The Coalition of Finance Ministers for Climate Action

Strategic climate risk modeling for economic resilience: a guide for Ministries of Finance

World Bank

A contribution to the 'Compendium of Practice from a Global Community of Ministries of Finance and Leading Organizations: Economic analysis and modeling tools to assist Ministries of Finance in driving green and resilient transitions'

Topic: Addressing the climate policy questions facing Ministries of Finance: the economic and fiscal impacts of climate change

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This note outlines the relevance of different modeling approaches to Ministries of Finance (MoFs) in understanding and responding to climate risks. Chronic and acute physical climate risks impact macroeconomic systems differently, necessitating tailored approaches for policy formulation. MoFs can use global circulation models (GCMs) to assess future climate impacts, but must handle the significant variations in these models, especially for precipitation forecasts. Economic damage assessments should differentiate between risk types, ideally through biophysical models for actionable policy recommendations rather than relying solely on aggregate econometric methods. These models are crucial for detailing climate-induced damage shocks and potential adaptation scenarios, which can be integrated into macroeconomic models for comprehensive policy analysis.

For MoFs, the types of questions these approaches can help tackle include the economic implications of climate risks, the cost and benefits of adaptation strategies, and the allocation of resources for resilience. The most appropriate models for decision-making in MoFs are those that provide detailed sector-specific insights, such as biophysical models that can be integrated into macroeconomic frameworks to assess policy impacts.

To build domestic analytical capacity over time, MoFs might start with cost-effective global datasets for initial climate impact investigations before investing in more resource-intensive biophysical models. This staged approach allows for the development of analytical tools that are most impactful for the country's specific context. Additionally, MoFs need to differentiate between common physical shocks and rare extreme events to craft suitable policy responses, which may include insurance mechanisms or emergency funds.

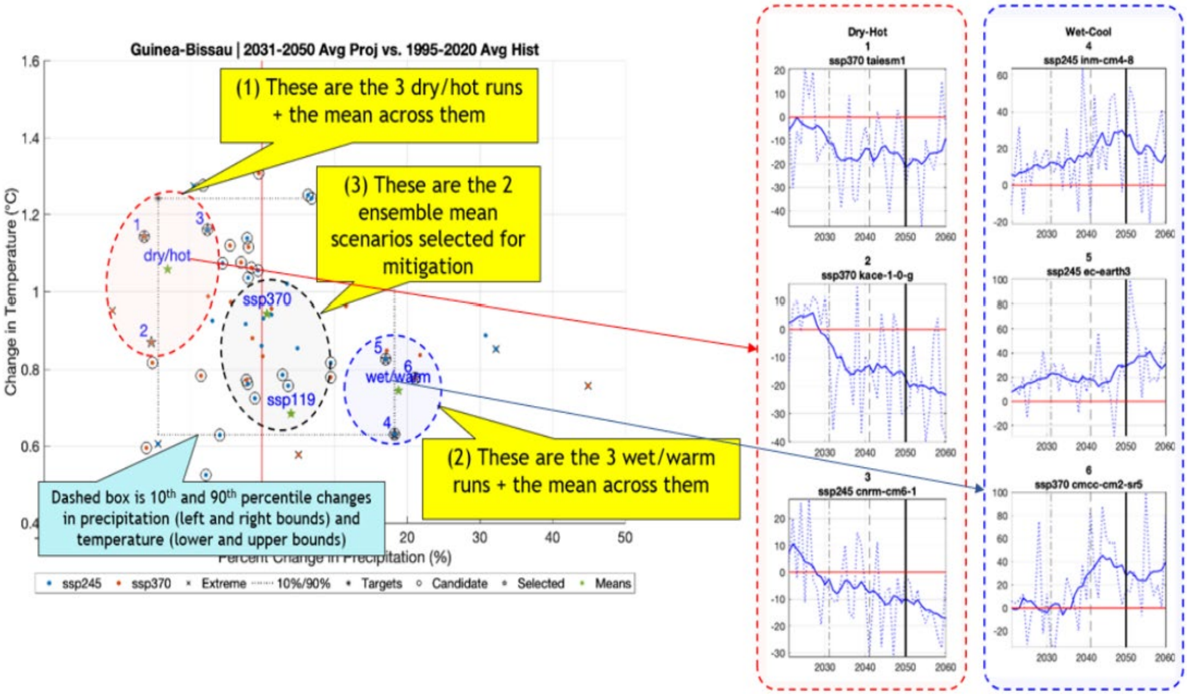
In summary, MoFs can leverage a combination of GCMs, biophysical models, and econometric methods to address climate risks in their macroeconomic framework, with a focus on building domestic capacity to refine these tools and ensure they are aligned with the specific economic and social contexts of their countries.

Chronic and acute physical climate risks both threaten macroeconomic systems, but in distinct ways. Chronic risks, or slow-onset risks, such as rising sea levels or gradual shifts in precipitation patterns, cause long-term disruptions to infrastructure, agriculture, and habitability. Acute risks, or high-impact, low-frequency events, such as extreme weather events (e.g., floods or heatwaves), deliver sudden shocks that can damage property, disrupt supply chains, and cause economic losses. While chronic risks pose existential threats, acute risks can trigger immediate economic crises.

GCMs act as primary inputs for climate economists studying future climate impacts, and they do not always agree. These complex computer programs simulate Earth's atmosphere, oceans, and land systems, allowing modelers to project how factors such as greenhouse gas emissions will influence temperature, precipitation, and other climate variables. In the latest phase (Phase 6) of the Coupled Model Intercomparison Project (CMIP), more than 30 models were used to simulate the same set of representative concentration pathways (RCPs).

While GCM outputs provide insights into climate change impacts, significant variations, especially in precipitation forecasts for individual countries, necessitate further analysis to formulate robust policy recommendations. GCM simulations contain a wealth of information that is crucial to preserve during the transfer to other models for impact analysis. A strategic subset of these simulations must be chosen to capture the underlying uncertainty and preserve the range of potential outcomes. Taking a mean forecast (or the Ensemble forecast) is not recommended as results tend to hide significant variations. Multiple scenarios should be considered for impact assessment to ensure an exhaustive range of vulnerabilities accurately reflect the climate risks.

Figure 1: Illustration of the range of simulations across climate models and scenarios for Guinea-Bissau



Note: The bottom right of the quadrant shows a selection of wet and warm results, while the top left corner shows a selection of dry and warm model results in contrast, for the same period of analysis.
Source: World Bank (2024), World Bank staff estimations and Industrial Economics, Incorporated

Assessing economic damages by risk type (e.g., urban flooding, crop yields, labor heat stress) from biophysical models offers a more actionable approach for policy recommendations compared with aggregate econometric methods (e.g., the impact of temperature increase on total output). The econometric approach leverages statistical analysis of existing data, and it excels at capturing large-scale trends and identifying economic vulnerabilities based on past experiences.[1] However, econometrics can struggle to account for entirely new climate phenomena or predict the cascading effects of complex disruptions. Moreover, by construction, econometrics tends to average out effects, muting outliers that may be critical to understanding risks. The alternative approach, enumeration, involves a more bottom-up strategy often based on biophysical models. Modelers painstakingly identify and quantify the various economic losses arising from specific climate impacts. This method offers a detailed picture of the potential costs across different sectors, including adaptation and resilience measures in an actionable way. However, enumeration can be time-consuming and data-intensive, especially for large-scale assessments, and may struggle to capture the full range of potential economic consequences.

1 The econometric approach utilizes time-series data, including geospatial GDP, temperature, and precipitation levels. To capture extreme weather events such as heat waves, the analysis incorporates nonlinear transformations of temperature and precipitation data. Panel analysis is a common methodology employed for this type of evaluation to gain robustness.

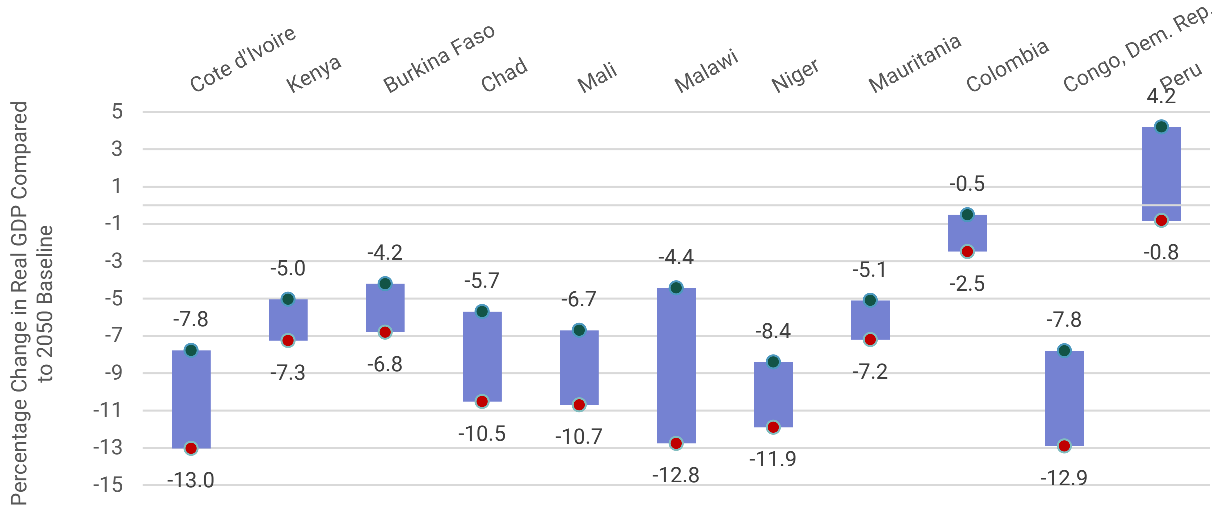
Table 1: Illustration of impact channels and hooks to macroeconomic models used in the World Bank's Country Climate and Development Report

Impact channels	Hook to macro-model			
	Labor productivity	Labor supply	Subsector productivity	Capital
Human health and development				
Labor heat stress	✓			
Human health		✓		
			✓	
Agriculture, water, and energy				
Rainfed crops			✓	
Irrigated crops			✓	
Erosion effects on crops			✓	
Livestock			✓	
Hydropower			✓	
Water supply				✓
Infrastructure				
Roads and bridges		✓		✓
Sea-level rise and storm surge				✓
Inland flooding				✓
Urban flooding				✓
Tropical cyclones				✓

Biophysical models play a crucial role in providing insights into climate-induced damage shocks and potential adaptation scenarios for integration into macroeconomic models. These models encompass a variety of systems, including crop production, hydrology, labor productivity under heat stress, and flood risks at fine levels of geographical detail (15 or 25 km^2 grids). They embody the principles of physics, chemistry, and biology to forecast the responses of natural systems to climatic changes, with GCMs serving as foundational inputs. A significant benefit of biophysical models is their ability to outline, evaluate, and cost tangible adaptation strategies and resilience mechanisms. Moreover, by interrelating the geographic location of economic activity with the geographic layout of climate change, they can identify the serious local damage effects that aggregated data might average out. Outputs from biophysical models can be incorporated into macroeconomic models to estimate their economic implications within a general equilibrium context. This process facilitates the analysis of various policy frameworks from a bottom-up perspective.

In the early stages of investigation, datasets from global sources offer a cost-effective alternative to resource-intensive biophysical models for initial climate impact investigations (see the companion note on data sources). Biophysical models, while powerful for in-depth climate impact and adaptation analysis, can be expensive in human resources and time-consuming to develop, especially in early stages of investigation. There is a risk of investing significant resources in these complex models only to find their impact on economic forecasts is negligible for a specific country context. However, simpler data-driven approaches can be a valuable first step. By identifying key channels through which climate change might affect the economy (e.g., changes in agricultural yields, water availability or floods), these initial investigations can guide the development of more refined biophysical models later, ensuring resources are directed toward the most impactful areas of analysis.

Figure 2: GDP impacts of climate change in 2050 in pessimistic scenarios, with current policies and with additional adaptation measures for selected countries



Notes: The red dots show the impact of climate change represented in Country Climate and Development Reports (CCDRs), with current policies and practices; the green dots show the impacts with recommended adaptation measures and their co-benefits. GDP impacts are derived from the World Bank's Macrofiscal Model (MFMod), the Mitigation, Adaptation, and New Technologies Applied General Equilibrium (MANAGE) model, and, in the case of the Democratic Republic of Congo, the Long-Term Growth Model (LTGM). Not all impact channels are modeled for each country, which makes the analysis partial. Modeling choices depend on the national context and are explained in each country's report.
Source: Authors

Differentiating between the most probable shocks and the rare, extreme events ("tail shocks"), is critical for crafting suitable policy responses (e.g., designing targeted insurance mechanisms, allocating emergency funds strategically, or optimizing public spending triggers to support post-disaster recovery). Adaptation and resilience policies for common physical shocks, such as those from natural disasters intensified by climate change, may differ from those designed for extreme tail shocks, which are typically examined in stress-testing exercises. For the more frequent types of shocks, insurance mechanisms are often necessary to mitigate most of the damage. In contrast, extreme shocks may necessitate fund mechanisms or the allocation of emergency spending and investments to manage nonlinear responses. In essence, while minor shocks can usually be managed by standard economic mechanisms, these mechanisms can exacerbate the impacts of major shocks, demanding targeted policy interventions. A striking example is the 2022 floods in Pakistan, whose total damage was estimated at nearly 5% of gross domestic product, against a backdrop of unprecedented rainfall, sometimes exceeding average monthly totals by six to seven times in some provinces, pushing between 8.4 and 9.1 million people into poverty (see Government of Pakistan, 2022).

Macroeconomic analysis of climate physical risks can miss relevant social impacts. Focused on national trends and economic indicators, macro analysis can mask how impacts vary across social groups. While it captures economic losses, it might struggle to quantify the social costs of displacement, and mental health burdens. Furthermore, its short-term focus overlooks the long-term social disruptions climate change can bring. Therefore, a comprehensive understanding requires supplementing macroeconomics with studies that capture the social dimension of climate change. For example, the 2016 to 2017 drought in East Africa caused an estimated combine US$13 billion loss in GDP (see Zaveri et al., 2017). Behind this headline number the UN World Food Programme (Khorsandi and Snowdon, 2017) estimated that over 20 million people faced severe food insecurity due to the drought.

Building a "no further policy" macroeconomic baseline to 2050 and beyond is fraught but is a good reference point. Uncertainty in future climate impacts, the potential for technological breakthroughs, complex economic feedback loops, the unlikelihood of true global inaction, and the short timeframe itself all make such a model inherently challenging. Assumptions might not hold true, potentially misestimating the true economic costs of inaction. **Despite these difficulties, it remains valuable as a reference point. It highlights the potential economic benefits of climate action and helps assess the costs faced in the case of inaction.**

Even though most severe warming and resulting damages are projected for beyond 2050, climate change modeling efforts have largely focused on near-term policy impacts. This is because the focus is on understanding the effectiveness of different policy interventions, such as emissions reductions, in mitigating future warming and in some adaptation planning. While the worst might be yet to come, these models provide crucial insights into how choices today can shape the trajectory of climate change and potentially minimize long-term damages in the latter half of this century. However, in certain circumstances, it is warranted to go beyond 2050, for certain discussions on adaptation (e.g., for small islands exposed to existential risks).

Some of the most critical risks defy easy quantification in amplitude and probability, which justifies an almost systematic methodological caveat when presenting the results. These unknowns—such as the potential for cascading ecosystem collapses or resource scarcity–related conflicts—pose immense threats but it is difficult to assign a precise likelihood to them or measure their full impact. For instance, the ecological and economic consequences of losing the Amazon rainforest are incredibly complex and potentially catastrophic, yet these cannot readily be translated into a dollar amount or a percentage chance of occurring. Despite the challenge of quantification, these very risks often hold the greatest potential for causing widespread disruption and societal instability, making them crucial considerations in developing climate change mitigation and adaptation strategies.

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