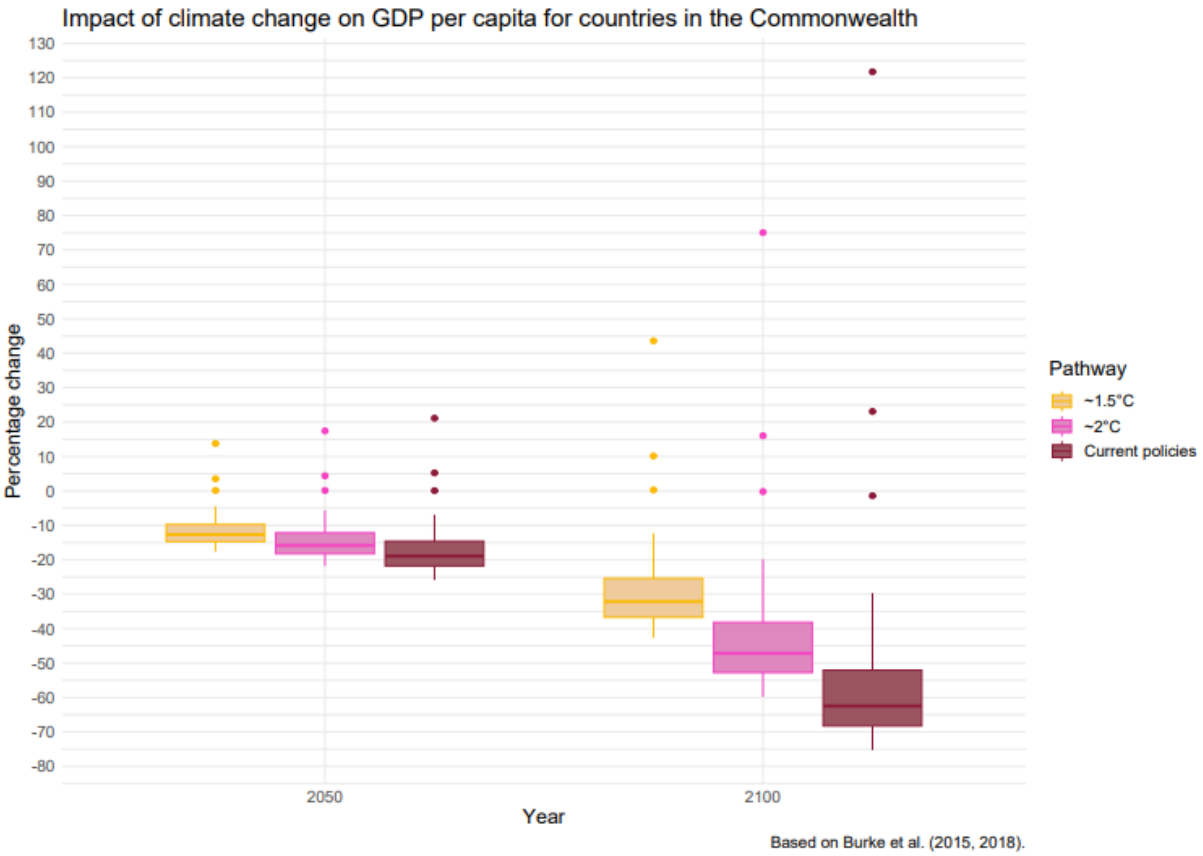
Projecting economic growth losses from climate impacts

Impacts of climate change on economic performance (here measured by country-level GDP per capita) were estimated using a two-step modelling procedure proposed by Burke et al. (2015, 2018). The first step estimates a historical relationship between GDP growth and climatic variables, and in the second step this relationship is extended to different temperature pathways over the 21st century to estimate how GDP growth might be affected by climate change (See Appendix 2 for a full methodology).

Our estimates are modelled projections which naturally have some limitations. The data assumes countries undertake no adaptation, so where adaptation happens, we would expect a reduction in the economic damage estimates; however, neither does the data predict the impacts of individual extreme events of which we are seeing an increasing number with more acute events and corresponding impacts happening in different Commonwealth countries in recent years. Recent research shows that extreme weather events are already reducing economic growth in many countries, and that lower income countries tend to experience greater reductions in GDP, widening global inequalities[1]. Therefore, even our drastic projections could be an underestimate given the impact of more frequent and acute weather events which themselves are likely driven at least partly by climate change.

The boxplots shown in Figure 1 capture the range of impacts on GDP for the 40 out of 56 countries in the Commonwealth where data is available. Countries vary in terms of the effects of climate change on their national GDP per capita, with all the developing countries negatively affected. Even in a 1.5C temperature pathway compatible with the limits set by the Paris Agreement, Commonwealth countries face a median GDP reduction of -13%. In a 2C scenario they face a reduction and -19% on a “current policy” scenario of around 2.7C in 2050[2]. At 2100 the numbers are even worse. Under a 1.5C pathway the median GDP reduction is -32%, at 2C it is -47% and under current policies it is -63%.

Figure 1



The effect of limiting the global mean temperature increase to the goals of the Paris Agreement becomes more pronounced at the end of the century where the median damage on the current policy pathway is -63% vs -32% in the 1.5°C pathway, implying that damages can be almost halved in a 1.5°C world, though they remain drastic.

	Year	Scenario	Median GDP change %
Commonwealth	2050	1.5°C	-12.7
Commonwealth	2050	2°C	-15.8
Commonwealth	2050	Current policies	-18.9
Commonwealth	2100	1.5°C	-32.2
Commonwealth	2100	2°C	-47.2
Commonwealth	2100	Current policies	-62.5

The most Impacted countries

Thirteen Commonwealth countries (Nigeria, Pakistan, Guyana, Sierra Leone, India, Ghana, Belize, Togo, Gabon, Bangladesh, Gambia, Mozambique, Cameroon) each face the prospect of seeing their economic growth reduced by at least -20% by 2050, and -67% by 2100, if climate change impacts eventuate in line with current policies. These are currently on track to deliver around 2.7C of global heating. The combined population of these 13 countries is 2.1 billion people, or more than one in four of all people living across the world[3].

Ten of these 13 are either low income or lower middle income countries according to the World Bank's classification[4]. This means that the average income per person in these ten countries is under $4,255 a year. Belize, Guyana and Gabon are all upper middle income countries but they are not rich - the maximum GDP per capita is Guyana at $10,000.

These 13 countries also have some of the lowest carbon emissions in the world. The median average per capita emissions for these ten countries is just 0.59 tons per year. This is 9 times smaller than the UK's per capita emissions, 24 times smaller than Canada's, and 26 times smaller than Australia's.

low income country
low middle income
high middle income

13 worst impacted countries by GDP hit

– all to suffer at least -20% by 2050 under current trajectory

Country	Year	Scenario	GDP change %	CO_2 emissions in tons per capita 2021
Nigeria	2050	1.5°C	-17.6	0.64
Nigeria	2050	2°C	-21.8	
Nigeria	2050	Current policies	-25.9	
Nigeria	2100	1.5°C	-42.6	
Nigeria	2100	2°C	-59.8	
Nigeria	2100	Current policies	-75.3	
Pakistan	2050	1.5°C	-16.3	0.99
Pakistan	2050	2°C	-20.2	

Pakistan	2050	Current policies	-24.2	
Pakistan	2100	1.5°C	-40.1	
Pakistan	2100	2°C	-57.2	
Pakistan	2100	Current policies	-73.1	
Guyana	2050	1.5°C	-16.4	3.84
Guyana	2050	2°C	-20.3	
Guyana	2050	Current policies	-24.2	
Guyana	2100	1.5°C	-40.2	
Guyana	2100	2°C	-56.9	
Guyana	2100	Current policies	-72.4	
Sierra Leone	2050	1.5°C	-16.1	
Sierra Leone	2050	2°C	-20	
Sierra Leone	2050	Current policies	-23.8	0.15
Sierra Leone	2100	1.5°C	-39.6	
Sierra Leone	2100	2°C	-56.2	
Sierra Leone	2100	Current policies	-71.7	
India	2050	1.5°C	-15.9	1.93
India	2050	2°C	-19.7	
India	2050	Current policies	-23.5	
India	2100	1.5°C	-39.3	
India	2100	2°C	-56	
India	2100	Current policies	-71.5	
Ghana	2050	1.5°C	-15.8	0.65
Ghana	2050	2°C	-19.6	
Ghana	2050	Current policies	-23.3	
Ghana	2100	1.5°C	-39	
Ghana	2100	2°C	-55.6	
Ghana	2100	Current policies	-71	
Belize	2050	1.5°C	-15.6	1.72
Belize	2050	2°C	-19.3	
Belize	2050	Current policies	-23.0	
Belize	2100	1.5°C	-38.3	
Belize	2100	2°C	-54.7	
Belize	2100	Current policies	-70.3	
Togo	2050	1.5°C	-15.1	0.27
Togo	2050	2°C	-18.7	
Togo	2050	Current policies	-22.3	
Togo	2100	1.5°C	-37.3	
Togo	2100	2°C	-53.4	
Togo	2100	Current policies	-68.8	
Gabon	2050	1.5°C	-14.9	2.44
Gabon	2050	2°C	-18.5	
Gabon	2050	Current policies	-22.1	
Gabon	2100	1.5°C	-37.0	
Gabon	2100	2°C	-53.2	
Gabon	2100	Current policies	-68.7	
Bangladesh	2050	1.5°C	-14.7	0.55
Bangladesh	2050	2°C	-18.2	
Bangladesh	2050	Current policies	-21.8	
Bangladesh	2100	1.5°C	-36.7	

Bangladesh	2100	2°C	-52.8	
Bangladesh	2100	Current policies	-68.3	
Gambia	2050	1.5°C	-14.7	0.25
Gambia	2050	2°C	-18.3	
Gambia	2050	Current policies	-21.8	
Gambia	2100	1.5°C	-36.7	
Gambia	2100	2°C	-52.8	
Gambia	2100	Current policies	-68.2	
Mozambique	2050	1.5°C	-14.5	0.22
Mozambique	2050	2°C	-18	
Mozambique	2050	Current policies	-21.5	
Mozambique	2100	1.5°C	-36.2	
Mozambique	2100	2°C	-52.3	
Mozambique	2100	Current policies	-67.9	
Cameroon	2050	1.5°C	-14.4	0.34
Cameroon	2050	2°C	-17.9	
Cameroon	2050	Current policies	-21.3	
Cameroon	2100	1.5°C	-36	
Cameroon	2100	2°C	-52	
Cameroon	2100	Current policies	-67.7	

The ten low or lower middle income countries that are expected to endure the most severe economic impacts of climate change in the Commonwealth are already dealing with extremely difficult weather and climate conditions.

In 2022 alone:

Floods in **Pakistan** killed 1,739 people, displacing more than 30 million and causing an estimated $15.2 billion in economic losses.[5]

India and Pakistan suffered from its worst March heatwave since records began 122 years ago with temperatures reaching 49C and birds falling from the sky in the state of Gujarat.

Floods in West Africa, which struck **Nigeria and Cameroon**, killed more than 600 people and displaced 1.3 million.

Cyclone Sitrang hit **Bangladesh**, displacing more than a million people, while back to back storms in Southeast Africa, which struck **Mozambique** in January, killed more than 300.

These countries need faster and more equitable economic growth to help overcome income poverty, the vulnerability to further climate change impacts and their lack of contribution to overall emissions. Yet they are not being sufficiently supported to adapt to climate change or deal with its lasting effects. Rich, polluting countries have failed to provide even the inadequate $100bn a year of climate finance promised annually for 2020-2025 for mitigation and adaptation.

Climate inequality at the heart of the Commonwealth

This data reveals the stark climate inequality within the Commonwealth. Per person Australia emits more than 188 times more carbon than fellow Commonwealth nation Malawi. Canada emits more than 179 times more.

In fact the per capita emissions of the Commonwealth's richest four countries (UK, Australia, Canada and New Zealand), 41.1 tons of C02, is 23 times larger than the 10 least emitting per capita Commonwealth countries combined (1.78 tons).

Not only are the emissions of these rich countries driving the climate impacts and economic harm experienced by the poorest and most vulnerable members of the bloc, these developed economies will suffer less due to the impact of climate change. To add to the injustice, these findings show that Canada may even economically benefit from temperature changes, as it is currently beyond what is considered to be the optimal annual temperature for economic productivity. With global heating, it's expected to come closer to this 'optimum' due to increased farmland and labour productivity.

However, a future Earth ravaged by climate change will not be a Canadian utopia. This optimal temperature approach doesn't take into account a host of uncertainties and extreme events that are already taking an economic toll on Canada. The model used for this study has been developed by Burke et al (2015, 2018) which focusses on the optimal temperature concept and doesn't factor in the potential costs of extreme weather events and knock-on effects to Canada of climate breakdown around the world.

A study by the Canadian Climate Institute in September 2022 showed that Canada's economy is already feeling the drag of extreme weather events. It calculated that by 2025 these impacts will be slowing Canada's economic growth by CAN$25 billion annually, which is equal to 50% of projected GDP growth.[6]

Canada's GDP will also suffer as global supply chains come under pressure and collapse due to more severe climate impacts around the world. Drought may set off civil wars in Africa and South America, entire cities and regions of the Middle East might become too physically hot to survive in, millions of migrants will likely be heading north to seek refuge in countries like Canada, and one-off superstorms that might destroy financial centres like London and New York could pitch

the global economy into a tailspin. Trading with countries suffering GDP reductions of up to 75% by 2100 will be chaotic.

One of the great unknowns about climate change is when certain tipping points could be triggered when permafrost in the northern hemisphere melts. This would release currently trapped potent greenhouse gasses, like methane, which would accelerate heating, resulting in further melting and the potential for a feedback loop that could cause runaway climate change and push global temperatures much higher than currently expected.

Climate change in the Commonwealth: A case study – The impact of drought in northern Kenya

The Horn of Africa is experiencing the worst drought in 40 years. Communities are experiencing catastrophic impacts of five, heading into the sixth, lost rainy season in the past two and a half years. The March-May 2022 rainy season was the

driest on record in the last 70 years—making the 2020-2022 dry spell surpass the horrific droughts in both 2010-2011 and 2016-2017 in duration and severity. Over 36 million people have now been affected by the drought which began in October 2020, including more than 24 million in Ethiopia, almost 8 million in Somalia and more than 4 million in Kenya. At least 21 million people are already waking each day to high levels of acute food insecurity and rising malnutrition across Ethiopia, Kenya and Somalia, and this figure could increase to between 23 and 26 million by February 2023.

The Loss and Damage is on an enormous scale, both economic and non-economic. The economic losses include almost 9 million livestock—which pastoralist families rely upon for sustenance and livelihoods—dead across the region. More than 16 million people cannot access enough water for drinking, cooking and cleaning across the Horn of Africa, including 8 million in Ethiopia, almost 4 million in Somalia and 4 million in Kenya, according to UNICEF. Many water points have dried up or diminished in quality, heightening the risk of water-borne diseases and increasing the risk of skin and eye infections as families are forced to ration their water use and prioritise drinking and cooking over hygiene.

Due to the scale of economic losses, families are taking desperate measures to survive, with over 1.3 million people across the region abandoning their homes in search of food, water and pasture for livestock, triggering further displacement in the region. Women and girls are most affected, for example, because girls tend to be the first to be forced out of school. When food is scarce, they eat last and least. Women and girls are having to walk longer distances to access water, increasing potential exposure to gender based violence. In Kenya, women report having to walk three times further for water. In Ethiopia and Kenya, child marriage has skyrocketed, increasing by 199% and 98%.

Recommendations

This data and analysis underscores the need for action to avert, minimise and address Loss and Damage since we can see the hugely unequal impacts on economic growth in low and middle income countries across the Commonwealth.

- **Get the Loss and Damage Fund agreed at COP27 up and running**; and rich countries to provide their fair share of finance, based on the polluter pays principle.

- Countries need to focus on averting, minimising and addressing Loss and Damage.

- **Avert** – Countries must take action in this decade to close emissions reduction gaps to stay within Paris limits of 1.5C to prevent escalating Loss and Damage.

- **Minimise** – The existing adaptation funding gap needs to be closed and countries should redouble efforts for climate finance to flow to countries most vulnerable to climate change to withstand existing and future climate.

- **Address** – Governments such as the UK should outline plans to raise its fair share of the Loss and Damage Fund, estimated to be £12.5 billion.

Appendix 1: Data by country

Country	Year	Scenario	GDP change %	CO_2 emissions in tons per capita 2021[7]
Nigeria	2050	1.5°C	-17.6	0.64
Nigeria	2050	2°C	-21.8	
Nigeria	2050	Current policies	-25.9	
Nigeria	2100	1.5°C	-42.6	
Nigeria	2100	2°C	-59.8	
Nigeria	2100	Current policies	-75.3	
Pakistan	2050	1.5°C	-16.3	0.99
Pakistan	2050	2°C	-20.2	
Pakistan	2050	Current policies	-24.2	
Pakistan	2100	1.5°C	-40.1	
Pakistan	2100	2°C	-57.2	
Pakistan	2100	Current policies	-73.1	
Guyana	2050	1.5°C	-16.4	3.84
Guyana	2050	2°C	-20.3	
Guyana	2050	Current policies	-24.2	
Guyana	2100	1.5°C	-40.2	
Guyana	2100	2°C	-56.9	
Guyana	2100	Current policies	-72.4	
Sierra Leone	2050	1.5°C	-16.1	
Sierra Leone	2050	2°C	-20.0	
Sierra Leone	2050	Current policies	-23.8	0.15
Sierra Leone	2100	1.5°C	-39.6	
Sierra Leone	2100	2°C	-56.2	
Sierra Leone	2100	Current policies	-71.7	
India	2050	1.5°C	-15.9	1.93
India	2050	2°C	-19.7	
India	2050	Current policies	-23.5	
India	2100	1.5°C	-39.3	
India	2100	2°C	-56.0	
India	2100	Current policies	-71.5	
Ghana	2050	1.5°C	-15.8	0.65
Ghana	2050	2°C	-19.6	
Ghana	2050	Current policies	-23.3	

Ghana	2100	1.5°C	-39.0	
Ghana	2100	2°C	-55.6	
Ghana	2100	Current policies	-71.0	
Belize	2050	1.5°C	-15.6	1.72
Belize	2050	2°C	-19.3	
Belize	2050	Current policies	-23.0	
Belize	2100	1.5°C	-38.3	
Belize	2100	2°C	-54.7	
Belize	2100	Current policies	-70.3	
Togo	2050	1.5°C	-15.1	0.27
Togo	2050	2°C	-18.7	
Togo	2050	Current policies	-22.3	
Togo	2100	1.5°C	-37.3	
Togo	2100	2°C	-53.4	
Togo	2100	Current policies	-68.8	
Gabon	2050	1.5°C	-14.9	2.44
Gabon	2050	2°C	-18.5	
Gabon	2050	Current policies	-22.1	
Gabon	2100	1.5°C	-37.0	
Gabon	2100	2°C	-53.2	
Gabon	2100	Current policies	-68.7	
Bangladesh	2050	1.5°C	-14.7	0.55
Bangladesh	2050	2°C	-18.2	
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Bangladesh	2100	1.5°C	-36.7	
Bangladesh	2100	2°C	-52.8	
Bangladesh	2100	Current policies	-68.3	
Gambia	2050	1.5°C	-14.7	0.25
Gambia	2050	2°C	-18.3	
Gambia	2050	Current policies	-21.8	
Gambia	2100	1.5°C	-36.7	
Gambia	2100	2°C	-52.8	
Gambia	2100	Current policies	-68.2	
Mozambique	2050	1.5°C	-14.5	0.22
Mozambique	2050	2°C	-18.0	
Mozambique	2050	Current policies	-21.5	
Mozambique	2100	1.5°C	-36.2	
Mozambique	2100	2°C	-52.3	

Mozambique	2100	Current policies	-67.9	
Cameroon	2050	1.5°C	-14.4	0.34
Cameroon	2050	2°C	-17.9	
Cameroon	2050	Current policies	-21.3	
Cameroon	2100	1.5°C	-36.0	
Cameroon	2100	2°C	-52.0	
Cameroon	2100	Current policies	-67.7	
Brunei	2050	1.5°C	-14.4	
Brunei	2050	2°C	-17.9	
Brunei	2050	Current policies	-21.3	23.5
Brunei	2100	1.5°C	-35.9	
Brunei	2100	2°C	-51.7	
Brunei	2100	Current policies	-67.0	
Namibia	2050	1.5°C	-13.8	
Namibia	2050	2°C	-17.1	
Namibia	2050	Current policies	-20.6	1.59
Namibia	2100	1.5°C	-34.7	
Namibia	2100	2°C	-50.7	
Namibia	2100	Current policies	-66.7	
Malaysia	2050	1.5°C	-13.9	
Malaysia	2050	2°C	-17.2	
Malaysia	2050	Current policies	-20.6	7.6
Malaysia	2100	1.5°C	-34.9	
Malaysia	2100	2°C	-50.5	
Malaysia	2100	Current policies	-65.8	
Botswana	2050	1.5°C	-13.0	
Botswana	2050	2°C	-16.2	
Botswana	2050	Current policies	-19.5	2.51
Botswana	2100	1.5°C	-33.0	
Botswana	2100	2°C	-48.7	
Botswana	2100	Current policies	-64.5	
Malawi	2050	1.5°C	-13.1	
Malawi	2050	2°C	-16.3	
Malawi	2050	Current policies	-19.6	0.08
Malawi	2100	1.5°C	-33.1	
Malawi	2100	2°C	-48.6	
Malawi	2100	Current policies	-64.2	
Sri Lanka	2050	1.5°C	-13.2	

Sri Lanka	2050	2°C	-16.4	
Sri Lanka	2050	Current policies	-19.7	0.95
Sri Lanka	2100	1.5°C	-33.6	
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Sri Lanka	2100	Current policies	-64.0	
Uganda	2050	1.5°C	-12.7	
Uganda	2050	2°C	-15.9	
Uganda	2050	Current policies	-19.0	0.13
Uganda	2100	1.5°C	-32.3	
Uganda	2100	2°C	-47.6	
Uganda	2100	Current policies	-63.1	
Zambia	2050	1.5°C	-12.2	
Zambia	2050	2°C	-15.3	
Zambia	2050	Current policies	-18.3	0.39
Zambia	2100	1.5°C	-31.3	
Zambia	2100	2°C	-46.3	
Zambia	2100	Current policies	-61.8	
Bahamas	2050	1.5°C	-12.7	
Bahamas	2050	2°C	-15.7	
Bahamas	2050	Current policies	-18.8	5.85
Bahamas	2100	1.5°C	-32.0	
Bahamas	2100	2°C	-46.8	
Bahamas	2100	Current policies	-61.8	
Tanzania	2050	1.5°C	-12.2	
Tanzania	2050	2°C	-15.2	
Tanzania	2050	Current policies	-18.3	0.21
Tanzania	2100	1.5°C	-31.2	
Tanzania	2100	2°C	-46.1	
Tanzania	2100	Current policies	-61.5	
St. Vincent & Grenadines	2050	1.5°C	-12.6	
St. Vincent & Grenadines	2050	2°C	-15.6	
St. Vincent & Grenadines	2050	Current policies	-18.7	2.05
St. Vincent & Grenadines	2100	1.5°C	-31.8	
St. Vincent & Grenadines	2100	2°C	-46.5	
St. Vincent & Grenadines	2100	Current policies	-61.4	
Solomon Islands	2050	1.5°C	-12.3	
Solomon Islands	2050	2°C	-15.3	
Solomon Islands	2050	Current policies	-18.4	0.45

Solomon Islands	2100	1.5°C	-31.4	
Solomon Islands	2100	2°C	-46.0	
Solomon Islands	2100	Current policies	-60.8	
Trinidad & Tobago	2050	1.5°C	-12.0	
Trinidad & Tobago	2050	2°C	-14.9	
Trinidad & Tobago	2050	Current policies	-17.8	23.68
Trinidad & Tobago	2100	1.5°C	-30.5	
Trinidad & Tobago	2100	2°C	-44.9	
Trinidad & Tobago	2100	Current policies	-59.6	
Samoa	2050	1.5°C	-10.9	
Samoa	2050	2°C	-13.6	
Samoa	2050	Current policies	-16.3	1.34
Samoa	2100	1.5°C	-28.1	
Samoa	2100	2°C	-41.6	
Samoa	2100	Current policies	-55.9	
Rwanda	2050	1.5°C	-10.4	
Rwanda	2050	2°C	-13.0	
Rwanda	2050	Current policies	-15.7	0.13
Rwanda	2100	1.5°C	-27.1	
Rwanda	2100	2°C	-40.8	
Rwanda	2100	Current policies	-55.6	
Vanuatu	2050	1.5°C	-10.0	
Vanuatu	2050	2°C	-12.5	
Vanuatu	2050	Current policies	-15.0	0.55
Vanuatu	2100	1.5°C	-26.0	
Vanuatu	2100	2°C	-38.9	
Vanuatu	2100	Current policies	-52.8	
Mauritius	2050	1.5°C	-9.9	
Mauritius	2050	2°C	-12.3	
Mauritius	2050	Current policies	-14.8	3.44
Mauritius	2100	1.5°C	-25.7	
Mauritius	2100	2°C	-38.5	
Mauritius	2100	Current policies	-52.3	
Eswatini	2050	1.5°C	-9.3	
Eswatini	2050	2°C	-11.7	
Eswatini	2050	Current policies	-14.1	0.91
Eswatini	2100	1.5°C	-24.4	
Eswatini	2100	2°C	-37.2	

Eswatini	2100	Current policies	-51.4	
Kenya	2050	1.5°C	-9.1	
Kenya	2050	2°C	-11.4	
Kenya	2050	Current policies	-13.7	0.37
Kenya	2100	1.5°C	-23.9	
Kenya	2100	2°C	-36.4	
Kenya	2100	Current policies	-50.3	
Papua New Guinea	2050	1.5°C	-9.2	
Papua New Guinea	2050	2°C	-11.5	
Papua New Guinea	2050	Current policies	-13.8	0.86
Papua New Guinea	2100	1.5°C	-24.1	
Papua New Guinea	2100	2°C	-36.5	
Papua New Guinea	2100	Current policies	-50.1	
Cyprus	2050	1.5°C	-8.6	
Cyprus	2050	2°C	-10.9	
Cyprus	2050	Current policies	-13.2	6.11
Cyprus	2100	1.5°C	-22.8	
Cyprus	2100	2°C	-35.0	
Cyprus	2100	Current policies	-49.1	
Fiji	2050	1.5°C	-8.5	
Fiji	2050	2°C	-10.6	
Fiji	2050	Current policies	-12.8	1.59
Fiji	2100	1.5°C	-22.4	
Fiji	2100	2°C	-33.9	
Fiji	2100	Current policies	-46.7	
South Africa	2050	1.5°C	-6.4	
South Africa	2050	2°C	-8.0	
South Africa	2050	Current policies	-9.8	7.34
South Africa	2100	1.5°C	-17.3	
South Africa	2100	2°C	-27.3	
South Africa	2100	Current policies	-39.6	
Australia	2050	1.5°C	-4.4	15.09
Australia	2050	2°C	-5.7	
Australia	2050	Current policies	-6.9	
Australia	2100	1.5°C	-12.3	
Australia	2100	2°C	-19.9	
Australia	2100	Current policies	-29.7	
New Zealand	2050	1.5°C	0.2	6.59

New Zealand	2050	2°C	0.1	
New Zealand	2050	Current policies	0.1	
New Zealand	2100	1.5°C	0.3	
New Zealand	2100	2°C	-0.2	
New Zealand	2100	Current policies	-1.4	
United Kingdom	2050	1.5°C	3.5	5.15
United Kingdom	2050	2°C	4.4	
United Kingdom	2050	Current policies	5.2	
United Kingdom	2100	1.5°C	10.2	
United Kingdom	2100	2°C	16.0	
United Kingdom	2100	Current policies	23.1	
Canada	2050	1.5°C	13.8	14.3
Canada	2050	2°C	17.4	
Canada	2050	Current policies	21.1	
Canada	2100	1.5°C	43.6	
Canada	2100	2°C	75.0	
Canada	2100	Current policies	121.8	

Appendix 2: Methodology

Impacts of climate change on economic performance (here measured by country-level GDP per capita) were estimated using a two-step modelling procedure proposed by Burke et al. (2015, 2018). The first step estimates a historical relationship between GDP growth and climatic variables, and in the second step this relationship is extended to different temperature pathways over the 21st century to estimate how GDP growth might be affected by climate change.

There is no consensus so far in economics and statistics on the "right" theoretical approach to estimate economic damages of climate change and the numbers vary widely depending on the initial specification and the modelling approach. One of the most prominent sources of differences stems from the choice between estimating damage to the level of output in an economy (i.e., impact on GDP in a single year or at a point in time) or whether it impacts economic growth (i.e., impact on GDP growth via damages to natural and human capital, under-

investment, etc.). Resulting estimates from the two approaches vary primarily because the growth effects accumulate over time and are, by definition, substantially larger than level effects. Growth based effects from prominent global assessments based on top-down econometrics vary between 7% (Kahn et al. 2019) and 23% (Burke et al. 2015) globally, while the level-based effects are centered around 1-2% of GDP reduction globally (Newell et al., 2021).

The analysis here is based on an econometric approach proposed in prominent papers of Marshall Burke and colleagues published in Nature magazine in 2015 and 2018.

Historical relationship between per capita GDP growth, temperature and precipitation is estimated using a fixed effects model with the following equation:

$$\Delta lnGDP_{i,t} = \beta_1 T_{i,t} + \beta_2 T_{i,t}^2 + \beta_3 P_{i,t} + \beta_4 P_{i,t}^2 + \mu_{i,u} + u_t + \theta_{1,i} t + \theta_{1,i} t^2 + \varepsilon_{i,t}$$

where the dependent variable is GDP growth of country i in year t, T and P are the average temperature and precipitation in year t, μ_i represents country-fixed effects that control for heterogeneity between countries that do not vary over time (e.g. historical legacy, institutions or culture), υ_t are year-fixed effects that account for common global shocks in a given year (e.g. financial crisis), and θ_1i t + θ_2i t^2 are country-specific linear and quadratic time trends, which allow GDP and temperature to evolve flexibly (e.g. account for positive growth trends of both variables without confounding the relationship). Inclusion of the three types of fixed effects means that the estimated coefficients β_1 - β_4 can be interpreted as actual impacts of temperature and precipitation that are independent of non-climate related confounding factors. Only temperature variable (coefficients β_1 and β_2) is statistically significant in different specifications tested and this relationship holds robustly across alternative models. The non-linear (quadratic) relationship between GDP and climate variables allows the effect of warming to differ depending on the country's average temperature.

Several bootstrapping techniques (by country; by year; by five-year blocks) have been used to quantify uncertainty in coefficient estimates β_1 and β_2. Bootstrapping uses different sampling methods to derive improved estimates of standard errors and confidence intervals.

Coefficient estimates obtained from the historical regression model are used in the second step of the analysis in combination with climate model projections of temperature to

obtain projected future per capita GDP growth. Here we present three scenarios of global warming:

A Paris Agreement-compatible pathway of the global mean temperature (GMT) increase limited to 1.5°C in 2100

A less ambitious Paris-compatible limit of 2°C in 2100

A "current policy" pathway that results in the increase of around 2.7°C (2°C – 3.6°C) in 2100 compared to the pre-industrial period based on the latest update of the Climate Action Tracker (CAT) from November 2021

Future GDP growth in the climate change scenarios is compared to the "baseline" scenarios available from the socio-economic scenario framework – the Shared Socioeconomic Pathways (SSPs) (O'Neill et al. 2017) – which are the basis for climate impact assessments in the 6th Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). The SSPs are meant to represent a range of plausible futures of socio-economic components in a hypothetical world without climate change. They are used as baselines in comparisons to scenarios with climate change. Here we use the SSP1 scenario which is meant to be most compatible with the 1.5°C-consistent pathway. Baseline SSP scenarios can also be explored here.

Caveats:

Estimates presented here are based on an econometric model that is based on the relationship between GDP growth and temperature, without accounting for the possible impacts of extreme events. Incorporating climate extremes such as droughts, floods or storms that could have a substantial impact on economic performance. Recent advances in damage estimates that include extreme events are significantly larger than the ones who do not, implying that the optimal temperature pathways are the ones that limit global warming in line with the Paris Agreement (Piontek et al., 2021). Additionally, it is useful to keep in mind that adaptation measures which could potentially alleviate some of the damage are not incorporated here either.

Endnotes

1
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