

Rezai, Armon; Ruch, Franz; Choudhary, Rishabh; Francois, John Nana Darko

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Fiscal Policy's Role in Economic Resilience to Climate Shocks

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Poschingerstr. 5, 81679 Munich, Germany

Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de

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Abstract

The impacts of climate change on developing economies are becoming increasingly severe, creating challenges for risk management and requiring enhanced levels of resilience. This paper explores how to mitigate the effects of such climate shocks on developing economies, placing a particular focus on the role fiscal policy in creating and strengthening an economy's resilience. Using data on natural disasters, the analysis shows that economies with constrained fiscal space experience more pronounced negative effects. In an application to a small open economy, the paper tests the presence of the non-linearity of short- and long-run disaster impacts in the World Bank's macroeconomic and fiscal model and illustrates the importance of fiscal policy in mitigating shocks.

JEL-Codes: H200, H120, O440, O470, Q540.

Keywords: fiscal policy, economic resilience, climate, natural disasters.

*Armon Rezai**

*Vienna University of Economics and Business
Vienna / Austria
arezai@wu.ac.at*

Franz Ruch

*Fiscal Policy and Sustainable Growth
World Bank, Washington DC / USA
fruch@worldbank.org*

Rishabh Choudhary

*Fiscal Policy and sustainable Growth
World Bank, Washington DC / USA
rchoudhary@worldbank.org*

John Nana Darko Francois

*Fiscal Policy and Sustainable Growth
World Bank, Washington DC / USA
jfrancois1@worldbank.org*

*corresponding author

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1. Introduction

Climate change and its impacts are becoming increasingly severe and communities in developing economies are disproportionately affected. Despite the significant impacts of climate change-related disasters, policies designed to mitigate them are still underrepresented in the macroeconomic analysis of governments and the international institutions advising them (Hochrainer-Stigler 2021, World Bank 2013). This is particularly true of climate disasters' implications for government finances and the macroeconomy more generally. Current fiscal policy tools often treat climate damages as unlikely, and do not prioritize mitigation and adaptation responses, which results in inclusion of negligible or no fiscal or macroeconomic impact including on economic growth, the external balance, or debt sustainability.

The intensification of climate-related disaster risks creates a more challenging environment for successful risk management. With ongoing climate change, the risk of impacts surpassing a tipping point such as the economy's coping capacity—"threshold risks"—is increasing (Reichstein, Riede, and Frank 2021). There is also potential that climate-related disasters are reinforced by other economic risks ("risk compounding" or "cascading risk"). This systemic aspect of natural disasters requires that the impacts of climate change be considered when forecasting economic developments and designing fiscal policies (Hochrainer-Stigler et al. 2023). Most models employed to advise policy makers lack adequate representation of climate risks, their interaction with countries' economic growth and fiscal sustainability, the fiscal policy response to mitigate these risks, and how they interact with other economic risks faced by developing countries (Reichstein, Riede, and Frank 2021). In this paper, we look at how economic resilience can be enhanced to mitigate the effects of such climate shocks through fiscal policy. We focus on the developing-economy context while taking account of threshold and cascading climate risks.

Economic resilience is a function of an economy's exposure, vulnerability, and absorptive capacity to climate shocks (IPCC 2023) and fiscal policy plays an important role in withstanding and recovering from these shocks. We begin by discussing these in the context of threshold risks and risk compounding associated with natural disasters and climate impacts. Threshold risks are where small changes around a threshold (or tipping point) lead to significant and potentially difficult to reverse shifts in economic dynamics. Compounding risks are where multiple risks interact and amplify each other, requiring systemic risk management strategies, including fiscal policies, to mitigate the impact of natural disasters and environmental risks on economies. Such risk management is particularly relevant for developing economies that have limited coping capabilities and are more vulnerable to shocks. Fiscal policy can mobilize the funds necessary for post-disaster

response efforts and a rapid recovery (that is, the countercyclical role of fiscal policy for economic resilience), but fiscal policy is also crucial in pre-disaster planning, as it can incentivize investments in long-term resilience, transfer risks, and provide the fiscal space for debt-financed crisis response.

Next, we highlight the link between climate risks and fiscal policy empirically, aiming to quantify the impact of climate shocks on output given existing fiscal policies. Using data from the EM-DAT database for the number of people killed or affected by natural disasters, our analysis indicates that economies with constrained fiscal space, proxied by high government debt, procyclical policies, and running persistent deficits, experience more pronounced negative effects from natural disasters, indicating a reduced ability to respond effectively.

We then use the World Bank's macro-fiscal model (MFMod) to study the effects of natural disasters on economic resilience and fiscal resilience. MFMod is one of the World Bank's main forecasting tools and provides the basis for tailored country analysis. Its primary purpose is to generate country-specific forecasts of the main macroeconomic and fiscal variables and to assess the potential effects of policy changes. Importantly, the MFMod framework permits the evaluation of policy (and climate-related disaster) impacts alongside traditional economic indicators like economic growth, fiscal sustainability, price inflation, and stability of the external account. Hallegatte, Jooste, and McIsaac (2024) use MFMod to study macroeconomic consequence of natural disasters with a focus on monetary policy. Harnessing the detailed representation of the national accounts in MFMod, we focus on the fiscal aspects of natural disasters. Thus, we are combining macroeconomic modeling with the “financing gap” analysis of disaster research (Mechler et al. 2006).

We model the impact of a climate shock on a small open economy with strong reliance on tourism and vulnerability to climate events. We simulate the effect of a 5 and 10 percent destruction shock to the country's existing capital stock, emulating the effects of a natural disaster. We explore several ways of funding reconstruction efforts (debt-financing, redirection of existing current and capital expenditure, or increases in revenue) and we test for the presence of threshold effects by doubling the size of the disaster shock. This leads to more adverse GDP effects within five years and persistently disproportionately higher effects in the long run. The effects vary across modes of funding reconstruction efforts. In the absence of reconstruction efforts, we find a doubling in GDP loss throughout the simulation period. Hence, the presence of threshold effects is due to the government's (in)ability to absorb the larger climate shock. To test for risk compounding, we repeat this exercise in the presence of other macroeconomic shocks and find no evidence that this creates a different response of the economy to the climate shock.

The paper proceeds as follows. In section 2 we describe threshold risks and risk compounding and how they relate to economic resilience. We also provide a perspective on the role of fiscal policy for mitigating impacts on the economy. In section 3, we show the empirical link between climate shocks and economic resilience in the context of existing fiscal policy outcomes. In section 4, we study threshold and cascading effects in MFMod and provide scenarios for how these effects impact economic resilience. Finally, section 5 provides a discussion of the policy implications of threshold risks and risk compounding and some concluding remarks.

2. Threshold and compound risks, economic resilience, and fiscal policy: A framework

Frequency, intensity, and duration of natural disasters are projected to increase because of climate change (IPCC 2023). Economies need to develop capacities and implement policies to successfully cope and adapt to these risks such that they can withstand climate-induced and economic shocks, mitigate the impact on lives and livelihoods, and swiftly recover output to its full potential. Risks are the result of natural hazards, but also of the economy's exposure and vulnerability to such hazards (IPCC SREX 2012). The Sendai Framework for Disaster Risk Reduction defines a disaster as a “serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts” (UNDRR 2016).

Robust risk management policies reduce impacts of environmental hazards while maintaining effective management of other economic risks. A country's adequate level of adaptive and coping capacity depends on specific risk profiles but also the interaction across risks and trade-offs in their management. We focus on two aspects of risks to the economy emanating from natural disasters: threshold and compound risks.

Threshold risks describe probabilities of crossing a particular threshold or triggering tipping events. A tipping event is a situation in which a relatively small change in external conditions at a critical threshold, or point, can lead to a significant and often irreversible shift in the state of a system. Tipping events are associated with non-linear dynamics, where the response of the system becomes disproportionately amplified beyond a certain threshold. Threshold risks, therefore, refer to situations in which the effect of the same type of shock differs in their magnitude depending on the state of the system. A small change or shock to the system leads to a disproportionately large and potentially irreversible shift in economic dynamics, depending on how close the system is to a threshold (or tipping) point. These points can manifest in various economic contexts, signaling

abrupt changes in market behavior, investor sentiment, or overall economic stability. Economic examples of tipping risks are bubbles in financial markets, where asset prices can drop suddenly and substantially due to minor shocks (for example, a change in investor confidence or external economic conditions) after having experienced rapid and unsustainable growth previously (Kindleberger 1978; Blanchard 1979). Similarly, debt dynamics are subject to threshold points, where servicing that debt becomes increasingly challenging. Economies with high levels of debt are prone to reach such a tipping point: a small economic shock or an increase in interest rates can trigger a debt crisis, in which debt becomes unserviceable, leading to fiscal distress and potential default (Minsky 1986; Adrien and Shin 2010). Passing a tipping point often leads to persistent alterations in the state or behavior of a system, with self-reinforcing feedback mechanisms driving and stabilizing the new state.

Risk compounding occurs when several risks interact or amplify each other, necessitating more complex risk mitigation policies (UNDRR 2016). Such risks can exacerbate the overall impact of each individual risk and create cascading effects, making it harder to address each risk in isolation. Economic risks, natural disasters, and health crises are typical situations in which compounding risks arise. In triggering feedback loops and risk compounding, the compounding effect strains the resilience of systems and exacerbates the overall risk scenario. Managing compounding risks, therefore, demands a nuanced and comprehensive approach that considers the intricate interplay between different risk factors, especially in the face of global challenges like pandemics and climate change. The cross-sectoral nature of compounding risks requires coordinated and multifaceted responses, emphasizing the importance of enhancing overall resilience and fostering collaboration across various domains to effectively address the complexity of compounded challenges.

Threshold and compound risks are of particular importance for developing economies given their disproportionate vulnerability to shocks and limited ability to cope with the impacts (for example, because of high debt or limited fiscal space). Natural disasters and climate risks are only one source of instability faced by governments in these economies and various economic risks already threaten financial stability, economic growth, and governments' ability to provide essential public services. Challenges for governments include the vulnerability of revenue streams to market fluctuations and a rapid increase of spending, but also administrative risk-absorption capacities. Important sources of risk also emanate from global markets, in the form of shifts in external demand, the availability and costs of debt finance, and currency fluctuations. These economic risks are already subject to threshold effects, cascading dynamics, and self-reinforcing dynamics. For example, substantial previous accumulation of external debt increases financial fragility and worsens the risk

profile of a country, a government's debt financing problem can spill over into currency markets, and foreign exchange dynamics are often self-reinforcing. The outsized importance of commodities and agricultural products in developing economies creates significant linkages between environmental risk (natural disasters and climate change induced changes in weather patterns) and economic risk. Economic activity in the primary sector and the processing of its products often translates into the public finance structure of these economies, interlinking environmental and economic risks and introducing volatility to public revenues and budgetary planning.

Economic resilience is the ability of countries to withstand shocks, including those stemming from climate-related events, and swiftly recover their output to its full potential. Risk is determined by the interplay of hazard, exposure, and vulnerability (IPCC 2023). Hazards are the likelihood of an adverse natural event to occur. While climate change impacts hazards (and their rates), they can be assumed exogenous. Hence, policy efforts can influence economic resilience via three critical elements:

- Exposure to Climate Shocks represents the presence of people or objects (for example, the number of people or value of capital stock) in an area potentially affected by a climate related event (for example, extreme rainfall, wildfires, droughts). Lowering the presence reduces exposure.
- Vulnerability to Climate Shocks refers to implications of a realized hazard for the exposed people or objects. Risk management can reduce the implications of risks (for example, through adaptation measures) and lower vulnerability.
- Resilience to Climate Shocks describes the absorptive capacity and the ability to recover swiftly after a climate-related shock. Sound fiscal management and adequate fiscal buffers boost absorptive capacity.

Risk management is the development and implementation of “plans, actions, strategies or policies to reduce the likelihood and/or magnitude of adverse potential consequences, based on assessed or perceived risks” (IPCC 2023). It involves ex-ante and ex-post measures: while climate change mitigation efforts aim to lessen the impacts of risks by diminishing the hazard itself, climate change adaptation efforts aim to minimize the impacts by lowering both the exposure and the vulnerability to risks. Risk management strategies identify potential risks, quantify their likelihood and potential impacts on the economy, and develop appropriate risk-mitigation strategies. These include risk prevention and adaptation to lower vulnerability to shocks, and fiscal planning and regulatory compliance to increase capacity to rebuild and preparedness for rapid crisis management once a risk materializes (see, for example, Cevik and Huang 2018). Taken together, these measures foster

economic resilience—the capacity to foresee, withstand, and recover from the adverse effects of shocks.

Governments regularly employ policies and regulation to mitigate economic and financial risks. In response to these risks, fiscal management entails contingency planning, strategic diversification of revenue sources, fiscal reserves, and the utilization of other fiscal instruments like fiscal rules to navigate uncertainties. These traditional tools of fiscal policy for addressing economic shocks, such as increasing government spending and reducing taxation to stimulate the economy, are also appropriate for stabilizing an economy in the wake of natural disasters and other adverse environmental shocks. Governments can allocate emergency funds for rapid response efforts and spending on infrastructure projects, social programs, and targeted stimulus packages which can boost income levels and create jobs. Fiscal policy, however, also plays a crucial role in building long-term resilience, beyond addressing natural disaster shocks by providing immediate relief and facilitating recovery. Fiscal policy can incentivize investments in disaster-preparedness infrastructure, which may be underprovided by market participants, that reduces the impact of disasters by underwriting insurance schemes and other risk mitigation instruments to offer financial protection for individuals, businesses, and public infrastructure.

The stabilizing role of fiscal policy is particularly relevant in the context of natural disasters and climate shocks. Fiscal policy can transfer risk from the private sector to the public sector, enabling firms and households to continue spending, and prevents the worst effects of deleveraging, and spends when the private sector is unable or unwilling to. Governments require sufficient fiscal space to fulfill this function of de-risking the private sector while also deploying fiscal policy, in the form of higher public spending and lower taxation, at an adequate scale. Risk management creates and preserves the budgetary room to respond to economic and environmental risks by maintaining fiscal discipline (including through fiscal rules), responsible financial management, and growth-enhancing policies. These include precautionary budget surpluses and low levels of public debt as well as robust economic growth to increase the sustainability of public finances. Governments can choose to transfer the financial risks associated with natural disasters or climate events to international capital markets by re-insuring themselves in international markets using catastrophe (“cat”) bonds. Cat bonds operate as a form of insurance for governments which pay investors regular premia, but if a specified catastrophe occurs, the principal may be used to fund disaster recovery efforts. Instead of bearing the full financial burden of responding to a disaster, the government can access funds from investors who hold the cat bonds. In tapping international capital markets, governments gain access to a diverse pool of investors which can lead to more efficient and competitive financing compared to domestic or regional sources; potentially reducing

the overall cost of securing funds for disaster risk management, improving budgetary planning, and lowering the cost of natural risks for governments. International financial institutions, like the World Bank and International Monetary Fund, provide similar financial assistance for economic and environmental risks. Such financial support is particularly beneficial when a government is faced with large-scale natural disasters that exceed its coping ability.

3. Empirical relationship between climate and fiscal policy

This section estimates the impact of climate shocks on output looking for threshold and compounding effects and studying impacts in the context of existing fiscal policy outcomes. We operationalize climate shocks as natural disasters (such as floods, drought, earthquakes, etc.), which are projected to increase with climate change, and show that there is some evidence of compounding effects but not threshold effects (except where threshold effects are considered an inability of government to respond to the disaster because of limited fiscal space). Climate shocks are also more detrimental in economies with limited fiscal space (proxied by high debt), those that generally implement procyclical policy, and those that on average run primary budget deficits, suggesting an inability to react to these shocks and mitigate their impact. A government's effectiveness does not seem to matter for the impact of climate shocks.

3.1. Methodology

To determine the impact of climate shocks on output, panel local projection models following Auerbach and Gorodnichenko (2012) and Jorda (2005) are estimated. These models identify impulse response functions through consecutive regressions at different horizons (h):

$$y_{i,t+h} - y_{i,t-1} = \alpha_{i,h} + T_t + \Pi_{i,h}(L)x_{i,t} + \beta_{i,h}shock_{i,t} + \mu_{i,t+h} \quad (1)$$

where $\alpha_{i,h}$ are country fixed effects for country i at year h ($=1,2,\dots,6$), T_t are time effects, $x_{i,t}$ are a vector of control variables, $y_{i,t}$ is log real GDP per capita, and $shock_{i,t}$ are climate shocks. The model is estimated to reflect cumulative responses (that is, $y_{i,t+h} - y_{i,t-1}$). The control variables include government debt to GDP, an index measuring vulnerability to climate shocks, government effectiveness, broad money supply growth, and lagged income per capita. Time fixed effects should account for common global shocks like the global financial crisis and the pandemic. Equation 1 is used to establish the baseline impact of climate shocks on the level of output. We are also interested in how output evolves over time (that is, an economy's resilience to climate shocks) given fiscal policy variables. This is implemented using a nonlinear version of equation 1 as follows:

$$y_{i,t+h} - y_{i,t-1} = (1 - F(z_t))[\alpha_{i,h} + T_t + \Pi_{i,h}(L)x_{i,t} + \beta_{i,h}shock_{i,t} + \mu_{i,t+h}] \\ + F(z_t)[\alpha_{i,h} + T_t + \Pi_{i,h}(L)x_{i,t} + \beta_{i,h}shock_{i,t} + \mu_{i,t+h}] \quad (2)$$

where $F(z_t)$ is a dummy variable on various fiscal policy and business cycle variables (z_t) where 1 is defined as an adverse outcome. For example, the impact of climate shocks may differ in economies with high levels of government debt, those in recession, or those that generally implement procyclical policy (government spending tends to rise in good times and fall in bad times).

3.2. Data

We focus on natural disasters (such as floods, drought, earthquakes, etc.) from the EM-DAT database. While natural disasters are only a subset of broader climate shocks and are not always directly related to climate change, they are nonetheless informative on some aspects of the process of climate change as the frequency of many of these natural disasters increase (most clearly droughts and extreme temperature).

Floods stand out as one of the most recurrent natural calamities worldwide. In recent years, the incidence of such disasters has surged. Among the regions most impacted, East Asia and Pacific (EAP) bears the brunt, closely trailed by Sub-Saharan Africa. However, it is not solely the frequency that alarms but also the severity. The proportion of the population affected annually has notably escalated, averaging around 3 percent (Figure 1.A). Particularly concerning is the EAP region, where an average of about 6 percent of the population faces the consequences of natural disasters each year (Figure 1.B.).

EM-DAT compiles data on total persons affected, total deaths, and total economic damages of natural disasters from various sources, including UN agencies, non-governmental organizations, reinsurance companies, research institutes, and press agencies. It records human and economic losses at the country level for disasters meeting at least one of the following criteria: 10 fatalities, 100 affected people, a declaration of a state of emergency, or a call for international assistance. In reviewing event-specific data, we note a decreasing prevalence of missing values (as a fraction of events reported) over time. Missing observations for total affected/deaths hover around 25 percent, while missing observations for damages range from 50 to 75 percent. Consequently, we opt to concentrate solely on population affected and deaths in our intensity measure. Acknowledging that data availability has expanded since 2000, thanks to technological advancements allowing wider

coverage and improved reporting (as noted by EM-DAT), we focus our analysis on data from 2000 onwards.

We define an intensity shock, measuring the number of people affected by natural disasters using data from EM-DAT following Fomby, Ikeda, and Loayza (2013), as:

$$Intensity_{i,t} = \frac{Total\ deaths_{i,t} + 0.3 * Total\ affected_{i,t}}{Population_{i,t}}$$

where I is the country and t is years.² Unlike in Fomby, Ikeda, and Loayza (2013), and more recently Bayoumi, Quayyum, and Das (2021), we use the actual intensity measure as the climate shock rather than a dummy variable based on some threshold value. Table 1 provides the name, description, and source of the other variables used in this section. Loayza et al. (2012) show that the type of disaster may matter for its impact on the economy, however, we study all disasters.

We assume that any unreported event is considered to be a non-occurrence, and hence assigned an intensity value of zero. This decision is supported by several factors. First, the improved data coverage by EM-DAT from 2000 onwards significantly reduces the likelihood of major events going unreported. Also, within our sample we notice an association between missing damage values and lower climate shock intensities, suggesting that unreported events are likely to be smaller in scale. Second, we underscore the importance of establishing a counterfactual scenario without any shocks. Solely analyzing climate event datasets might not provide a complete picture of counterfactual fiscal resilience impacts. Therefore, treating all periods outside of reported events as zero allows us to approximate a counterfactual scenario devoid of shocks.

3.3. Results

Natural disaster shocks are associated with a statistically significant decline in output, with no empirical evidence supporting threshold effects related to the size of the shock and some evidence of compounding effects. Figure 2.A shows the impact of all available climate shocks and large climate shocks that affect 1 percent of the population. It is based on close to 3,000 natural disasters from 2000 to 2021 in 156 economies. These shocks are associated with a loss of output that is statistically significant up to eight years after the disaster. There is no evidence of threshold effects as the impacts are similar when these shocks are large, that is, they are in the 95th percentile of the

² It is also possible to define a damages shock which looks at the economic cost of a natural disaster. We prefer an intensity shock, however, for several reasons. First, there are less than half as many damages observations as observations on people affected by natural disasters. Second, damages are likely based on insured damages. Third, estimates of economic cost are harder to determine and more subjective.

distribution. Moreover, when climate shocks occur when an economy is already facing a negative output gap, there is evidence that the initial impact of that climate shock is larger, which suggests that risk compounding may be present (figure 2.B).

Next, we estimate the models wherein we distinguish between fiscal characteristics of countries. There is some evidence that the state of fiscal policy matters for the ability of countries to minimize the impact of climate shocks. First, countries with higher debt levels tend to experience larger output losses in years following natural disasters. Countries with government debt above 50 percent of GDP (close to the median in this sample) have statistically significant losses in the level of output of 0.4 percentage point relative to negligible and not significant impacts for those below this threshold (figure 2.C). Economies with lower debt also do not experience multi-year declines, suggesting an ability to respond to the disasters and return GDP back to previous levels. Second, economies that ran procyclical fiscal policy on average over the last four decades (measured as the correlation between the cyclical component of real GDP and government expenditure using an HP-filter) tended to experience multi-year losses from climate shocks, peaking at 0.2 percentage point after four years (figure 2.D). By comparison, economies that tended to implement countercyclical policy on average saw no losses in the level of output. Third, economies that on average ran a primary deficit over the past four decades saw statistically significant and persistent losses to the level of output compared to those that ran primary surpluses (figure 2.E). Finally, more effective governments did no better in limiting losses from natural disasters (figure 2.F).

The findings are similar when only EMDEs are included. Also, the results are similar if the intensity shock is defined only by those affected instead of also deaths.

4. Threshold and cascading effects in a macroeconomic model: An application

In this section we illustrate the relevance of threshold and compound effects from climate risks in the context of the World Bank's macroeconomic model, and their implications for fiscal policy in an application to a stylized small open economy.

We envision a medium-sized island nation with significant climate vulnerability including exposure to extreme weather events. Many such economies face temperatures and precipitation patterns which make it susceptible to increased cyclones, floods, heatwaves, and droughts because of climate change. Populated coastal areas are often at risk for sea-level rise and erosion that pose threats to human settlements and ecosystems. Agriculture sectors, which still employ large portions of the labor force, and therefore are crucial for livelihoods, are often not technologically advanced and prone to changes in temperature and precipitation patterns which in turn create risks for food

security. In many island nations, climate change also poses threats to water supply and overall socio-economic stability and health risks, which may arise as climate change influences the spread of diseases. Many island economies feature large tourism sectors, and services' contribution to GDP, therefore, disproportionately affects the economy's development.

4.1. Natural disaster shock scenarios

We devise natural disaster shocks to explore the potential effects of climate risks on such a model economy. In particular, we are interested to know:

- how the severity of climate risks in the form of a natural disaster can have non-linear impacts on macroeconomic performance,
- how the presence of other economic risks (for example, shocks to trading partners, internal business cycle fluctuations, or shocks in currency markets) compounds the risks posed by climate change, and
- how fiscal policy can ameliorate the impacts of climate shocks and threshold and compound risks, in particular.

To do so, we adapt one of the World Bank's macroeconomic models. MFMod is a structural econometric model that captures the macroeconomic income and product accounts and is capable of representing an economy's flow of funds across sectors and for major income types (Burns et al. 2019). Similarly, the economy's interactions with its trading partners and specific sectors (for example, the labor market or the energy sector) are modeled in detail. MFMod's long-run behavioral relationships are derived from economic theory, while short-run adjustment to these long-run relationships is estimated empirically from economic data.³ MFMod permits the forecasting of its main economic variables (like economic growth, consumer inflation, and balance of the current account) and policy implications (for example, debt sustainability). We also draw on the World Bank's Climate Change and Development Reports (CCDR) framework. CCDRs introduce climate change via changes in hazard rates, exposure, and impacts in MFMod and analyze how these changes impact a country's development path.⁴ In addition to focusing on increasing resilience via adaptation, they also study how a transition to a low-carbon economy can be financed, thereby identifying cost-effective and equitable climate policy options. CCDRs utilize

³ Several accounting identities and market clearing conditions (so-called 'adding-up constraints') close the model.

⁴ MFMod is a flexible macroeconomic model that is continuously improved and adjusted. This includes many fit-for-purpose versions of MFMod that are used for country-specific and topic-specific work by World Bank staff.

the most recent data available for the economic and climate variables and provide country-specific policy recommendations.

We extend this analysis by testing for threshold and cascading risks in MFMod and by highlighting the importance of fiscal policy in mitigating environmental disaster risks. To do so, we simulate the effect of natural disasters of different sizes in the presence of other macroeconomic shocks. In particular, we simulate the effects of capital destruction from natural disasters of the magnitudes of 5 and 10 percent of the economy’s capital stock. We repeat these exercises in the presence of external shocks to test for risk compounding in MFMod. Our model setup follows Hallegatte, Jooste, and McIsaac (2024) who focus on monetary policy. Natural disasters destroy a fraction of the economy’s capital stock which lowers the economy’s productivity. Reconstruction efforts can repair affected capital and help to restore productivity. In the absence of reconstruction, capital depreciates at the regular rate. In the model of Hallegatte, Jooste, and McIsaac (2024), reconstruction occurs via redirection of existing public investment.⁵ We keep this form of reconstruction financing as our baseline and extend the analysis to the following public funding sources: debt financing, expenditure cuts, and revenue increases.⁶ The latter two are set to offset increases in public investment in a budget-neutral manner. Given our focus on fiscal policy’s role in financing reconstruction, we do not consider measures to increase disaster preparedness (for example, investments in adaptation, contingency funds, or private insurance).⁷ Figure 3 and tables 2-6 present our simulation results.

A 5 percent of the capital stock destruction without any reconstruction efforts (reported in table 2) induces an immediate drop in GDP of nearly 2 percent relative to the no-disaster baseline, with output loss increasing to nearly 2.5 percent over the next 15 years as the economy shifts to a lower potential output trajectory, and a persistent deviation from baseline for several decades. Table 2 reports key macroeconomic variables over a 30-year period, all relative to the baseline in which the shock does not occur (note that in MFMod potential GDP relies on lagged capital stock; thus, as a result, the shock to capital only impacts the economy in the following year). The bottom two rows illustrate the supply-side implications of the shock with potential GDP and capital stock

⁵ Damages to capital stock are captured by a damage function in destructed capital K^D and normal capital K , so that effective capital stock is $K^{eff} = \left(1 - \frac{K^D}{K}\right)^{\frac{1}{1-\alpha}} K$. With potential output of standard Cobb-Douglas form, terms can be rearranged to produce the potential output after damages: $Y^{pot} = AL^\alpha (K^{eff})^{1-\alpha} = \left(1 - \frac{K^D}{K}\right) AL^\alpha K^{1-\alpha}$.

⁶ The effects of revenue mobilization using tax increases vary across versions of MFMod, as the elasticity of some revenue items can differ.

⁷ We use the off-the-shelf version of MFMod as recently applied to an island economy. MFMod already includes a damage module to simulate the effects of natural disasters. We rely on this module for our simulations and extend it to allow for fiscal funding of reconstruction investments.

dynamics, revealing adverse effects on the economy's productive capacity. The 5 percent drop in the capital stock reduces potential output by 3 percent. This translates into an immediate reduction of GDP by 1.9 percent, which is mostly driven by a reduction in investment and consumption. The disproportionately larger drop in potential GDP leads to producer price inflation. The reduction in GDP also leads to a slight widening of the public deficit due to automatic stabilizers (that is, revenue is falling more than expenditure). Imports fall by 2 percent in the immediate aftermath of the disaster, and exports fall due to reduced competitiveness, causing the trade deficit to narrow and the real exchange rate to appreciate. While capital stock and potential GDP slowly approach their no-disaster baseline in the following years despite the fall in investment, economic output continues to diverge in subsequent years with the reduction relative to baseline peaking at nearly 2.5 percent after several decades. Investment's divergence peaks at 3 percent in the first few years but remains depressed throughout the whole simulation period. By year 30, the economy remains in a worse state—capital stock and all demand components are lower. Only the prices and the current account balance revert back to baseline.

Directing public investment toward reconstruction (reported in table 3) significantly speeds up the economy's recovery and limits its output loss. While the initial shock to GDP is similar, the deviation from baseline is at most 2 percent and falls sooner and more quickly. Due to the reduced investment in new capital in this scenario, where half of public investment is redirected, the economy's growth potential remains below baseline over the entire simulation period. This recovery scenario is the case generally considered in MFMod and also the one studied by Hallegatte, Jooste, and McIsaac (2024). The immediate impact of the disaster reported in table 3 is identical to the one in table 2. The economy recovers, however, more quickly with all economic indicators closer to baseline. The redirection of public investment to reconstruction efforts repairs all capital stock within five years. The depression of private investment demand because of the fall in output together with lower public investment in new capital stock translates to lower long-run growth. After 30 years, capital stock is 1.6 percent below baseline, while potential and actual output are almost 1 percent below baseline.

Next, we consider how fiscal policy can improve the economy's recovery from a disaster in the short and long run. To facilitate the comparison to the case of a redirection of public investment considered above in table 3, we hold the resources flowing into reconstruction efforts constant and only vary their funding source. In table 4, the government finances reconstruction via the issuance of new debt rather than a redirection of existing financing. The provision of additional resources to the economy increases government expenditure and investment levels, thereby repairing destroyed capital stock and providing fiscal stimulus. Debt-financing of reconstruction increases the debt-to-

GDP ratio by up to 10 percentage points in year 10 relative to baseline. Fiscal consolidation reduces output in the years following reconstruction with the effect that debt is only 3.4 percentage points above baseline 30 years after the disaster. Capital stock and potential and actual output are, however, close to their baseline.

Imposing temporary budget-neutral cuts in public expenditure to finance reconstruction investment (reported in table 5), reduces aggregate demand beyond the disaster's negative output shock and causes deflation (relative to baseline). Lowering government consumption by about 45 percent for four and a half years imposes significant short-run costs via lower demand and higher unemployment in order to achieve a quicker recovery relative to the debt-financed reconstruction scenario with most macroeconomic variables close to their no-disaster baseline values 10 years after the disaster shock. In the long run, the scenarios are alike with most variables close to baseline in year 30. Interestingly, mobilization of additional government revenue to finance reconstruction (reported in table 6) has similar effects on output as debt-financing without the cost of a larger debt burden and the need for fiscal consolidation in future. The tax-and-spend scenario allows the positive effects of fiscal stimulus to compensate for the disaster-induced fall in aggregate demand, while stoking slightly more consumer price inflation than under debt-financing.⁸

4.2. Threshold and cascading effects and fiscal policy

We double the destruction of capital caused by a natural disaster to 10 percent to test for the presence of threshold effects in MFMod. We find that a doubling of the destruction of capital translates into roughly a doubling of its effects on the economy. The effects are, however, disproportionately larger when the economy cannot scale its reconstruction efforts to the shock size. As in section 3, we find that sound fiscal policy can strengthen economic resilience by providing the fiscal space necessary to fund reconstruction at the necessary scale.

In the baseline reconstruction case, wherein half of public investment is directed towards reconstruction, the time to repair all affected capital stock increases from five to ten years. Keeping a larger damaged stock for longer affects the economy negatively. The depression of aggregate demand and all its components persists in the medium run. For example, output 5 years after the disaster is more than 2 percentage points smaller with a large shock (-3.9 percent vs. -1.7 percent,

⁸ Countries with low tax revenue to GDP may benefit from raising tax revenue above a certain threshold (see, for example, Gaspar, Jaramillo, and Wingender 2016). The nonlinear effect of raising tax on output is not modeled in the standard version of MFMod used in this paper.

both relative to the no-disaster baseline).⁹ In the medium term, the economy remains disproportionately affected by the disaster with the loss in GDP more than double that of the low-damage scenario. This disproportionality of the negative disaster impacts persists in the long run with output 2.5 percent below the no-disaster baseline after 30 years, relative to the 1.1 percent reported in Table 2 for the smaller shock. A destruction of capital caused by a natural disaster, therefore, reduces economic output in the long run and also the more so for larger shocks.

The ability of fiscal policy to finance reconstruction effectively, while minimizing the effects of mobilizing this financing, determines the extent that threshold risks materialize. When reconstruction investment is financed by government debt, the fiscal stimulus due to the provision of additional resources in the low-damage scenario (reported in table 4) softens the reduction in demand in the first years at the cost of greater fiscal consolidation later. Increasing the shock size without increasing the stimulus size in the immediate post-disaster years leads to a significant drop in output of 2.3 percent relative to the no-disaster baseline before continued debt-financed reconstruction enables the recovery. Again, we find that this significantly more adverse outcome (relative to the low-damage debt-finance scenario) is a direct consequence of the portion of the damage not repaired (equal to the low-damage no-construction scenario). Once reconstruction progresses beyond low-damage efforts (that is, addressing additional damage after year five), the economy that receives further stimulus recovers quickly, and the speed of the recovery falls once debt-financing ends after ten years post-disaster and slows further before settling into its long-run growth path towards the end of the next decade. Again, the economy fully recovers but GDP remains 1.2 percent lower than its no-disaster baseline in the long run. This is 0.9 percentage point larger than in the low-damage scenario.

Threshold risks are most pronounced when reconstruction is financed via budget-neutral cuts in expenditure. While reducing expenditure to finance reconstruction leads to a larger initial decline in GDP, output recovered quickly to slightly below the no-disaster baseline in the low-damage case. In the high-damage scenario, the recovery cannot fully recover to its baseline. Once reconstruction is completed, output stabilizes around half a percentage point below the no-disaster baseline. The tax-and-spend scenario in the high-damage scenario, again, combines the positive fiscal stimulus of debt-finance without incurring the need for consolidation in the long run. The recovery trajectories in output for these two scenarios are similar, while the debt-to-GDP ratio is

⁹ This difference equals the additional shock in the no-reconstruction scenario, that is the first years of reconstruction in the current high-damage scenario can be understood as the sum of the low-damage scenario plus the low-damage no-construction scenario. The high-damage scenario, however, diverges from this sum as it continues to reconstruct capital beyond the five-year period of the low-damage scenario.

0.7 percentage point higher after 10 years relative to the no-disaster baseline in the revenue-financed reconstruction scenario. It is nearly 16 percentage points higher, when reconstruction is financed by issuance of new debt.

Small open island economies face several sources of macroeconomic risk. To study compounding risks, we analyze how the presence of other shocks alters the impact of a natural disaster shock. We focus on external shocks (devaluation of real exchange rate or exogenous changes in export demand) and change the no-disaster baseline to a situation where such an external shock is present. We find that this does not alter the effects of a natural disaster when compared across baselines. Yet, we find the presence of threshold risks due to the economy's endogenous response to the disaster. Most developing economies are not able to scale their crisis response and reconstruction efforts linearly to the magnitude of a disaster shock. Thresholds in a country's coping capacity lead to disproportionately larger negative effects when the disaster shock is large. Details of this disproportionality vary depending on which fiscal instrument is used to finance reconstruction. We also find that natural disasters have level effects on economic output in MFMMod as the economy does not return to its no-disaster baseline within our simulation period. This holds even when the disaster is small and the reconstruction efforts are completed within five years. This deviation from the no-disaster baseline is particularly pronounced in the scenario wherein reconstruction is financed by diverting public funds from other investment projects, as this funding type harms capital accumulation and thereby output growth in the long run.

5. Policy recommendations and final remarks

Climate-related disasters have the potential to worsen the prevailing economic challenges encountered by developing countries. This is especially true in the current global economic landscape marked by high inflation, sluggish economic growth, and mounting debt. The econometric results and the findings from the model study uncover the timely and critical role of fiscal policy in attenuating the negative economic impact of climate disasters. In particular, our results highlight that output losses are markedly smaller in countries with a lower debt-to-GDP ratio than in countries where the debt-to-GDP ratio exceeds 50 percent. These findings imply that prudent fiscal policies which ensure good management of debt levels (for example, binding fiscal rules like a debt rule), as well as efforts to mobilize additional revenue to create fiscal buffers, would allow governments to adequately respond to climate shocks. Mobilizing additional revenue effectively, however, requires a holistic approach that takes into account strategies to improve the policy, administration, and legal aspects of the implementation of taxes (Benitez et al. 2023).

Furthermore, we find evidence that economies that ran procyclical government spending policies and ran deficits on average over many decades face economically larger and longer-lasting negative impacts from climate shocks. On the other hand, economies with countercyclical spending and that run primary budget surpluses on average faced little to no output losses. This suggests that fiscal strategies that save windfalls during economic upturns (for example, during commodity booms) and spend these savings during economic downturns allow governments to effectively respond to climate shocks. In contrast, spending during economic booms and cutting spending during economic downturns can worsen and lengthen the duration of the adverse impact of climate shocks on economies.

Several policy options are available to create the necessary buffers for a future with more frequent and intense climate shocks. When a natural disaster hits, the impact on government finances can be large, requiring additional spending for reconstruction and decreasing revenue through damaging income or tax relief for those affected. To adequately deal with the additional spending, governments can create contingency reserves and natural disaster funds. Contingency reserves are funds within the annual budget that provide some degree of flexibility to adapt to changing conditions. A natural disaster fund is a dedicated pool of funds with rules about how the funds can be used, and its size is determined by the likely liability faced by the government in previous disasters that account for the rising severity and frequency of disasters (Guerson 2016). Governments could also use catastrophe bonds and other insurance mechanisms to transfer some of the risk of disaster to third parties (Polacek 2018).

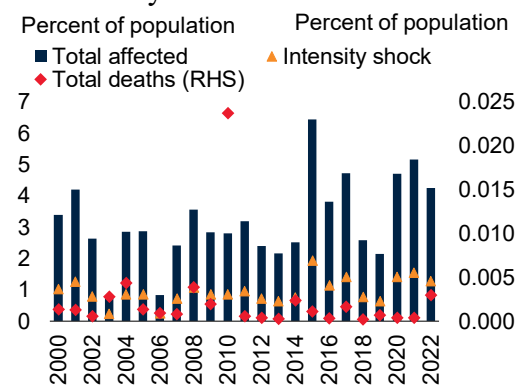
Beyond the role of these fiscal instruments in curbing the negative impact of climate-related disasters, the strengthening of government effectiveness plays a critical role in attenuating the negative effects of climate shocks. Specifically, our results reveal that countries with more effective governments saw no losses from climate shocks relative to statistically significant losses in countries with weak government effectiveness. Consequently, the improvement of the quality of fiscal policy formulation and implementation, as well as the credibility of the government's commitment to such policies, can be critical for addressing climate vulnerabilities and their related impact on output. Medium-term expenditure frameworks are a powerful way to align spending with strategic goals and ensure the planning needed to address future climate shocks (World Bank 2012).

In summary, the implication of our findings reinforces the argument that “good” fiscal planning and management is an important starting point to mitigate the effects of climate-related shocks.¹⁰ Policy makers, therefore, could prioritize building fiscal buffers along the lines of maintaining a healthy debt-to-GDP ratio, strengthening revenue mobilization, conducting countercyclical spending policies, and improving government effectiveness. In addition to these direct implications of our findings on the risk-mitigating mechanisms of climate shocks, policy strategies should include establishing contingency funds to help alleviate the negative effects of climate shocks on public finances and hence, output.

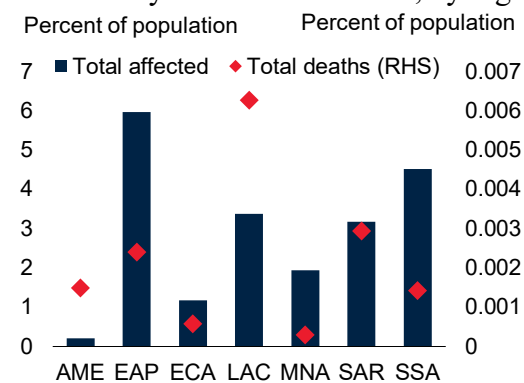
¹⁰ Future work could explore other ways to identify threshold and cascading impacts in a subset of vulnerable economies and using other empirical modeling strategies. It could also explore the simulation of these effects in other macroeconomic models.

Figure 1. Distribution of natural disasters over time and across regions

A. Intensity of natural disasters



B. Intensity of natural disasters, by region

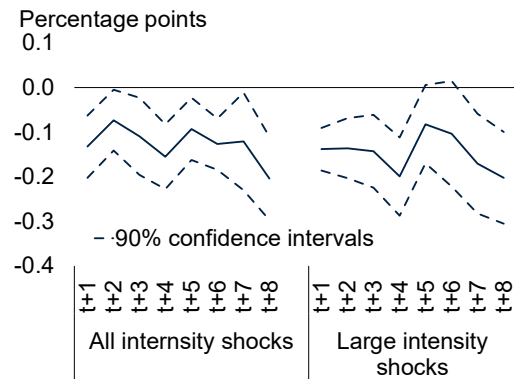


Sources: EM-DAT, WDI (Population data).

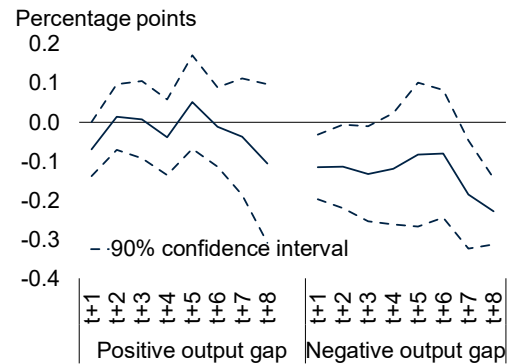
Note: The average of affected as a ratio to population, death to population and intensity shock across countries in a given year (in panel A) and across countries in a given region over 2000-22 (in panel B).

Figure 2. Impact of natural disasters on output

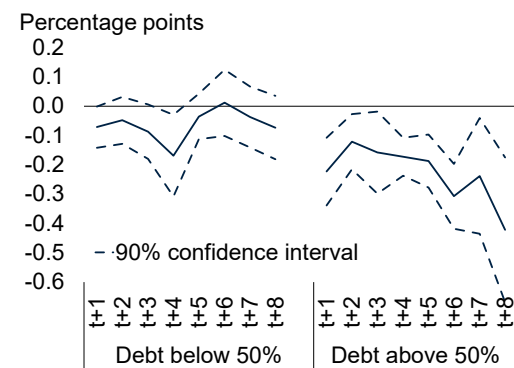
A. Impact of a natural disaster affecting 1 percent of population on log real GDP per capita



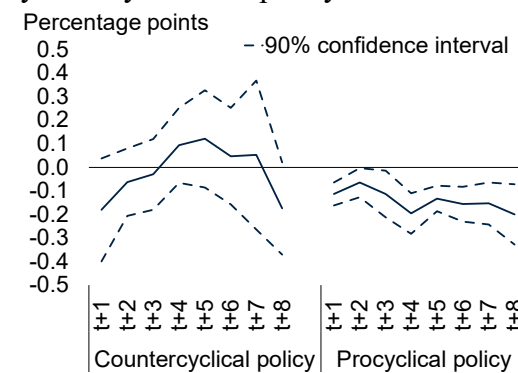
B. Impact on log real GDP per capita, by business cycle



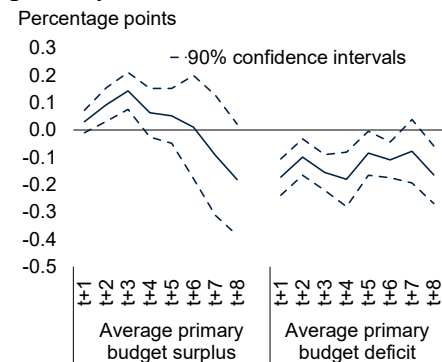
C. Impact on log real GDP per capita, by debt level



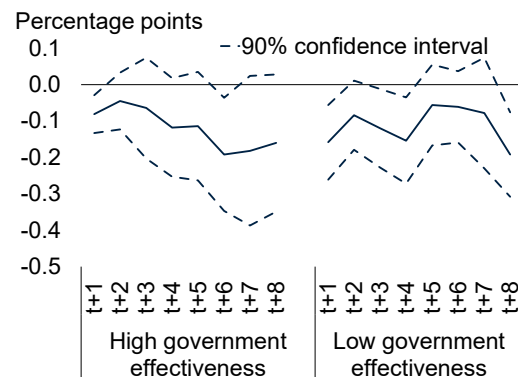
D. Impact on log real GDP per capita, by cyclical policy



E. Impact on log real GDP per capita, by primary fiscal balance to GDP



F. Impact on log real GDP per capita, by institutions



Sources: EM-DAT, World Bank.

Note: "t" is years.

A. "All intensity shocks" based on 3041 observations for 156 economies over 21 years. "Large intensity shocks" based on those in the 90th percentile (or 421 observations).

B. Output gap defined using an HP-filter with lambda of 6.25. Switching variable is lagged one year.

C. Median government debt is 46.9 percent of GDP. Switching variable is lagged one year.

D. Based on the correlation between the cyclical components of real GDP and government expenditure from 1990 to 2021 where the cycle is defined using an HP-filter with lambda of 6.25.

E. Based on the average primary budget position to GDP from 1990 to 2023.

F. "High government effectiveness" reflects the Worldwide Governance Indicator above its 50th percentile rank.

Figure 3. Response of GDP, consumer prices, and fiscal balance (as percentage of GDP and difference to no-disaster baseline) to a 5 percent (left) and 10 percent (right) climate-induced shock to capital stock

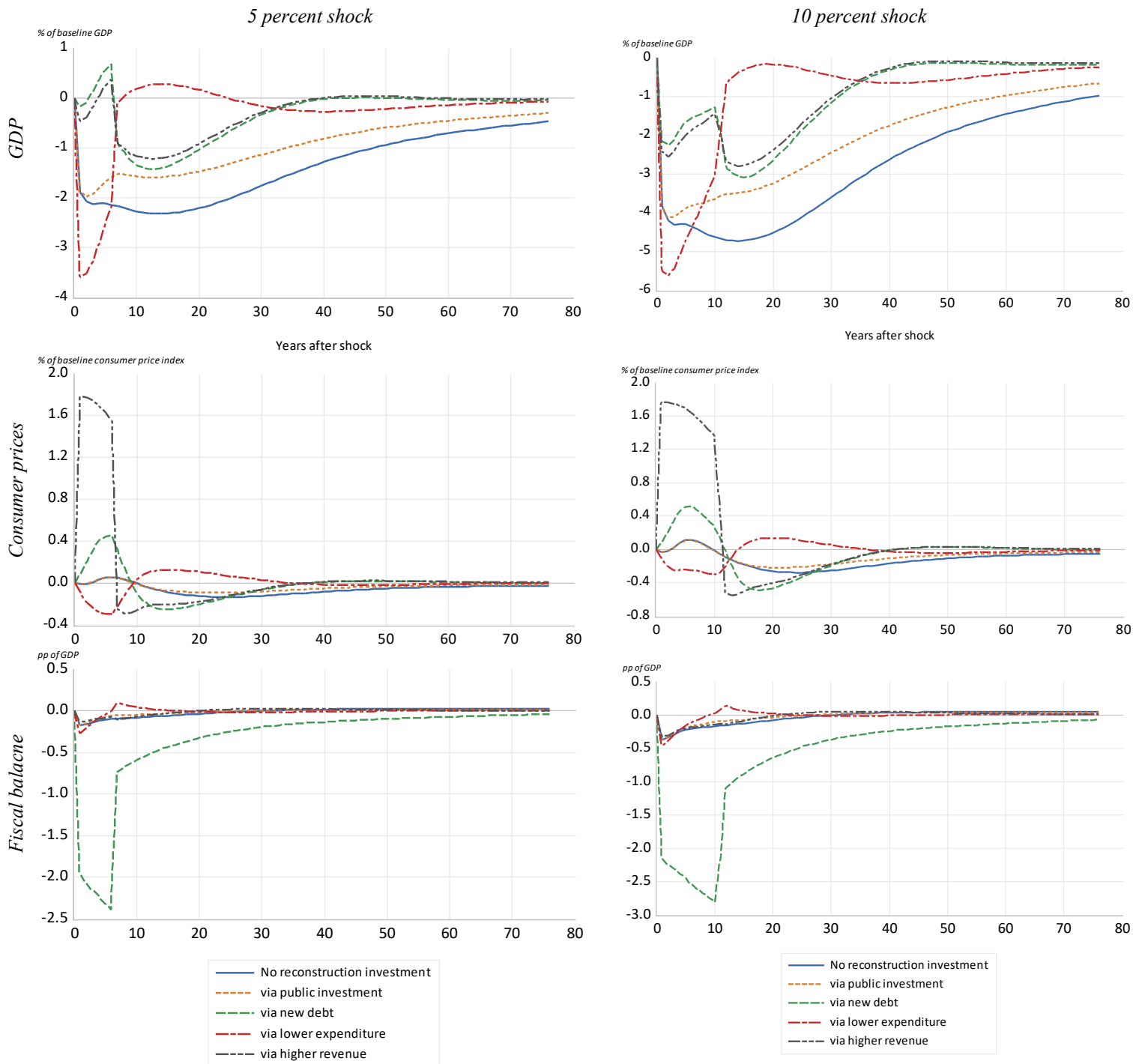


Table 1. Data sources

| Variable name | Description | Transformation | Source |
|-----------------------------|--|------------------------|---|
| GDP per capita | Gross domestic product per capita, constant prices | Log | IMF World Economic Outlook |
| Gross government debt | General government gross debt | Percent of GDP | IMF World Economic Outlook |
| Climate vulnerability index | Propensity or predisposition of human societies to be negatively impacted by climate hazards. | Index | University of Notre Dame |
| Government effectiveness | Perceptions of the quality of public services | Index | Worldwide Governance Indicators, World Bank |
| Broad money | Annual growth in the sum of currency outside banks; demand deposits; savings and foreign currency deposits; bank and traveler's checks; and other securities. | Annual growth, percent | World Development Indicators |
| Spending cyclicalities | Correlation between the cyclical components of real GDP and government expenditure from 1990 to 2021 where the cycle is defined using an HP-filter with lambda of 6.25 | Correlation | Own calculations |
| Output gap | Real GDP from HP-filter trend with lambda of 6.25 | Percent of trend GDP | Own calculations |
| Primary budget balance | Average primary balance from 2000 to 2021 | | |

Source: World Bank.

Note: HP = Hodrick Prescott.

Table 2. The macroeconomic effects of a 5 percent climate-induced shock to capital stock without reconstruction

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|--|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -1.9 | -2.1 | -2.1 | -2.1 | -2.1 | -2.3 | -2.1 | -1.8 |
| Private consumption | 0.0 | -2.1 | -2.3 | -2.2 | -2.1 | -2.0 | -2.0 | -2.0 | -1.8 |
| Government consumption | 0.0 | -0.4 | -1.0 | -1.5 | -1.8 | -2.0 | -2.6 | -2.8 | -2.3 |
| Total investment | 0.0 | -2.9 | -2.9 | -2.9 | -3.0 | -3.0 | -2.9 | -2.0 | -1.4 |
| Exports | 0.0 | -0.1 | -0.2 | -0.3 | -0.5 | -0.6 | -1.1 | -1.0 | -0.6 |
| Imports | 0.0 | -2.2 | -2.3 | -2.2 | -2.1 | -1.9 | -1.3 | -0.6 | -0.6 |
| Current account balance (pp of GDP) | 0.0 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.3 | 0.1 | 0.0 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.3 | 0.4 | 0.2 | 0.1 |
| Consumer prices | 0.0 | -0.0 | -0.0 | 0.0 | 0.0 | 0.0 | -0.0 | -0.1 | -0.1 |
| Real exchange rate | 0.0 | 0.1 | 0.2 | 0.4 | 0.6 | 0.8 | 1.4 | 1.3 | 0.8 |
| Import prices | 0.0 | -0.1 | -0.1 | -0.2 | -0.3 | -0.5 | -1.0 | -1.2 | -0.8 |
| Export prices | 0.0 | -0.0 | 0.0 | 0.1 | 0.2 | 0.2 | 0.3 | 0.1 | 0.0 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | -1.9 | -2.0 | -1.9 | -1.9 | -1.8 | -1.9 | -1.9 | -1.7 |
| Expenditures | 0.0 | -0.7 | -0.9 | -1.0 | -1.0 | -1.1 | -1.3 | -1.7 | -1.7 |
| Deficit (pp of GDP) | 0.0 | -0.2 | -0.2 | -0.1 | -0.1 | -0.1 | -0.1 | -0.0 | -0.0 |
| Debt (pp of GDP) | 0.0 | 0.7 | 0.8 | 0.9 | 0.8 | 0.8 | 0.8 | 0.6 | 0.3 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -3.0 | -2.9 | -2.8 | -2.8 | -2.7 | -2.5 | -2.0 | -1.6 |
| Capital stock | -5.0 | -4.9 | -4.8 | -4.7 | -4.6 | -4.5 | -4.1 | -3.3 | -2.5 |

Sources: MFMod, World Bank; Authors' calculations.

Note: Table shows deviations as percent from a baseline scenario.

Table 3. The macroeconomic effects of a 5 percent climate-induced shock to capital stock with reconstruction financed by redirection of public investment

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|--|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -1.9 | -1.9 | -1.9 | -1.7 | -1.7 | -1.5 | -1.4 | -1.1 |
| Private consumption | 0.0 | -2.1 | -2.2 | -2.1 | -1.7 | -1.6 | -1.3 | -1.3 | -1.1 |
| Government consumption | 0.0 | -0.4 | -1.0 | -1.4 | -1.7 | -1.8 | -1.8 | -1.8 | -1.4 |
| Total investment | 0.0 | -2.9 | -2.8 | -2.7 | -2.5 | -2.4 | -1.9 | -1.2 | -0.8 |
| Exports | 0.0 | -0.1 | -0.2 | -0.3 | -0.4 | -0.6 | -0.8 | -0.7 | -0.4 |
| Imports | 0.0 | -2.2 | -2.1 | -2.0 | -1.7 | -1.5 | -0.7 | -0.4 | -0.4 |
| Current account balance (pp of GDP) | 0.0 | 0.4 | 0.4 | 0.4 | 0.3 | 0.3 | 0.2 | 0.0 | 0.0 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.3 | 0.3 | 0.1 | 0.0 |
| Consumer prices | 0.0 | -0.0 | -0.0 | 0.0 | 0.0 | 0.0 | -0.0 | -0.1 | -0.1 |
| Real exchange rate | 0.0 | 0.1 | 0.2 | 0.4 | 0.5 | 0.7 | 1.1 | 0.9 | 0.5 |
| Import prices | 0.0 | -0.1 | -0.1 | -0.2 | -0.3 | -0.4 | -0.8 | -0.8 | -0.5 |
| Export prices | 0.0 | -0.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.1 | 0.0 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | -1.9 | -1.9 | -1.8 | -1.5 | -1.4 | -1.2 | -1.3 | -1.1 |
| Expenditures | 0.0 | -0.7 | -0.8 | -0.9 | -0.9 | -0.9 | -0.9 | -1.2 | -1.1 |
| Deficit (pp of GDP) | 0.0 | -0.2 | -0.2 | -0.1 | -0.1 | -0.1 | -0.0 | -0.0 | 0.0 |
| Debt (pp of GDP) | 0.0 | 0.7 | 0.8 | 0.8 | 0.7 | 0.7 | 0.5 | 0.4 | 0.1 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -3.0 | -2.8 | -2.6 | -2.3 | -2.1 | -1.6 | -1.3 | -1.0 |
| Capital stock | -5.0 | -4.6 | -4.3 | -3.9 | -3.5 | -3.2 | -2.7 | -2.1 | -1.6 |

Sources: MFMod, World Bank; Authors' calculations.

Note: Table shows deviations as percent from a baseline scenario.

Table 4. The macroeconomic effects of a 5 percent climate-induced shock to capital stock with reconstruction financed by public debt issuance

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|--|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -0.2 | -0.0 | 0.2 | 0.4 | 0.6 | -1.3 | -1.0 | -0.3 |
| Private consumption | 0.0 | -1.6 | -1.3 | -0.7 | -0.2 | 0.4 | -0.2 | -1.0 | -0.5 |
| Government consumption | 0.0 | -0.2 | -0.5 | -0.7 | -0.7 | -0.8 | -1.7 | -1.7 | -0.5 |
| Total investment | 0.0 | 3.6 | 3.8 | 3.9 | 4.0 | 4.3 | -1.3 | 0.2 | 0.2 |
| Exports | 0.0 | -0.3 | -0.7 | -1.2 | -1.7 | -2.2 | -2.3 | -0.6 | 0.1 |
| Imports | 0.0 | -0.1 | 0.3 | 1.0 | 1.6 | 2.4 | 1.9 | 0.8 | -0.1 |
| Current account balance (pp of GDP) | 0.0 | 0.0 | -0.0 | -0.1 | -0.1 | -0.2 | -0.3 | -0.4 | -0.1 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 0.1 | 0.3 | 0.6 | 0.9 | 1.1 | 0.7 | -0.1 | -0.2 |
| Consumer prices | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | -0.1 | -0.2 | -0.1 |
| Real exchange rate | 0.0 | 0.3 | 0.9 | 1.5 | 2.2 | 2.8 | 3.0 | 0.8 | -0.2 |
| Import prices | 0.0 | -0.1 | -0.3 | -0.6 | -0.9 | -1.3 | -2.4 | -0.9 | 0.0 |
| Export prices | 0.0 | 0.2 | 0.4 | 0.6 | 0.9 | 1.0 | 0.5 | -0.1 | -0.1 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | -0.1 | 0.3 | 0.8 | 1.3 | 1.8 | -0.6 | -1.2 | -0.5 |
| Expenditures | 0.0 | 13.3 | 14.5 | 15.7 | 16.9 | 18.0 | 3.4 | 1.1 | 0.9 |
| Deficit (pp of GDP) | 0.0 | -2.0 | -2.1 | -2.2 | -2.2 | -2.3 | -0.6 | -0.3 | -0.2 |
| Debt (pp of GDP) | 0.0 | 2.0 | 3.7 | 5.2 | 6.7 | 8.1 | 9.1 | 5.9 | 3.4 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -3.0 | -2.5 | -2.0 | -1.7 | -1.2 | -0.5 | -0.4 | -0.1 |
| Capital stock | -5.0 | -4.2 | -3.5 | -2.8 | -2.1 | -1.5 | -1.0 | -0.6 | -0.2 |

Sources: MFMod, World Bank; Authors' calculations.

Note: Table shows deviations as percent from a baseline scenario.

Table 5. The macroeconomic effects of a 5 percent climate-induced shock to capital stock with reconstruction financed by reduction in public expenditure

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|--|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -3.6 | -3.5 | -3.3 | -2.9 | -2.5 | 0.2 | 0.2 | -0.2 |
| Private consumption | 0.0 | -2.5 | -2.7 | -2.5 | -2.2 | -1.9 | -0.5 | 0.1 | -0.1 |
| Government consumption | 0.0 | -44.2 | -44.6 | -44.9 | -45.1 | -45.0 | 0.4 | 0.5 | -0.1 |
| Total investment | 0.0 | 3.4 | 3.9 | 4.5 | 5.0 | 5.7 | 0.2 | -0.5 | -0.5 |
| Exports | 0.0 | 0.1 | 0.4 | 0.6 | 0.9 | 1.1 | 1.2 | 0.2 | -0.2 |
| Imports | 0.0 | -4.1 | -4.2 | -4.1 | -3.9 | -3.7 | -1.5 | -0.8 | -0.1 |
| Current account balance (pp of GDP) | 0.0 | 0.8 | 0.8 | 0.7 | 0.7 | 0.6 | 0.2 | 0.2 | 0.1 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 0.4 | 0.3 | 0.1 | -0.0 | -0.1 | -0.4 | 0.1 | 0.1 |
| Consumer prices | 0.0 | -0.1 | -0.2 | -0.3 | -0.3 | -0.3 | 0.0 | 0.1 | 0.0 |
| Real exchange rate | 0.0 | -0.2 | -0.5 | -0.8 | -1.1 | -1.4 | -1.5 | -0.3 | 0.2 |
| Import prices | 0.0 | -0.0 | 0.1 | 0.2 | 0.4 | 0.6 | 1.3 | 0.4 | -0.1 |
| Export prices | 0.0 | -0.1 | -0.3 | -0.4 | -0.5 | -0.6 | -0.3 | 0.1 | 0.1 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | -3.1 | -3.3 | -3.1 | -2.9 | -2.6 | -0.2 | 0.3 | -0.0 |
| Expenditures | 0.0 | -1.3 | -1.9 | -2.2 | -2.3 | -2.3 | -0.5 | 0.3 | 0.1 |
| Deficit (pp of GDP) | 0.0 | -0.3 | -0.2 | -0.1 | -0.1 | -0.0 | 0.0 | -0.0 | -0.0 |
| Debt (pp of GDP) | 0.0 | 1.2 | 1.3 | 1.3 | 1.2 | 1.1 | -0.1 | -0.2 | 0.1 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -3.0 | -2.6 | -2.1 | -1.7 | -1.1 | -0.2 | -0.2 | -0.3 |
| Capital stock | -5.0 | -4.2 | -3.5 | -2.8 | -2.0 | -1.3 | -0.4 | -0.4 | -0.4 |

Sources: MFMod, World Bank; Authors' calculations.

Note: Tables show deviations as percent from a baseline scenario.

Table 6. The macroeconomic effects of a 5 percent climate-induced shock to capital stock with reconstruction financed by increase in public revenue

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|-------------------------------------|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -0.4 | -0.4 | -0.1 | 0.0 | 0.2 | -1.2 | -0.9 | -0.3 |
| Private consumption | 0.0 | -1.8 | -1.5 | -0.9 | -0.4 | 0.0 | -0.3 | -0.8 | -0.5 |
| Government consumption | 0.0 | -0.2 | -0.1 | -0.1 | -0.0 | 0.0 | -1.6 | -1.6 | -0.5 |
| Total investment | 0.0 | 3.3 | 3.2 | 3.4 | 3.6 | 3.8 | -0.6 | 0.2 | 0.2 |
| Exports | 0.0 | -0.8 | -1.4 | -1.9 | -2.4 | -2.7 | -1.9 | -0.6 | 0.1 |
| Imports | 0.0 | -0.1 | 0.3 | 1.1 | 1.9 | 2.7 | 2.0 | 0.8 | -0.1 |
| Current account balance (pp of GDP) | 0.0 | 0.5 | 0.5 | 0.4 | 0.4 | 0.3 | -0.3 | -0.3 | -0.1 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 1.6 | 1.8 | 2.0 | 2.1 | 2.2 | 0.4 | -0.1 | -0.2 |
| Consumer prices | 0.0 | 1.8 | 1.8 | 1.7 | 1.7 | 1.6 | -0.3 | -0.2 | -0.1 |
| Real exchange rate | 0.0 | 2.7 | 3.5 | 4.2 | 4.8 | 5.3 | 2.5 | 0.7 | -0.1 |
| Import prices | 0.0 | -0.4 | -0.9 | -1.4 | -1.9 | -2.4 | -2.3 | -0.9 | 0.0 |
| Export prices | 0.0 | 0.3 | 0.5 | 0.6 | 0.7 | 0.7 | 0.2 | -0.1 | -0.1 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | 17.8 | 18.0 | 18.5 | 18.8 | 19.1 | -0.8 | -1.0 | -0.4 |
| Expenditures | 0.0 | 15.0 | 15.2 | 15.5 | 15.8 | 16.0 | -0.3 | -1.0 | -0.6 |
| Deficit (pp of GDP) | 0.0 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | -0.1 | 0.0 | 0.0 |
| Debt (pp of GDP) | 0.0 | -0.3 | -0.2 | -0.3 | -0.3 | -0.3 | 0.9 | 0.6 | 0.0 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -3.0 | -2.6 | -2.1 | -1.7 | -1.3 | -0.6 | -0.3 | -0.1 |
| Capital stock | -5.0 | -4.2 | -3.5 | -2.9 | -2.2 | -1.6 | -1.0 | -0.5 | -0.2 |

Source: MFMod, World Bank; Authors' calculations.

Note: Tables show deviations as percent from a baseline scenario.

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Annex A: Glossary on Risk Management

The IPCC (IPCC, 2018, ch.2) defines the effects of natural disasters as the combination of natural hazards, exposure, vulnerability and coping and adaptive capacities:

Hazards “The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources” (AR6).

Exposure “The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected” (AR6, WGIII).

Impacts “The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather/climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and well-being, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes and can be adverse or beneficial.”

Coping capacity “The ability of people, institutions, organisations and systems, using available skills, values, beliefs, resources, and opportunities, to address, manage and overcome adverse conditions in the short to medium term” (UNISDR, 2009; IPCC, 2012).

Adaptive Capacity “The ability of systems, *institutions*, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences” (MA, 2005).

Vulnerability “The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt” (AR6, WGIII).

Risk “The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, livelihoods, health and well-being, economic, social and cultural assets and investments, infrastructure, services (including ecosystem services), ecosystems and species.

In the context of climate change impacts, risks result from dynamic interactions between climate-related hazards with the exposure and vulnerability of the affected human or ecological system to the hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and likelihood of occurrence, and each may change over time and space due to socio-economic changes and human decision-making (see also risk management, adaptation and mitigation).

In the context of climate change responses, risks result from the potential for such responses not achieving the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the Sustainable Development Goals (SDGs) (see also risk trade-off). Risks can arise, for example, from uncertainty in implementation, effectiveness or outcomes of climate policy, climate-related investments, technology development or adoption, and system transitions.”

Compound risks “arise from the interaction of hazards, which may be characterised by single extreme events or multiple coincident or sequential events that interact with exposed systems or sectors.”

Risk management “Plans, actions, strategies or policies to reduce the *likelihood* and/or magnitude of adverse potential consequences, based on assessed or perceived *risks*.”

Risk trade-offs “The change in the portfolio of risks that occurs when a countervailing risk is generated (knowingly or inadvertently) by an intervention to reduce the target risk.” (Wiener and Graham, 2009).

Risk transfer “The process of formally or informally shifting the financial consequences of particular risks from one party to another whereby a household, community, enterprise or state authority will obtain resources from the other party after a disaster occurs, in exchange for ongoing or compensatory social or financial benefits provided to that other party.”

Annex B: Choice of governance indicators in panel local projection model

Six indicators of governance are sorted into three categories¹¹: a) Government selection, monitoring, and replacement processes; b) Government capacity for policy formulation and implementation; c) Respect for governing institutions by citizens and the state. Given our interest in fiscal resilience, we focus solely on indicators within category b): government effectiveness and regulatory quality. Our analysis suggests a strong correlation between these indicators, as evident from hierarchical clustering depicted in the dendrogram below (Figure B1). Thus, we choose government effectiveness, which exhibits the highest average correlation with other indicators (Table B1), as our primary focus.

Table B1: Pairwise correlation across six different world governance indicators.

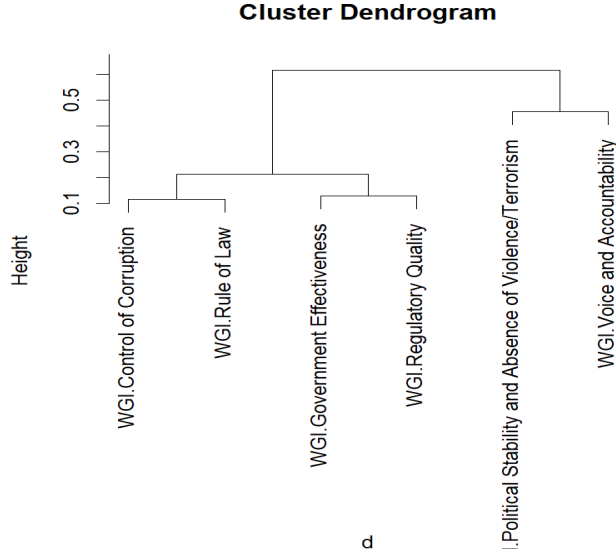
| | Control of Corruption | Government Effectiveness | Political Stability & Absence of Violence / Terrorism | Regulatory Quality | Rule of Law | Voice and Accountability |
|---|-----------------------|--------------------------|---|--------------------|-------------|--------------------------|
| Control of Corruption | 1.00 | 0.92 | 0.75 | 0.87 | 0.94 | 0.78 |
| Government Effectiveness | 0.92 | 1.00 | 0.72 | 0.93 | 0.93 | 0.76 |
| Political Stability and Absence of Violence/Terrorism | 0.75 | 0.72 | 1.00 | 0.67 | 0.79 | 0.69 |
| Regulatory Quality | 0.87 | 0.93 | 0.67 | 1.00 | 0.90 | 0.79 |
| Rule of Law | 0.94 | 0.93 | 0.79 | 0.90 | 1.00 | 0.83 |
| Voice and Accountability | 0.78 | 0.76 | 0.69 | 0.79 | 0.83 | 1.00 |

Source: World Bank; Authors' calculations.

Note: All pairwise correlations are statistically significant at 1% level.

¹¹ Kaufmann and Kraay (2023).

Figure B1: Hierarchical Clustering of different governance indicators.



Appendix C MFMod further results

Table C1. The macroeconomic effects of a 10 percent climate-induced shock to capital stock without reconstruction

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|--|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -3.9 | -4.2 | -4.3 | -4.3 | -4.3 | -4.6 | -4.5 | -3.6 |
| Private consumption | 0.0 | -4.3 | -4.7 | -4.6 | -4.4 | -4.1 | -4.0 | -4.2 | -3.6 |
| Government consumption | 0.0 | -0.8 | -2.1 | -3.1 | -3.7 | -4.2 | -5.3 | -5.7 | -4.7 |
| Total investment | 0.0 | -5.9 | -6.0 | -6.1 | -6.1 | -6.2 | -5.9 | -4.2 | -2.9 |
| Exports | 0.0 | -0.1 | -0.3 | -0.6 | -1.0 | -1.3 | -2.3 | -2.2 | -1.3 |
| Imports | 0.0 | -4.3 | -4.6 | -4.6 | -4.3 | -4.0 | -2.7 | -1.4 | -1.3 |
| Current account balance (pp of GDP) | 0.0 | 0.7 | 0.8 | 0.9 | 0.9 | 0.8 | 0.7 | 0.2 | 0.1 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 0.1 | 0.2 | 0.3 | 0.5 | 0.7 | 0.9 | 0.5 | 0.1 |
| Consumer prices | 0.0 | -0.0 | -0.0 | 0.0 | 0.1 | 0.1 | -0.0 | -0.3 | -0.3 |
| Real exchange rate | 0.0 | 0.1 | 0.4 | 0.8 | 1.2 | 1.7 | 3.0 | 2.8 | 1.8 |
| Import prices | 0.0 | -0.1 | -0.3 | -0.5 | -0.7 | -0.9 | -2.1 | -2.5 | -1.7 |
| Export prices | 0.0 | -0.0 | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | 0.3 | 0.1 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | -3.8 | -4.1 | -4.0 | -3.8 | -3.7 | -3.8 | -4.1 | -3.5 |
| Expenditures | 0.0 | -1.3 | -1.8 | -2.1 | -2.1 | -2.2 | -2.6 | -3.6 | -3.5 |
| Deficit (pp of GDP) | 0.0 | -0.4 | -0.3 | -0.3 | -0.3 | -0.2 | -0.2 | -0.1 | -0.0 |
| Debt (pp of GDP) | 0.0 | 1.5 | 1.7 | 1.8 | 1.8 | 1.7 | 1.7 | 1.3 | 0.6 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -6.1 | -6.0 | -5.8 | -5.7 | -5.6 | -5.1 | -4.2 | -3.2 |
| Capital stock | -10.0 | -9.8 | -9.5 | -9.3 | -9.2 | -9.0 | -8.2 | -6.7 | -5.2 |

Source: MFMod; World Bank. Authors' calculations.

Note: Table shows deviations as percent from a baseline scenario.

Table C2. The macroeconomic effects of a 10 percent climate-induced shock to capital stock with reconstruction financed by redirection of public investment

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|--|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -3.9 | -4.1 | -4.1 | -4.0 | -3.9 | -3.6 | -3.2 | -2.5 |
| Private consumption | 0.0 | -4.3 | -4.6 | -4.4 | -4.0 | -3.7 | -3.1 | -3.0 | -2.5 |
| Government consumption | 0.0 | -0.8 | -2.1 | -3.0 | -3.6 | -3.9 | -4.4 | -4.2 | -3.2 |
| Total investment | 0.0 | -5.9 | -5.8 | -5.8 | -5.7 | -5.6 | -4.5 | -2.7 | -1.9 |
| Exports | 0.0 | -0.1 | -0.3 | -0.6 | -0.9 | -1.2 | -2.0 | -1.5 | -0.8 |
| Imports | 0.0 | -4.3 | -4.5 | -4.4 | -3.9 | -3.5 | -1.8 | -0.8 | -0.9 |
| Current account balance (pp of GDP) | 0.0 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.5 | 0.1 | 0.0 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | 0.8 | 0.3 | 0.0 |
| Consumer prices | 0.0 | -0.0 | -0.0 | 0.0 | 0.1 | 0.1 | -0.0 | -0.2 | -0.2 |
| Real exchange rate | 0.0 | 0.1 | 0.4 | 0.8 | 1.2 | 1.6 | 2.6 | 2.0 | 1.1 |
| Import prices | 0.0 | -0.1 | -0.3 | -0.4 | -0.7 | -0.9 | -1.9 | -1.8 | -1.1 |
| Export prices | 0.0 | -0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.1 | 0.0 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | -3.8 | -4.0 | -3.8 | -3.5 | -3.3 | -2.9 | -3.0 | -2.4 |
| Expenditures | 0.0 | -1.3 | -1.8 | -2.0 | -2.0 | -2.0 | -2.2 | -2.7 | -2.5 |
| Deficit (pp of GDP) | 0.0 | -0.4 | -0.3 | -0.3 | -0.2 | -0.2 | -0.1 | -0.0 | 0.0 |
| Debt (pp of GDP) | 0.0 | 1.5 | 1.7 | 1.7 | 1.6 | 1.5 | 1.3 | 0.9 | 0.3 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -6.1 | -5.8 | -5.5 | -5.3 | -5.0 | -3.8 | -2.9 | -2.2 |
| Capital stock | -10.0 | -9.5 | -9.1 | -8.6 | -8.2 | -7.8 | -5.9 | -4.6 | -3.5 |

Source: MFMod; World Bank. Authors' calculations.

Note: Table shows deviations as percent from a baseline scenario.

Table C3. The macroeconomic effects of a 10 percent climate-induced shock to capital stock with reconstruction financed by public debt issuance

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|--|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -2.2 | -2.3 | -2.1 | -1.9 | -1.7 | -1.3 | -2.7 | -1.2 |
| Private consumption | 0.0 | -3.8 | -3.8 | -3.2 | -2.4 | -1.8 | -0.4 | -2.3 | -1.6 |
| Government consumption | 0.0 | -0.6 | -1.6 | -2.3 | -2.7 | -3.0 | -3.4 | -4.2 | -1.9 |
| Total investment | 0.0 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 | 2.6 | -0.3 | 0.2 |
| Exports | 0.0 | -0.3 | -0.9 | -1.5 | -2.2 | -2.9 | -4.7 | -1.8 | 0.0 |
| Imports | 0.0 | -2.3 | -2.1 | -1.5 | -0.6 | 0.3 | 4.3 | 1.9 | -0.1 |
| Current account balance (pp of GDP) | 0.0 | 0.4 | 0.4 | 0.4 | 0.3 | 0.2 | -0.5 | -0.9 | -0.4 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 0.1 | 0.4 | 0.8 | 1.2 | 1.5 | 1.9 | -0.1 | -0.3 |
| Consumer prices | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.3 | -0.5 | -0.2 |
| Real exchange rate | 0.0 | 0.4 | 1.1 | 2.0 | 2.9 | 3.7 | 6.3 | 2.4 | 0.0 |
| Import prices | 0.0 | -0.2 | -0.4 | -0.8 | -1.3 | -1.8 | -4.1 | -2.6 | -0.3 |
| Export prices | 0.0 | 0.2 | 0.4 | 0.8 | 1.1 | 1.3 | 1.6 | -0.1 | -0.2 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | -2.1 | -1.9 | -1.3 | -0.7 | -0.2 | 0.6 | -2.7 | -1.5 |
| Expenditures | 0.0 | 12.4 | 13.3 | 14.4 | 15.6 | 16.6 | 20.0 | 1.6 | 1.0 |
| Deficit (pp of GDP) | 0.0 | -2.1 | -2.2 | -2.3 | -2.4 | -2.5 | -2.8 | -0.6 | -0.4 |
| Debt (pp of GDP) | 0.0 | 2.7 | 4.6 | 6.1 | 7.6 | 9.0 | 15.6 | 11.8 | 6.8 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -6.1 | -5.6 | -5.1 | -4.6 | -4.1 | -2.1 | -1.3 | -0.7 |
| Capital stock | -10.0 | -9.1 | -8.3 | -7.5 | -6.8 | -6.1 | -2.8 | -2.0 | -1.0 |

Source: MFMod; World Bank. Authors' calculations.

Note: Table shows deviations as percent from a baseline scenario.

Table C4. The macroeconomic effects of a 10 percent climate-induced shock to capital stock with reconstruction financed by reduction in public expenditure

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|--|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -5.5 | -5.6 | -5.4 | -5.1 | -4.7 | -3.1 | -0.2 | -0.5 |
| Private consumption | 0.0 | -4.7 | -5.0 | -4.9 | -4.4 | -4.1 | -2.7 | -0.5 | -0.3 |
| Government consumption | 0.0 | -43.7 | -44.8 | -45.5 | -46.0 | -46.2 | -45.9 | 0.2 | -0.4 |
| Total investment | 0.0 | 0.2 | 0.7 | 1.2 | 1.8 | 2.3 | 5.1 | -1.0 | -1.1 |
| Exports | 0.0 | 0.1 | 0.2 | 0.3 | 0.4 | 0.4 | 1.4 | 0.6 | -0.3 |
| Imports | 0.0 | -6.3 | -6.5 | -6.4 | -6.0 | -5.7 | -4.8 | -1.8 | -0.6 |
| Current account balance (pp of GDP) | 0.0 | 1.2 | 1.2 | 1.2 | 1.1 | 1.0 | 0.8 | 0.4 | 0.2 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 0.5 | 0.3 | 0.3 | 0.2 | 0.2 | -0.2 | 0.0 | 0.2 |
| Consumer prices | 0.0 | -0.1 | -0.2 | -0.2 | -0.3 | -0.2 | -0.3 | 0.1 | 0.1 |
| Real exchange rate | 0.0 | -0.1 | -0.2 | -0.3 | -0.4 | -0.6 | -1.7 | -0.8 | 0.3 |
| Import prices | 0.0 | -0.1 | -0.1 | -0.0 | 0.0 | 0.1 | 0.9 | 0.8 | -0.1 |
| Export prices | 0.0 | -0.1 | -0.3 | -0.3 | -0.4 | -0.4 | -0.7 | 0.0 | 0.1 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | -5.1 | -5.3 | -5.2 | -4.8 | -4.5 | -3.2 | -0.2 | -0.3 |
| Expenditures | 0.0 | -2.0 | -2.8 | -3.2 | -3.4 | -3.5 | -3.4 | -0.2 | -0.2 |
| Deficit (pp of GDP) | -0.0 | -0.5 | -0.4 | -0.3 | -0.2 | -0.2 | 0.0 | 0.0 | -0.0 |
| Debt (pp of GDP) | 0.0 | 2.0 | 2.2 | 2.3 | 2.2 | 2.0 | 1.1 | -0.4 | -0.1 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -6.1 | -5.6 | -5.1 | -4.6 | -4.1 | -1.7 | -0.8 | -0.7 |
| Capital stock | -10.0 | -9.2 | -8.3 | -7.5 | -6.7 | -5.9 | -2.1 | -1.2 | -1.2 |

Source: MFMod; World Bank. Authors' calculations.

Note: Table shows deviations as percent from a baseline scenario.

Table C5. The macroeconomic effects of a 10 percent climate-induced shock to capital stock with reconstruction financed by increase in public revenue

| | Year 0 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Year 10 | Year 20 | Year 30 |
|--|--------|--------|--------|--------|--------|--------|---------|---------|---------|
| Economic Activity | | | | | | | | | |
| GDP | 0.0 | -2.4 | -2.6 | -2.4 | -2.2 | -2.0 | -1.5 | -2.4 | -1.1 |
| Private consumption | 0.0 | -4.1 | -3.9 | -3.3 | -2.6 | -2.1 | -0.7 | -2.1 | -1.4 |
| Government consumption | 0.0 | -0.6 | -1.2 | -1.7 | -2.0 | -2.1 | -2.5 | -3.9 | -1.7 |
| Total investment | 0.0 | 0.2 | 0.1 | 0.2 | 0.4 | 0.6 | 2.8 | -0.1 | 0.3 |
| Exports | 0.0 | -0.8 | -1.6 | -2.3 | -2.9 | -3.4 | -4.9 | -1.7 | -0.0 |
| Imports | 0.0 | -2.4 | -2.1 | -1.3 | -0.3 | 0.6 | 4.8 | 2.0 | -0.0 |
| Current account balance (pp of GDP) | 0.0 | 0.8 | 0.9 | 0.9 | 0.8 | 0.7 | 0.0 | -0.7 | -0.3 |
| Prices | | | | | | | | | |
| Producer prices | 0.0 | 1.6 | 1.9 | 2.2 | 2.4 | 2.6 | 2.7 | -0.0 | -0.3 |
| Consumer prices | 0.0 | 1.8 | 1.8 | 1.7 | 1.7 | 1.7 | 1.4 | -0.4 | -0.2 |
| Real exchange rate | 0.0 | 2.8 | 3.8 | 4.7 | 5.5 | 6.2 | 8.4 | 2.3 | 0.1 |
| Import prices | 0.0 | -0.5 | -1.1 | -1.7 | -2.3 | -2.9 | -4.9 | -2.4 | -0.3 |
| Export prices | 0.0 | 0.3 | 0.5 | 0.7 | 0.9 | 1.0 | 1.1 | -0.0 | -0.2 |
| Fiscal | | | | | | | | | |
| Revenues | 0.0 | 15.5 | 15.6 | 16.0 | 16.5 | 16.9 | 17.7 | -2.4 | -1.4 |
| Expenditures | 0.0 | 14.0 | 14.0 | 14.2 | 14.4 | 14.6 | 15.0 | -2.3 | -1.7 |
| Deficit (pp of GDP) | 0.0 | -0.3 | -0.3 | -0.3 | -0.2 | -0.2 | -0.1 | -0.0 | 0.0 |
| Debt (pp of GDP) | 0.0 | 0.5 | 0.6 | 0.6 | 0.6 | 0.6 | 0.7 | 1.4 | 0.2 |
| Supply Side | | | | | | | | | |
| Potential GDP | 0.0 | -6.1 | -5.6 | -5.1 | -4.6 | -4.2 | -2.1 | -1.1 | -0.6 |
| Capital stock | -10.0 | -9.2 | -8.4 | -7.6 | -6.9 | -6.2 | -2.9 | -1.8 | -0.9 |

Source: MFMod; World Bank. Authors' calculations.

Note: Table shows deviations as percent from a baseline scenario.