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Acknowledging Cross-Disciplinary Gaps Can Improve Macroclimate Modeling

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Key Takeaways

- Current knowledge gaps suggest that cross-disciplinary research and knowledge sharing can pave the way for improvements in macroeconomic climate modeling.
- Economists and climate scientists also need to overcome fundamental differences in modeling approaches. A better understanding of key climate factors and the uncertainty of outcomes could improve the inclusion of climate processes in economics.
- Climate is one of many risks facing investors and should be assessed in a broader context since political, economic, and financial risks often take higher priority in the near term.

The current quantification of global macroeconomic physical climate risks leaves room for improvement and requires cross-disciplinary collaboration. We have identified three areas of focus to bridge existing gaps:

- Reconciling concepts and increasing understanding across disciplines. Economics and climate science have more to offer than data on GDP, temperature, and precipitation, and must ensure that their terminologies and methods align.
- Bridging modeling differences. Economists prefer a small set of key drivers that can represent complex climate phenomena to assess economic effects in a dynamic framework.
- Embedding climate risks in the broader context. Assessing the effects of climate risks on the economy, the broader society, and financial decisions relies on understanding how climate risks compare with competing risks, and how they interact with other political economy objectives, constraints, and preferences.

The rising pervasiveness of physical climate risks within other disciplines emphasizes their dynamic and multivariate nature. Climate risks cause feedback in physical, natural, and human systems, which are interconnected. This feedback includes risks from shocks that cascade from the physical to the social sphere or vice versa, tipping points that prompt irreversible climatic changes, and indirect dependencies on nature.

Those dynamics remain poorly understood and their evaluation can differ widely across disciplines. In this article, we propose three foundational pillars to combine economic and climate models in a more thorough way than has been done to date.

1 – Bridge The Knowledge Gap

Cross-disciplinary collaboration rests on a common understanding of concepts and data needs. Both economists and climate scientists have a limited understanding of the other discipline. For example, most climate scientists are not versed in the theoretical and modeling techniques used in economics (production functions, integrated assessment models, general equilibrium models, etc.). Similarly, most economists are not proficient in the theoretical and modeling techniques used in climate science (radiative transfer, convection, ocean circulation, glaciology, soil hydrology, etc.).

Additionally, the complexity of the physical, socioeconomic, and natural systems involved means that economists and climate scientists are operating near their own frontiers of knowledge. This makes it even more difficult to develop and maintain a reasonable understanding of the other discipline's methods, data, and limitations.

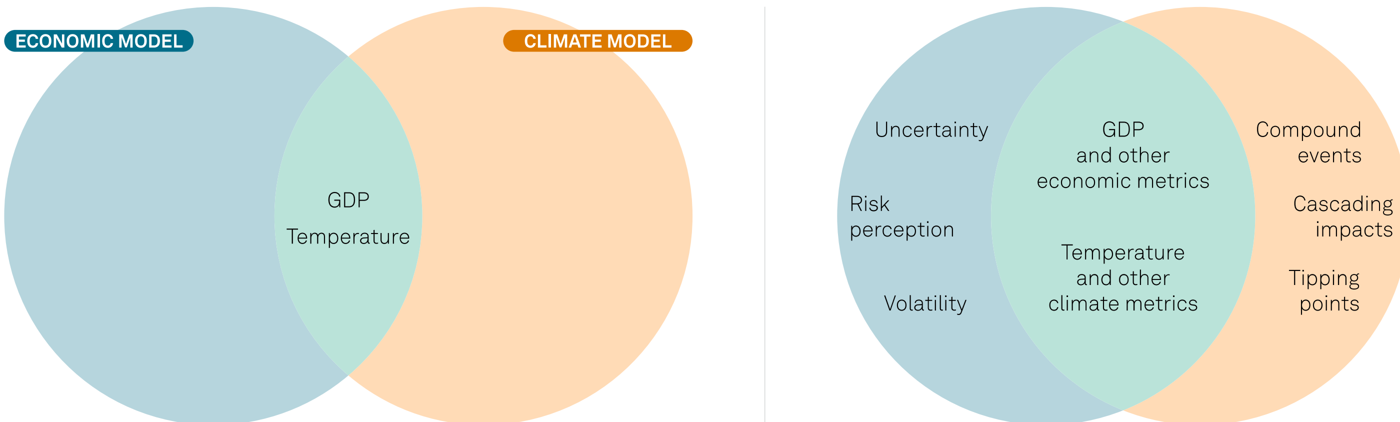
Some attribute the lack of urgency to tackle climate change to economists' reliance on a narrow measure of welfare, namely GDP (see chart 1). Macroeconomic models have generally not addressed climate in the past, nor have they considered measures of environmental wealth, such as natural capital. Thus, interactions of human activity with nature and the weather, and the associated societal trade-offs, have been abstracted away.

Chart 1

The overlap between economic and climate models is small and focuses on GDP and temperature

Models currently only have a few metrics in common

The consideration of additional metrics would increase the overlap



Examples of economic models
- IAMs
- Structural general equilibrium models: CGEs
- Econometric/statistical models

Examples of climate models
- Earth-system models (CMIP6); ensemble boosting
- Process-based impact models, ISIMIP

CGE--Computable general equilibrium. CMIP6--Coupled model intercomparison project phase 6. IAM--Integrated assessment model. ISIMIP--Inter-sectoral impact model intercomparison project. Source: S&P Global Ratings.

In practice, economists rely on a broader range of indicators than GDP to understand societal dynamics. Even so, climate scientists are seemingly unaware of differences between measures of flows--for example GDP--and measures of stocks, such as the capital stock and labor. Linking only GDP--a flow--to climate hazards can provide counterintuitive results: The need to rebuild after a natural disaster can increase flow of economic activity, even though the stock of physical capital and wealth has been damaged.

Over the years, economists have made progress toward integrating environmental factors in their models. Efforts are continuously underway to improve societies' measures of wealth, for example by integrating natural capital in the national accounts. Modelers have also been able to assess some of the economic damages associated with the realization of physical climate risks.

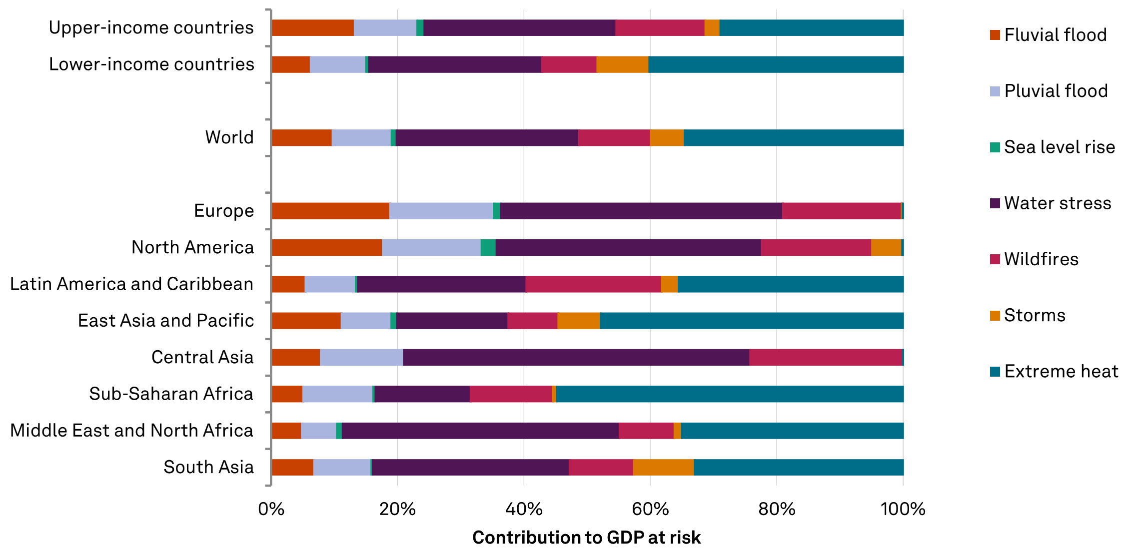
Translated via integrated assessment models (IAMs), those damage functions have provided a way to quantify the social cost of carbon--a key measure to assess the benefits of climate mitigation or the costs of higher carbon emissions. They have also led to a more widespread climate scenario analysis, which is key to understanding systemic risk linked to climate risks in the financial.

Yet measurement is still an issue and economists must bridge an information gap to assess physical risks. Economists mostly focus on temperature when including climate in their models, although they can choose among many data and measures, including compound effects from the interactions of different phenomena. For example, measures of water flows and stress are mostly overlooked, even though their effects are likely to be substantial globally (see chart 2).

Chart 2

Water-related hazards are likely to be the main sources of potential physical risk-related losses globally

Climate hazards' contribution to potential economic losses under a slow-transition scenario (SSP3-7.0) in 2050, absent adaptation



GDP at risk represents the share of GDP that could be lost annually due to high exposure to physical risks, in the absence of adaptation to climate risk, without accounting for changes in the economic geography and structure and assuming all hazards occur every year. Sources: S&P Global Ratings, S&P Global Sustainable1 (2023).

The Importance Of Terminology Alignment

Economists and climate scientists often use the same term to refer to different issues. For example, most economists define "tipping point" in the mathematical realm of system stability, while climate scientists use the term more generally to describe long-term regime change or a structural change, which can also be applied to societal dynamics. These conceptual misalignments can lead to misunderstandings between the two disciplines.

2 – Overcome Fundamental Differences In Modeling Approaches

In addition to increasing cross-disciplinary awareness, it is necessary to reconcile differences between economists' and climate scientists' modeling frameworks.

Tackle the dimensionality issue

Integrating the data richness of climate science into more compact methodologies for the financial world requires identifying key drivers of the local climate. These include many variables, some of which are defined in relation to human, industrial, and natural systems.

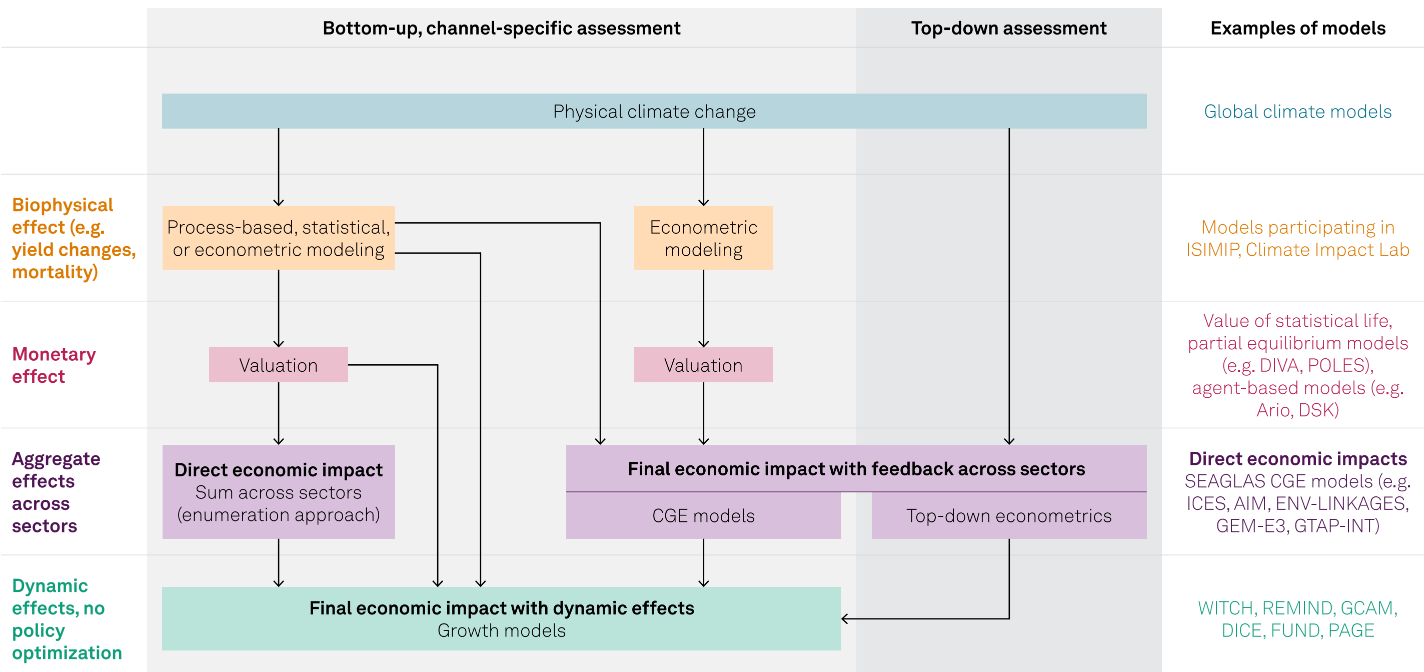
For example, heat stress on humans is measured by assessing how temperature, humidity, and wind affect the human body, whereas the effects of heat on electricity demand may be measured by a different metric, such as the number of days the temperature exceeds a particular level, and by how much.

The principle of parsimony is often desired in economic models. The inclusion of more variables in modeling increases computational costs and the complexity of the model. Intuitively, using more variables to represent changes in climate dynamics should ensure all economic effects are accounted for. Instead, it can blur the clarity of effects in economic modeling. This is why economists have used simplified representations of the world or summary measures--such as temperature--to understand high-level macroeconomic effects.

Static models in a modeling chain approach have bridged the dimensionality issue (see chart 3). We note, however, that this raises other problems of consistency--modeling techniques, scenario assumptions, spatial resolution, and indicators do not always match across models from different disciplines--and compounds uncertainty across models and parameters.

Chart 3

The interdisciplinary modeling chain is complex



CGE--Computable general equilibrium. Sources: Piontek, F., Drouet, L., Emmerling, J. et al.: Integrated perspective on translating biophysical to economic impacts of climate change. Nat. Clim. Chang. 11, 563–572 (2021).

Impact models that put the damage function in the center are not easily reconciled with general equilibrium models, where damages are not identified via economic channels, but derived from a residual. For example, climate effects are often applied to the productivity term in the GDP growth function. Adding up impacts from different models also leads to overidentification, while disregarding feedback and interactions across physical hazards, and in the economic and financial space.

Reconciling the principle of parsimony with the multi-dimensional challenge matters because the two approaches have not provided consistent results and thus hindered a consensus on the extent of economic impacts. Climate scientists could help economists by providing clarity about a small set of key climate characteristics and their effects. Identifying such factors in the physical science space can help economists expand climate emulators beyond temperature metrics, while maintaining low dimensionality and thus tractability.

This includes a stronger focus on identifying key hazard metrics, for example droughts or floods. It also prioritizes accounting for extremes, standard deviation, and non-linearities (for example, compound events), and warrants a broader definition of natural capital that also includes land use, water, or biodiversity metrics.

Reconcile modeling approaches

Combining climate model outputs with economic models requires a better consideration of fundamental differences in dynamic frameworks to ensure consistency in how economic and physical interactions are represented and an improved understanding of methodological limitations.

To start with, climate science models lack agency: they do not assume that agents solve optimization problems. Instead, they focus on the relationship between physical processes, specifically how incoming, absorbed, and outgoing radiation affect the long-term path of global average temperature. Perturbations are random and reflect the unpredictability of weather systems, which means running the same model twice can produce different results.

Using the mean from different climate models helps overcome some of this uncertainty. Yet, it puts little emphasis on tail risks and climate volatility. Additionally, climate processes are prone to non-linearities, such as regime changes, whose incidence is unknown or highly uncertain. This means the relationship between different climate scenarios may not necessarily be additive.

In contrast, economic models often study the long-run equilibrium properties of a socioeconomic system. Economic equilibria can be disrupted by short-term factors and shocks. But over the long run, it is anchored by supply side fundamental factors. These include the accumulation of physical capital, as well as workforce demographics and productivity gains.

This means models can map out different ways to get to the same target--for example, the same GDP level can be achieved with different levels of physical capital and labor. Beyond that, they are able to showcase trade-offs for the agents that are maximizing an objective function (for instance, consumption over time). Over time, these models are usually converging back to a steady state.

These modeling differences highlight that simply adding a measure of "natural capital" or "climate state" to economic models may not suffice to represent climate dynamics accurately. Climate emulators--which are an integral part of models, for example IAMs--could incorporate a higher degree of the randomness and uncertainty that is embedded in climate systems. This can be done via stochastic modeling techniques, such as Monte Carlo simulations.

In economic models, the assumption that shocks are independent and identically distributed (or stationary) may not hold for climate events. For example, weather conditions in one region can be correlated with events in another. At the same time, some of those modeling techniques, such as insurers' natural catastrophe models, may rely too much on historical event distributions to estimate the magnitude and frequency of shocks.

Combining economic models with earth system models could help identify deeper relationships between the two systems. This will require reconciling spatial and temporal dimensions, stochastic or deterministic modeling techniques, and testing new linkages--for example at the sub-national level -to include global climate factors, such as atmospheric and oceanic effects.

In particular, tail risks--that is, low-probability, high-impact events, such as compound, cascading events, as well as tipping points--are still largely understudied at the intersection of economics and physical science. In this context, assessing the relative importance and interaction of climatic and non-climatic factors, the effects of vulnerability and exposure, and the role of sector and regional specificities would shed more light on the materiality of those risks. Case studies that span time, space, sectors, and multiple hazards could explain those dynamics.

Beware of interdependencies with nature

Climate models hardly consider interdependencies with nature and biodiversity. These models represent some aspects of vegetation and land use, but from the perspective of their effects on the energy balance of the climate system, not from the perspective of natural capital and biodiversity. Those matter when they affect the plausibility of scenarios. Economic models lag far behind in this area.

Preserving nature and mitigating physical risks may not always present the same trade-offs for resource use. For example, some high-mitigation scenarios may not be compatible with the use of water resources for large-scale carbon capture and storage.

3 – Adopt A Multidimensional View Of Risk

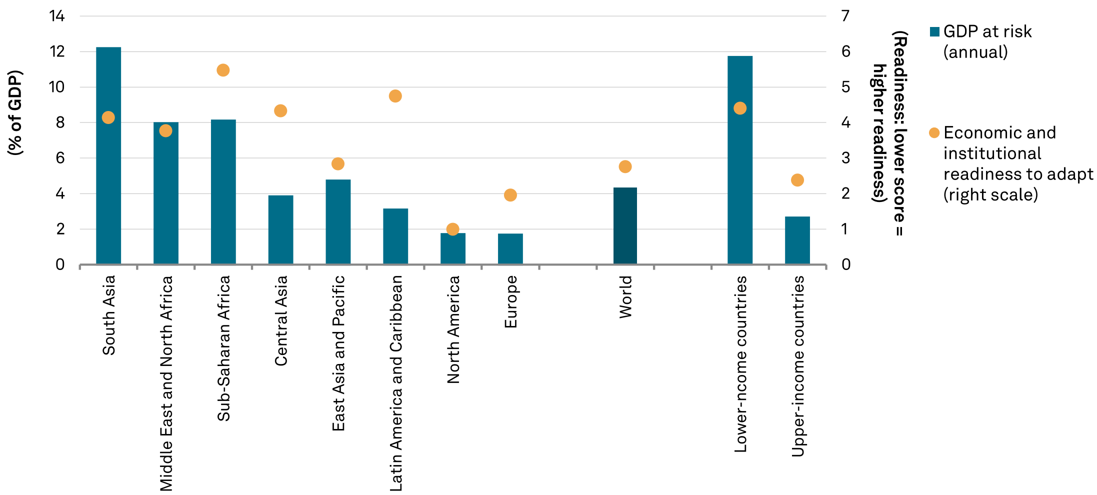
Climate is one of many risks facing humankind and may not always rank first in terms of materiality. In climate impact assessments, climate risks are often portrayed as the most important risk--partly because they are the focus of these assessments. This, however, presents a potential omitted variable bias and can reduce the credibility of these assessments.

Other risks--including political, financial, and regulatory risks--may have a more material effect on investment decisions and economic dynamics. For example, countries with a higher average temperature have more to lose from climate change, but those countries are also less developed and have weaker institutions (see chart 4). They may also suffer from weak health systems and poor housing and employment prospects. Understanding which risks are most relevant can help inform the trade-offs that policymakers and investors face when tackling climate risks through mitigation and adaptation investments.

Chart 4

Countries most exposed to climate change are already more at risk

Potential GDP at risk from physical hazards and the readiness to cope with their effects under a slow transition scenario (SSP3-7.0) in 2050, absent adaptation



GDP at risk represents the share of GDP that could be lost annually due to high exposure to physical risks, in the absence of adaptation to climate risk, without accounting for changes in the economic geography and structure and assuming all hazards occur every year. Readiness provides a relative picture of countries' ability to avoid and respond to some of these losses based on their economic and institutional strength. Readiness is a measure of vulnerability to climate effects, based on countries' economic and institutional strength. Sources: S&P Global Ratings, S&P Global Sustainable1 (2023).

Hence, it is central to highlight how the mitigation of climate risks interacts with other political economy objectives--such as intertemporal and distributional issues--and constraints, for example financial means, as well as institutional and geopolitical risks. The valuation of the future--represented by the discount rate in economic models--preferences, and differences in ethical conceptions matter in this context.

At the same time, a stronger focus on the economic and financial sources of vulnerability to climate effects could improve our understanding of how resilience and adaptation to physical risks will vary across countries, sectors, and income levels.

More clarification is also necessary on how climate-related risks influence financial decisions beyond stress testing. Uncertainty, risk aversion, and risk perception are central when making investment decisions because they affect pricing and the distribution of relative returns. It is therefore important to characterize the type of uncertainties related to climate risks--such as the boundaries of our knowledge--measure changes in climate risk perception and beliefs--for example, attitudes toward the robustness of climate assessments--and assess the volatility and variability of climate metrics.

Next Steps

Cross-disciplinary research can pave the way for improvements in macroclimate impact modeling. Reconciling the physical science with the economic discipline requires a better understanding of key climate factors, differences in dynamic modeling, and how nature and the climate affect and interact with social and investment decisions within the constraints set by economic trade-offs. Economists and climate scientists should work together to draw clearer feedback links between climate, nature, economic and financial systems.

Related Research

- Lost GDP: Potential Impacts Of Physical Climate Risks, Nov. 27, 2023

External Research

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