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The Fiscal Impact of Extreme Weather and Climate Events
Evidence for EU Countries

Nicola Gagliardi, Pedro Arévalo and Stéphanie Pamies

Abstract

Assessing fiscal risks from climate change is a critical and challenging issue. In this paper, we analyse the fiscal implications of acute physical risks from climate change, as we aim to capture debt sustainability risks associated with extreme weather and climate events. This is done by providing stylised stress tests for selected EU Member States, designed as shocks to public finances and growth. To do so, we rely on a comparative approach. Climate-related aggravating factors to debt sustainability are captured via a global natural disaster database and available forward-looking estimates of economic losses from different climate events, projected under different global warming pathways. Our results highlight that extreme weather and climate events may pose risks to debt sustainability, although remaining manageable across the EU under standard global warming scenarios. Our findings emphasise the relevance of implementing large-scale, rapid, and immediate climate mitigation and adaptation measures to dampen the adverse economic and fiscal impacts of potentially more frequent and intense extreme events, thereby reducing countries' exposure, their vulnerability, and debt sustainability risks.

JEL Classification: Q54, H12, H63.

Keywords: climate change, extreme weather and climate events, acute physical risks, debt sustainability analysis, public debt.

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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 (IPCC, 2021). The rise in anthropogenic GHGs represents 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' (Stern, 2007).

As a result, global temperature has been increasing markedly over the past century. According to the IPCC (2021), 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.

Large-scale, rapid, and immediate mitigation measures have the potential to limit climate change and its related effects. According to the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report (AR6; IPCC, 2021), 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 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 (IPCC, 2021).

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 (IPCC, 2022).[1,2] This may either occur 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 – so called *chronic physical* risks), or via more intense and frequent extreme weather and climate events (e.g. storms, floods, droughts, heat waves – so called *acute physical* risks. Limiting global warming to 1.5°C is expected to reduce risks to ecosystems and human activities. Every additional 0.5°C of global warming is likely to exert a significant increase on both the intensity and frequency of extreme weather and climate events, such as severe heatwaves, heavy precipitation, and drought (IPCC, 2021).

Moreover, the risk of non-linearities and tipping points may increase the likelihood for catastrophic and irreversible outcomes to occur. Nowadays, there is widespread agreement that tail-risks are real and the risk of catastrophic and irreversible disaster is rising (Lenton et al., 2019; Krogstrup and Oman, 2019; IPCC 2018, 2014), implying 'potentially infinite costs of unmitigated climate change' (Krogstrup and Oman, 2019, pp.11; Weitzman, 2011), with no backstop in the event of catastrophic climate change (Aglietta et al., 2018). Hence, unless a sharp decline in GHG emissions occurs before the mid of this century, global warming is very likely to have catastrophic consequences for entire ecosystems and exert negative impacts on our society, particularly on the most vulnerable (IPCC, 2018).

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[1] Natural hazards become disasters when 'human lives are lost, and livelihoods damaged or destroyed' (CRED, 2020, p. 8). In this paper, we focus on natural hazards and disasters caused by 'extreme weather or climate events. Earthquakes are not included in our definition.

[2] The distinction between *extreme weather* and *extreme climate* events is not clear-cut and mainly depends on the adopted time scale (IPCC, 2012). 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, p. 117).

Physical risks from climate change also entail economic and fiscal consequences. Adverse economic impacts may occur through shocks to the supply and demand side of the economy caused, among others, by damage and disruption to critical infrastructure and property, reduced labour productivity, lower consumption and investment, and disruption to global trade flows. Public finances are likely to be equally affected via, for instance, increased public spending, materialisation of contingent liabilities, and/or output losses.

In this paper, we provide an empirical assessment of the potential impact of climate-related physical risks on public finances from an EU perspective. In particular, we focus on *acute* physical risks from climate change, as we aim to capture debt sustainability impacts associated with extreme weather and climate events. This is done by providing stylised stress tests for selected EU Member States, designed as shocks to public finances and growth. Climate-related aggravating factors to debt sustainability are captured by relying on a global natural disaster database (EM-DAT) as well as available forward-looking estimates of economic losses from different climate events (PESETA IV, Joint Resarch Centre, European Commission).

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

Our results highlight that extreme weather and climate events may pose risks to fiscal (debt) sustainability in several countries, although remaining manageable under standard global warming scenarios. In particular, the simulated extreme event exerts a significant and persistent negative impact on debt projections. The adverse fiscal impact increases in higher projected warming scenarios. Overall, our results appear to be heterogeneous across countries and remain, nevertheless, surrounded by large uncertainties. Our findings emphasise the relevance of implementing large-scale, rapid, and immediate climate mitigation and adaptation measures to dampen the adverse economic and fiscal impacts of potentially more frequent and intense extreme events, thereby reducing countries' exposure, their vulnerability, and debt sustainability risks.

The rest of the paper is organised as follows. Section 2 sets the scene by illustrating the main macroeconomic and fiscal impacts typically associated with climate change. Section 3, and its related sub-sections, illustrate our debt sustainability stress tests. We begin with a comprehensive review of the theoretical and empirical literature on the macroeconomics of natural disasters (sub-section 3.1). We then explore available global natural disaster loss databases and provide stylised facts on Europe (sub-section 3.2). Our assumptions and modelling approach (sub-section 3.3), alongside our main results (sub-section 3.4), are subsequently illustrated. Section 4 concludes with an overview of potential caveats to our analysis and related way forwards.

2. THE MACROECONOMIC AND FISCAL IMPACT OF DISASTERS

Climate change entails two sources of risks with economic and fiscal consequences. On the one hand, *physical risks*, defined as 'those risks that arise from the interaction of climate-related hazards (including hazardous events and trends) with the vulnerability of exposure of human and natural systems, including their ability to adapt' (Batten et al., 2016, p.5). In turn, *physical risks* from climate change are distinguishable in *acute* and *chronic*. *Acute physical risks* identify extreme weather and climate events, which tend to cause immediate damage and lead to potential short- and medium-term consequences. *Chronic physical risks* may cause permanent damage over the medium and long term, as they reflect more gradual, and often irreversible, transformations of the environment due to global warming. On the other hand, *transition risks*, related to mitigation policy efforts, may arise from the economic and fiscal consequences stemming from the transition to a low-carbon economy (Batten et al., 2020). In spite of such conceptual distinction (which we rely upon throughout the paper), *physical* and *transition risks* 'are not independent of each other but tend to interact' (Batten et al., 2020; p. 3), as inadequate policy actions to fight climate change can aggravate physical risks and, in turn, intensify transition risks (European Commission, 2021b; NGFS, 2020). In what follows, we illustrate the main macroeconomic and fiscal impacts associated with climate change risks, with a particular focus on Europe.

2.1. PHYSICAL RISKS

***Physical risks* from climate change are overall increasingly associated with adverse economic impacts, mostly occurring through shocks to the supply and demand sides of the economy.** This is particularly the case for *acute physical* risks, stemming from extreme weather and climate events. The latter may cause, among others, damage and disruption to the capital stock, loss of hours worked due to extreme events, disruption to trade flows, as well as reduction in consumption and investment (see sub-section 3.1 for more details). Similarly, *chronic physical risks* (i.e. due to gradual global warming) may adversely affect the economy via, for instance, loss of hours worked due to extreme heat, resource diversion from investments in productive capital to climate change adaptation, and shifts in investment and consumption patterns[3] (see Batten et al., 2020; Batten, 2018; for a thorough review). The most adverse impacts are likely to be borne by communities located in areas with high exposure to climate disasters, as well as in those with lower capacity to prepare for and cope with such events. Sectors heavily reliant on natural resources and stable climate conditions (e.g. agriculture, fishing) for the good functioning of their economic activities are expected to experience greater impacts (USGCRP, 2018).

The macroeconomic impacts from *physical risks* are expected to be heterogeneous across the EU. In Europe, the overall exposure has not (so far) been as large as in other parts of the world. In addition, the impacts have varied greatly across individual years, countries, and regions. For instance, between 1980 and 2019, a large share (more than 60%) of total reported economic losses from weather and climate-extremes in Europe has been caused by a small number (less than 3%) of all unique registered events (European Commission, 2021b).[4] Recent models also show that the economic burden from

[3] Nevertheless, in specific sub-regions (e.g. Northern ones), some positive economic impacts from gradual global warming might potentially occur via, for instance, benefits on the agriculture (e.g. new crop varieties and higher crop productivity) and/or tourism sectors (European Commission, 2021b; Feyen et al., 2020; Farid et al, 2016; EEA, 2012).

[4] The five most expensive climate extreme events in EU Member States were the following, in decreasing order of magnitude (2017 values): the 2002 flood in Central Europe (over EUR 21 billion in losses); the 2003 drought and heat wave (almost EUR 15 billion in losses); the 1999 winter storm Lothar (around EUR 13 billion in losses); the October 2000 flood in Italy and France (around EUR 13 billion in losses), the 2013 floods in central Europe (almost EUR 11 billion in losses) (European Commission, 2021b; based on reinsurer Munich Re's NATCATService; see https://www.eea.europa.eu/ims/economic-losses-from-climate-related).

physical risks is expected to exhibit a clear regional divide. In particular, *Southern regions* in Europe are likely to experience much larger negative impacts through the effects of heatwaves, water scarcity, droughts, and forest fires (e.g. via increased human health risks and mortality, reduced labour productivity, agricultural losses, energy availability, reduced suitability for tourism). On the contrary, *Northern parts of Europe* could generally experience positive impacts from a warmer temperature, with benefits on sectors such as agriculture (e.g. new crop varieties and higher crop productivity), energy supply, and tourism.[5] As a result, aggregate losses in *Southern regions* are expected to be several times larger compared to those in the *north of Europe* (European Commission, 2021b; Feyen et al., 2020; Farid et al, 2016; EEA, 2012).

Nevertheless, the overall assessed economic impact of *physical risks* from climate change may suffer from underestimation. This may be due to simplifying underlying assumptions on both the (expected) negative and positive impacts, the potential exclusion of catastrophic outcomes possibilities, the exclusion of significant, but not easily includable, phenomena (e.g. ecosystem degradation and collapse), as well as other complex interactions (Stern, 2013). Bottom-up (i.e. sectoral) approaches typically provide a partial equilibrium perspective (i.e. not covering all relevant impacts in the economic system). On the contrary, top-down approaches (such as the damage functions generally used in climate-economic Integrated Assessment Models - IAMs) often suffer from methodological caveats (e.g. adequate common metric for costing different elements, choice of the discount rate; European Commission, 2021b, 2020a; Dimitrijevics et al., 2021; Dietz et al 2020). Hence, while they provide qualitative indications on how complex systems behave, accurate quantitative predictions are not yet available.

Adverse macroeconomic developments from *physical risks* could also pose challenges to the sustainability of public finances. Public finances are likely to be affected in multiple ways by climate change. First, *directly*, such as increased public spending to replace damaged assets and infrastructures, to support vulnerable households or firms, as well as via 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). *Indirect* impacts on public finances are also likely to occur in several instances, such as reduced tax revenue due to output losses following disruptions of economic activity in climate-sensitive sectors and regions. Vulnerability to climate change might even generate increasing risks of uncertainty, affecting the creditworthiness and the international financial accessibility of a given country (see sub-section 3.1; Radu, 2021; Zenios, 2021; European Commission, 2020a). The fiscal impact of *physical risks* is also entwined with countries' ability to adapt, by anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause. Adaptation, aimed at increasing resilience to adverse weather effects in the long term and reducing the severity of climate damages to more moderate effects, is expected to require significant public expenditure (including investment) in climate-proofing infrastructure, among others.[6,7]

2.2. TRANSITION RISKS

Besides risks from direct *physical* impacts, the *transition* to a low-carbon economy is also expected to exert significant effects on the economy and public finances (i.e. *transition risks* from climate change)**.** Despite exerting different positive pressures on climate change itself or on resilience

[5] However, negative impacts on the agricultural and forestry ecosystems in the north of Europe may also occur, mainly through increasing risks of pests and diseases, nutrient leaching, and reduced soil organic matter (EEA, 2012).

[6] Examples of *adaptation* measures include modifying construction regulation for making buildings resilient to higher temperature and/or extreme weather events, developing drought-tolerant crops, promoting forestry practices that could reduce vulnerability to storms and fires (European Commission, 2020a).

[7] See COM(2021) 82 final.

to climate, the different range of *mitigation* policy options[8] are also likely to have specific impacts on the economy. The overall macroeconomic impact is expected to depend on the timing and design of policies to support the transition. The conventional argument is that *transition risks* underpin, at least in the short term, a trade-off between reduction of current emissions, which comes at a direct mitigation cost, and long-term environmental quality (Baur et al., 2021; Zenios, 2021; Feyen et al., 2020; NGFS, 2020; Batten, 2018; OECD, 2015). While this does not necessarily mean that economic growth will decline, the transition is expected to lead to asymmetrical impacts and adjustment costs at sectoral level and for parts of the society (European Commission, 2018).[9] Additionally, the climate transition may potentially affect the underlying composition of growth, with more resources devoted to investment and less to consumption, given the expected accelerated obsolescence of certain existing capital stock (Pisani-Ferry, 2021; European Commission, SWD(2020) 176 final).

While public finances will play a central role in the climate transition, they are also likely to be subject to significant challenges. On the one hand, mitigation efforts should reduce the risks and economic and fiscal costs from climate change in the long term, with milder impacts in terms of damages, growth, and borrowing needs (Zenios, 2021). On the other hand, such policies are expected to result in an upward pressure on public finances in the short and medium term. For example, higher public expenditure is likely to be required in the form of public subsidies supporting a clean energy transition as well as other social and compensatory policies. For the EU as a whole, the overall additional investment needs for the green transition have been estimated to around EUR 520 billion per year for the period up to 2030 (European Commission, 2021c).[10] More specifically, the additional energy system investment needs (including transport) to reach the 55% emissions reduction target (i.e. 'Fit for 55' package)[11] have been estimated to around EUR 390 billion per year during 2021-2030 relative to 2011-2020. The public sector will play an important role in carrying out part of these investments directly and in cooperating and/or providing support for private investors, e.g. via private-public partnerships and State aid schemes in support of the deployment of renewable energy or the decarbonisation of industry.[12] At the same time, additional revenue will be raised through carbon pricing instruments (Pisani-Ferry, 2021; European Commission, 2020a,b).

2.3. CLIMATE CHANGE AND FISCAL SUSTAINABILITY FRAMEWORKS

Despite its considerable relevance, the analysis of climate-related risks has often been absent from fiscal sustainability frameworks of international institutions, notably due to inherent difficulties in conceptualising and quantifying such aspects. Notwithstanding these difficulties, modules tentatively examining potential implications from climate-related risks on the sustainability of public finances have recently seen a surge. Recent analyses on the matter relate to the United Kingdom OBR (2021) and the Swiss Federal Department of Finance (2021).[13] At the EU level, notable initiatives on fiscal matters and climate change relate to ongoing work on 'green budgeting' (Battersby et al., 2021; Bova, 2021), disaster-risk financing (Radu, 2021), and disater risk-management (European

[8] Examples of *mitigation* policies include carbon taxation, emission trading schemes, specific regulations or tax incentives that promote the use of clean energy, (e.g. renewable energy or zero-emission transport), or more efficient energy use (i.e. scaling up the energy efficiency of domestic appliances or buildings).

[9] For instance, a contraction in economic activity in the mining and extraction of fossil fuels is expected. An impact on energy-intensive industries or the automotive sector can also be expected, as these sectors will need to be structurally transformed. Other sectors, such as renewable energy or construction, are expected to face stronger demand, but they may face bottlenecks. In addition, lower and higher-income households will be differently affected, due to their budget constraints but also their borrowing capacity that influence their capacity to procure more efficient assets. At the same time, the transition is expected to spur growth in new sectors (i.e., 'green growth'). See European Commission (2018), COM (2018) 773 final.

[10] See European Commission (2021c), COM (2021) 662 final.

[11] See https://ec.europa.eu/clima/eu-action/european-green-deal/delivering-european-green-deal_en.

[12] See SWD (2021) 621 final, Table 7.

[13] For an overview of official institutions encompassing climate risks into fiscal sustainability and financial stability frameworks, see European Commission (2020a).

Commission, 2021d). Moreover, the 2019 Debt Sustainability Monitor (European Commission, 2020a) provides a conceptual framework on how to encompass climate change impacts on growth and public finances in the standard European Commission's Debt Sustainability Analysis (DSA).

On this basis, this paper aims to provide an empirical assessment of the potential impact of climate-related risks on public finances from an EU perspective. This is in line with the action points of the new EU Climate Adaptation Strategy. In particular, we focus on *acute physical risks* from climate change, as we aim to capture debt sustainability impacts associated with extreme weather and climate events. This is done by providing stylised stress tests in the context of the standard European Commission's Debt Sustainability Analysis framework for selected EU Member States. To build our debt stress tests, presented in Section 3, we adopt a stepwise approach. We begin with a comprehensive review of the theoretical and empirical literature on the macroeconomics of natural disasters (sub-section 3.1). We then explore available global natural disaster loss databases and provide stylised facts on Europe (sub-section 3.2). Our assumptions and modelling approach (sub-section 3.3), alongside our main results (sub-section 3.4), are subsequently illustrated. We conclude with an overview of potential caveats to our analysis and related way forwards (Section 4).

3. STRESS TESTS ON THE FISCAL IMPACT OF EXTREME WEATHER AND CLIMATE EVENTS

3.1. THE MACROECONOMICS OF NATURAL DISASTERS

Climate-related disasters are expected to exert significant economic and fiscal impacts. In this section, we provide an overview of the theoretical and empirical research on the macroeconomics of natural disasters (Batten, 2018). 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 events. Our aim is to define a set of evidence-based assumptions for our debt stress tests.

The emerging consensus in the literature is that natural disasters tend to exert, on average, adverse impacts on economic growth in the short term. The latter may occur 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, for instance, extreme weather and climate events may significantly affect the agriculture sector, but also cause loss or damage to buildings, technology and relevant infrastructure. More generally, extreme events may lead to capital stock loss or disruption, with consequent impacts 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, thus affecting consumption and investment. Global interactions with affected trading partners may further cause reduced trade flows, value chain disruptions, and inflationary pressures.[14] Ultimately, supply and demand shocks are expected to interact and entail, at least in the short term, an immediate disruption to output and growth.

[14] See Batten et al., (2020) and Batten (2018) for more a detailed decomposition and review of the macro-economic impacts (as well as implications for monetary policy) of climate change.

However, in the medium and long term, countries' macroeconomic dynamics may be expected to follow three, alternative, pathways (Batten et al., 2020; Batten, 2018; Hsiang and Jina, 2014):

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 path than before the event;

2. ***Recovery to trend:*** if 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;

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

Despite mixed empirical evidence, most studies appear to confirm the immediate negative impact on growth in the aftermath of a high-intensity disaster. In the medium and long term, the 'no recovery' hypothesis is the most supported.[15] However, recent works clearly emphasise the relevance of adequate disaster insurance coverage to counteract such drawbacks. In particular, uninsured losses appear to be the main driver behind the adverse macroeconomic shocks of natural catastrophes, both on impact and over the long term, insofar as productive capital is not replaced. On the contrary, 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 recovery (Fache Rousová et al., 2021; Von Peter et al., 2012). In particular, not only does adequate insurance coverage supports post-catastrophe recovery (e.g. funding reconstruction projects), but it also appears to cushion the contemporaneous impact of the disaster (i.e. contributing to prevention and disaster risk management *ex-ante*).[16]

In turn, natural disasters are likely to have different impacts on public finances.[17] In the case of extreme weather and climate events, this may occur directly, via an upward pressure on public expenditure. This could be due to costs incurred to replace damaged (and/or lost) assets and infrastructure, social transfers to affected populations, and relief aid to affected industries and businesses. Extreme events may further 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, indirect impacts on public finances might also arise. This may be due to reductions in tax revenue, 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 sovereign capacity to meet debt payments over the medium term. Relatedly, vulnerability to natural disasters might generate increasing risks of uncertainty, affecting the creditworthiness and the international financial accessibility of a country (Radu, 2021; Zenios, 2021; European Commission, 2020a).

[15] For an overview of the empirical evidence around the short- and long-term economic impact of natural disasters, see Hallegatte et al. (2020), Batten et al., (2020), and Batten (2018).

[16] 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, p. 16).

[17] This section focuses on the economic and fiscal impacts of extreme weather and climate 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 European Commission (2020a).

Empirical evidence on the fiscal impact of natural disasters, especially for advanced economies, is quite limited and often based on selected case studies. Recent initiatives relate to the macro-fiscal impacts of earthquakes and floods in EU member states (World Bank, 2021)[18] and to the role of fiscal policy to moderate the effects of natural disasters in US states (Canova and Pappa, 2021). Other existing works tend to highlight a relatively small, although negative, fiscal impact, with respect to the size of the economy. In particular, an overall fiscal impact between 0.3% and 1.1% of GDP is found for selected natural disasters occurring in the US and the EU (Heipertz and Nickel, 2008). Studies on a wider sample of countries find similar results, with a fiscal deficit increase between 0.23% and 1.4% of GDP, depending on the country group (Lis and Nickel, 2010).[19] Moreover, the fiscal response is found to be heterogeneous across disasters and degrees of insurance coverages (Melecky and Raddatz, 2011). Nevertheless, such estimates may suffer from significant downward bias, mostly due to 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.[20] More importantly, all such estimates, based on past data, may be somewhat outdated, given the recent and expected increasing risk of relevant natural disasters driven by human-induced climate change.

3.2. DATA AND STYLISED FACTS

This section describes the past and current exposure of EU countries to extreme weather and climate events, associated economic losses, as well as their corresponding insurance coverage. Our aim is to identify the most vulnerable countries for which triggering 'extreme event stress tests' in the Debt Sustainability Analysis (DSA) would be most relevant. To do so, we rely on the Emergency Event Database (EM-DAT); a global, publicly accessible, database held by the Centre for Research on the Epidemiology of Disasters (CRED, UCLouvain, Belgium).[21] This database provides worldwide geographical (e.g. location, country), human (e.g. fatalities, affected), and economic (e.g. economic losses, insured value) information, from 1900 to present, on six types of natural (i.e. geophysical, meteorological, hydrological, climatological, biological, and extra-terrestrial) and three types of technological (i.e. industrial, transport and miscellaneous accidents) disasters, at the country level.[22] In the database, weather and climate disasters are reported under the categories of meteorological (e.g. extreme temperatures, storms), hydrological (e.g. floods), and climatological events (e.g. droughts, wildfires).

[18] The report provides valuable evidence on the disaster risk-financing in the EU. Nevertheless, some limitations should be acknowledged. These mainly relate to the coverage of natural disasters (i.e. focus on earthquakes and floods), assumptions on the real sector impacts, as well the ability of the model to correctly estimate the impact of natural disasters on public debt. This is mainly due to the fact that the impact on expenditure is more easily describable than the one on revenue. In turn, this may affect the accuracy of the estimation of the fiscal balance, increasing the forecasting error for public debt.

[19] The identification of natural disasters differs across studies, depending on data availability. Heipertz and Nickel (2008) focus on of the 4 most extreme weather events in the EU since 1990 and of the 2 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 which satisfy 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.

[20] 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.

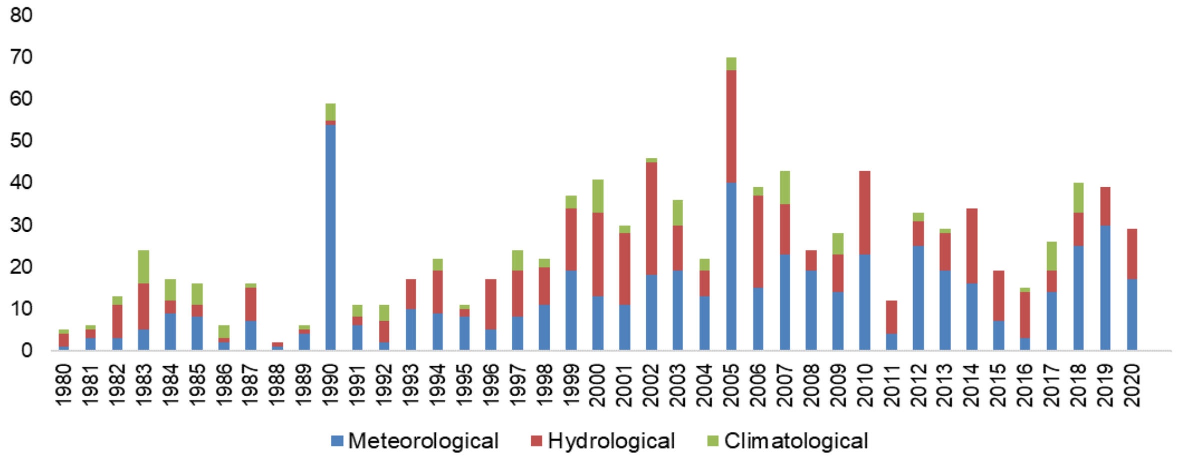
[21] We have also explored alternative global natural disaster databases, namely NatCat (MunichRE) and SIGMA (SwissRE). However, neither is publicly available, beyond aggregate figures, and could not be used to illustrate sufficiently detailed (i.e. year- and country-specific) stylised facts on natural disasters for the EU (see Box 4.1).

[22] In the EM-DAT database, only disasters conforming to one of the following criteria are included: i) 10 omore people deceased; ii) 100 or more people affected; iii) a declaration of a state of emergency; iv) a call for international assistance. For an overview and comparison of existing natural disaster databases, see Box 4.1

3.2.1. Historical trends and taxonomy of extreme events in the EU

For the period 1980-2020, EM-DAT reports 1,117 natural disasters in the EU, of which 1,040 are weather- and climate-related.[23] The yearly number of natural disasters (meteorological, hydrological, and climatological) is shown in Graph 3.1.

Graph 1: **Number of weather- and climate-related events in the EU, by disaster subgroup, 1980-2020**



Note: Meteorological (e.g., extreme temperatures, storms), hydrological (e.g., floods), climatological (e.g., droughts, wildfires).

Source: European Commission, based on The Emergency Events Database (EMDAT; CRED, UCLouvain).

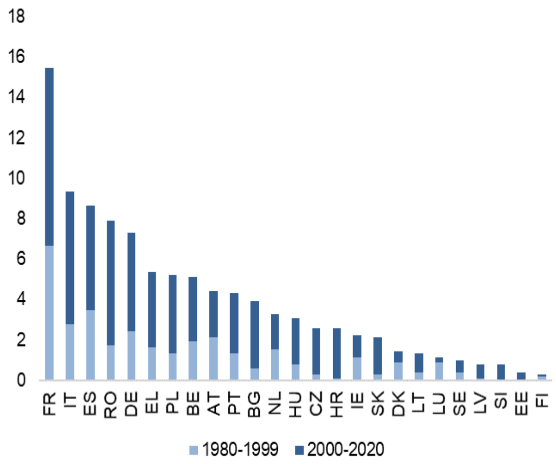
Meteorological events have been the most reported, with 543 total disasters over the entire period, followed by hydrological (389) and climatological (108) disasters, respectively. According to the EM-DAT database, storms and floods account for almost 70% (i.e. 35% each) of total reported disasters, alongside extreme temperature episodes (18%) and, to a lesser extent, wildfires (8%), droughts (3%), and landslides (2%).

A country-level analysis shows that the distribution of events has been quite uneven across countries, over the 1980-2020 period (see Graph 3.2). For instance, France represents the most hardly struck country, with around 15% of total reported events, followed by Italy (9.3%), Spain (8.7%), Romania (7.8%), and Germany (7.3%). An average of around 5% of total disasters has affected Greece, Poland, Belgium, Austria, and Poland, respectively. The remaining countries follow, with an average of around 3% each, with the exception of Sweden, Latvia, Slovenia, Estonia, and Finland, where only a negligible impact (i.e., less than 1%) is reported.

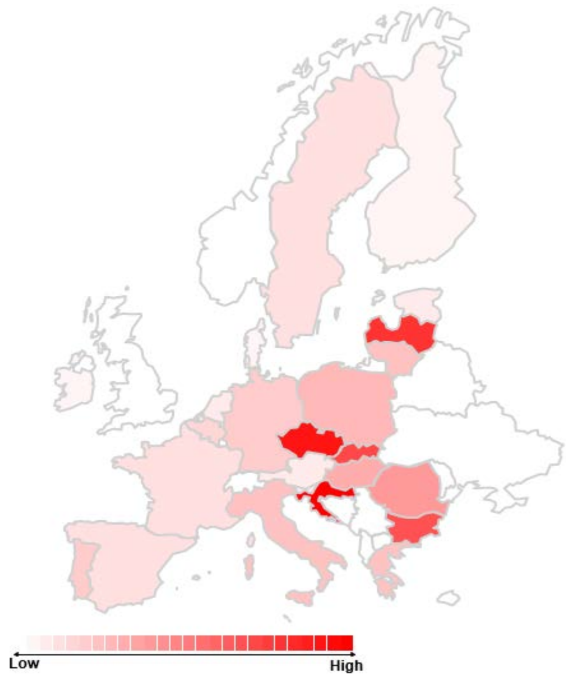
However, over the past 20 years, a significant increase in the number of disasters has mainly concerned Central-Eastern European countries. This has been particularly the case for Croatia, Czechia, Latvia, Slovakia, Bulgaria, Romania, and Hungary; alongside some Southern European countries (i.e. Italy, Greece, and Portugal) (Graph 3.3)

[23] We focus on data from 1980 onwards, due to risks of significant underreporting in the past.

Graph 3.2. **Number of weather and climate events, % EU total, by country and decade**



Graph 3.3. **Increase in weather and climate events, by country, 2000-2020**



Note: In the LHS graph, meteorological (e.g., extreme temperatures, storms), hydrological (e.g., floods), climatological (e.g., droughts, wildfires). In the RHS graph, information for Malta and Cyprus is missing.

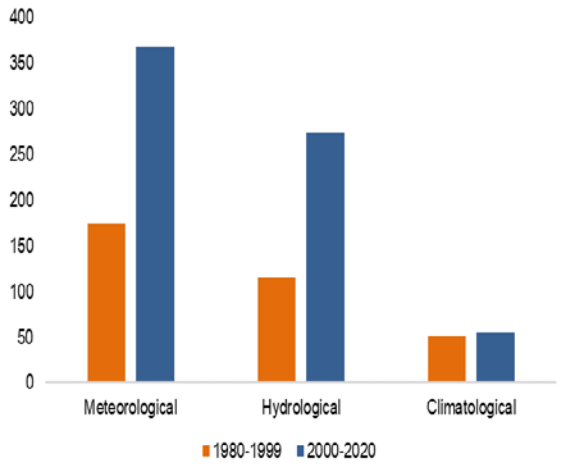
Source: European Commission, based on The Emergency Events Database (EM-DAT; CRED, UCLouvain).

Meteorological and hydrological events have been mostly responsible for such an increase (Graph 3.4). In particular, over the period 2000-2020, a total of 368 meteorological events (*versus* 175 in the period 1980-1999) and 274 hydrological events (*versus* 115) have been reported. On the contrary, the amount of reported climatological events appears to have remained stable over time.[24]

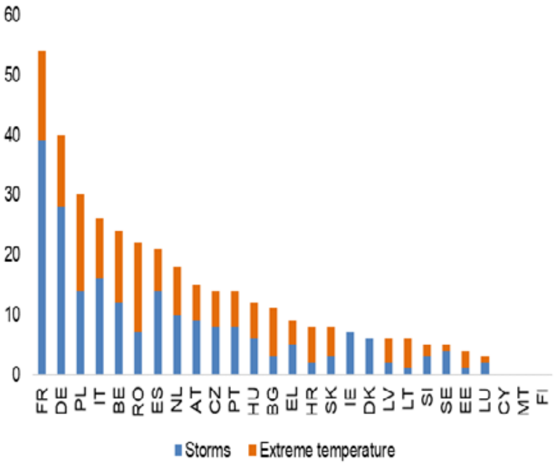
A disaster-based analysis over the past 20 years also reveals a quite heterogeneous incidence across the EU. Within meteorological events, the greatest incidence has been reported in France (54 events), Germany (40 events), Poland (30 events), Italy (26 events), and Belgium (24 events). In all cases, storms have been the most relevant disaster type, affecting almost 60% of the total. Overall, the incidence seems to have been stronger in Central and Southern European countries (Graph 3.5).

[24] However, such figures may suffer from underreporting, given significant data gaps around specific disaster types, such as heatwaves (reported under 'Meterological' events), and the difficulty to measure some disasters, such as droughts (reported under 'Climatological' events) (CRED, 2020).

Graph 3.4. **Number of weather and climate events, disaster sub-group, 1980-99 vs. 2000-20**



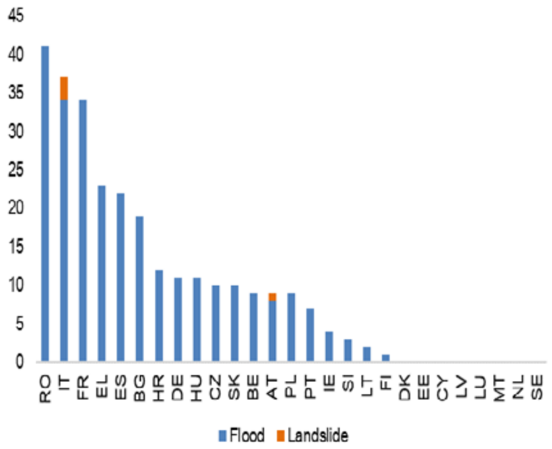
Graph 3.5. **Number of meteorological events, by disaster type and country, 2000-20**



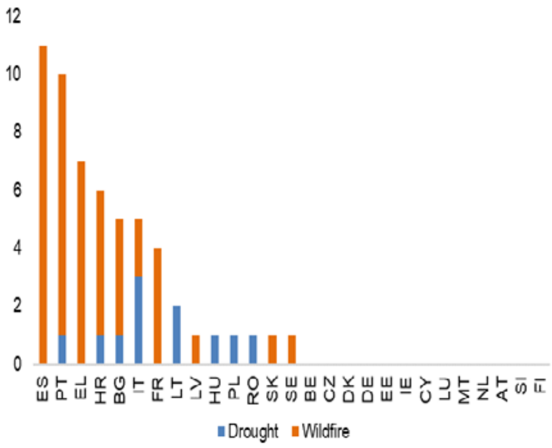
Note: in the LHS graph, meteorological (e.g., extreme temperatures, storms), hydrological (e.g., floods), climatological (e.g., droughts, wildfires). In the RHS graph, information for Malta and Cyprus is missing.

Source: European Commission, based on The Emergency Events Database (EM-DAT; CRED, UCLouvain).

Graph 3.6. **Number of hydrological events, by disaster type and country, 2000-20**



Graph 3.7. **Number of climatological events, by disaster type and country, 2000-20**



Note: Information for Malta and Cyprus is missing.

Source: European Commission, based on The Emergency Events Database (EMDAT; CRED, UCLouvain).

Recent hydrological events have been disproportionately driven by floods, representing almost the totality of reported disaster types (Graph 3.6). In this respect, Romania represents the most struck country (41 events), together with Italy and France (34 events). In addition, an average of around 22 events is reported for Greece, Spain, and Bulgaria. Overall, a higher occurrence of floods is reported in Central and Central Eastern European countries. Moreover, relatively few episodes of landslides are found in Italy and Austria (i.e., around 1%).

Climatological events have followed a relatively regional pattern (Graph 3.7), as wildfires represent the most relevant disaster (i.e., around 80% of the total) in Southern European countries. Overall, severely affected countries have been Spain (11 events) and Portugal (10 events), followed by Greece (7 events), Croatia (6 events), Bulgaria and Italy (5 events). The occurrence of droughts has been slightly more widespread, with episodes reported in Central, Southern European, as well as some Baltic countries.

3.2.2. Future trends

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 extremes (IPCC, 2021, EEA, 2017). Existing projections are mainly based on academic studies and reports and are surrounded by large uncertainty. This mainly reflects challenges in modelling assumptions and in unaccounted risks of potential non-linearities and climate tipping points. Evidence from existing literature shows projected increases in severity, duration, and/or extent of several events, particularly for heat waves, heavy precipitations, floods, droughts, and wildfires. However, the impacts are not evenly dispersed across Europe (EEA, 2017).

In particular, extremely high temperatures are projected to become more frequent and last longer during this century, **with the strongest waves expected in Southern and South-eastern Europe** (EEA, 2017; Russo et al., 2014). At the same time, over the course of the 21st century, a progressively warmer atmosphere is likely to lead to a higher intensity of precipitation as well as longer dry spells in Europe (EEA, 2017; Hov et al., 2013; Seneviratne et al., 2014). This implies an increase in heavy daily precipitation across most of Europe in winter, but an equally remarkable decrease (especially for southern and south-western Europe) in summer (EEA, 2017; Jacob et al., 2014). Consequently, in regions with higher likelihood of heavy precipitation, the frequency and/or the intensity of landslides is also expected to increase (EEA, 2017).

Relatedly, simulations highlight a significant expected increase in floods in specific European regions for the end of the 21st century (i.e. north-west and southeast France, northern Italy, some parts of southeast Spain, the Balkans, and the Carpathians). Milder increases are expected for central Europe. On the contrary, decreased events are projected in large parts of north-eastern Europe (due to milder winter temperature, lower snow accumulation and, consequently, less melt-associated flood) (EEA, 2017; Alfieri et al., 2015; Rojas et al., 2013, 2012). When considering droughts, most models project drier conditions for southern Europe for the mid-21st century. In contrast, droughts occurrence is projected to decrease in most parts of northern Europe (EEA, 2017; Henrich and Gobiet, 2011; van der Linden and Mitchell, 2009). In turn, increases in warming, droughts, heatwaves, and dry spells are expected to affect the length and severity of wildfires, particularly in southern European countries (EEA, 2017; Moreno, 2014; Lindner et al., 2010).

3.2.3. Economic losses from extreme events

Current available data show a contained average economic impact due to extreme events. According to EM-DAT, over the period 1980-2020, economic losses from extreme weather and climate events accounted for a total of 3% of GDP across EU countries. The *annual* average economic losses amount to less than to 0.1% of GDP in the EU.[25] The total estimated economic losses are

[25] The 3% figure represents the average of *total* economic losses (% of GDP), reported over the period 1980-2020, across EU countries. The annual average economic losses (in % of GDP) roughly corresponds to the figure reported in the NatCat (MunichRE) database (not publicly available at detailed level), with an *annual* average of around 0.1% of GDP for the EU over the period 1980-2019 (European Commission, 2021b). The small difference is mainly attributable to reporting (see Box 4.1).

defined as the value of all damages to property, crops, and livestock, as well as other losses related to the disaster.[26] While such figure may not yet appear as macro-economically significant, it is also very likely to represent an underreporting of the actual effects of natural hazards. Aside from data collection challenges, this also relates to the specific aim of the existing global natural disaster databases (see Box 4.1). In addition, annual economic losses underlie significant distributional impacts, with important variations across time and country, depending on the occurrence of natural disasters.

Past economic losses have been more significant in some EU countries and years. In particular, total economic losses, over the period 1980-2020, range from almost 8% of GDP in Spain to 7% of GDP in Czechia, 5% in Romania and Portugal, to less than 1% of GDP for The Netherlands, Estonia, Lithuania, Sweden, Belgium, and Ireland.[27] In addition, the contribution of natural disasters to the overall economic losses is not homogeneous across countries and time as, quite often, single events have managed to cause a significant share of total reported economic losses (see Table 3.1).

Table 3.1. **Selected major extreme events 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 temperature	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

Note: Related economic losses are the economic losses associated to the selected extreme event reported in the table. Total economic losses are the total reported for the country over the period 1980-2020. Data on Malta and Cyprus are missing.

Source: European Commission, based on The Emergency Events Database (EM-DAT; CRED, UCLouvain).

Over the entire 1980-2020 period, the economic impacts in the EU have been heterogeneous across disasters. The majority of losses from extreme events seems to have been associated with hydrological and meteorological disasters, respectively. The impact has also 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 a value of around 29% observed during the 1980-1999 period.

3.2.4. Future impacts

Some recent studies have also tried to quantify the projected economic impacts of extreme events. Some illustrative projections are provided by the European Commission's Joint Research

[26] The registered figure corresponds to the value at the moment of the event (https://www.emdat.be/Glossary).

[27] However, such figures remain an underestimation, given worldwide underreporting of disaster-related losses (CRED, 2020).

Centre PESETA project (Feyen et al., 2020), which provides multi-sectoral assessment of the impacts of climate change in Europe.[28] The latest update (PESETA IV) relies on a combination of process-based and empirical models to assess the expected economic impacts (i.e. economic losses) of a subset of natural catastrophes (droughts, costal floods, river floods, windstorms), under three future global warming scenarios. For each selected event, expected economic losses are projected under the mitigation benefits of achieving the Paris Agreement targets (1.5°C and 2°C) as well as higher warming scenarios (3°C – expected to occur only in the long term, in absence of adequate mitigation), and compared to baseline climate conditions (Feyen et al., 2020).[29] The evaluation of economic impacts is made within a specific setting of the state of the economy. In particular, projections of economic losses (in 2015 values) are provided on the basis of a 'dynamic assessment', that is, 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' (Feyen et al., 2020, pp. 15; European Commission, 2015).[30]

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 become a further multiple. In particular, the PESETA IV projections show that economic losses are expected to be 1.9 times bigger than under the baseline climate, if the more ambitious Paris Agreement target (1.5°C) were to materialise 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 EU regional aggregates are shown in Table 3.2.[31]

Table 3.2. **Factor Increase (FI) in economic losses for the 1.5°C and 2°C warming scenario, by mid-century, regional aggregates**

Regional aggregate	1.5°C scenario	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**

Note: Following PESETA IV, the following countries are included in the different sub-groups: *Mediterranean* (Portugal, Spain, Italy, Malta, Cyprus, Slovenia, Croatia, Greece); *Atlantic* (Ireland, France, Belgium, The Netherlands, Luxembourg); *Continental* (Austria, Germany, Denmark, Poland, Czechia, Slovakia, Romania, Bulgaria, Hungary); *Boreal* (Finland, Sweden, Lithuania, Latvia, Estonia). Factor increases are built with respect to the climate baseline (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 computations, based on the PESETA IV project (Feyen et al., 2020).

[28] PESETA stands for 'Projection of Economic Impacts of Climate Change in Sectors of the European Union based on bottom-up Analysis'. Similar projections of economic impacts can also be found in the context of the COACCH (CO-designing the Assessment of Climate Change costs), an innovative research project that gathers leading experts on climate change sciences from 13 European research institutions. In this paper, we focus on the results from the PESETA IV project.

[29] The basis for projections of economic losses is the period 1981-2010 (Feyen et al., 2020). The projected economic impacts presented in this paper (and extracted from the PESETA IV project) assume no adaptation measure is in place. However, in the PESETA IV study, the costs and benefits of adaptation options for selected events (i.e. floods) are also modelled. For the remaining events, this has not been feasible at pan-European scale.

[30] The PESETA IV project also adopts a 'static' approach, comparing how global warming and climate change would impact today's population and economy. However, the absolute damage figures may be unrealistic (and highly conservative), as they do not consider the long-term dynamic growth of the overall economies (Feyen et al, 2020; pp. 15).

[31] Yet, it is important to stress that such aggregate figures mask significant heterogeneity across countries and climate events and they represent an underestimation of the expected economic impacts from climate events. The PESETA IV projects does not fully capture the effects of extreme events or the risks of passing tipping points. The purpose of its estimates is to provide the general patterns of climate change impacts across the EU and the potential benefits of climate policy actions (Feyen et al., 2020).

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 (see Table 3.3). The latter are expected to rise threefold under the more favourable warming scenario, but be almost eight-to-fifteen times higher in the 2°C and 3°C warming scenarios, respectively. This outcome is largely linked to the greater exposure of people and assets, driven by the future socioeconomic development. Moreover, such figures mask significant heterogeneity across regional aggregates. In both the medium and long term, compared to the 1.5°C scenario, increasing global warming is likely to exert stronger economic impacts on *Atlantic* countries (i.e. Ireland, France, Belgium, The Netherlands, Luxembourg). According to PESETA IV, this is mainly related to higher expected vulnerability of such areas to flooding episodes. More intense and frequent floods also appear to be behind the projected increase for *Boreal* (i.e. Finland, Sweden, Lithuania, Latvia, and Estonia) and *Continental* (i.e. Austria, Germany, Denmark, Poland, Czechia, Slovakia, Romania, Bulgaria, Hungary) ones. Conversely, droughts are expected to be mostly responsible for the higher projected losses in *Mediterranean* (i.e. Portugal, Spain, Italy, Malta, Cyprus, Slovenia, Croatia, Greece) countries.

Table 3.3. **Factor Increase (FI) in economic losses for the 1.5°C, 2°C, and 3°C warming scenario, by the end of the century, regional aggregates**

Regional aggregate	1.5°C scenario	2°C scenario	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**

Note: Following PESETA IV, the following countries are included in the different sub-groups: *Mediterranean* (Portugal, Spain, Italy, Malta, Cyprus, Slovenia, Croatia, Greece); *Atlantic* (Ireland, France, Belgium, The Netherlands, Luxembourg); *Continental* (Austria, Germany, Denmark, Poland, Czechia, Slovakia, Romania, Bulgaria, Hungary); *Boreal* (Finland, Sweden, Lithuania, Latvia, Estonia). Factor increases are built with respect to the climate baseline (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 computations, based on the PESETA IV project (Feyen et al., 2020).

While providing useful projections, the economic impacts included in the PESETA IV project are not comprehensive of all potential consequences from climate changes. In particular, they do not include other key items (e.g. irreversible damage to nature and species losses) nor, especially, the consequences of passing tipping points. In addition, they do not manage to capture the full effects of extreme events in all sectors. Hence, such projections are only meant to serve as a *lower bound* of the expected adverse economic impacts from climate change in the EU (Feyen et al., 2020). Nevertheless, such future trends corroborate the relevance of concerted action towards the ambitious 1.5°C Paris Agreement target, to counteract disproportional increases in economic losses due to rising *frequency* and *intensity* of extreme events.

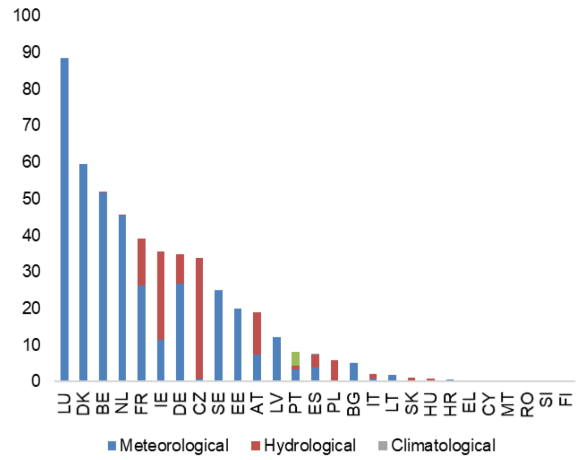
3.2.5. The role of insurance coverage

Adequate insurance coverage can reduce the adverse economic impacts of natural disasters. While not preventing the loss of assets, well-designed climate risk insurance policies help to 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 (Cebotari and Youssef, 2020; Schäfer et al., 2016; European Commission, 2013).[32] In this respect, the situation is quite heterogeneous across the EU (see Graph 3.7). Overall, almost 80% of insurance coverage concerns meteorological disasters,

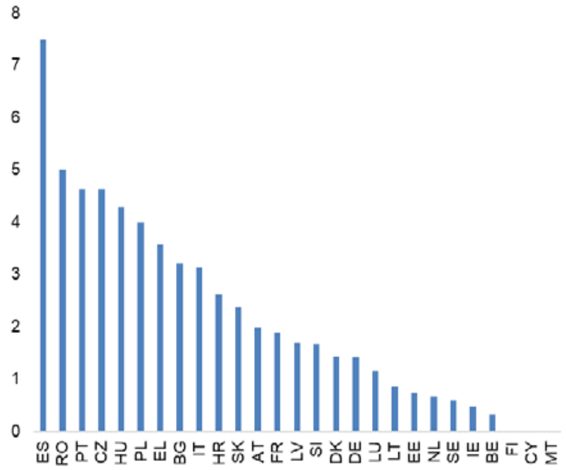
[32] For European Commission (2013), see COM (2013) 213 final.

followed by hydrological ones. The coverage rate for extreme weather and climate events ranges from around 90% in Luxembourg to around 60% in Denmark, 50% in both Belgium and The Netherlands. An average of 35% of losses receive cov8erage in France, Ireland, Germany, and Czechia, 20% in Sweden, Estonia, Austria, and Latvia. At the other end of the spectrum, we find countries (mostly Southern and Eastern European) with either quite small (i.e. less than 6%) or almost negligible coverage rates (i.e. an average of 1%).[33,34]

Graph 3.7. **Coverage of extreme events, by disaster subgroup and country, 1980-2020**



Graph 3.8. **Uninsured economic losses from extreme events (% of country GDP), by country, 1980-2020**



Note: Information for Malta and Cyprus is missing.

Source: European Commission, based on The Emergency Events Database (EMDAT; CRED, UCLouvain).

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 events (see Graph 3.8). In particular, in terms of countries' economic size, the most exposed countries appear to have been mostly Southern and Eastern European ones. This is the case for Spain (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. On the contrary, a more modest exposure tends to be found in countries exhibiting sufficient insurance coverage, despite relatively high occurrences of natural disasters (e.g., Germany, Belgium, and Austria).

[33] It is important to stress that, similarly to economic losses, also insured losses may suffer from partial underreporting in the EM-DAT database. For instance, publicly available information from the NatCat (MunichRE) dataset highlights even higher insurance coverage in Germany and France (i.e., around 50% - https://www.eea.europa.eu/ims/economic-losses-from-climate-related). However, the available NatCat figures only provide an aggregate picture, without access to public information on the country-based, yearly, distribution of (economic and insured) losses to be used in our analyses.

[34] A notable recent initiative on the insurance protection gap for natural catastrophes in Europe relates to the 'Pilot dashboard on protection gap for natural catastrophes', https://www.eiopa.europa.eu/document-library/feedback-request/pilot-dashboard-insurance-protection-gap-natural-catastrophes_en.

3.3. STRESS TESTS CALIBRATION

Given the unavoidable rise of climate pressures in the years ahead, a thorough analysis of potential fiscal sustainability implications from climate change is of great importance. Current budgetary frameworks often present limitations to assess fiscal risks associated to climate change.[35] In what follows, we aim to provide first stylised stress tests on the fiscal impact of *acute physical risks* from climate change (i.e. extreme weather and climate events). This is done by drawing upon the conceptual framework introduced in the 2019 Debt Sustainability Monitor (European Commission, 2020a), 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 events over the medium term, in the form of aggravating factors to debt sustainability.

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 (i.e. based on the Autumn forecast 2021), should a past extreme event reoccur in the medium term. To account for potential interactions between climate change and the expected intensity/frequency of extreme events, the impact is further calibrated according to different global warming scenarios (1.5°C and 2°C). In each scenario, we assume the specific extreme event to simultaneously exert: i) a *direct* impact on government accounts (i.e. via the primary balance), thus affecting the debt level; and ii) an *indirect* impact via GDP (growth and level) effects (also affecting the debt ratio, via denominator effects).[36]

3.3.1. Assumptions and methodology

The *direct* shock to public finances (via the primary balance) is constructed based on past country-specific exposure to extreme events, **augmented by the expected increase in economic losses from extreme events due to climate change**. In particular, we first rely on the annual distribution (from 1980 to 2020) of the *uninsured* economic losses (% of GDP) available for all EU countries from the EM-DAT database.[37] Then, for each country, we identify the *maximum* of the annual distribution as an instance of 'extreme' (or 'tail event') occurrence.[38] Subsequently, in order to account for the likely increase in economic losses from climate events due to a warmer climate, we compute the overall *direct* fiscal impact by interacting the country-specific extreme value (i.e., the *maximum*) with a given Factor Increase (FI).

Our FI is constructed, on a regional basis[39], relying on estimates of expected economic losses from extreme events associated with future global warming levels, and provided in the context of the European Commission's JRC PESETA IV project (see sub-section 3.2 for details). In the PESETA IV study, economic losses are projected for both the medium (under the assumption of 1.5°C and 2°C higher temperature), and the long term (where global warming of 3°C higher is also assumed).

[35] See the European Commission (2020a).

[36] The intuition behind our 'extreme event stress tests' draws upon the International Monetary Fund (IMF) and the World Bank, that have recently introduced, in their revised Joint Debt Sustainability Framework for Low-Income Countries (IMF/WB LIC DSF), a tailored stress test for natural disasters (see IMF, 2018). Their 'natural disaster' stress test relies on the EM-DAT database and is only triggered for countries vulnerable to such risks and tailored to the country-specific history, while not being directly linked to future expected effects of climate change. However, our stress tests differ with respect to calibration methodology and country selection criteria.

[37] Information on Malta and Cyprus is not provided in the EM-DAT database.

[38] While there is no single definition for what is meant by extreme events, the latter are generally defined as 'either taking *maximum* values or *exceedance* above pre-existing high thresholds' (Stephenson, 2008; pp. 12).

[39] Following PESETA IV, we identify four regional aggregates: *Mediterranean*, *Atlantic*, *Continental*, and *Boreal*.

In our stress tests, we only apply a medium-term perspective. Hence, our fiscal shock is constructed by relying on the FI in economic losses projected for the medium-term 1.5°C and 2°C scenarios (see Table II.2.2 and Table II.2.3), respectively.[40] In each scenario and country, our assumed *direct* fiscal impact (i.e. extreme value interacted with the respective FI – see Table II.2.5) is 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). A country's (initial) primary balance may already include provisions for natural disasters, and the existence of common emergency funds (e.g. European Union Solidarity Fund - EUSF) may cover some damages. However, for the sake of simplicity, we show what would be the approximate overall impact on public finances (via a country's primary balance), should a past extreme event reoccur in the medium term, while also calibrating its impact under different global warming pathways.[41,42]

Table 3.4. **Assumed direct fiscal impact of a one-off extreme event (% of GDP), by country and warming scenarios (1.5°C and 2°C), applied in 2024**

	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

Note: For instance, in Czechia, 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 FI 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 3.2).

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

[40] In particular, the PESETA IV 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 to reduce greenhouse gas emissions is taken (IPCC, 2018). The absence of any significant mitigation measures may also increase the likelihood of a closer 2°C warming scenario.

[41] In addition, the calibration of the shock based on *uninsured* losses allows to already account for some risk sharing between private and public sector. The historical data used for the initial calibration are likely to be affected by underreporting (as explained in the previous section).

[42] For references of alternative assumptions used in existing empirical studies on the fiscal impact of extreme events, see European Commission (2020a).

As for *indirect* shocks to GDP (both growth and level), we rely on recent empirical evidence on the macroeconomic impacts of natural disasters (see sub-section 3.1). In particular, given our focus on uninsured economic losses, we first assume an adverse shock to growth in the aftermath of a disaster. To this purpose, we rely on estimates from a recent study of the European Insurance and Occupation Pensions Authority (EIOPA) on OECD countries (Fache Rousová et al., 2021). The study finds that large-scale disasters with low insurance coverage exert, 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) 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.[43] This is in line with recent empirical evidence on 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 (Batten, 2018; Von Peter et al., 2012).

3.3.2. Triggering criteria

The stress tests are only triggered for a set of particularly exposed countries. **To this purpose, we rely on specific selection criteria.** In particular, out of the EU countries exhibiting (according to the EM-DAT database) the highest overall share of *uninsured* economic losses (% GDP) and the highest overall number of natural disasters, over the 1980-2020 period, we select those that:

1. Have experienced *at least* 2 peaks[44] in the number of reported events, and;
2. Have experienced an increase in the number of reported events over the last 20 years, and;
3. Are at '*medium-to-high*' vulnerability to *acute physical risks* in the long term, according to the SwissRE Climate Economic Index[45]

On this basis, we trigger the stress tests for 13 EU Member States. These include Spain, Romania, Portugal, Czechia, Hungary, Poland, Greece, Italy, Austria, France, Belgium, Germany and The Netherlands.

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

[44] 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.

[45] SwissRE developed a 'Climate Economic Index', which ranks countries according to their expected vulnerability to climate change risks. Information is only available for some EU countries. For more details, see https://www.swissre.com/institute/research/topics-and-risk-dialogues/climate-and-natural-catastrophe-risk/expertise-publication-economics-of-climate-change.html.

3.4. STRESS TESTS RESULTS

The stress tests show non-negligible fiscal impacts in some countries. The simulated debt projections for the selected countries are reported in Table 3.5.

As expected, both the 1.5°C and 2°C scenarios result in progressively higher debt-to-GDP projections, respectively, compared to the baseline.

- Among the most exposed countries, we find *Spain*, with the debt-to-GDP ratio 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, as well as 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 the end of the projection horizon.

- *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.

While pointing to manageable risks so far, our stress tests confirm the macroeconomic relevance of climate-related disasters and the related risks to government finances. 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. The limited difference between the 1.5°C and the 2°C scenarios relates to the multiplication factor applied (based on the PESETA IV study – see Footnotes 28, 29, and 31). A more extreme scenario (i.e. an increase of global temperatures by 3°C) would lead to more abrupt (non-linear) impacts. Overall, these results also 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.

Moreover, several elements should be considered in the interpretation of our climate scenarios. Due to current data and methodological limitations, the present assessment necessarily builds on several simplifying assumptions. In addition, our assessment only provides a partial perspective of climate-related fiscal (debt) sustainability risks, given our focus on fiscal impact of acute physical risks. Moreover, our results are likely to represent an underestimation of the expected fiscal impact. This may be due to potential underreporting of economic losses in global disaster databases, 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.

Table 3.5. **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

Note: 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 European Commission's 10-year baseline debt-to-GDP projections (i.e. based on the Autumn forecast 2021).

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

4. CONCLUSION

Assessing fiscal risks from climate change is a critical and challenging issue. This paper illustrates some first stylised stress tests on the fiscal impact of extreme weather and climate event for selected EU countries, designed as shocks to public finances and growth, in the context of the European Commission's standard Debt Sustainability Analysis framework. Our purpose is to capture risks associated with *one-off* climate events, over the medium term, in the form of aggravating factors to debt sustainability. This exercise is also in line with the action points reflected in the 2021 EU Climate Adaptation Strategy, as it develops ways to measure the potential impact of climate-related risks on public finances and an assessment of risks to long-term public debt sustainability, with the aim to build macro-fiscal resilience to climate change.[46]

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

Our results highlight that extreme weather and climate events may pose risks to fiscal (debt) sustainability in several countries, although remaining manageable under standard global warming scenarios. In particular, the simulated extreme event exerts a significant and persistent negative impact on debt projections. The adverse fiscal impact increases in higher projected warming scenarios. Overall, our results appear to be heterogeneous across countries and remain, nevertheless, surrounded by large uncertainties.

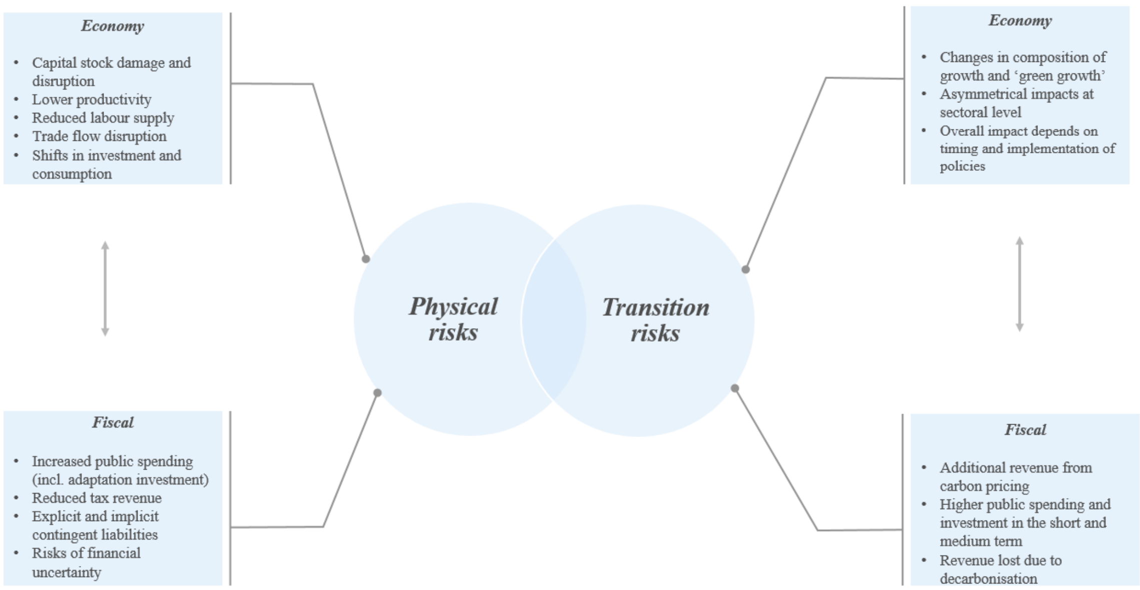
While, compared to other existing fiscal challenges (e.g. linked to population ageing), our results point to manageable risks so far, they highlight that (*acute) physical risks* from climate change may pose some risks to countries' fiscal (debt) sustainability in several countries. **Large-scale, rapid, and immediate mitigation measures have the potential to limit climate change and its related effects.** Our findings also point to the relevance of implementing adequate adaptation policies, including insurance and climate-resilient debt instruments to provide financial resilience to climate change and dampen the fiscal impact of climate-related events, thus reducing potential debt sustainability risks. Robust and effective Disaster Risk Management frameworks and disaster risk financing strategies contribute to reducing the potential fiscal cost of natural disasters and increasing incentives to take action to reduce vulnerability while, at the same time, providing financial support. In addition, increasing insurance penetration can support post-disaster recovery, reduce vulnerability and promote resilience (European Commission, 2021).

The assessment of fiscal risks associated to extreme weather and climate events suffers from data limitations. As documented in this paper, practical caveats remain. Modelling limitations and current data availability constitute important challenges. The existing international datasets recording extreme weather and climate 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.

[46] See COM(2021) 82 final.

Besides risks from direct *physical* impacts, climate change adaptation and mitigation policies are also expected to exert significant effects on the economy and public finances (Graph 4.1). *Physical* and *transition* risks 'are not independent of each other but tend to interact' (Batten et al., 2020; pp. 3), as inadequate policy actions to fight climate change can aggravate *physical* risks and, in turn, intensify *transition* risks (European Commission, 2021b; NGFS, 2020). The first estimations provided in this paper cover only one aspect of fiscal challenges raised by climate change, namely related to *acute physical* risk.

Graph 4.1 **Economic and fiscal challenges from climate change**



Note: The list of vulnerabilities is non-exhaustive and only meant as an illustration. For instance, physical risks (in the form of a gradual transformation of the environment) could also have positive supply side effects in some regions, which are not presented here. Transition risks, related to mitigation policy efforts, refer to the the economic and fiscal consequences stemming from the transition to a low-carbon economy.

Source: European Commission; Batten (2018).

Going forward, a broader assessment will therefore need to encompass the fiscal impact of mitigation policies aimed at supporting the transition to climate-neutral economies, as well as of adaptation policies, aimed at anticipating the adverse effects of climate change and taking appropriate action to prevent or minimise the damage they can cause. The transition to climate neutral economies will require significant additional investment and major adjustments in productive sectors, labour markets and consumption patterns. The overall macroeconomic and fiscal impact will depend on the timing and design of policies supporting the transition. In addition, the transition to climate neutrality represents major economic opportunities in a range of sectors where the EU can develop a global leadership. Overall, the development of standard harmonised reporting frameworks at EU level remains an essential aspect to build fiscal resilience. This includes the need for better reporting and assessments of the macroeconomic impacts of planned climate mitigation and adaptation policies, and the potential fiscal risks related to these.

Box 4.1: OVERVIEW OF NATURAL DISASTER DATABASES

Comprehensive and comparable data for the monitoring of the macroeconomic impact of climate-related disasters is lacking today. Existing databases generally vary according to their geographical focus (i.e. global, regional, and national), event-reporting framework (i.e., multi-hazard or (single) hazard-based), and related reporting on human/economic implications (Faiella et al., 2020). Here, we focus on a description and comparison of global, multi-hazards databases. The reason is twofold. Given their extensive coverage, they represent the most adequate source to perform analyses with a European perspective. Moreover, they are the only instances to report extensive information on disaster-related economic losses. In this regard, we look and compare three main international databases: EM-DAT (CRED), NatCat (MUNICH RE), and Sigma (SWISS RE). In addition, we provide an overview of the Risk Data Hub (RDH) loss dataset, recently developed by the European Commission's Joint Research Centre (JRC).

EM-DAT (CRED, UCLouvain)

The Emergency Event Database (EM-DAT) is a global, publicly accessible database held by the Centre for Research on the Epidemiology of Disasters (CRED, UCLouvain, Belgium). It includes data on the occurrence and impact of over 20,000 natural and technological disasters from 1900 to the present day. EM-DAT classifies disasters according to they type of hazard that provokes them. In particular, based on the underlying hazard (e.g. earthquakes, storms, floods, drought, etc.), natural disasters are distinguished into six main groups (i.e. geophysical, meteorological, hydrological, climatological, biological, extra-terrestrial).

EM-DAT also collects data on technological disasters, such as industrial and transport accidents. In order for a disaster to be recorded into the database, at least one of the following criteria must be fulfilled: i) 10 or more people deceased; ii) 100 or more people affected; iii) a declaration of a state of emergency; iv) a call for international assistance. Information is obtained from various sources including UN, governmental and non-governmental agencies, insurance companies, research institutes and press agencies. The presence of a threshold for data inclusion naturally implies a reduced number of entries. The chosen data sources may also lead, in some cases, to under-reporting of disasters. Events are entered on a country-level basis, alongside geographical (e.g. location, country), human (e.g. fatalities, people affected) and economic (e.g. economic losses, insured value) information related to the event. Data on economic and insured losses are reported directly from the source. More specifically, information on economic impacts include total estimated damage, reconstruction costs, and insured losses. Total estimated losses (in 000' US$ current value) are defined as the value of all damages to property, crops, and livestock, and other losses related to the disaster. The registered figure corresponds to the damage value at the moment of the event and may also include a breakdown by sector (e.g. social, infrastructure, production, environment, etc.). Reconstruction cost (in 000' US$ current value) represent costs for the replacement of lost assets. Finally, insured losses (in 000' US$ current value) are the part of economic damages covered by insurance companies.

NatCat (MunichRE)

NatCat is a global, private disaster database maintained by Munich Reinsurance Company (MUNICH RE). It focuses exclusively on natural disasters and currently covers the period 1980-2019. Four categories of events (and their entire duration) are entered on a country basis. In particular, the dataset identifies: i) geophysical (e.g. earthquakes and volcanic activity), ii) meteorological (e.g. severe storms), iii) hydrological (e.g. floods and landslides), and iv) climatological events (e.g. droughts and cold waves). NatCat includes information on the number of fatalities, as well as disaster-related economic and insured losses. No information is provided on losses due to infrastructure damage or malfunction, losses to most publicly owned assets, or indirect losses due to business interruption. In view of its nature, priority on data sources is given to official internal reports on direct insurance claims and reinsurance periodicals. The absence of an inclusion threshold for a given disaster implies a greater number of reported entries compared to other datasets. However, NatCat's reporting rationale implies less available data on countries exhibiting lower insurance coverage, as losses from climate-related hazards that MunichRe does not reinsure are not included (Faiella et al., 2020; Menoni and Margottini, 2011).

Box 4.1. **OVERVIEW OF NATURAL DISASTER DATABASES (continued)**

Table 1: Overview of natural disaster databases	EM-DAT	NatCat	SIGMA
Access	Public	Private	Private
Provider	CRED - UCLouvain	MunichRE	SwissRE
Period covered	1900-present	1980-present	1970-present
Country coverage	Global	Global	Global
Disaster type	Natural (considering epidemics), technological, conflicts	Natural	Natural, man-made
Entry threshold	Present	Not present	Present
Estimation of economic losses	No standard procedure	Own methodology	Own methodology
Data sources	UN, governmental and non-governmental agencies, insurance companies, research institutes and press agencies.	Internal reports, reinsurance periodicals	Newspapers, direct insurance and reinsurance periodicals, specialist publications, insurers and reinsurers reports

SIGMA (SwissRE)

The SIGMA database is a global, private database maintained by SWISS Reinsurance Company (SwissRE). It includes both natural and 'man-made' disasters from 1970 to present. Disasters are recorded on an event entry basis and recorded information includes dead, missing, injured, and homeless, along with detailed accounting of insured and uninsured damages. Data entry is conditional upon at least one of the following occurrences: i) 20 or more deaths; ii) 50 or more injured; iii) 2000 or more homeless; iv) strict economic criteria (insured losses exceed more than $14m (marine) and $28m (aviation), $35m (all other losses and/or total losses in excess of $70m). This may lead to a limited number of available observations. Information is obtained from newspapers, direct insurance and reinsurance periodicals, specialist publications (in printed or electronic form) and reports from insurers and reinsurers. In SIGMA, total losses are defined as those directly attributable to a major event (e.g. damage to buildings, infrastructure, vehicles, etc.). While losses due to business interruption, following property damage, are somewhat reported, other indirect losses, such as loss of earnings by suppliers due to disabled businesses, estimated shortfalls in GDP and other non-economic losses, are not included. SWISSRe highlights that total included losses are estimated and communicated in very different ways. In turn, this does not allow a direct comparison across events.

Table 1 summarises the main differences between the EM-DAT, NatCat, and SIGMA databases.

Risk Data Hub - European Commission, JRC

In an effort to bridge the gaps between the information generated from different sources, especially at the European level, the European Commission's Joint Research Centre (JRC) has developed a Risk Data Hub (RDH) loss dataset, aiming at developing a centralised pan-European platform for collection of loss and damages data. In particular, the RDH Historical Event Catalogue consists in a collection of past events (and related losses and damages) occurred in EU, created from a wide array of data published in several sources and databases. The data collected is not an aggregation of official national datasets, but rather a collection of sources that become complementary in a collection of existing practises. Given its multi-source nature, the RDH underlies differences in the identification of disaster-related economic losses. Nevertheless, the RDH constitutes a major contribution to the fragmented disaster databases currently available, thus paving the way towards an improvement of past-event loss and damage assessment (Faiella et al., 2020).

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