The Coalition of Finance Ministers for Climate Action

The NGFS's approach to the macroeconomic assessment of physical risks

Network for Greening the Financial System (NGFS)

Thomas Allen, Benjamin Alford, and Léopold Gosset

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Assessing the macroeconomic implications of physical risks is plagued with numerous theoretical and practical challenges. Providing tangible estimates of the range of possible impacts remains necessary for planning by central banks, and similarly by Finance Ministries, despite fundamental uncertainty in the tail of the distribution of these risks. Reasons for these assessments include but are not limited to: (i) macroeconomic forecasting exercises in the short run, in light of natural catastrophes; (ii) assessing the cost of a lack of mitigation action in the long run; (iii) assessing the scale of the adaptation challenge, even if more granular approaches may be required for local-level decision-making. However, these assessments need to reflect the uncertainties around the estimates.

Box 1: General context for the NGFS's work on the macroeconomic assessment of physical risks

The NGFS, launched at the Paris One Planet Summit on 12 December 2017, is a group of central banks and supervisors that, on a voluntary basis, are willing to share best practices and contribute to the development of environmental and climate risk management in the financial sector, and to mobilize mainstream finance to support the transition toward a sustainable economy.

As of July 2024, its membership consisted of 141 members and 21 observers. Work is structured around six dedicated workstreams and task forces,[1] including the workstream on *Scenario Design and Analysis*, which is responsible for the production of the NGFS climate scenarios. These scenarios aim to provide a common and up-to-date reference point for understanding how climate change and climate transition drivers could evolve in different futures. To that end, they bring together a global, harmonized set of transition pathways (e.g., energy-related variables), physical climate change impacts2 and country-level macroeconomic variables associated with each scenario. They may be used for scenario analysis and disclosure, strategy, and policy alignment, and further academic research.

The NGFS's approach to the economic assessment of the implications of climate change has been to explicitly recognize the current insufficiency of appropriate data, metrics and tools, and to advocate for an incremental approach based on regular updates of the best existing scientific evidence. The development of the NGFS scenarios is planned over iterations to reflect the necessity for improvements as the community improves its understanding of the dynamics at stake and clarifies its specific needs, as well as to account for the evolution of the scientific consensus, which implies relying on peer-reviewed academic work and working with climate scientists. At each iteration, the NGFS has aimed to further advance the modeling suite and to be transparent about the underlying assumptions of its scenarios and their limitations. With respect to the scope of physical risk assessment, for example, iterations have allowed the NGFS scenarios to consider the macroeconomic impact of the rising frequency and severity of extreme events.

Some systemic risk factors remain beyond the scope of the NGFS scenarios, such as the consequences of crossing tipping points, and indirect societal impacts such as migration and conflicts, compound risks, or non-market effects. The range of climatic events modeled, although already extensive and expending, is not complete. These limitations may call for adaptations by the users themselves, depending on their objectives, as explained in the explanatory note published in January 2024. For example, NGFS scenarios should not serve as a standalone instrument for a cost-benefit analysis on the opportunity of climate action.

NGFS long-term scenarios currently model the impacts of acute and chronic physical risk separately. Indeed, physical risks are typically distinguished between chronic and acute.

- **Acute risks** arise from extreme events, such as heatwaves, landslides, floods, cyclones, wildfires, and storms.
- **Chronic risks** result from gradual changes, such as rising temperatures, sea-level rise, water stress, biodiversity loss, land-use change, habitat destruction, and resource scarcity.

[1] See the full list of Workstreams and Task Forces here.
[2] See the range of hazard and impact variables in the Climate Impact Explorer.

This distinction is sometimes blurred: changing precipitation patterns are a chronic risk, while flooding due to particularly heavy rainfall is an acute risk. Moreover, chronic and acute risks act in combination; marine submersion is an acute risk, but it is made more likely by sea-level rise.

The methodological approach of the NGFS scenarios to chronic and acute physical risk assessments is updated and improved yearly (see Table 1 and below). While chronic risk assessments rely on a top-down approach with macroeconomic damage functions, acute physical risk assessments aggregate granular impacts through peril-specific models.

Table 1. Evolution of approaches to chronic and acute physical risk assessment in NGFS scenarios

NGFS scenarios iteration	**Chronic** physical risk assessment	**Acute** physical risk assessment
Phase I (2019)	Display of the global GDP impact of three damage functions: Nordhaus (2017), Howard and Sterner (2017), and Kalkuhl and Wenz (2020).	Modeling of specific physical phenomena (Inter-Sectoral Impact Model Inter-comparison Project (ISIMIP)), such as evolution of **flood risk.**
Phase II (2021)	Full macroeconomic modeling of country-level impacts of Kalkuhl and Wenz, 2020 (middle-bound of literature)**.**	Modeling of exposure and direct annual losses associated with **river flooding** and **cyclones** (CLIMate ADAptation (CLIMADA) model), based on the phenomena described in ISIMIP.
Phase III (2022)	Use of the **95th percentile of the temperature and impact trajectories** for the implementation of the damage function in the *Current Policies* and *Nationally Determined Contributions (NDC)* scenarios.	Impacts on global GDP now modeled for **river flooding** and **cyclones** (through shock on capital).
Phase IV (2023)	No significant evolution.	Two additional perils with different transmission channels (**droughts** and **heatwaves**). GDP impacts for all four perils now available at country level.
Phase V (2024)	New damage function (median estimates of Kotz et al., 2024) leading to 2×/3× higher damages.	No evolution.

Assessment of chronic physical risks

On the assessment of chronic physical risks, the NGFS has been working with recognized climate scientists to select and implement a range of damage functions, aiming to reflect the scientific consensus and adjusting to users' and stakeholders' feedback. Damage functions help link the evolution of climate variables with their economic impacts. While there are a variety of approaches in the literature, damage functions based on econometric studies typically show higher impacts. Econometric approaches identify relationships between chronic variables (e.g., mean temperature) and macroeconomic variables and then project their impacts into the future using forward-looking inputs from climate science. **Appendix 1 below** shows a range of impacts and approaches in the literature: the Howard and Sterner (2017) meta study showed impacts of between 0.3% and 23% for a range of temperature changes between 3.4°C and 4.3°C. Recent studies—especially Kotz et al. (2024) and Bilal and Känzig (2024)—have extended this range.

The varying impacts in the empirical literature for a given temperature target are linked to different methodological choices, including:

- The **level of permanence of effects**, which may go from transitory level effects on gross domestic product to permanent effects on growth, and gives different views of resilience
- The **scope and granularity of climate variables**, which influence how much climate science input is required in projections; these variables may focus on the global temperature or consider a range of climate variables at other levels of geographical granularities (e.g., temperature and precipitation variability at a subnational level).

The relative simplicity and data-based approach of empirical damage functions is a strength, but it also brings limitations. Calibrated on past data, the damage function literature struggles in particular to model the impact of crossing climate tipping points, and to capture nonlinearities, amplifying the effects and the systemic impacts of the future climate. Additionally, future resilience and adaptation patterns are challenging to model.

The NGFS's approach to damage functions across phases has been the following (see Table 1):

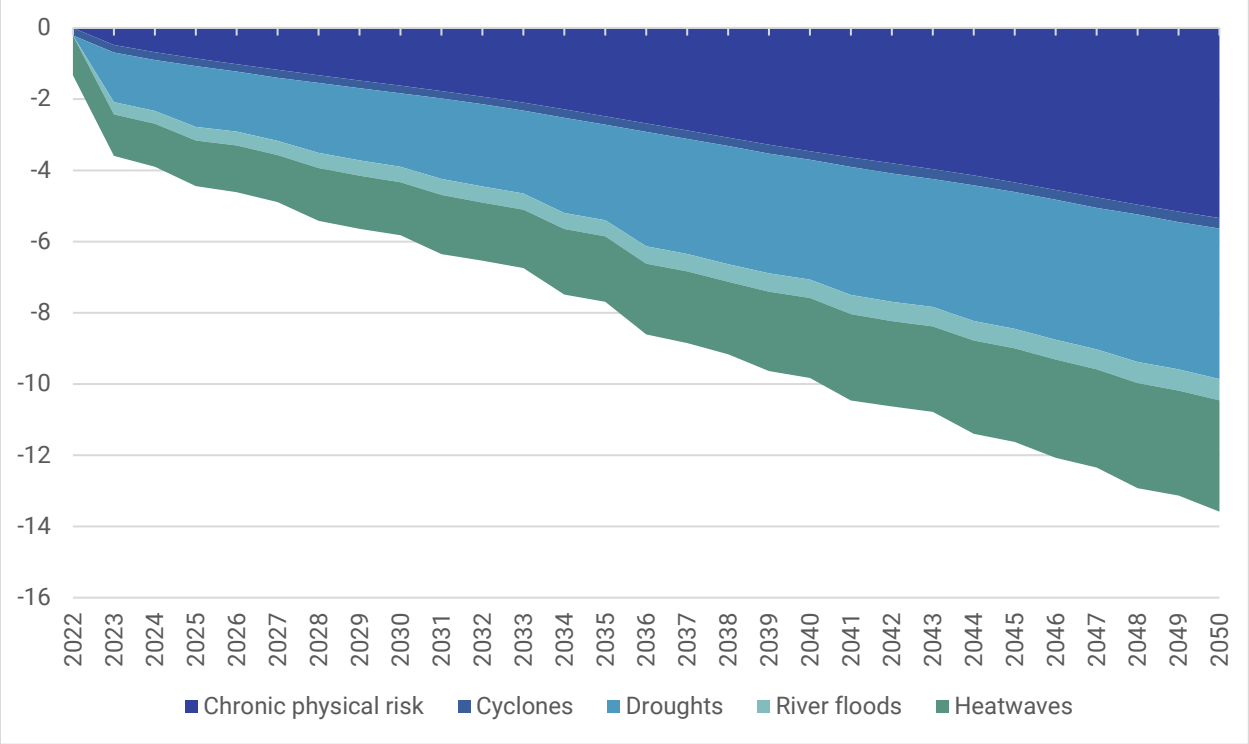
- In **phase I**, the global GDP impacts of three damage functions with varying impacts and approaches (empirical or meta-study based) were displayed. They were compared to a broader sample of seven damage functions, to show the uncertainty in the literature.
- In **phases II to IV**, country-level macroeconomic impacts of chronic physical risk have been modeled using the Kalkuhl and Wenz (2020) damage function. This function has a panel econometrics approach fit for country-level impacts and is in line with the average projections of the literature. The decision was made to consider the higher end of its uncertainty range (e.g., 95th percentile of impacts and 95th percentile of temperature from phase III onwards for the *Current Policies* scenario), so as to limit the risk of underestimating impacts.

In the view of the NGFS scientific consortium, recent methodological advancements now point toward higher damages than considered by the average projections in the literature. Phase V of the NGFS scenarios, published in November 2024, will thus introduce a damage function (**Kotz et al., 2024**) in line with these advancements.

The new damage function makes two main advances: (i) it includes a broader scope of climate variables (accounting for, e.g., temperature and precipitation variability, beyond mean temperature) and (ii) it models the semi-persistent effects of climate shocks on economic growth, offering a middle ground between purely transitory impacts and permanent effects on growth.

Chronic global GDP impacts should rise from between −2 % (*Net Zero 2050*) and −6 % (*Current Policies*) (see Figure 1) in 2050 for Phase IV scenarios compared with a counterfactual GDP, to between −7 % and −15 % in 2050 for the next phase. Although these estimations would be at the higher end in terms of the literature on impacts, some recent work, such as Bilal and Känzig (2024), may yield even higher impacts with a comparable temperature target (see Appendix 1 for examples of relevant studies). The NGFS remains committed to updating its assessment of physical risks as the scientific consensus evolves.

Figure 1: Physical risk impacts in *Current policies* scenario, phase IV (in % of GDP)



Note: Impacts are with respect to a baseline scenario without acute physical risk. Chronic physical risk based upon Phase IV Current Policies..
Source: Authors, based on data from NGFS (2023)

On the assessment of acute physical risks

Similarly to chronic risks, assessing the macroeconomic impacts of acute physical risks in a forward-looking way is difficult given the multiplicity of transmission channels and the necessity to better account for second-round effects. Acute physical impacts from climate change propagate to the broader economy through supply (e.g., capital destruction by windstorms, drops in labor productivity through heatwaves), demand (e.g., household wealth and income, consumer and business confidence), and financial channels (including those that foster resilience, such as high insurance coverage). The absolute and relative strengths of these channels vary by the type and intensity of the physical hazard (NGFS, 2024). In the short run, forecasting exercises have for instance proven historically difficult to implement, given the uncertainty on resilience (e.g., the Federal Reserve's forecasts after Hurricane Katrina in 2005). In the long run, it may be necessary to use simplified approaches to capture insights on the long-term trajectories for the impact of acute events.

Across iterations, the NGFS scenarios have aimed to broaden the set of acute perils considered and the types of transmission channels modeled, and to provide macroeconomic impacts (see Table 1 for an overview). In future iterations, priorities will include the improvement of the interaction with chronic risk, given that the expansion of the set of variables used in damage functions (e.g., temperature variability) may increase the risk of overlap in the estimations. For the upcoming short-term NGFS scenarios, the physical risk assessment will rely on acute physical risk modeling.

Overall, the approach of the NGFS to chronic and acute physical risk assessment, in long-term scenarios but also in the soon-to-arrive short-term scenarios, is focused on iterative improvements and transparency. The objective is to allow the users—including Ministries of Finance—to understand assumptions and limitations, so that they may correctly adapt these scenarios to their own needs.

Main takeaways for MoFs

- **There is no one-size-fits-all approach to physical risk modeling**, as the chronic versus acute approach of the NGFS illustrates: aggregate approaches such as macroeconomic damage functions need to be mixed with more detailed modeling of transmission channels.
- **The NGFS observes recent scientific advancements that point toward higher damages than previously considered in the literature.** The NGFS is committed to updating its assessment of the physical risk impact as the scientific consensus evolves.
- **Any use of the NGFS scenarios should come with an understanding of their underlying hypotheses and their limitations and will require complements to meet users' specific objectives.** In this regard, the NGFS provides detailed public information on its modeling as well as guidance to users on how to use the NGFS climate scenarios (see the explanatory note). Information on how to access the NGFS scenario data and technical documentation is available here.

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Appendix 1. Range of GDP impacts of damage functions from econometric studies

Studies	Range of damages	Range of temperature change
Burke et al. (2015)	23%	3.7°C*
Kalkuhl and Wenz (2020) Used in NGFS scenarios phase IV	7–14%	3.5°C
Kahn et al. (2021)	7–13%	3.7°C*
Kotz et al., 2024 Used in next phase of NGFS scenarios	19%	~2°C**
Bilal and Känzig (2024)*	30%	~2°C

*Notes: * RCP 8.5 range estimate: 2.6°C–4.8°C. ** Results are given for 2049, independent of warming scenarios (the range of ~2°C is a mean estimate of all RCP scenarios around 2050)*
Source: Authors, based on NGFS (2024)