macro-economic Multimodel Intercomparison Project on indirect economic impacts of extreme events (macroMIP)

Summary

The MYRIAD_EU project and the Research Unit Sustainability and Climate Risks at the University of Hamburg conducted a workshop to initiate a new macro-economic multimodel intercomparison project on indirect economic impacts of extreme events (macroMIP). The workshop was held as a post conference event of the 30th Annual Conference of the European Association of Environmental and Resource Economists on the 20th of June 2025 in Bergen, Norway at the Norwegian School of Economics (NHH). The macroMIP workshop, convened by Jana Sillmann, Elco Koks, and Benjamin Blanz, was attended by different experts, such as macroeconomic modelers, IAM modellers, risk assessment experts, and impact modelers, also representing the ISIMIP community.

As climate extremes are no longer distant threats but rather urgent tangible realities reshaping the consequences of climate change for our economy, environment and society, the aim of the macroMIP workshop was to set an agenda for a large-scale macro-economic Model Intercomparison Project (macroMIP) to improve our understanding of the direct and indirect economic impacts of climate change. Keynotes by Francesco Bosello, Franziska Piontek, and Elco Koks underscored the urgent need for comprehensive assessments and comparative analyses of macroeconomic models to better understand the (in)direct economic impacts of climate extremes. Bosello highlighted the key modeling challenge of bridging local-scale climate impacts with aggregated macroeconomic models. Piontek emphasized the importance of coordinated efforts, such as through ISIMIP, to link biophysical and economic assessments. Koks argued for an integrated, cross-scale framework like that applied in the MIRACA project, which uniquely focuses on asset-level impacts cascading to macroeconomic outcomes.

The workshop and discussions focused on how to compare indirect impacts of extreme events in macroeconomic models to improve the understanding of the mechanisms of indirect impacts and to make the assumptions behind different macroeconomic models more transparent. This understanding will allow improvements in the assessment of climate extremes' total economic impacts and provide a comprehensive framework for understanding how local and short-term events can propagate through global supply chains or transmission channels, offering more accurate and actionable insights for sustainable transformation.

The next steps for macroMIP entail drafting a protocol for stylized experiments for protocol will support implementing consistent experiments across diverse modeling approaches while acknowledging their different capacities and temporal scope. A follow up meeting is planned in August 2025 to finalize and distribute the protocols with modeling groups for running the first macroMIP experiment. macroMIP will closely collaborate with ISIMIP to identify opportunities for harmonized ISIMIP input into macroeconomic modeling experiments as well as distribution of eventual model results through the ISIMIP platform.

Abbreviation	Description
ABM	Agent Based Model
CGE	Computational General Equilibrium
GDP	Gross Domestic Product
IAM	Integrated Assessment Model
I-O	Input-Output
ISIMIP	The Inter-Sectoral Impact Model Intercomparison Project
macroMIP	Macroeconomic Model Intercomparison Project
SSP	Shared Socio-economic Pathway

Keynote Speakers:

1. Jana Sillmann
2. Francesco Bosello
3. Franziska Piontek
4. Elco Koks
5. Benjamin Blanz

Pitch Presenters:

1. Vito Avakumovic
2. Nina Knittel
3. Celian Colon
4. Shouro Dasgupta

Workshop Synthesis

The macroMIP workshop was opened by Jana Sillmann where Sillmann emphasizes that c*limate extremes are not just statistics; they are no longer distant threats but rather urgent tangible realities that are reshaping the consequences for our economy, environment and society.* Heatwaves, floods, and heavy rainfall are becoming increasingly frequent and severe and are posing systemic risks. The impacts of these hazard events are not evenly distributed and are deeply shaped by the other three main features of risk (1) Vulnerability (how sensitive a system is to being harmed), and (2) exposure (the extent to which a system is in contact with potential hazards), and (3) responses (the human behaviors or societal actions mitigating or exasperating the risks). The nexus of these three features can unravel cascading effects and thus amplify the overall compounding damage across different sectors as they have complex interactions between hazards, exposures, vulnerabilities, risks, and responses.

The introduction by Sillmann posed the fundamental question: *How can we connect these damages to economic metrics?* Acute hazards like floods, heatwaves and other extreme events, and chronic hazards like rise in sea-level, temperature increases can disrupt economic activities both immediately and indirectly through supply chain interruptions, physical damages to assets and shifts in resource availability. The central theme of the workshop was to explore methodologies that quantify indirect damage (or losses) incurred and comprehensive assessment and comparison of relevant macroeconomic modeling.

Keynotes by Francesco Bosello, Franziska Piontek, and Elco Koks highlighted the urgent need for comprehensive assessments and comparative analyses of macroeconomic models to better understand and mitigate the economic impacts of climate extremes. Moreover, these risks are not only physical but also transitional. As economies attempt to shift away from fossil fuels, new uncertainties arise. Companies fear regulatory changes, shifts in market demand, and stranded assets. These transition risks add to the complexity of managing climate-related financial exposures. Furthermore, Sillmann stresses that *there is currently a stark adaptation gap*: fewer than 20% of companies have formal adaptation strategies, and most are unlikely to adopt them soon based on a 2024 S&P report (Munday et al., 2024). This gap is largely due to the difficulty in modeling physical climate risks and the lack of economic incentives to invest in adaptation when future costs remain uncertain. Addressing the adaptation gap and improving risk modeling are vital steps toward safeguarding economic stability in the face of escalating climate challenges. The key takeaways from the keynotes highlight the importance of the impacts from climate extremes in connection with vulnerability and exposure of affected sectors, the variety of hazards impacting sectors, the significant adaptation gap, and the necessity of enhanced modeling and preparedness to effectively respond to climate risks.

The second keynote by Francesco Bosello emphasized the key gap between knowledge and modeling. Bosello highlighted *the challenge of reconciling local-scale climate impacts with models that operate at more aggregated spatial levels*. CGE models are inherently structured at national or broad regional scales, which presents significant challenges when attempting to represent localized extreme events. These events often occur at spatial resolutions that do not align with administrative boundaries or the aggregated nature of CGE frameworks. Bosello further claims that *this spatial mismatch complicates the integration of physical damage observed at finer scales into macroeconomic analyses conducted through CGEs*.

A key feature of CGE models is its ability to distinguish between direct[1] and indirect[2] effects. The investigations of these losses are pertinent as they have the potential to address and/or forecast future economic consequences under different climate scenarios and analyze past events to disentangle direct from indirect effects. Bosello proposes *a soft link* approach where physical damage is translated into economic variables which the CGE model can compute and process. However, due to spatial scale mismatch these damages are diminished. Thus, losing substantial detail and richness.

Bosello highlights the significant potential of CGE models in analyzing the economic impacts of climate change, while emphasizing the need for cautious application due to their inherent limitations. There is an ongoing discussion on the growing promise of integrating CGE models

---

[1] Direct impacts typically involve stock losses, such as damage to physical assets.

[2] Indirect impacts predominantly relate to flow losses, including disruptions to income, production, and overall wealth.

with advanced tools such as artificial intelligence, machine learning, and big data, as they can help bridge the gap between micro-level impact data and macroeconomic modeling. These technologies are particularly valuable in reconstructing missing data, estimating adaptation costs, and enhancing input coverage, thereby improving the models' ability to capture the localized, short-term, and complex nature of extreme climate impacts. Bosello points to both forward-looking[3] and retrospective applications[4] which enhance the utility of CGE models for scenario analysis and policy evaluation. Bosello suggests *future research should prioritize improving scale compatibility, integrating adaptation costs, and leveraging data science to close informational gaps between micro and macroeconomic domains, thereby strengthening the robustness and relevance of climate-economic modeling.*

The third keynote by Franziska Piontek explored the possibilities of bridging the gap between biophysical impacts and economic consequences. Piontek delineated the importance of connecting different approaches to modelling the economic impacts of climate change through academic community initiatives like ISIMIP.

In this keynote session, Piontek discussed the possibility and outcomes of combining top-down[5] and bottom-up[6] economic modelling methods. It is further pointed out that *a significant gap exists in biophysical impacts*. The current economic models often lack direct links to physical and ecological processes, leading to incomplete assessments. While some work has been done through climate and impact emulators, more effort is needed to connect biophysical data, especially trade-related cascading effects across regions. It is important to understand the key processes and impacts that require focusing on scenarios that explore tipping points (critical thresholds where small changes can lead to disproportionate systemic effects). This gives us a perspective to understand socio-economic vulnerabilities and potential crises.

Navigating the complexities of uncertainty and risk heightens the ongoing challenges to integrated modeling and decision-making. Scenario and storyline approaches can help to explore potential futures and the role of tipping points. Nevertheless, the tools to incorporate and quantify these risks within economic models are limited.

Several gaps require attention to advance future research and practice. There is a need for models that can simulate medium term (decadal), and long term (centennial) impacts to understand the potential threat to economic and social stability. The juxtaposition of mitigation efforts, adaptation

[3] Assessing future scenarios of extreme events and climate change.

[4] Disentangling direct and indirect impacts from past events.

[5] The top-down method primarily involves aggregate damage functions applied to gross domestic product (GDP), aiming to quantify overall damages without delving into specific mechanisms or pathways. Its strength lies in simplicity and high-level insights; however, it lacks the capacity to elucidate the processes, channels, or feedback mechanisms through which climate impacts influence economic dynamics

[6] The bottom-up approach, exemplified by CGE (Computable General Equilibrium) modeling, focuses on detailed sectoral, regional, and process-specific impacts. It captures the complex interactions within economic systems, including trade, resource allocation, and sectoral responses.

strategies, and impacts presents a complex landscape, and unraveling these dynamics is crucial for informed decision-making.

The fourth keynote by Elco Koks highlighted the need for an integrated framework that connects physical risks to economic outputs across scales and shared the results from the MIRACA[7] project. Koks portrayed the importance of integrating macroeconomic perspectives into infrastructure resilience planning; particularly for institutions like the World Bank, European Investment Bank, and others, which acknowledge the widespread societal and economic disruptions caused by infrastructure failure. MIRACA examines the spatial unit of 'asset' where it assesses the effect of hazards like floods and earthquakes on individual infrastructure components such as power substations, transportation nodes, and industrial sites.

The exploration of multi-hazard infrastructure approaches requires detailed hazard and event level footprints. The event sets include historic and stochastic models that are vital to simulate cascade effects and assess risk probabilistically. Koks shares that *developing comprehensive, probabilistic hazard event databases remains a challenge.*

Modeling impacts involves translating asset-level damages into broader economic losses by analyzing how infrastructure failures disrupt supply and demand across sectors. This requires accounting for the criticality of network components and their potential to trigger cascading failures. Koks shares that *by coupling infrastructure damage assessments with macroeconomic models, researchers can gain a more nuanced understanding of potential physical climate risks.* This approach was exemplified through a case study that overlaid flood maps with infrastructure vulnerability data to identify the most critical sites for protection. This coupled approach also integrates maritime trade data to assess port disruptions' effects on global supply chains. Using a probabilistic Monte Carlo method to simulate infrastructure connections. The analysis showed that flood-induced disruptions to power substations can amplify economic losses by up to 30% in extreme scenarios if vulnerabilities remain unaddressed. Koks states that *different hazard types, like chronic or acute risks, require tailored modeling strategies, with macroeconomic models suited for long-term, chronic hazards, and input-output models for sudden shocks.* However, this approach posits limitations as there is a need for a comprehensive macroeconomic model that can capture societal propagation and effects across regions. Koks thus claims that *addressing this limitation will enable the understanding of the full scope of climate-related disruptions.* There is a need for more coordinated efforts to improve data availability, event databases, and refined modelling techniques to better inform investment decisions for infrastructure resilience under climate change.

In the fifth keynote Benjamin Blanz introduced the model comparison framework developed in the MYRIAD-EU project with a focus on disaster (direct[8] and indirect[9]) impacts and the implications of impacts cascading through economic systems. MYRIAD-EU is actively

[7] MIRACA shares similarities with the Myriad project but uniquely emphasizes asset-level impacts cascading up to macroeconomic consequences.

[8] Direct impacts are defined as immediate consequences without behavioral response

[9] Indirect impacts are defined as changes to regional or sectoral output that is different from the direct impacts. They are caused by effects which unfold as economic agents adjust, and systems recover.

developing hazard event sets, such as floods, earthquakes and storms, which will be helpful to generate capital damage estimates across sectors. The case study presented by Blanz was of an Earthquake with its epicenter in Romania. Results from the IIASA-ABM showed Romania facing a sharp 4% GDP loss in the immediate months of the event's impact, while surrounding countries saw temporary gains due to reconstruction demand, especially in the construction sector. However, after two years, indirect losses emerged in other countries, particularly in the insurance and financial sectors. By year three, a net reduction in output was observed across the board. In contrast, the GRACE (CGE) model, operating in a static configuration, produced a much smaller impact estimate. This highlighted differing spatial and sectoral pattern; most notably, a larger effect in agriculture and a divergence in which regions benefited or lost out.

Blanz highlighted key challenges in comparing outputs of macroeconomic modelling pertaining to the endogenous versus exogenous treatment of reconstruction dynamics within models. He proposed using the recovery dynamics of models with endogenous reconstruction as an input to those that require exogenous reconstruction timeseries and thereby achieve a better comparability of results.

Blanz highlighted a critical finding that while both (IIASA-ABM and GRACE) models addressed the same hazard event, their outcomes in terms of economic consequences varied widely due to structural differences in assumptions, reconstruction dynamics, and capital treatment. Blanz further highlighted the central aim of macroMIP to *understand why models differ opening avenues of improvement. He further* suggested that in order to *separate direct from indirect impacts, models could be rerun without behavioral responses to direct impacts in addition to the full model evaluation. This would allow the determination of the effect of direct impacts on output and form the basis for the quantification* of indirect impacts, as well as the *interregional, intersectoral, and intertemporal contributions to total damages.*

The macroMIP workshop hosted four pitch presentations wherein different modelers could share their model results that are in alignment and relevant to the central theme of the workshop. The goal of these presentations was to provide insights into others' work and ideas on the topic, and to inspire discussion that would inform the design of the macroMIP protocol.

Vito Avakumovic's pitch critically examines how aggregation methods in climate impact modeling significantly influence the estimation of economic damages. Structural models often underestimate damages due to assumptions such as perfect labor allocation and idealized economic feedback, which fail to capture real-world disruptions in production factors, particularly labor market adjustments. In contrast, assessments using population-weighted aggregation typically project substantially higher damage compared to GDP-weighted methods. Clarification of the weighting schemes used is essential, as they yield markedly different global damage estimates and imply divergent normative judgments about distributional priorities. GDP-weighted damage functions are particularly relevant in macroeconomic modeling because they better reflect economic heterogeneity and exposure across countries. Avakumovic suggested that *greater transparency and methodological consistency in aggregating climate damages is needed* and *improved alignment across modeling approaches, explicit consideration of emission pathway* *dependencies, and enhanced comparability of damage functions are crucial for strengthening the credibility and policy relevance of integrated assessment models.*

Nina Knittel discusses a detailed multi-model analysis of flood events in Austria, focusing on revealing indirect risks within complex socioeconomic systems. The study compares two macroeconomic modeling approaches: a CGE model and an ABM, each calibrated for 2014. The analysis quantifies indirect economic impacts of floods, emphasizing the importance of accounting for distributional consequences across different household groups and sectors. Results indicate that sectors producing publicly provided goods and services, and demand goods experience high indirect risks. Approximately one-third of sectors showed low indirect risk, while some sectors displayed indirect benefits due to their role in flood recovery. Upon comparing the two models, it was revealed that contrasting dynamics: the CGE model exhibits negative impacts that gradually return to baseline, whereas the ABM, which focuses on extreme negative shocks, shows positive effects emerging rapidly for severe flood events (100- and 1000-year return periods). The ABM's positive outcomes are linked to endogenous economic behaviors, including reconstruction spending, albeit potentially financed by increasing debt; this factor is implicitly modeled in the CGE framework. This pitch highlighted the relevance of the chosen metric: GDP may not fully capture welfare impacts as it can increase due to reconstruction activities post-disaster. Welfare-based metrics might offer improved comparability across models and more meaningful assessments of flood impacts. Knittel claims *while GDP is a common measure, welfare-based metrics have a better potential to capture the true societal impacts.*

Célian Colon discusses an ongoing initiative to foster model intercomparison for disaster cost assessment, developed in collaboration with the World Bank. The motivation stems from the need to understand diverse dimensions of economic impacts following disasters, exemplified by an earthquake in Ecuador in 2016. This event provided rich data, including monthly transactions and balance sheet information, which serve as a foundation for empirical analysis of both direct and indirect costs. Four different models were employed to capture various aspects of the disaster's economic consequences (1) MANAGE model from the World Bank; (2) Baqaee & Farhi CGE model developed in collaboration with IMF emphasizing inter-sectoral dependencies; (3) (Bo)ARIO model, a dynamic input-output model tailored for disasters in collaboration with ETHZ and World Bank (4) Disrupt SC, a spatial ABM for supply chain disruptions disruption analysis. Colon's key objective was to identify h*ow these models complement each other and to guide policymakers and practitioners on their optimal use depending on timing and data constraints.* Colon's results suggest that *some models are better suited for immediate post-disaster assessments, capturing rapid impacts, while others are more appropriate for long-term recovery analysis.* Colon shares that *the idea is to start broad, allowing different models to participate in a shared platform before potentially subdividing protocols based on model clusters or approaches*. This would encourage mutual understanding of each modeling approach's assumptions and limitations, thereby enriching the quality and applicability of disaster cost assessments.

Shouro Dasgupta's pitch highlighted a significant gap in current macroeconomic models - *the limited integration of labor-specific climate impacts*. Despite labor accounting for up to 50% of total value added in many sectors and countries, few macro models have explicitly incorporated labor shocks or damage functions. Dasgupta claims that *this oversight is critical because labor is one of the most directly and immediately affected inputs in the face of climate extremes, particularly heat stress*. The focus on labor is driven by the availability of extensive empirical data and the potential to generate damage functions that reflect heterogeneity across sectors, regions, and globally.

The macroMIP workshop hosted four breakout group discussions where different modelers discussed (group 1) direct impact experiments[10], (group 2) physical impacts to economic losses[11], (group 3) participating model criteria and how to fit them into ISIMIP protocols[12] and (group 4) indirect impact metrics[13]. The overarching goal of these discussion groups was to establish the basis of a coherent framework for integrating climate impact data into macroeconomic models by aligning experimental design, data translation protocols, participation criteria, and impact metrics

The central challenge identified by Group 1 was to design harmonized shocks (both direct and indirect) that account for different model structures while maintaining comparability. They proposed a case study using ISIMIP labor impacts on agriculture as a starting point and emphasized the need to test how models behave under these controlled conditions to inform future protocols.

Group 2 focused on the differences in model complexity and resolution. They acknowledged that simplified models (like IO) and complex models (like IAMs or CGEs) handle shocks differently due to differences in assumptions, input data, and internal dynamics. They proposed standardized percentage-based shocks (e.g., capital stock reduction) but recognized that these may not translate consistently across all models or regions. A key takeaway was the need for guidelines on re-gridding and disaggregating biophysical data to better fit economic models.

Group 3 discussed the importance of aligning shocks with SSPs and ensuring that outputs (like GDP, welfare, or consumption) are policy-relevant and empirically grounded. They suggested

---

[10] The aim of this breakout group was to discuss which direct impact experiments should be run as part of the macroMIP. These could be one off shocks (e.g. extreme events), recurring, or persistent changes to model parameters (e.g. reduced labour productivity from higher average heat). Ideally these experiments should use the existing ISIMIP outputs and fit into the ISIMIP protocol.

[11] The aim of this breakout group was to discuss the protocol for translating the outputs of the physical impacts modelling into inputs suitable for the macroeconomic models. They also discussed methods of aggregation to different model scales, ensuring consistency of the impacts across evaluated macro models; consider whether the different macroeconomic modelling approaches can be covered by a single protocol, i.e. if consistency between them can be ensured, or if separate protocols are needed for the differing approaches

[12] The aim of this breakout group was to discuss the protocol for translating the outputs of the physical impacts modelling into inputs suitable for the macroeconomic models. The protocol should include methods of aggregation to different model scales, ensuring consistency of the impacts across evaluated macro models. This group should also consider whether the different macroeconomic modelling approaches can be covered by a single protocol, i.e. if consistency between them can be ensured, or if separate protocols are needed for the differing approaches

[13] The aim of this breakout group was to discuss suitable metrics to measure the contribution of indirect impacts to the overall total impacts of a specific event or scenario. The governing question was how to quantify indirect impacts in a way that is comparable across structurally different economic modelling approaches. This would also contribute towards inclusion of indirect impacts as an explicit part of damage functions of integrated assessment models.

modeling labor and asset losses from extreme events (e.g., floods, tropical cyclones) and emphasized maintaining internal model consistency while capturing multiple impact channels (labor, capital, growth). They proposed that shocks should be stylized yet rooted in realistic socioeconomic contexts.

Group 4 tackled model comparability from a structural perspective. They proposed metrics to quantify model complexity and adaptability to shocks. While some models can turn transmission channels on/off, this affects their core structure and limits cross-model comparability. Instead, they recommended a simple approach to run models with and without shocks and compare baseline deviations. However, a consensus emerged that it is important to distinguish between short-term, one-time extreme event shocks and chronic, long-term climate stressors, proposing two separate but linked protocols.

Several cross-cutting themes emerged throughout the workshop. The central agreement on the use of standardized economic shocks such as losses in labor, land, or capital as model inputs, with outputs like GDP or sector-specific production used for comparison. It highlighted the need to carefully design these shocks to be comparable across models, while accounting for differences in structure, resolution, and assumptions. The representation of different modelers and their approaches brought out interesting perspectives on harmonization and preserving model-specific strengths. Some modelers cautioned that enforcing uniform shock implementation could lead to oversimplification and loss of insight from complex models. Others emphasized the value of empirical grounding, especially the use of observed damage functions (e.g., labor productivity reductions due to heat stress) to enhance realism and policy relevance.

Building on the shared foundation, the next steps for macroMIP focusses on drafting a stylized experiment in two distinct but complementary protocols: (1) the impacts of chronic stressors (e.g., persistent heat or flooding) over time (2) the indirect economic impacts of acute, extreme events (e.g., natural disasters). These protocols would support consistent experimentation across diverse modeling approaches while acknowledging their different capacities, spatial, and temporal scope. These protocols will be shared with the modelers in August 2025 for feedback and discussions. The next meeting of the macroMIP modelers will be scheduled for August/September 2025 with the agenda of finalizing the protocol and running the first stylized experiment. We aim to strengthen our collaboration with the ISIMIP community by sharing the results of our initial experiment and maintaining ongoing engagement. Through this collaboration, we seek to identify opportunities for harmonizing ISIMIP input data with the macroeconomic modeling experiments we are developing. Furthermore, we are committed to ensuring that our results are made accessible through the ISIMIP platform, thereby contributing to the broader scientific community.