IV. Stress tests on the fiscal impact of extreme weather and climate-related events

By Nicola Gagliardi, Pedro Arevalo and Stéphanie Pamies

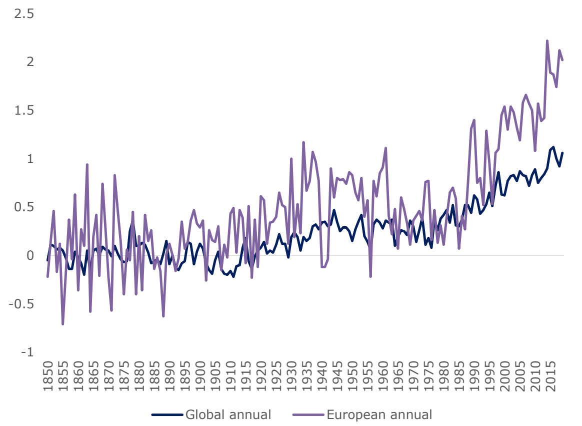
Abstract: *This section analyses the potential impact of climate change on public finances. We focus on the acute physical risks from climate change, with the aim of capturing the fiscal (debt) sustainability impacts associated with extreme weather and climate-related events. This is done by providing first, stylised stress tests in the context of the standard European Commission's Debt Sustainability Analysis (DSA) framework for selected EU Member States, using a comparative approach. Climate-related aggravating factors to fiscal (debt) sustainability are captured by drawing on information from a global natural disaster database as well as forward-looking estimates of economic losses from different climate events projected under different global warming pathways. Our results highlight that extreme weather and climate-related events may pose risks to fiscal (debt) sustainability in several countries, though the risks remain manageable under standard global warming scenarios. Our findings emphasise the importance of taking large-scale, rapid, and immediate climate mitigation and adaptation measures to dampen the adverse economic social and fiscal impacts of potentially more frequent and intense extreme events. This will reduce countries' exposure, vulnerability, and debt sustainability risks ([54]).*

IV.1. Introduction

Climate change is one of the biggest challenges of our times. There is broad scientific consensus that human activities are unequivocally responsible for the observed increases in greenhouse gases (GHGs) concentration in the atmosphere ([55]). The rise in anthropogenic GHGs generates a unique and global negative externality of the consumption of carbon-intensive goods, making climate change 'the greatest market failure that the world has ever seen' ([56]).

As a result, global temperature has been increasing markedly over the past century. According to the United Nations Intergovernmental Panel on Climate Change (IPCC), emissions of GHGs from human activities are responsible for approximately 1.1°C of warming since 1850-1900, increasing at a rate of 0.2°C per decade since the 1970s. The impact has intensified over the last decade. Over 2010-2019, the global mean near-surface temperature was 0.9°C to 1.03°C warmer than the pre-industrial level. European land temperatures have increased even faster, by 1.7°C to 1.9°C, over the same period (Graph IV.1).

Graph IV.1: **Global and European temperature anomalies, 1850-2019**



(1) Temperature anomalies (i.e. degree Celsius differences) are presented relative to a 'pre-industrial' period between 1850-1899.
Source: European Commission, based on the European Environment Agency, Annual Global (Land and Ocean) temperatue anomalies - HadCRUT (degree Celsius) provided by Met Office Hadley Centre observations datasets.

Large-scale, rapid and immediate mitigation measures have the potential to limit climate change and its related effects. According to the IPCC's Sixth Assessment Report ([57]), average global temperature is expected to already reach or exceed 1.5°C of warming within the next 20 years. Under high (SSP3-7.0) and very high (SSP5-8.5) projected GHGs emission scenarios - i.e. assuming the world

([54]) This Section is an extract from Gagliardi *et al.* (2022), 'The Fiscal Impact of Extreme Weather and Climate Events: Evidence for EU Countries', European Economy Discussion Paper, European Commission, *forthcoming*, based on the related chapter published under the Fiscal Sustainability Report 2021, European Economy, Institutional Paper 171, April 2022, European Commission.

([55]) IPCC (2021), 'Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change', Cambridge University Press.

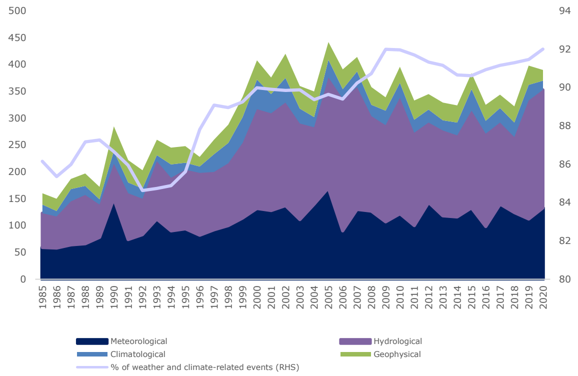
([56]) Stern, N. & Stern, N. H. (2007), 'The economics of climate change: the Stern review', Cambridge University Press.

([57]) IPCC (2021), *op. cit.*

would take a carbon-intensive pathway, in the absence of adequate mitigation policies - global warming of about 3°C to more than 5°C higher might occur by the end of the century. Limiting global warming to 1.5°C is expected to reduce risks to ecosystems and human activities ([58]).

Human-induced climate change has increased the risks of *physical* hazards, which will continue to intensify and interact with other risks, endangering both human and other natural systems ([59]) ([60]). These risks may emerge via a gradual (and, often, irreversible) global warming-driven transformation of the environment (e.g., ecosystem collapse, global sea level rise, and melting ice sheets –called *chronic physical risks*). Or they may emerge via more intense and frequent extreme weather and climate-related events (e.g. storms, floods, droughts, heat waves – called *acute physical risks* – Graph IV.2) ([61]). Every additional 0.5°C of global warming is likely to cause a significant increase in both the *intensity* and *frequency* of extreme weather and climate-related events, such as severe heatwaves, heavy precipitation, and drought ([62]). The risk of non-linearities and tipping points may further increase the likelihood for catastrophic and irreversible outcomes to occur ([63]).

Graph IV.2: **Global number of natural disasters, 1985-2020**



(1) LHS: number of meteorological (e.g. exteme temperature, storms), hydrological (e.g. floods), climatological (e.g. drought, wildfires), geophysical (e.g. earthquakes) events.
(2) RHS: the % (in terms of total natural disasters) of weather and climate-related events (i.e. meteorological, hydrological, climatological), shows as a 5-year moving average.
Source: European Commission, based on the Emergency Events Database (EM-DAT; CRED, UCLouvain).

Climate-driven *physical* risks also entail economic and fiscal consequences ([64]). Adverse economic impacts may occur through shocks to the supply and demand side of the economy caused by damage and disruption to critical infrastructure and property, reduced labour productivity, lower consumption and investment, disruption to global trade flows and other effects. Public finances are likely to be equally affected via, for instance, increased public spending, contingent liabilities materialising, and/or output losses.

Given the unavoidable rise of climate pressures in the years ahead, it is essential to analyse the potential macroeconomic and fiscal sustainability implications of climate change. This section analyses the potential impact of climate-related risks on public finances. In particular, we aim to capture the fiscal (debt) sustainability impacts associated with *acute physical risks* of climate change, notably arising from extreme weather and climate-related events ([65]). To carry out the analysis, we

([58]) IPCC (2021), *op. cit.*; United Nations Framework Convention on Climate Change (UNFCC; 2021), 'Conference of the Parties serving as the meeting of the Parties to the Paris Agreement', Glasgow.
([59]) IPCC (2022), 'Summary for Policymakers. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.
([60]) Natural hazards become *disasters* when 'human lives are lost, and livelihoods damaged or destroyed' (CRED (2020), 'The Human Cost of Disasters (2000–2019)', United Nations Office for Disaster Risk Reduction, p. 8). In this chapter, we focus on natural *hazards* and *disasters* caused by 'extreme weather or climate-related' events. Earthquakes are not included in our definition.
([61]) The distinction between *extreme weather* and *extreme climate* events is not clear-cut and mainly depends on the adopted time scale. In particular, 'extreme weather events are associated with changing weather patterns, that is, within time frames of *less than a day* to a *few weeks*'. Instead, 'extreme climate events happen on *longer time scales*, and can be the accumulation of (extreme or non-extreme) weather events (such as the accumulation of moderately below-average rainy days over a season leading to substantially below-average cumulated rainfall and drought conditions' (IPCC (2012), 'Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change', Cambridge University Press, p. 117).
([62]) IPCC (2021), *op. cit.*
([63]) Lenton, T. M., *et al.* (2019) 'Climate tipping points—too risky to bet against', *Nature*, pp. 592-595.

([64]) Batten, S. (2018), 'Climate change and the macro-economy: a critical review', *Bank of England Staff Working Paper*, No. 706.
([65]) In addition to risks from direct *physical* impacts, the transition to a low-carbon economy is also expected to have significant effects on the economy and public finances (i.e. *transition risks* from climate change). While *physical* and *transition risks* 'are not independent of each other but tend to interact' (Batten et al. (2020), 'Climate change: Macroeconomic impact and implications for monetary policy', *Ecological, Societal, and Technological Risks and the Financial Sector*, Palgrave Macmillan, p. 16), due to methodological reasons this chapter strictly focuses on the

provide first, stylised, stress tests in the context of the standard European Commission's Debt Sustainability Analysis (DSA) framework for selected EU Member States.

This Section is structured as follows. Sub-Section IV.2 gives an overview of the main theoretical and empirical literature on the macroeconomics of disasters. Sub-Section IV.3 presents stylised facts on Europe. Sub-Section IV.4 describes our assumptions, the stress-test approach, and our main results. Sub-Section IV.5 concludes.

IV.2. The macroeconomics of disasters

In this sub-section, we provide an overview of the theoretical and empirical research on the macroeconomics of natural disasters ([66]). While still at its infancy, this literature provides a useful starting point to examine the economic and related fiscal impacts of extreme weather and climate-related events. Our aim is to define a set of evidence-based assumptions to underpin our debt sustainability stress tests.

The emerging consensus in the literature is that, on average, natural disasters tend to exert adverse impacts on economic growth in the short term ([67]). The effects can flow via several transmission channels, affecting the main growth drivers through unanticipated shocks to the supply and demand side of the economy. On the supply side, extreme weather and climate-related events may significantly affect the agriculture sector and cause loss or damage to buildings, technology and infrastructure. More generally, extreme events may lead to capital stock loss or disruption, with repercussions on labour productivity, input shortages, and price volatility. Concurrently, losses from extreme events may lead to shocks on the demand side of the economy, via reductions in wealth and financial assets, which has a knock-on effect on consumption and investment. Global links with affected trading partners may cause reduced trade flows, value chain disruptions, and inflationary pressures ([68]). Supply and demand shocks are expected to interact and to cause, at least in the short term, an immediate disruption to output and growth.

However, over the medium to long term, countries' macroeconomic dynamics may be expected to follow three, alternative, paths ([69]):

1. *Creative destruction*: After an initial shock following a disaster, a period of faster growth might occur. This is the outcome of reconstruction efforts, aimed at replacing lost capital with new, modern, and innovative units. The economy is set to be on a higher growth path than before the event;

2. *Recovery to trend*: Though growth is expected to slow down in the aftermath of a disaster, output should gradually converge to its pre-disaster trend via a catching-up effect. The negative impact on growth is therefore only temporary ([70]);

3. *No recovery*: A disaster is expected to restrain growth due to the destruction of productive capital and durable consumption goods. Under this scenario, output does not rebound and remains permanently lower over the long term.

Despite mixed empirical evidence, most studies appear to confirm that a high-intensity disaster has an immediate negative impact on growth. In the medium and long term, the '*no recovery*' hypothesis is the most supported ([71]). However, recent works clearly emphasise the importance of adequate disaster insurance coverage to offset these drawbacks. In particular, *uninsured losses* appear to

macroeconomic and fiscal impact of *(acute) physical* risks from climate change.

([66]) Batten, S. (2018), *op. cit.*

([67]) Ibid.

([68]) See Batten, S. *et al.* (2020), *op. cit.* for a detailed review of the macro-economic impacts as well as monetary policy implications of climate change.

([69]) *Ibid.*; Batten (2018), *op. cit.*; Hsiang, S. M., and Jina, A. S. (2014), 'The causal effect of environmental catastrophe on long-run economic growth: Evidence from 6,700 cyclones', *National Bureau of Economic Research*, No. w20352.

([70]) The 'recovery to trend' hypothesis argues that growth should temporarily suffer in the aftermath of a natural disaster but should eventually rebound, causing income levels to converge back to their pre-disaster trend. A rebound might be expected as the marginal product of capital would rise when capital and labor become relatively scarce after a disaster (due to destruction and mortality), causing individuals and wealth to migrate into devastated locations until output recovers to the regional trend. The underlying logic of this hypothesis has mixed empirical support (For details, see Hsiang, S. M., and Jina, A. S. (2014), *op.cit.*).

([71]) This conclusion is reported as an average impact from available studies so far. The latter encompass a wide range of countries, including advanced economies. For an overview of the empirical evidence around the short- and long-term economic impact of natural disasters, see Hallegatte et al. (2020), 'From poverty to disaster and back: A review of the literature.' *Economics of Disasters and Climate Change*, 4(1), 223-247; Batten *et al.*, (2020) *op. cit.*; Batten (2018) *op. cit.*

be the main driver behind the adverse macroeconomic shocks of natural catastrophes, both in terms of their impact and over the long term, insofar as productive capital is not replaced. By contrast, sufficiently insured losses are shown to be inconsequential in terms of foregone output. Disaster insurance coverage plays an important cushioning role, minimising the adverse shock to output and at the same time supporting the recovery ([72]). In particular, adequate insurance coverage appears to support post-catastrophe recovery (e.g., funding reconstruction projects) and cushion the contemporaneous impact of the disaster (i.e. contributing to prevention and disaster risk management) ([73]) .

In turn, natural disasters are also likely to have different impacts on public finances ([74]). For extreme weather and climate-related events, there may be *direct* impacts via upward pressure on public expenditure. This could be due to costs incurred to replace damaged (and/or lost) assets and infrastructure, social transfers to help the affected populations, and relief aid to affected industries and businesses. Extreme events may also lead to the materialisation of both *explicit* (e.g. relief or disaster-specific transfers to local governments, government guarantees for firms and public-private partnerships) and *implicit* contingent liabilities (e.g. public support to distressed financial institutions).

At the same time, disasters can have *indirect* impacts on public finances. These may include reductions in tax revenues following disaster-driven disruptions to economic activity in climate-sensitive sectors and regions. Funding reconstruction projects and post-disaster outcomes through budgetary resources reallocation and/or additional domestic/external borrowing might also affect the country's capacity to meet debt payments over the medium term. Related to this, vulnerability to natural disasters might generate increasing risks of uncertainty, affecting a country's creditworthiness and access to international financial accessibility ([75]).

Empirical evidence on the fiscal impact of natural disasters, especially for advanced economies, is quite limited and often based on selected case studies. Recent research has covered the macro-fiscal impacts of earthquakes and floods in EU Member States ([76]) and the role of fiscal policy to moderate the effects of natural disasters in US states ([77]). Other works have highlighted a relatively small but negative fiscal impact of individual disasters, with respect to the size of the economy.

This research finds that selected natural disasters occurring in the US and the EU have had an overall fiscal impact between 0.3% and 1.1% of GDP ([78]). Studies on a wider sample of countries find similar results. An additional large scale extreme event implies a fiscal deficit increase ranging between 0.23% and 1.4% of GDP, on average, depending on the country group ([79]). Moreover, the research finds that the fiscal response differs by disaster and degree of insurance coverage ([80]). Nevertheless, these estimates may be prone to underestimating the effect, mostly due to

([72]) Fache Rousová *et al.* (2021), 'Climate change, catastrophes and the macroeconomic benefits of insurance', *Financial Stability Report*, European Insurance and Occupational Pensions Authority, July 2021; Von Peter *et al.* (2012), 'Unmitigated disasters? New evidence on the macroeconomic cost of natural catastrophes', *BIS Working Papers*, No. 394.

([73]) This may be due, for instance, to insurance companies requiring specific building codes and disaster risk management practices to (also) limit the extent of their own liabilities (Von Peter et al., 2012, op. cit., p. 16).

([74]) This section focuses on the economic and fiscal impacts of extreme weather and climate-related disasters. However, public finances may also be subject to (direct and indirect) impacts from climate change policies (i.e. adaptation and/or mitigation). For an overview of these, see the 'Debt Sustainability Monitor 2019', European Economy, Institutional Paper 120, January 2020, European Commission.

([75]) Radu, D. (2021), 'Disaster Risk Financing: Main Concepts and Evidence from EU Member States', European Economy, Discussion Paper 150, October 2021, European Commission; Zenios, S. A. (2021), 'The risks from climate change to sovereign debt in Europe', Available at SSRN 3891078.

([76]) World Bank (2021), 'Financial Risk and Opportunities to Build Resilience in Europe', World Bank.

([77]) Canova, F. and Pappa, E. (2021), 'Costly Disasters and the Role of Fiscal Policy: Evidence from US States', European Economy — Fellowship Initiative Discussion Paper 151, November 2021.

([78]) Heipertz, M., and Nickel, C. (2008), 'Climate change brings stormy days: case studies on the impact of extreme weather events on public finances', Available at SSRN 1997256.

([79]) Lis, E. M., and Nickel, C. (2010), 'The impact of extreme weather events on budget balances', *International Tax and Public Finance*, 17(4), 378-399. The identification of natural disasters differs across studies, depending on data availability. Heipertz and Nickel (2008) focus on the four most extreme weather events in the EU since 1990 and the two most extreme events that occurred in the US since 1990, for which the direct budgetary impact could be gathered. Lis and Nickel (2010) only consider large-scale events that meet at least one of the following criteria: (i) the number of persons affected is no less than 100,000, (ii) the estimated damage costs of the extreme weather events are no less than 1 billion US dollars (in constant 2000 dollars), (iii) the number of persons killed is no less than 1,000, (iv) the estimated damage costs are above 2% of GDP.

([80]) Melecky, M., and Raddatz, C. E. (2011), 'How do governments respond after catastrophes? Natural-disaster shocks and the fiscal stance', *Natural-Disaster Shocks and the Fiscal Stance* (February 1, 2011), World Bank Policy Research Working Paper, 5564.

inherent difficulties in quantifying economic and fiscal outcomes. This may be due to the use of simplifying assumptions, differences in data, estimation methods, and identification approach ([81]). More importantly, all these estimates may be somewhat outdated, given the recent and expected increasing risk of disasters caused by human-induced climate change.

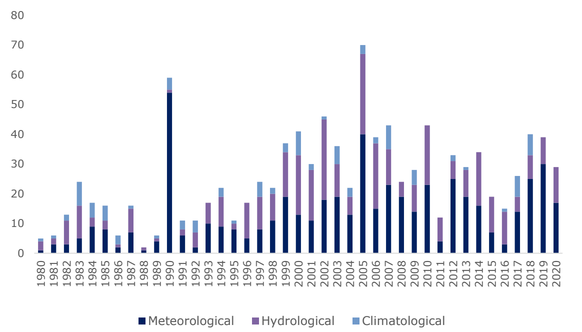
IV.3.Stylised facts on Europe

This Sub-Section describes the exposure of EU countries to extreme weather and climate-related events and the corresponding economic losses these events would cause. Our aim is to identify the most exposed and vulnerable countries for which it would be relevant to run stress tests under the DSA.

Trends of weather and climate-related events in the EU

Over the period 1980-2020, the EU experienced a total of 1,040 weather and climate-related disasters (out of 1,117 natural disasters) (Graph IV.3). Meteorological events were the most reported type of disaster, with 543 events recorded over that period, followed by hydrological (389) and climatological (108) ones. Storms and floods accounted for almost 70% (i.e. 35% each) of all reported disasters, alongside extreme temperature episodes (18%) and, to a lesser extent, wildfires (8%), droughts (3%), and landslides (2%) ([82]).

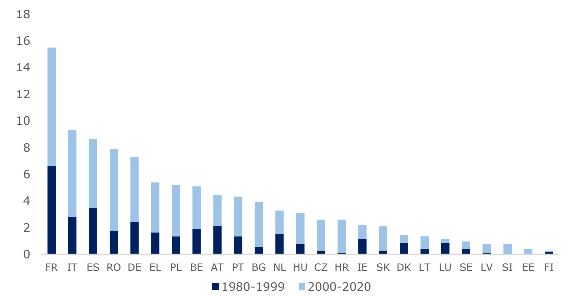
Graph IV.3: **: Number of weather and climate-related disasters in the EU, by disaster sub-group, 1980-2020**



(1) Meteorological (e.g. extreme temperature, storms), hydrological (e.g. floods), climatological (e.g. drought, wildifires)
Source: European Commission, based on the Emergency Events Database (EM-DAT; CRED, UCLouvain).

A country-level analysis shows that the events recorded over the 1980-2020 period were distributed quite unevenly across countries (Graph IV.4). France was the most struck country, reporting around 15% of all reported events, followed by Italy (9.3%), Spain (8.7%), Romania (7.8%), and Germany (7.3%). An average of around 5% of all disasters were reported in Greece, Poland, Belgium, Austria and Poland. The remaining countries recorded an average of around 3% each, with the exception of Sweden, Latvia, Slovenia, Estonia, and Finland, which recorded less than 1% of disasters.

Graph IV.4: **Geographical distribution (% of EU total) of weather and climate-related events in the EU, 1980-2020, per decade**



(1) Information for MT and CY is missing.
Source: European Commission, based on the Emergency Events Database (EM-DAT; CRED, UCLouvain).

Over the past 20 years, central-eastern European countries recorded a significant increase in the number of disasters (Graph IV.4). This has been particularly the case for Croatia, Czechia, Latvia, Slovakia, Bulgaria, Romania, and Hungary, alongside some southern European countries (Italy,

([81]) For instance, Heipertz and Nickel (2008) only focus on selected natural disasters and rely on long-term averages of budgetary elasticities to translate the economic damage (as % of GDP) into implied deficit increase. More sophisticated estimation methods data structures are used in both Lis and Nickel (2010) as well as in Melecky and Raddatz (2011). However, the former are not able to distinguish between direct and indirect fiscal impacts of extreme events. Instead, the fiscal response to natural disasters using annual (rather than higher frequency data), as in Melecky and Raddatz (2011), may lead to potential identification issues.

([82]) In the EM-DAT database, weather and climate-related disasters are identified in three main disaster subgroups (meteorological, hydrological, and climatological). In turn, each disaster subgroup encompasses main disaster types. In particular, meteorological events include episodes of extreme temperature, fog, and storms. Hydrological events include floods, landslides, and wave actions. Last, climatological events include episodes of drought, glacial lake outburst, and wildfires. For details, see https://www.emdat.be/classification.

Greece, and Portugal). Meteorological and hydrological events (mainly driven by storms and floods) were the main disaster types accounting for this increase.

Looking ahead, climate change is expected to lead to a significant increase in the frequency and strength of many types of weather and climate-related events ([83]). Evidence from literature shows projected increases in the severity, duration, and/or extent of several events, particularly heat waves, heavy precipitation, floods, droughts, and wildfires. However, the impacts are not expected to be felt evenly across Europe ([84]).

Economic losses from weather and climate-related events

Current available data indicate that, on average, the economic impact of weather and climate-related events should be contained. Over the period 1980-2020, economic losses accounted for a total of 3% of GDP in the EU. The annual average economic losses amount to less than to 0.1% of GDP ([85]). Although these figures may not (yet) appear as macro-economically significant, they are also very likely to suffer from underreporting of the actual effects ([86]). In addition, annual economic losses mask distributional impacts, with significant variations over time and across countries, depending on the occurrence of natural disasters.

Over the period 1980-2020, total economic losses ranged from almost 8% of GDP in Spain, 7% of GDP in Czechia, 5% in Romania and Portugal, to less than 1% of GDP in the Netherlands, Estonia, Lithuania, Sweden, Belgium, and Ireland. The effect of natural disasters on the overall economic losses has not been even over time as, quite often, single events have caused a significant share of total reported economic losses (Table IV.1).

Table IV.1: **Selected major weather and climate-related disasters and associated economic losses, by country, type and year**

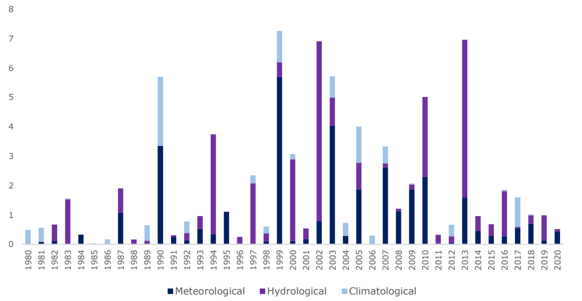
Country	Year	Disaster type	Related economic losses, % GDP	Total economic losses over 1980-2020, % GDP
BE	1990	Storm	0.5	0.8
BG	2005	Flood	1.5	3.3
CZ	1997	Flood	3.0	6.9
DK	1999	Storm	1.5	3.0
DE	2002	Flood	0.6	2.2
EE	2005	Storm	0.9	0.9
IE	1990	Storm	0.2	0.6
EL	1990	Drought	1.0	3.6
ES	1983	Flood	2.3	7.7
FR	1999	Storm	0.8	2.8
HR	2000	Extreme temp.	1.1	2.6
IT	1994	Flood	0.9	3.2
LV	2005	Storm	1.9	1.9
LT	2006	Drought	0.7	0.9
LU	1990	Storm	2.9	3.1
HU	1986	Drought	2.0	4.3
NL	1990	Storm	0.5	1.2
AT	2002	Flood	1.1	2.4
PL	1997	Flood	2.2	4.3
PT	2003	Wildfire	1.0	4.9
RO	2000	Drought	1.3	5.0
SI	2007	Storm	0.8	1.7
SK	2004	Storm	0.9	2.4
FI	1990	Storm	0.0	0.0
SE	2005	Storm	0.7	0.8

(1) 'Related economic losses' stand for the economic losses associated with each weather and climate disaster reported in the table. Total economic losses are the total reported for the country over the period 1980-2020. Data for CY and MT are missing.
Source: European Commission, based on the Emergency Events Database (EM-DAT; CRED, UCLouvain).

In the EU, hydrological and meteorological events have caused the majority of losses from weather and climate-related disasters. The impact has even increased over the past 20 years, with weather and climate-related events accounting for a cumulative 50% of total reported economic losses from natural disasters, compared to around 29% observed during the 1980-1999 period (see Graph IV.5).

([83]) IPCC (2021), *op. cit.*
([84]) EEA (2017), 'Climate change, impacts and vulnerability in Europe 2016 - An indicator-based report', European Environment Agency.
([85]) Based on the Emergency Events Database (EM-DAT; CRED, UCLouvain). The total estimated economic losses are defined as the value of all damages to property, crops, and livestock, as well as other losses related to the disaster. The registered figure corresponds to the value at the time of the event (https://www.emdat.be/Glossary).
([86]) This relates to data collection challenges and to the specific aim of different global natural disaster databases (See Box II.2.1, Part II, Chapter II, Fiscal Sustainability Report 2021, European Economy Institutional Paper 171, April 2022, European Commission)

Graph IV.5: **Economic losses from extreme weather and climate-related events in the EU (% of total events), by disaster subgroup, 1980-2020**



(1) Meteorological (e.g. extreme temperatures, storms), hydrological (e.g. floods), climatological (e.g. droughts, wildfires). Total events also include earthquakes.
Source: European Commission, based on the Emergency Events Database (EM-DAT; CRED, UCLouvain).

Economic losses from natural disasters are projected to increase at least two-to-threefold in the EU, by mid-century. By the end of the century, losses may increase by a further multiple ([87]). In particular, projections show that, compared to baseline climate conditions ([88]), economic losses are expected to be 1.9 times bigger by mid-century if global warming were contained to the (more ambitious) Paris Agreement target (1.5°C) by mid century. The impact would be 2.5 times bigger under the 2°C target, within the same horizon. The expected factor increase in projected economic losses for the EU's main regional aggregates are shown in Table IV.2.

In the longer term (by the end of the century), meeting the Paris target of 1.5°C will prove essential to contain increases in economic losses (Table IV.3). Losses are expected to rise threefold under the more favourable warming scenario, but to reach almost eight-to-fifteen times higher in the 2°C and 3°C warming scenarios. This is largely linked to the greater exposure of people and assets, driven by future socioeconomic development (i.e. linked to the growth of the size of the economy). Moreover, these figures mask significant differences across regions.

Table IV.2: **Factor increase in economic losses for the 1.5°C and 2°C warming scenarios, by mid-century, regional aggregates**

Regional aggregate	MF 1.5°C scenario	MF 2°C scenario
Mediterranean	x2.0	x2.3
Atlantic	x2.3	x3.4
Continental	x1.7	x2.1
Boreal	x1.6	x2.3
EU	**x1.9**	**x2.5**

(1) Mediterranean (PT, ES, IT, MT, CY, SI, HR, EL); Atlantic (IE, FR, BE, NL, LU); Continental (AT, DE, DK, PL, CZ, SK, RO, BH, HU); Boreal (FI, SE, LT, LV, EE).
(2) Factor increases are built with respect to baseline climate conditions (1981-2010) used in the PESETA IV project and represent the expected increase in economic losses from natural catastrophes under different global warming scenarios.
Source: European Commission, based on the PESETA IV project (Feyen et al., 2020, op.cit.)

Table IV.3: **Factor increase in economic losses for the 1.5°C, 2°C, and 3°C warming scenarios, by the end of the century, regional aggregates**

Regional aggregate	MF 1.5°C scenario	MF 2°C scenario	MF 3°C scenario
Mediterranean	x3.2	x6.6	x10.8
Atlantic	x3.8	x13.9	x25.1
Continental	x2.6	x5.4	x11.0
Boreal	x2.6	x5.6	x12.8
EU	**x3.0**	**x7.9**	**x14.9**

(1) Mediterranean (PT, ES, IT, MT, CY, SI, HR, EL); Atlantic (IE, FR, BE, NL, LU); Continental (AT, DE, DK, PL, CZ, SK, RO, BH, HU); Boreal (FI, SE, LT, LV, EE).
(2) Factor increases are built with respect to baseline climate conditions (1981-2010) used in the PESETA IV project and represent the expected increase in economic losses from natural catastrophes under different global warming scenarios.
Source: European Commission, based on the PESETA IV project (Feyen et al., 2020, op.cit.)

Nevertheless, the projected economic impacts do not include all potential consequences from climate changes. They do not include other key items (e.g. irreversible damage to nature and species losses) and the consequences of passing tipping points. In addition, they do not capture the full effects of extreme events in all sectors. Hence, these projections are only meant to serve as a *lower bound* of expected adverse economic impacts from climate change in the EU ([89]).

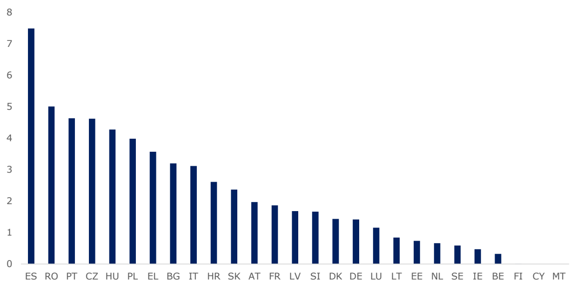
([87]) Feyen *et al.* (2020), 'Climate change impacts and adaptation in Europe', JRC PESETA IV final report (No. JRC119178), JRC Science for Policy Report, Joint Research Centre, European Commission. Projections of economic losses (in 2015 values) in the PESETA IV project are provided on the basis of a dynamic assessment', evaluating how natural catastrophes combined with different global warming levels would impact EU society 'as projected for 2050 and 2100 according to the ECFIN Ageing Report 2015 projections of population and the economy.
([88]) In the PESETA IV project, projections of economic losses are calculated against specific 'baseline climate conditions', identified as the period 1981-2010 (Feyen *et al.*, 2020).
([89]) Ibid.

The role of insurance coverage

Adequate insurance coverage can reduce the adverse economic impacts of natural disasters. Though they do not prevent the loss of assets, well-designed climate risk insurance policies help countries better manage and mitigate the economic impact of disasters, by acting as a safety net and buffer after an extreme event while, at the same time, promoting risk awareness ([90]).

In turn, the distribution of *uninsured* economic losses, or the 'climate protection gap' provides a more comprehensive overview of EU countries' past relative economic exposure to extreme weather and climate-related events (Graph IV.6).

Graph IV.6: **Cumulative uninsured economic losses from weather and climate events (% of country GDP), by country, 1980-2020**



(1) The figures reported come from EM-DAT, which provide data on total and insured economic losses. As also documented in the Fiscal Sustainability Report (Part II, Chapter II), this dataset is likely to suffer from underreporting. However, this is the only publicly available dataset with a broad coverage on extreme weather and climate-related events.
(2),Information for CY and MT is missing.
Source: European Commission, based on The Emergency Events Database (EM-DAT; CRED, UCLouvain).

This shows that in terms of countries' economic size, the southern and eastern European countries appear to have been the most exposed. This is the case for Spain (with cumulated uninsured economic losses representing 7.5% of GDP over 1980-2020), Romania (5% of GDP), Portugal, Czechia, Hungary (4.5% of GDP), followed by Poland (around 4% of GDP) and an impact ranging from 3% to 3.5% of GDP for Greece, Bulgaria, and Italy. By contrast, countries with sufficient insurance coverage, despite having relatively high occurrences of natural disasters, have a lower economic exposure (e.g. Germany, Belgium, and Austria) ([91]).

IV.4.Stress tests

The following section provides first stylised stress tests on the fiscal impact of *acute physical risks* from climate change. This is done by drawing upon our review of the literature and the stylised facts presented above. Our purpose is to capture risks associated with *one-off* extreme weather and climate-related events over the medium term, in the form of aggravating factors to debt sustainability.

Assumptions and methodology

In our stress tests, we adopt a comparative approach. We illustrate, in a given country, the deviation from the Commission's 10-year baseline debt-to-GDP projections, should a past extreme event reoccur in the medium term. However, to account for potential interactions between climate change and the expected intensity/frequency of extreme events, we then further calibrate the impact according to different global warming scenarios (1.5°C and 2°C). In each scenario, we assume the specific extreme event to simultaneously exert both a *direct* impact on government accounts (i.e. via the primary balance), thus affecting the debt level, and an *indirect* impact via GDP (growth and level) effects (also affecting the debt ratio, via denominator effects) ([92]).

The *direct* shock to public finances (via the primary balance) is calculated based on past country-specific exposure to extreme events, augmented by the expected increase in economic losses from extreme events due to climate change. We first rely on the annual distribution (from 1980 to 2020) of the *uninsured* economic losses (% of GDP) available

([90]) Cebotari, A., & Youssef, K. (2020). Natural Disaster Insurance for Sovereigns: Issues, Challenges and Optimality, *IMF Working Paper*, WP/20/3, Schäfer et al., (2016), 'Making climate risk insurance work for the most vulnerable: seven guiding principles', *Policy report 2016, No.1,* UNU-EHS Publication Series, European Commission (2013), COM(2013) 213 final.

([91]) For additional stylised facts on exposure to weather and climate-events in the EU, see Gagliardi et al. (2022), *op. cit.*

([92]) The intuition behind our 'extreme event stress test' scenarios partly draws on the work by International Monetary Fund (IMF) and the World Bank, which recently brought in a tailored stress test for natural disasters in their revised Joint Debt Sustainability Framework for Low-Income Countries (see the Guidance Note on the Bank-Fund Debt Sustainability Framework for Low Income Countries, 2017). However, their 'natural disaster' stress test relies on the EM-DAT database and is tailored to the country-specific history, but not to future expected impacts from climate change. Our stress tests take a novel approach, both in terms of calibration methodology and country selection criteria (see Sub-Section IV.4 for details).

for all EU countries from the EM-DAT database (93). Then, for each country, we identify the *maximum* of the annual distribution as an instance of 'extreme' (or 'tail event') occurrence (94). Subsequently, in order to account for the likely increase in economic losses from climate events due to a warmer climate, we calculate the overall direct fiscal impact by interacting the country-specific extreme value (i.e. the maximum) with a given factor increase (95).

In our stress tests, we take a medium-term perspective. So we calculate the *direct* fiscal shock by relying on the factor increase computed for the 1.5°C and 2°C medium-term scenarios (Table IV.2) (96). In each scenario, our assumed *direct* fiscal impact (i.e. country-specific extreme value multiplied with the corresponding factor increase see Table IV.4) is translated into a *one-off* adverse shock on the country's debt trajectory via an impact on the primary balance. This is applied in the first year after the European Commission's government debt forecast horizon (i.e. in 2024) (97) (98).

(93) Information on Malta and Cyprus is not provided in the EM-DAT database. In line with the literature presented in Section IV.2, *uninsured losses* appear to be the main driver behind the adverse macroeconomic shocks of natural catastrophes.

(94) While there is no single definition for what is meant by extreme events, they are generally defined as 'either taking *maximum* values or *exceedance* above pre-existing high thresholds' (Stephenson, D. B. et al. (2008). 'Definition, diagnosis, and origin of extreme weather and climate events.' *Climate extremes and society*, 340, p. 12).

(95) Our factor increase is constructed on a regional basis. Following the PESETA IV project (Feyen *et al.* (2020), *op.cit.*), we identify four regional aggregates: *Mediterranean*, *Atlantic*, *Continental*, and *Boreal*.

(96) The PESETA IV (*ibid.*) study projects economic losses under the 1.5°C and 2°C scenarios as expected to occur by mid-century. Economic losses associated with the 3°C scenario are only projected for the end of the century. While the medium-term projections (i.e., by mid-century) are more forward-looking than our debt projection horizon (2021-2032), recent evidence shows that the 1.5°C limit is already likely to be reached as early as 2030 and the early 2050s, unless concerted action is taken to reduce greenhouse gas emissions (IPCC, 2018). The absence of any significant mitigation measures may also increase the likelihood of a closer 2°C warming scenario.

(97) A country's (initial) primary balance may already include some provisions for natural disasters, and common emergency funds (e.g. EUSF) may partly cover some damages. However, for the sake of simplicity, we show what would be the approximate overall impact on public finances, should a past extreme event reoccur in the medium term, in the absence of significant climate mitigation and adaptation measures. The calibration of the shock based on *uninsured* losses allows to already account for potential risk-sharing between the private and public sector.

(98) For references of alternative assumptions used in empirical studies on the fiscal impact of extreme events, see the Debt Sustainability Monitor 2019, *op. cit.* Our stress tests are based on the European Commission's Autumn 2021 macroeconomic and fiscal forecast.

Table IV.4: **Assumed direct fiscal impact of a one-off extreme event (% GDP), by country and warming targets (1.5°C and 2°C),**

	1.5°C scenario	2°C scenario
BE	0.4	0.5
BG	2.7	3.2
CZ	4.3	5.2
DK	0.9	1.0
DE	0.9	1.1
EE	1.2	1.7
IE	0.4	0.6
EL	2.0	2.4
ES	4.5	5.3
FR	1.2	1.7
HR	2.4	2.8
IT	1.7	2.0
CY	n.a.	n.a
LV	2.7	3.8
LT	1.2	1.7
LU	2.4	3.4
HU	3.5	4.3
MT	n.a.	n.a
NL	0.5	0.8
AT	1.6	2.0
PL	3.4	4.1
PT	2.1	2.4
RO	2.8	3.4
SI	1.6	1.9
SK	1.6	1.9
FI	0.0	0.0
SE	0.9	1.2

(1) For instance, in CZ, the fiscal shock in the 1.5°C scenario amounts to 4.3% of GDP. This value is obtained as follows: the maximum value of uninsured losses (% GDP) in Czechia was recorded in 1997 and amounted to 2.5% of GDP. In our stress tests, this value is multiplied by a factor increase of 1.7 (corresponding to the factor increase identified under the 1.5°C scenario for the country's corresponding regional aggregate (i.e. Continental - see Table IV.2). The direct fiscal shock is then translated into a *one-off* adverse shock on the debt trajectory, via an impact on the primary balance, applied in the first year after the European Commission's government debt forecast horizon (i.e. in 2024).
Source: European Commission, based on The Emergency Events Database (EM-DAT; CRED, UCLouvain) and the PESETA IV project (Feyen et al., 2020, op.cit.).

As for *indirect* shocks to GDP (i.e. both growth and level), we rely on recent empirical evidence. Given our focus on *uninsured* economic losses, we first assume an adverse shock to growth to occur in the aftermath of a disaster. To this end, we rely on estimates from a recent study of the European Insurance and Occupation Pensions Authority on OECD countries (99). The study finds that large-scale disasters with low insurance coverage have, on average, an adverse effect (of around -0.5%) on annual GDP growth rate. In turn, we assume, for each country, a reduction in actual GDP growth (i.e. an impact of -0.5% compared to the baseline)

(99) Fache Rousová *et al.* (2021), *op. cit.*

in the same year of the direct fiscal shock (i.e. 2024). In addition, we assume that the adverse effect on GDP growth translates into permanently lower levels of GDP, compared to the baseline ([100]). This is in line with recent empirical evidence of the long-term macroeconomic consequences of uninsured natural catastrophes, pointing to '*no recovery*' effects – with post-disaster output continuing to grow in the long term, but on a lower trajectory ([101]).

Main results

The stress tests are only carried out for a set of highly exposed and vulnerable countries ([102]). These are Spain, Romania, Portugal, Czechia, Hungary, Poland, Greece, Italy, Austria, France, Belgium, Germany, and The Netherlands.

The stress tests show non-negligible fiscal impacts in some countries. The results of the simulated debt projections for the selected countries are reported in Table IV.5 and Graph IV.7.

- *Spain* is one of the most affected countries. The debt-to-GDP ratio is projected to be higher, in 2032, by 4.5 pps of GDP and 5.2 pps of GDP in the 1.5°C and 2°C scenarios respectively, compared with the baseline, also given the high debt level.

- Similar results are found for *Czechia*, with a difference of 4.0 pps of GDP and 4.7 pps of GDP respectively by 2032 compared with the baseline, and for *Hungary*, where the 1.5°C (2°C) warming scenario is projected to result in 3.1 (3.7) additional percentage points in the debt-to-GDP ratio by 2032.

([100]) In our stress tests, this translates into an adverse effect on potential GDP growth.

([101]) Batten (2018), *op.cit.*; Von Peter *et al.* (2012), *op.cit.*

([102]) We rely on specific selection criteria. In particular, out of the EU countries that had over the 1980-2020 period (according to the EM-DAT database) the highest overall share of *uninsured* economic losses (% GDP) and the highest overall number of natural disasters, we select those countries that: i) have experienced at least 2 peaks in the number of reported events, and; ii) have experienced an increase in the number of reported events over the last 20 years, and; iii) are at 'medium-to-high' vulnerability to acute physical risks in the long term, according to the SwissRE Climate Economic Index ('The economics of climate change: no action not an option.', Swiss RE institute, April 2021). A peak is identified if the number of natural disasters, for a given country and in a given year, is higher than the corresponding upper end (i.e. 90th percentile) of the country's annual number of observed events over 1980-2020.

Table IV.5: **Debt-to-GDP projections of selected countries, baseline versus 1.5°C and 2°C warming scenarios**

Debt-to-GDP projections					
Spain	**2021**	**2023**	**2024**	**2032**	**2032 change**
Baseline	120.6	116.9	120.3	126.1	
1.5°C scenario	120.6	116.9	125.4	130.6	4.5
2°C scenario	120.6	116.9	126.2	131.3	5.2
Romania	**2021**	**2023**	**2024**	**2032**	
Baseline	49.3	53.2	54.3	76.9	
1.5°C scenario	49.3	53.2	57.4	79.6	2.7
2°C scenario	49.3	53.2	57.9	80.1	3.2
Portugal	**2021**	**2023**	**2024**	**2032**	
Baseline	128.1	122.7	121.8	126.2	
1.5°C scenario	128.1	122.7	124.5	128.6	2.4
2°C scenario	128.1	122.7	124.9	129.0	2.7
Czechia	**2021**	**2023**	**2024**	**2032**	
Baseline	42.4	46.3	48.0	67.1	
1.5°C scenario	42.4	46.3	52.6	71.1	4.0
2°C scenario	42.4	46.3	53.5	71.8	4.7
Hungary	**2021**	**2023**	**2024**	**2032**	
Baseline	79.2	76.4	74.9	68.1	
1.5°C scenario	79.2	76.4	78.8	71.3	3.1
2°C scenario	79.2	76.4	79.5	71.9	3.7
Poland	**2021**	**2023**	**2024**	**2032**	
Baseline	54.7	49.5	48.2	48.3	
1.5°C scenario	54.7	49.5	51.8	51.1	2.8
2°C scenario	54.7	49.5	52.5	51.7	3.4
Greece	**2021**	**2023**	**2024**	**2032**	
Baseline	202.9	192.1	185.9	154.7	
1.5°C scenario	202.9	192.1	188.8	157.3	2.6
2°C scenario	202.9	192.1	189.2	157.5	2.8
Italy	**2021**	**2023**	**2024**	**2032**	
Baseline	154.4	151.0	150.6	161.6	
1.5°C scenario	154.4	151.0	153.0	163.9	2.2
2°C scenario	154.4	151.0	153.3	164.1	2.5
Austria	**2021**	**2023**	**2024**	**2032**	
Baseline	82.9	77.6	76.9	76.3	
1.5°C scenario	82.9	77.6	78.9	77.9	1.6
2°C scenario	82.9	77.6	79.2	78.1	1.9
France	**2021**	**2023**	**2024**	**2032**	
Baseline	114.6	112.9	114.2	122.3	
1.5°C scenario	114.6	112.9	116.0	123.8	1.5
2°C scenario	114.6	112.9	116.5	124.2	1.9
Belgium	**2021**	**2023**	**2024**	**2032**	
Baseline	112.7	114.6	116.5	133.6	
1.5°C scenario	112.7	114.6	117.5	134.4	0.8
2°C scenario	112.7	114.6	117.6	134.5	0.9
Germany	**2021**	**2023**	**2024**	**2032**	
Baseline	71.4	68.1	67.0	61.6	
1.5°C scenario	71.4	68.1	68.3	62.6	1.0
2°C scenario	71.4	68.1	68.4	62.8	1.1
The Netherlands	**2021**	**2023**	**2024**	**2032**	
Baseline	57.5	56.1	56.0	62.8	
1.5°C scenario	57.5	56.1	56.8	63.5	0.7
2°C scenario	57.5	56.1	57.1	63.7	0.9

(1) The 2032 change measures the difference, in 2032, between debt-to-GDP in the 1.5°C and 2°C scenarios, respectively, compared to the baseline.
Source: European Commission, based on The Emergency Events Database (EM-DAT; CRED, UCLouvain) and the PESETA IV project (Feyen et al., 2020, op.cit.).

- *Poland*, *Romania*, and *Greece* follow (with an average of 2.7 pps of GDP and 3.1 pps of GDP difference in 2032 compared with the baseline, in each scenario, respectively).

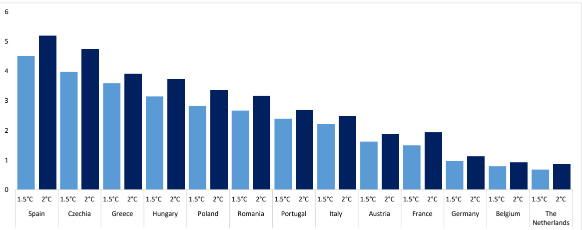
- In *Italy*, both the 1.5°C and 2°C scenarios are expected to lead to a difference of 2.2 pps of

GDP to 2.5 pps of GDP by the end of the horizon, compared to the baseline projections.

- The impact will also be quite significant for *Austria* and *France*, with projected difference of 1.5 pps of GDP and 1.9 pps of GDP compared with the baseline.

- *Germany*, *Belgium*, and *The Netherlands* report the lowest difference in debt-to-GDP ratios by the end of the horizon, in each warming scenario.

Graph IV.7: **Debt-to-GDP difference (pps.), 1.5°C and 2°C scenarios compared to the baseline, 2032**



Source: European Commission, based on The Emergency Events Database (EM-DAT; CRED, UCLouvain) and the PESETA IV project (Feyen et al., 2020, op.cit.)

Our stress tests confirm the macroeconomic relevance of climate-related disasters and the related risks to government finances, although remaining manageable under limited, medium-term, global warming scenarios. Despite the still favourable interest-growth rate differentials assumed in the projections, and the *one-off* nature of the simulated shock, the negative impact on debt projections appears significant and persistent over time. However, our results are likely to represent an underestimation of the expected fiscal impact. This is due to potential underreporting of economic losses in global disaster databases (unable to fully reflect damages to uninsured public assets), the use of *lower bound* estimates of the expected adverse economic impact from climate events in the EU, as well as unaccounted risks from non-linearities and tipping points, potential negative feedback effects across sectors, and/or adverse spillover effects across countries, combined with our medium-term perspective. Overall, our results support calls for increased policy attention to address the 'climate protection gap' as well as the need to strengthen climate-related risk management and financing frameworks, both at national and EU levels.

IV.5.Conclusion

This section illustrates stylised stress tests on the fiscal impact of extreme weather and climate-related event for selected EU countries. The tests are designed as shocks to public finances and growth, in the context of the European Commission's standard DSA framework. Our results highlight that *physical* risks from climate change may pose some risks to countries' fiscal (debt) sustainability. The findings underscore the need to take large-scale, rapid, and immediate mitigation and adaptation policies, including insurance and climate-resilient debt instruments, to boost countries' financial resilience to climate change and dampen the fiscal impact of climate-related events. Concerted action towards ambitious global and EU climate targets remains essential to reduce countries' exposure and vulnerability to climate change.

As documented, practical caveats remain. Modelling limitations and current data availability constitute important challenges. The present assessment necessarily builds on several simplifying assumptions and only provides a partial perspective of climate-related fiscal (debt) sustainability risks, given the focus on fiscal impact of *acute physical* risks. Relatedly, the existing international datasets recording extreme weather and climate-related events are not (fully) publicly available, and/or often provide a partial reporting of impacts. In addition, the reporting of total economic losses is not done following a common standard, which makes it difficult to disaggregate the total losses between private and public sector, with consequences on the estimation of related fiscal impacts.

Going forward, in addition to factoring in the risks from direct *physical* events, a broader assessment will need to encompass the net fiscal impact of mitigation policies aimed at supporting the transition to climate-neutral economies. It should also encompass adaptation policies, aimed to anticipate the adverse effects of climate change and to take appropriate action to prevent or minimise the damage they can cause. Overall, the development of standard harmonised reporting frameworks at EU level remains an essential aspect to build fiscal resilience. This includes better reporting and assessments of the macroeconomic impacts of extreme events, planned climate mitigation and adaptation policies, and the related potential fiscal risks.