



**The Coalition
of Finance Ministers
for Climate Action**

Stronger analytics for better financial resilience against climate shocks and disasters

World Bank—Finance, Competitiveness & Innovation Global Practice (FCI GP)

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This contribution showcases the framework and the suite of analytical tools and models on climate and disaster risk finance developed by the World Bank’s Crisis and Disaster Risk Finance global team to inform Ministries of Finance and other public sector entities in the design of cost-effective financial strategies against climate shocks and disasters. This approach has been used in more than 50 vulnerable emerging markets and developing economies to improve the financial resilience of the countries and people against climate shocks and disasters through fiscal and financial sector reforms and the development of innovative financial solutions, including private sector insurance solutions for governments, businesses, and households.

Climate and disaster risk finance framework

To inform cost-effective, risk-layered strategies for improving financial resilience to climate-related disasters, a suite of disaster risk finance (DRF) analytical tools, ranging from catastrophe risk models to financial risk management tools, can provide key insights (Figure 1).

Financial risk assessment tools

Financial risk assessment tools, including catastrophe risk models, originally developed for use by the (re)insurance industry, can be used to model the damages associated with extreme events, leveraging data on hazard, exposure, vulnerability, and financial policies (e.g., insurance coverage).¹ A key output of catastrophe risk models is a distribution of damage or financial loss estimates. This can be used for multiple applications, including estimates of climate-related contingent liabilities, financial protection gap analysis, and to inform climate risk finance instrument structuring and pricing. The damage estimate outputs from catastrophe risk models can also be used as an input to other models in a “modeling chain”—for example, macroeconomic models used to estimate the broader indirect economic impacts of disasters beyond the direct physical damages captured by catastrophe models.² Catastrophe risk models, which are particularly well suited for understanding tail risks, can be combined with historical loss data for more frequent events. The macroeconomic models can in turn be linked with other models for a range of additional applications, including sovereign credit rating analysis³ (using sovereign credit rating models linking macroeconomic indicators to credit rating changes), debt sustainability analysis (linking macro-model outputs with sovereign debt portfolio analytics), and financial sector impact analysis (using financial sector impact models).

Financial risk management tools

Financial risk management tools, including value-for-money analytics (Box 1), help governments make informed decision of sovereign climate and disaster risk financing strategies, including policies and instruments, that are cost-effective (e.g., represent strong value for money), given their risk profile, objectives (e.g., securing immediate access to funding for rapid response post disasters), and (budgetary and fiscal) constraints. The analytical approach builds on analytics of the risks facing the government and the funding gap (defined as the difference between estimated funding to be mobilized post disaster and available funding with financial instruments already in place) calculated for different disaster scenarios. A suite of analytical tools (based on integrated actuarial, financial, and economic analysis) can help build the government’s understanding of the trade-offs between the use of different risk finance instruments to reduce the funding gap—in line with its objectives and risk tolerance—in the most cost-effective way through a risk layered strategy (Box 2). Outputs from these modeling tools are metrics of the cost-effectiveness of different DRF strategy options. The analytical approach builds upon the framework for ex-ante evaluation of sovereign DRF instruments described

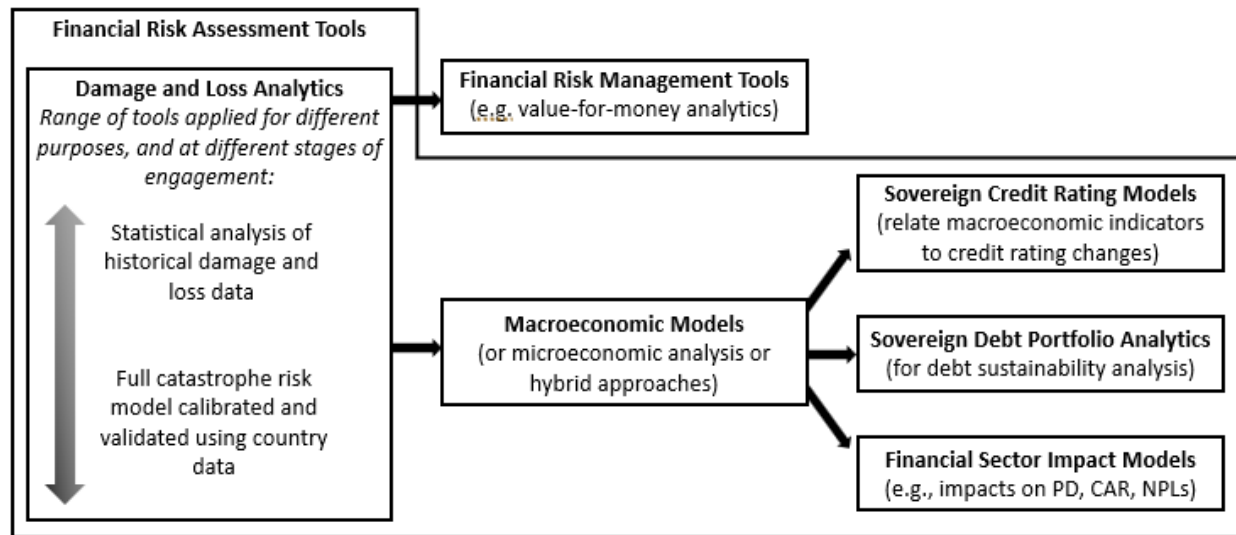
1 The “bottom-up” modeling approach used in catastrophe risk models is based on scientific and engineering knowledge of hazard, exposure, and vulnerability (each of which are explicitly captured in modules of the model). Each module of the model is typically calibrated and validated individually (e.g., based on scientific and engineering data), and the overall model is also calibrated and validated (e.g., based on historical events). This differs from other approaches used to model damages from climate-related physical risks, including economic damage functions based on analysis of empirical data on historical damages (without a detailed consideration of the underlying hazard, exposure, and vulnerability dynamics driving the risk).

2 See, for example, analysis in Morocco (World Bank, 2024a), Philippines (Hallegatte et al., 2022), Mexico (Dolk et al., 2023), Türkiye (Hallegatte et al., 2024).

3 See, for example, Bernhofen et al. (2024).

by Ghesquiere and Mahul (2010) and World Bank (2019). Quantitative analysis is complemented with broader considerations, including basis risk (the risk that the index measurement used for parametric risk transfer instruments will not match actual damages and losses) and quality of products, and additional benefits (e.g., risk signaling or incentives and links with risk management), as well as political economy and practical considerations.

Figure 1: Examples of climate and disaster risk finance analytics tools, embedded in a “modeling chain” framework



Source: Authors

Catastrophe risk models

While catastrophe risk models can provide quantitative insight into potential losses from small to extreme events, they are subject to substantial uncertainties and are highly dependent on input data quality and availability. A key strength of catastrophe risk models is that they can represent extreme, relatively infrequent events that may not be well represented in historical disaster records. Further, there is potential to incorporate future climate-projections data when developing the hazard module of these models, enabling the use of climate-conditioned catastrophe models to understand potential future climate-related disaster risks. Similarly, data on risk reduction measures can also be incorporated, enabling a comparison of risk profiles under different climate adaptation investment scenarios. However, these various model components and adjustments depend on key assumptions, and model results are subject to substantial uncertainties (e.g., due to uncertainties in climate modeling, uncertainties in underlying hazard, exposure and vulnerability data, and challenges of modeling specific adaptation investments, including nature-based solutions). The availability of catastrophe risk models varies across regions and perils (with commercial model providers typically focused on regions with large insurance markets). Where existing models are unavailable or not suitable, it may be necessary to invest in the development of a new model, which can require substantial resource commitments. A sequential approach, leveraging existing global and local datasets to provide initial risk estimates prior to investing in the development of a full catastrophe risk model, may be appropriate in such contexts. It may also be necessary to invest in the development exposure databases used as inputs to the models, depending on the model use cases (e.g., public assets databases to inform decisions about financial protection of public assets).

Financial risk management tools

Financial risk management tools can provide a robust quantitative framework for analytical evidence to inform policymakers’ financial decisions, but there is nonetheless a need to first set policy objectives. This approach enables the evaluation and comparison of climate risk finance strategies, enabling users to directly compare the cost of financing of defined contingent liabilities using

alternative risk finance strategies to meet the Government objectives. However, it cannot provide answers to some key policy questions that ultimately also contribute to financial decisions (e.g., what contingent liability a government “should” take on and how they “should” prioritize post-disaster spending—e.g., through payments to households and/or small and medium-sized enterprises (SMEs) or restoration of critical infrastructure). The answers to such questions are influenced by policy priorities and risk appetite considerations. There are also several methodological limitations (e.g., the assumption of linearity of instrument costs),⁴ necessitating expert judgement when interpreting results. The analysis is also dependent on the validity of the modeled loss risk profile used as input. Many assumptions are made as part of the analysis; hence, a sensitivity analysis of assumptions can be useful to understand the key drivers of uncertainty in the results.

Informing climate and disaster risk finance solutions

The climate and disaster risk finance framework

The climate and disaster risk finance framework, and its associated analytical tools, are critical for informing MoFs’ climate risk finance decisions relating to the budget, fiscal and debt risk management, and public financial management. While climate risk finance cuts across different government agendas, MoFs play an essential role, and successful climate risk finance actions are almost always led by the MoF. Numerous countries have established fiscal risk management divisions within their MoF, tasked with the identification, quantification, disclosure, and management of fiscal risks associated with disasters. Other units within the MoF (for example, budget management, asset and liability management, debt management, economic policy units, and sometimes insurance divisions or supervisors) are also increasingly engaged on the agenda. Catastrophe risk models support the quantification of government contingent liabilities associated with disasters. Financial response design tools can be used to design financial policies that manage these contingent liabilities, as part of comprehensive approaches to fiscal and debt risk management. As outlined above, catastrophe risk model outputs (e.g., damages expressed as capital stock destruction) can also be used as inputs to macroeconomic models that can provide estimates of disaster impacts on a range of macroeconomic variables of interest to MoFs (e.g., GDP and unemployment).

Evidence-based policy

Collectively, the above tools can provide evidence for policy questions relating to the development of a cost-effective climate and disaster risk finance strategy, and the design, structuring, and implementation of the mix of financial instruments included in the risk-layered strategy. How MoFs can access and make use of catastrophe risk models depends on the availability and ownership of existing models, as well as resources and capacity. Although catastrophe risk modeling has been undertaken in the academic, public, and private spheres, the private sector has driven this discipline forward. Many catastrophe risk models are proprietary, necessitating engagement with the private sector (e.g., catastrophe risk modeling firms)⁵ to access them. Depending on the use case, resources, and capacity, in the first instance, it may be most efficient to engage a modeling firm to run the model(s) (if available for the country and perils of interest) and provide outputs. However, some Governments have also invested in the development of internal risk modeling capacity and the development of public catastrophe risk models. This approach requires substantial investment, and collaboration across agencies is important (e.g., with disaster risk management agencies). Increasingly, there are also efforts involving academic, public, and private stakeholders to develop openly available models and standard open data formats. There are also several publicly available risk assessment tools, including risk profiles from some openly available models (e.g., the Global

⁴ Further methodological limitations are outlined by Ghesquiere and Mahul (2010), Clarke et al (2016) and in the DRFIP Financial Response Design Tool User Guide.

⁵ Examples include Moody’s RMS, Verisk, CoreLogic, KatRisk, Risk Frontiers, JBA, ERN, Fathom, Temblor, Reask, Ambiental, and GEM. The availability and quality of models from these vendors varies between perils and countries. Initiatives such as Oasis Hub provide a platform for access a range of models and catalogue model availability by peril, country, vendor, and license type.

Earthquake Model and CLIMADA), as well as tools for statistical analysis of historical loss data (e.g., the World Bank's [DRFIP Financial Risk Assessment Tool](#)).

The Disaster Risk Financing and Insurance (DRFI) Program Financial Response Design Tool

The World Bank's [DRFIP Financial Response Design Tool](#) can be used by MoFs for educational purposes. The tool is publicly available online, and can be used by MoFs to familiarize themselves with the analytical approach. However, MoFs are encouraged to solicit guidance from experts, including from the World Bank, on the use of financial response design tools, such as the DRFIP tool, for informing financial and policy decisions, to ensure that appropriate input assumption setting are used, to make a fully informed use of the tool's outputs, and, if necessary, to develop a more tailored analysis to address the specific financial or policy questions the MoF is seeking to answer.

Developing and applying catastrophe risk models and financial risk management tools

A key lesson, building on the implementation of the framework in more than 50 countries, is to ensure sufficient expertise is engaged when developing and applying catastrophe risk models and financial risk management tools. The development of these models and tools requires careful considerations about key assumptions, data, and calibration and validation. Their application for financial and policy decision-making requires adequate knowledge of the analytical methodologies, including key limitations and uncertainties. Required expertise may span multiple disciplines, including physical sciences, engineering, financial economics, and actuarial skillsets, which may not always exist within MoF teams. To ensure that model development, application, and interpretation are robust, MoFs may need to engage external experts. Given data and model availability may be limited in some countries, a sequenced approach may be useful, considering the multiple entry points to develop financial risk assessment analytics. For example, as an initial step, MoFs can leverage historical disaster risk data and globally available risk datasets to understand their disaster risk profile, prior to investing in more sophisticated catastrophe risk models at a later stage if deemed necessary.

Moving forward

Model updates

Ongoing investment is needed to update the models to leverage new scientific developments and to improve the data used in the models and tools, to ensure the risk view used for decision-making is robust. For improvements to the hazard module of catastrophe risk models, engagement with academia and risk modeling firms is critical to ensure the latest scientific advancements (e.g., improvements to hazard data granularity and representations of climate scenarios, and refinements to model assumptions) are incorporated. Similarly, ongoing engagement with disaster risk specialists and engineers is needed to further refine the vulnerability module of these models, which is associated with some of the largest uncertainties in the overall model. The collection of additional local data for model calibration and validation (e.g., data from post-disaster needs and damage assessments) can enable vulnerability assumptions to be refined to better represent local vulnerabilities and to reduce the common reliance on vulnerability assumptions based on data from other countries. Another critical area for improvement is the exposure data used as model inputs. Governments can invest in improving exposure datasets, for example, through the development and maintenance of public assets databases, in the case of modeling the risk to public assets, or of data on the populations or assets to be covered by public and/or private risk transfer schemes.

Model scope

These models and tools could be further enhanced by expanding their scope and linking them to other models to enable them to be used for a wider range of applications. For example, financial risk management tools, including value-for-money analytics, can be expanded to cover a broader scope of risk finance instruments (e.g., more recently developed instruments such as climate resilient debt clauses). Efforts are ongoing to improve catastrophe risk models to better represent potential climate adaptation measures, and to extend their ability to inform analysis of the indirect impacts of disasters

(e.g., via critical infrastructure and supply-chain disruptions). Catastrophe risk models are increasingly being applied as part of “modeling chains” connecting their outputs to macroeconomic models, which in turn connect to financial sector impact models or sovereign credit rating models. A similar “modeling chain” approach could be used for debt sustainability analysis, using the outputs from the models to analyze debt impacts using sovereign debt portfolio analysis. Further improvements can also be made regarding the linkages between the models, for example, with respect to how information on the geographic distribution of impacts modeled by spatially explicit catastrophe models can be better retained in macroeconomic and macrofinancial models, which presently typically only capture aggregate national level dynamics.

Climate and disaster risk finance analytics in action

Catastrophe models and financial response design tools have been used to inform DRF strategies and the design, structuring, and placement of DRF instruments in several countries.

- Over the past decade, Morocco has developed and applied catastrophe risk models for climate and disaster risk finance. In 2012, the country developed a catastrophe risk model, the Morocco Natural Hazards Probabilistic Risk Assessment (MnhPRA), which allows for the estimation of the economic impact of disasters (earthquakes, floods, tsunamis, droughts, and landslides) to inform, for example, the financial strategy of the solidarity fund Fonds de Solidarité contre les Événements Catastrophique (FSEC). Since 2021, the FSEC has been conducting additional disaster risk modeling efforts to estimate the financial costs of earthquakes, flooding, and landslides. These models have been used to inform the development of Morocco’s risk finance strategy and the structuring of financial instruments, including earthquake insurance.
- Mozambique has invested in the development of catastrophe risk modeling, which has been used by the MoF for the development of sovereign risk transfer products for tropical cyclones in alignment with their climate and disaster risk finance strategy.
- To inform its approach to financing protection of micro, small and medium enterprises (MSME) against droughts, Lesotho conducted a value-for-money analysis. The analysis found that a risk-layering strategy combining a reserve fund, limited budget reallocations, contingent credit, and insurance is the most cost-effective way to effectively protect MSMEs.
- An analysis of the cost efficiency of different CDRF instruments was used to inform the Government of Malawi’s financing plan for adaptive social protection against climate shocks. The analysis considered the likelihood of future drought events of various severities. Based on the results of the analysis, the Government decided to use a contingency fund to cover cash transfers to affected households during less severe droughts and a risk transfer instrument to cover the cost of larger scale-ups for more severe events.
- The development of a catastrophe risk model for the Philippines by its DoF with World Bank support, was used to inform the development of the disaster risk finance and insurance strategy adopted by the government in 2015, which informed the placement of a regional parametric insurance program in 2017–18 and a catastrophe bond in 2019. Since then, the government has continued to invest in the development of risk data and analytics. For example, the Government has established the National Asset Registry System (NARS), which stores more than 350,000 asset records worth almost US\$35 billion and has the analytical capabilities to inform its disaster risk finance and asset management efforts.
- Risk assessment tools, including tropical cyclone and flood models developed by, or to support, sovereign catastrophe risk pools (e.g., CCRIF, PCRIC, ARC, SEADRIF) have been used to inform the structuring and pricing of sovereign risk transfer instruments purchased by their member countries. For example, under the Pacific Catastrophe Risk Assessment and Financing Initiative (PCRAFI), a regional repository of hazard and national exposure data was established, laying the foundation for analytics to inform catastrophe risk insurance in the

region, as well as broader disaster risk management investments. This risk information has continued to be updated and further developed, with ongoing investments in risk model and exposure data updates.

Conclusion

A suite of analytical tools can be used to support the development and implementation of cost-effective climate and disaster risk finance strategies of vulnerable countries to improve their financial resilience. These models and tools continue to be developed, updated, and integrated with additional analytical models and approaches, enabling an increasingly broad range of applications. The extent to which MoFs have invested in the development and application of these models and tools varies, in part in relation to the stage of maturation of their climate and disaster risk finance agenda. Several countries have applied these tools in the initial stages of a climate and disaster risk finance diagnostic, and in the formulation of a disaster risk finance strategy.⁶ As the agenda on this topic has developed and matured, some MoFs have invested in the development of more bespoke models and tools to inform specific policy questions and programs (e.g., public assets insurance, sovereign risk transfer programs, etc.). The analysis produced using these approaches may be regularly updated (e.g., analysis of the protection gap and value for money of risk financing instruments may be updated based on changes in risk profile and changes in economic and (re)insurance market conditions). As such, models, tools, and analytical approaches continue to develop, with the current landscape continuously evolving.

Box 1. Value for money analysis

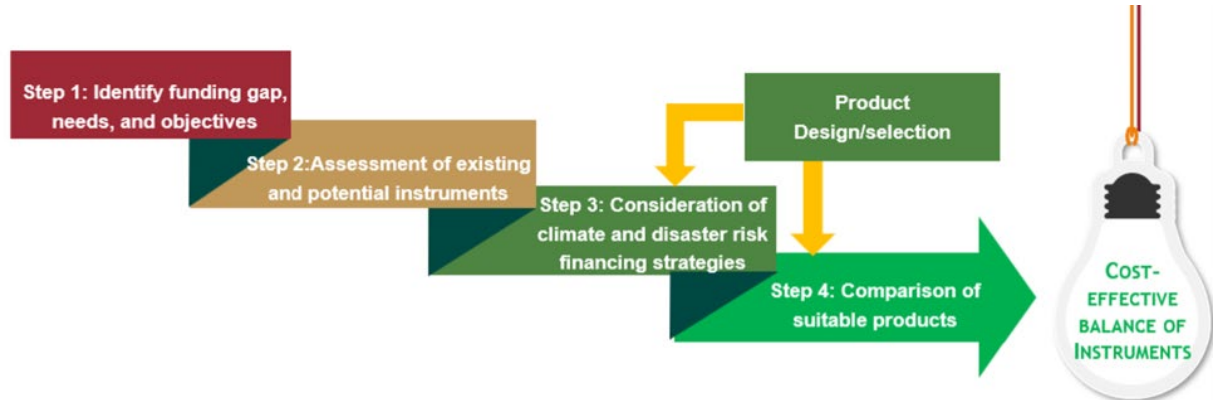
The World Bank's Climate and Disaster Risk Finance (CDRF) Value for Money process provides a sound and transparent methodology and a set of analytical tools to help governments develop their CDRF strategy. The World Bank's CDRF engagement with country clients starts with a [CDRF diagnostic](#), a World Bank core diagnostic product that provides evidence on disaster risk exposure, economic and financial cost implications, and funding needs. Governments use this diagnostic to inform their CDRF strategy and associated operational implementation plan, based on their policy priorities. The Value for Money process is a cornerstone of this process, supporting governments to make effective decisions on the selection and mix of risk financing instruments to finance their strategy.

The process captures and communicates the value of projects and investments in risk financing, such as through World Bank operations. Typical project economic analyses are not appropriate for risk financing, given they consider a deterministic, expected outcome, whereas the full value of risk finance investments is realized after infrequent events. A probabilistic approach is needed that considers the range of disasters scenarios which could occur.

The World Bank's Value for Money process is based on objective-setting, quantitative and qualitative analysis, and frequent stakeholder engagement. It relies on strong analytics—including actuarial science, economics, and catastrophe risk modeling. It builds on many years of experience of its application, blending technical analysis and political economy, via the following key steps (Figure 2).

⁶ See the Financial Protection Forum website (<https://www.financialprotectionforum.org/publications>) for published examples of climate and disaster risk finance diagnostics and strategies.

Figure 2: World Bank's Value for Money process



Source: Authors

Step 1. Identify and analyze the risks faced by the country and the associated financial needs for a given set of objectives, informed by a combination of in-country expertise and data, actuarial analysis, and catastrophe risk modeling. Estimate the funding gaps by comparing the funding needs and the CDRF finance instruments currently used by the country, for simulated possible disaster risk scenarios.

Step 2. Based on diagnostics and stakeholder consultation, consider the range of possible financial instruments alongside existing instruments to reduce funding gaps in line with government objectives and available budgets and possible sources of external support, including grants from donor partners.

Step 3. Conduct economic and actuarial analysis to assess the relative value and costs of alternative blends of possible instruments. Complement with sensitivity testing to assess how the results vary with factors such as market conditions and disaster experience.

Step 4. Complement the analysis with assessment of other considerations such as product quality (e.g., basis risk) and nonquantifiable benefits of certain instruments (e.g., behavioral incentives).

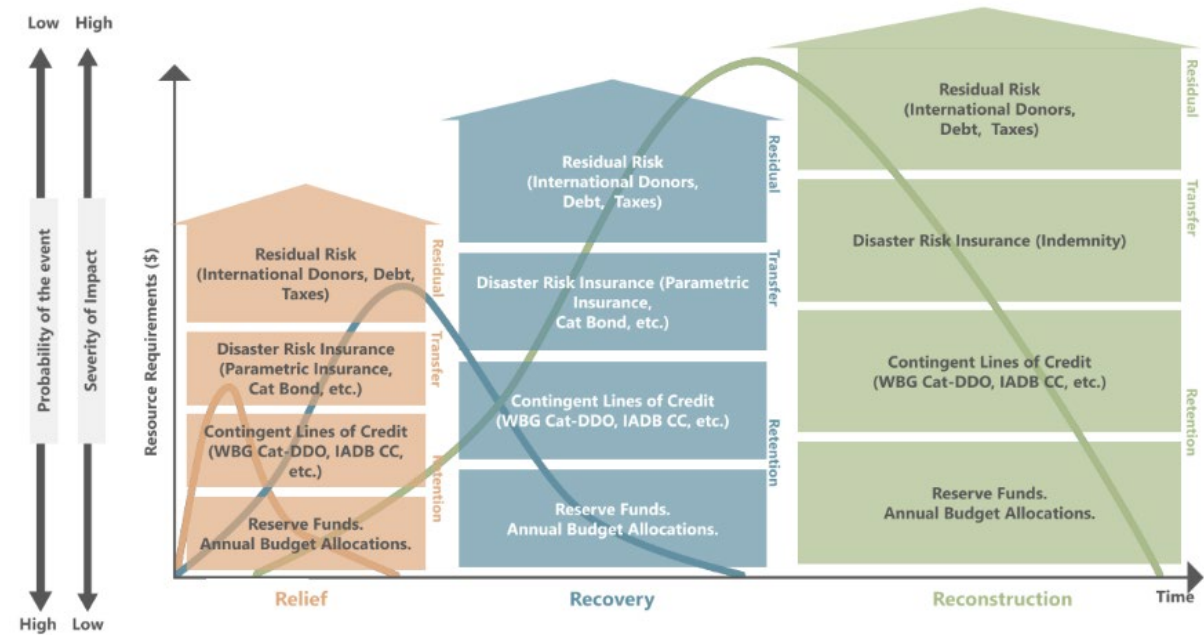
Box 2. Risk layering climate and disaster risk finance strategy

Climate and disaster risk finance tools can help manage the Government's financial needs for emergency responses following climate and other shocks. As the frequency and severity of climate-related shocks increase, countries require better tools for managing climate risks. Such instruments should be optimally combined within a risk-layered approach (Figure 3), aiming to secure an adequate amount of liquidity based on the severity and the frequency of disasters at the lowest possible cost.

A range of DRF instruments may be considered:

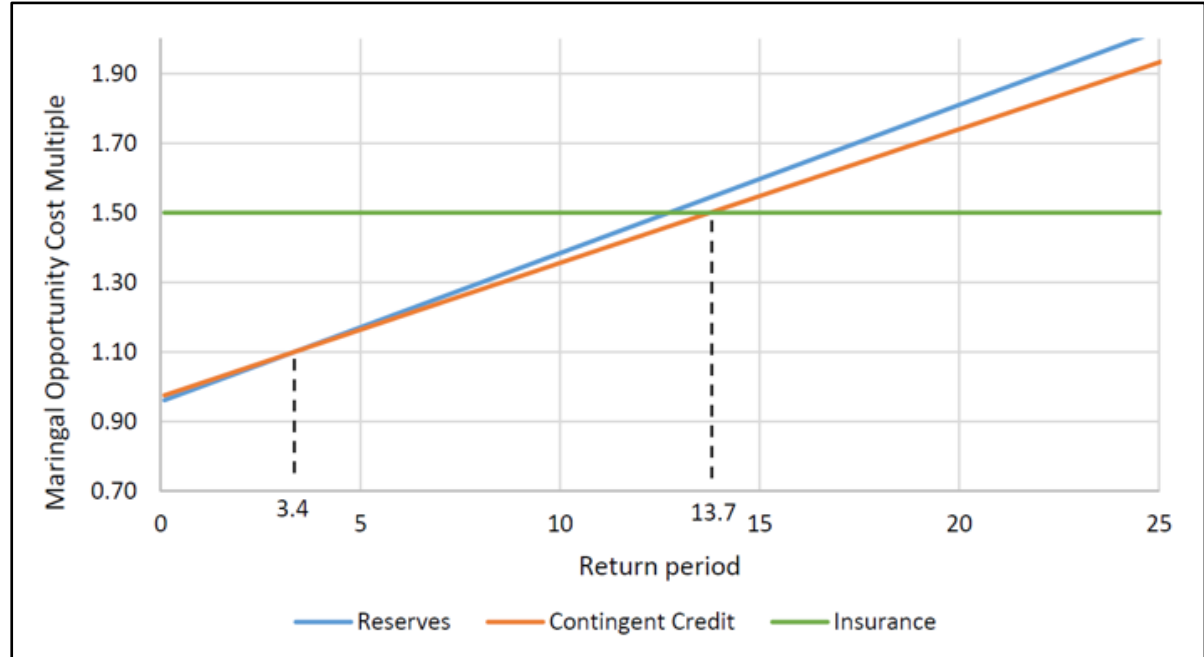
- **Contingency reserves** are a budgetary instrument that puts aside resources intended to finance unforeseen expenditures.
- **A contingent credit line** is an ex-ante instrument designed to provide budget support that can be accessed quickly during and after an eligible event.
- **A climate resilient debt clause (CRDC)** is embedded in loan or bond agreements to enable a borrowing country to pause its debt service in the event of a significant natural disaster.
- **Sovereign risk transfer instruments**, such as insurance or catastrophe bonds, allow governments to transfer some of their excess risk to the market, sometimes through catastrophe risk pools.

Figure 3: Risk-layered approach for climate and disaster risk finance



Source: Authors, based on Ghesquiere and Mahul (2010)

Figure 4: Optimization of financial instruments—illustrative example



Source: Clarke et al. (2017)

The optimal mix of climate risk finance instruments relies on a detailed assessment of the short-term financing gap and the respective costs of the financial instruments. Government should first determine the amount of liquidity needed following a climate shock (which depends on the nature, severity, and frequency of such shocks). Catastrophe risk models can be used to estimate the emergency losses caused by disasters, and hence the amount of liquidity to prearrange. Government should then combine different financial instruments to ensure that cheaper sources of

money are used first, with the most expensive instruments used only in exceptional circumstances. The optimum mix of instruments depends on the risk profile, the urgency of funding needs, and the characteristics of instruments available. Financial response design tools, including value-for-money analytics, can help to identify a cost-effective mix of instruments. Figure 1.2 shows the marginal opportunity cost multiple (MOCM)⁷ of each instrument; the instruments are layered by comparing their respective MOCMs and selecting the lowest one. In this illustrative example, the most cost-effective strategy involving the three instruments shown is to use:

- Prefinanced reserve fund to finance losses up to the 3.4-year return period (RP)⁸
- Contingent credit to finance losses from the 3.4-year RP up to the 13.7-year RP
- Insurance to finance more extreme disasters in excess of the 13.7-year RP.

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7 The MOCM presents the marginal opportunity cost of each financing instrument as a multiple of the estimated average loss in each corresponding layer of risk. The opportunity costs are taken to be the economic cost of using each financing instrument to fund the specific disaster expenditures. The MOCM thus enables different financing strategies to be compared, to determine which is the most cost effective.

8 The RP is the average time between event losses. For example, a three-year RP for a given loss L means that losses exceed L on average every three years.