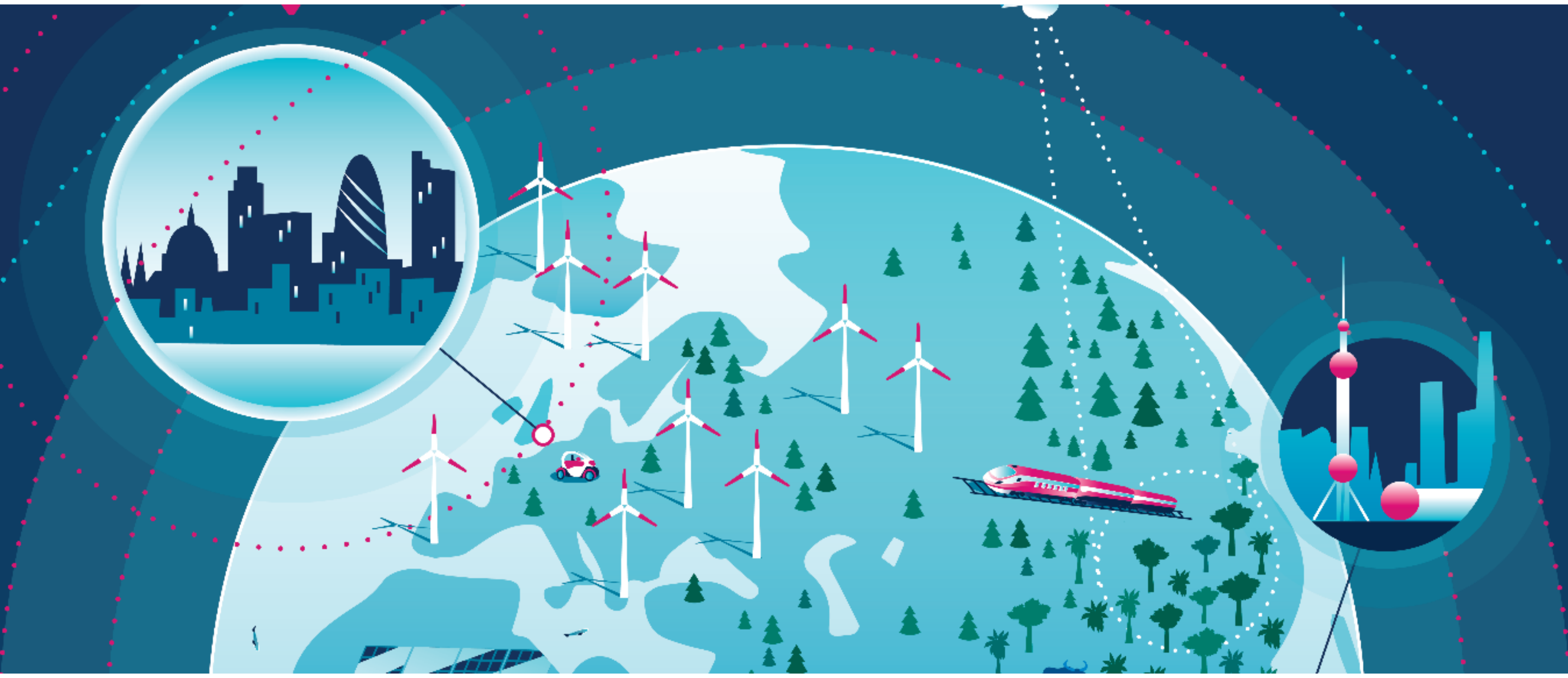
# Guidelines for quantifying disaster-related fiscal risks in Ethiopia



Federal Democratic Republic of Ethiopia Ministry of Finance

# Executive Summary

**Disasters pose a significant and increasing risk to Ethiopia's fiscal stability.** Ethiopia is vulnerable to a range of climatic and humanitarian disasters, including droughts, floods, pests, landslides, earthquakes, volcanos, epidemics and ethnic conflict. These disasters can reduce government revenues and increase government expenditure to an extent that may threaten fiscal stability. For example, the 2015/16 El Nino induced drought resulted in additional fiscal support of 18 billion Birr and tax revenue shortfalls compared to target. By the same token in 2015/16 real GDP grew by 8 percent compared to 10.4 percent growth in 2014/15 due to rainfall shortage which affected the agricultural production (Federal Government of Ethiopia, 2019; Ministry of Finance, 2019). As Ethiopia's economy develops, its population urbanises and the effects of climate change take hold, the fiscal impacts of disasters are expected to become more material.

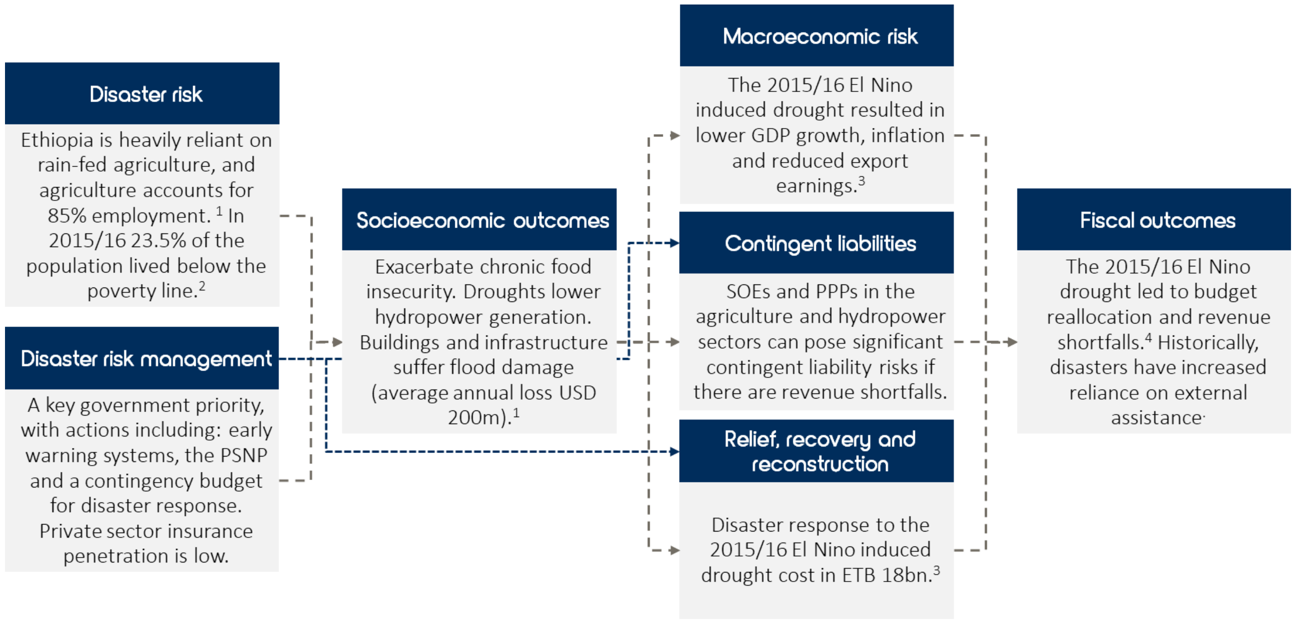
**These guidelines build on earlier work by the Ministry of Finance (MoF) to better understand and manage these risks.** The MoF's 2019 Fiscal Risk Statement (FRS) represents an important first step in identifying disaster-related fiscal risks, but the channels through which hazards affect the government's fiscal position and the magnitude of their prospective impacts are not comprehensively analysed. These guidelines outline an analytical framework and accompanying Excel tool for quantifying disaster-related fiscal risks, which will strengthen the Fiscal Policy Directorate's capacity to understand, analyse and manage these risks.

**The report identifies critical pathways through which floods and droughts have fiscal impacts and sets out a methodology for quantifying these impacts.** Droughts and floods are the most important natural hazards faced by Ethiopia, respectively affecting 1.5 million and 250,000 people per year on average (World Bank, 2019a). They affect Ethiopia's economy and society in different ways, with droughts affecting larger numbers of people but floods leading to more severe damages to assets and infrastructure. The approach to estimating the fiscal consequences of these risks combines 'bottom-up' and 'top-down' approaches adopted internationally, tailored to match the critical impact channels in Ethiopia, available data and implementing capacity. It measures impacts through three main pathways:

- **Macroeconomic risks**, as impacts of disasters on production and trade propagate through the economy, affecting tax revenues, spending levels and Ethiopia's trade balance. Impacts of floods and droughts on export earnings from hydro-power generation and agricultural commodities are expected to be particularly material.
- **Contingent liabilities** that can be triggered by the disaster, including implicit contingent liabilities where the government is widely expected to support households and businesses. Liabilities related to state-owned entities (SOEs) and public-private partnerships (PPPs) are an important component of this for Ethiopia.
- **Relief, recovery and reconstruction costs** in order to respond to the disaster. The Ethiopian state is expected to bear a higher share of these costs, relative to international assistance, as its economy grows to attain middle income status.

Fiscal outcomes are summarised using indicators of long-term debt sustainability and short-term fiscal stability.

Figure 1 Pathways of drought and flood related fiscal risks in Ethiopia




Source: Vivid Economics with information from 1) (World Bank, 2019b); 2) (FDRE National Planning Commission, 2017); 3) (Ministry of Finance, 2019) and 4) (Federal Government of Ethiopia, 2019)

**Going forward, the framework can be disseminated and integrated into decision making.** This can take place on three levels:

- The framework of impact pathways gives a narrative basis for understanding the fiscal risks from flood and drought. This can be used by the government in activities to manage its fiscal exposure – for example through negotiating terms of PPPs – and in assigning ownership of sources of risk across government, which can improve incentives to manage risks (IMF, 2008).
- Once risks have been quantified, the analysis can be used to prioritise risk management activities and to develop a disaster risk finance strategy. This will reduce risks where doing so offers value for money, and make cost effective use of disaster risk finance instruments to provide post-disaster funding, following a risk layering approach.
- By publishing information on fiscal risks and planned mitigation in the FRS, the government can foster investor confidence in the stability of its fiscal position.

**These guidelines can serve as a live document, as risk information developed through the framework can be continually updated, refined and extended.** Key aspects of this will be in increasing the coverage of hazards and in explicitly linking fiscal risk information to disaster risk management and finance strategies.

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# Acronyms and abbreviations

| | | | |
|---|---|---|---|
| ART | Alternative Risk Transfer (instruments) | GoE | Government of Ethiopia |
| CAPRA | Central America Probabilistic Risk Assessment Platform | GVA | Gross Value Added |
| CAT | Catastrophe (bonds) | HRD | Humanitarian Requirements Document |
| CATSIM | IIASA's Catastrophe Simulation Model | IIASA | International Institute for Applied Systems Analysis |
| COVID-19 | Coronavirus disease | IMF | International Monetary Fund |
| DRF | Disaster Risk Financing | MEFF | Medium-Term Macroeconomic and Fiscal Framework |
| DRM | Disaster Risk Management | MoA | Ministry of Agriculture |
| DRR | Disaster Risk Reduction | MoF | Ministry of Finance |
| ECRC | Environment and Climate Research Centre | MoR | Ministry of Revenues |
| FAO | Food and Agriculture Organisation of the United Nations | NDRMC | National Disaster Risk Management Commission |
| FCDO | Foreign, Commonwealth & Development Office | ODA | Offical Development Assisstance |
| FDRE | Federal Democratic Republic of Ethiopia | OECD | Organisation for Economic Cooperation and Development |
| FOREX | Foreign Exchange Market | PPP | Public Private Partnership |
| FRS | Fiscal Risk Statement | PSNP | Productive Safety Net Programme |
| FSM | Federated States of Micronesia | SAM | Social Accounting Matrix |
| FST | Fiscal Stress Test | SOE | State Owned Enterprise |
| GDP | Gross Domestic Product | SPEI | Standardised Precipitation-Evapotranspiration Index |
| GERD | Grand Ethiopian Renaissance Dam | UKSA | UK Space Agency |
| GEXFR | Gross External Financing Requirements | WTO | World Trade Organisation |

# Introduction

**The high risk of disasters in Ethiopia poses threats to the country's fiscal stability.** Disaster-related fiscal risk refers to the deviation in fiscal outcomes from budget or fiscal projections due to disaster (IMF, 2016). Ethiopia is vulnerable to a number of climatic and humanitarian disasters, including droughts, floods, pests, landslides, earthquakes, volcanos, epidemics and ethnic conflict. These disasters can cause tax revenues to be lower than expected and / or increase expenditure, to an extent that may threaten fiscal sustainability. For example, the 2015/16 El Nino induced drought resulted in additional fiscal support of 18 billion Birr and tax revenue shortfalls compared to target. By the same token in 2015/16 real GDP grew by 8 percent compared to 10.4 percent growth in 2014/15 due to rainfall shortage which affected the agricultural production (Federal Government of Ethiopia, 2019; Ministry of Finance, 2019).

**These guidelines build on earlier work by the Fiscal Policy Directorate to quantify disaster-related fiscal risk – and when implemented can help strengthen DRM.** The Fiscal Policy Directorate has made an important first step in identifying these disaster-related fiscal risks, as evidenced by the 2019 FRS. However, the quantification of these risks is not currently done in a systematic way. Quantifying disaster-related fiscal risk could be used to inform the Medium-Term Macroeconomic and Fiscal Framework (MEFF) and fiscal policy, as well as supporting broader objectives within the Federal Democratic Republic of Ethiopia (FDRE) for DRM. These guidelines outline an analytical framework for quantifying disaster-related fiscal risk, which will strengthen the Fiscal Policy Directorate's capacity to understand, analyse and manage these risks. The guidelines focus on two hazards (drought and flood) but can be extended to analyse other risks.

**The guidelines for flood, drought, epidemics and pests rest on a common analytical framework, tailored to Ethiopia's needs.** The framework estimates the physical and social impacts of four key hazards, mapping the channels of impact to economic and fiscal outcomes. The accompanying Excel tool estimates the macroeconomic effects of disasters and calculates the impact on fiscal health indicators. This approach draws on international best practice for modelling disaster-related fiscal risks, but has been adapted to take into account the specific nature of risks in Ethiopia, the capacity of the MoF, data availability and the need to create usable outputs.

**These guidelines have been prepared by Vivid Economics, the Environment and Climate Research Centre (ECRC) at the Policy Studies Institute and OPM in collaboration with the MoF, line ministries and international development partners under FCDO's Building Resilience in Ethiopia (BRE) programme, co-financed by United States Agency for International Development (USAID)**. BRE encompasses all bilateral humanitarian assistance from the UK's Foreign, Commonwealth, and Development Office (FCDO) to resident Ethiopians affected by climate and humanitarian shocks; the programme intends to contribute to the objective of an 'Ethiopia that is more resilient to climate and humanitarian shocks. OPM is the Managing Agent for the provision of technical assistance under the BRE programme working across four workstreams, namely emergency health, disaster management, scalable safety nets, and disaster risk finance.

**These guidelines are structured across four chapters:**

- Chapter 1 explains how disasters can pose risks to fiscal sustainability and suggests some benefits to quantifying these risks;
- Chapter 2 sets out key climate and humanitarian hazards in Ethiopia and describes how these impact fiscal outcomes;
- Chapter 3 outlines how key disaster-related fiscal risks can be quantified using the Excel tool; and
- Chapter 4 suggests some next steps in integrating disaster-related fiscal risk analysis into a Fiscal Risk Statement, disaster risk financing strategy, and disaster risk reduction policies.

# 1 Disaster-related fiscal risks

**This chapter frames the way in which fiscal risks can stem from disasters and explains how understanding these risks can support policymaking.** Section 1.1 outlines the components of disaster risk and explains how fiscal risks can result from disasters. Section 1.2 then explains how quantifying disaster-related fiscal risk can support policymakers understand and plan for these risks.

## 1.1 The fiscal risks posed by disasters

**Disasters induce a serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses (Seck, 2007).** Disaster risk reflects the incidence of underlying hazards, the people and assets exposed to hazards, and the vulnerability of those exposed:

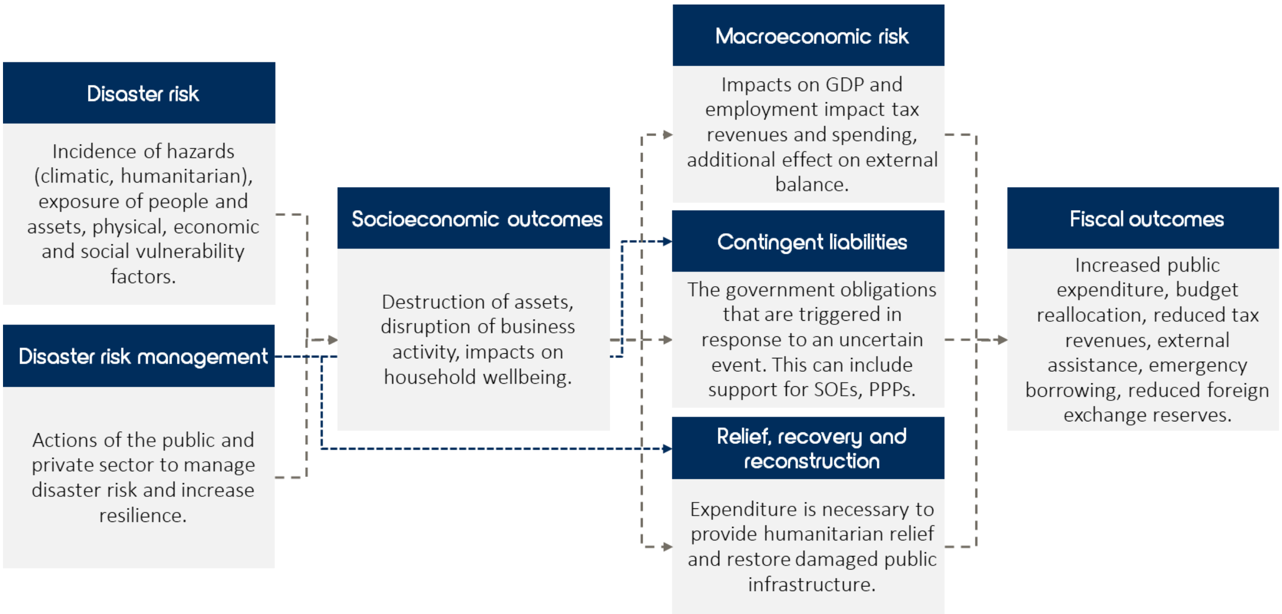
- A hazard is a process, phenomenon or human activity that may cause health impacts, property damage, social and economic disruption or environmental degradation. Hazards events include geological, meteorological, hydrological, climatological, oceanic, humanitarian and biological hazards often characterised by their location, frequency, magnitude and likelihood. These include floods, droughts, earthquakes, epidemics, conflict, pests and storms.
- Exposure is the situation of people, infrastructure, housing, production capacities located in hazard-prone areas. Measures of exposure can include the number of people per square kilometre or the types of assets in the area such as factories, hospitals and agricultural production.
- Vulnerability reflects physical, social, economic and environmental factors or processes that determine the susceptibility of an individual, a community, assets or systems to the impacts of hazards. This multidimensional factor spans building design, incidence of poverty and the efficacy of emergency response plans.

**Disaster risk management (DRM) includes pre- and post-disaster measures to improve economic and societal resilience to disasters.** Ethiopia is a signatory to the Sendai Framework for Disaster Risk Reduction (DRR), which aims to achieve 'the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries' (UNISDR, 2015). The framework is structured around four priorities for action:

- *understanding disaster risk* – understand disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment;
- *strengthening disaster risk governance to manage disaster risk* – define roles and responsibilities to guide, encourage and incentivise the public and private sectors to take action and address disaster risk;
- *investing in DRR for resilience* – public and private investment in disaster risk prevention and reduction through structural and non-structural measures;
- *enhancing disaster preparedness for effective response, and to Build Back Better in recovery, rehabilitation and reconstruction* – strengthen disaster preparedness for effective response and ensure capacities are in place for effective recovery.

**Disasters pose a frequent and sizeable source of fiscal risk.** Between 1950 and 2015, 40 countries experienced natural disasters that caused damage in excess of 10% of GDP (IMF, 2018). Natural disasters can also lead to significant reductions in household income and human capital investment, with a study in the Philippines showing household income declined by 6.6% for those directly affected in the year following a typhoon (GFDRR, 2014). The uncertain yet recurring nature of many types of disasters means that countries that are particularly susceptible face persistent uncertainty over both current and future tax revenue and government expenditure. Figure 2 outlines how hazards map onto fiscal outcomes. There are three main channels of fiscal risk: disaster relief, recovery and reconstruction; contingent liabilities and macroeconomic risk. These are outlined in the sections below.

Figure 2 Disaster impacts on individuals and assets result in fiscal risks to public balances




Note: Grey arrows indicate channels of impact, while blue arrows indicate mediating factors.
Source: Vivid Economics

**Public expenditure increases in response to a disaster due to relief, recovery and reconstruction costs.** Governments provide aid and support to those who are affected by disasters, relieving them of some of the economic, social and environmental costs incurred. The government may also have responsibility for repairing damaged public infrastructure and strengthening community resilience.

**Contingent liabilities are government obligations that are triggered when an uncertain event happens.** Explicit liabilities are legally binding liabilities such as pay-outs through government-backed insurance schemes in response to drought-driven crop losses. In addition to explicit liabilities, governments may face implicit liabilities, where the government bears no legal responsibility to respond but there is a public expectation of government assistance (IMF, 2016). These include the expectation that public infrastructure will be repaired following a flood,[1] or that government will support private sector businesses that are negatively impacted by a disaster. PPPs and SOEs can represent significant explicit and implicit contingent liabilities – for example there may be the expectation that the government will cover losses if a PPP project fails (an implicit liability), or there may be contractual obligations for the government to support these projects such as service level guarantees (explicit liabilities). A robust legal framework that clearly defines all contingent liabilities can help the government to understand and manage the risks they are exposed to, and manage expectations of both public and private entities when it does.

**Disasters also pose macroeconomic risk to fiscal outcomes.** The macroeconomic consequences of a disaster encompass *direct* economic impacts, where the disaster impairs production or trade or damages assets, and *indirect* impacts as a result of knock-on impacts on value chains or trading relationships. For example, a drought may reduce hydropower electric output, directly reducing output in the energy sector, then indirectly

[1] Note that fiscal risks associated with both disaster relief, recovery and reconstruction and macroeconomic risk can be expressed in the form of a contingent liability. For example, repairing damaged infrastructure would fall into the category of both disaster relief, recovery and reconstruction and a contingent liability. Similarly, increases in social safety net programmes may be an example of macroeconomic risk or a contingent liability. The framework outlined in Chapter 2 categorises different sources of risk clearly to ensure that there is no double counting of impacts.

reducing output in sectors such as manufacturing that require electricity for production. A reduction in GDP growth below expectations will typically result in lower than expected tax revenues and higher spending on social security. The disaster may also prompt fiscal stimulus measures to be introduced. Furthermore, the reduction in economic output can result in lower exports, which can threaten foreign exchange reserves and precipitate currency, debt or financial crises.

**Fiscal risks threaten the sustainability and stability of public finances.** Through the three channels outlined above, disasters can result in unplanned government expenditure, lower than forecast tax revenues and changes to the external balance. To meet the additional burdens caused by disaster, governments may be obliged to reallocate budget away from planned priorities, which may threaten long-term economic development. The government may alternatively meet spending requirements by raising tax rates, seeking concessional finance (loans or grants) from development partners or increasing debt. The disaster may result in a weaker exchange rate, which may increase debt servicing costs. If the government becomes unable to service or refinance its debt, this can result in severe instability, further exacerbating the negative impact of disaster on the macroeconomy.

## 1.2 The benefits of quantifying disaster-related fiscal risk

**There are three main benefits to analysing disaster-related fiscal risks:**

- **Disaster preparedness**: Governments that quantify disaster-related fiscal risks can put in place tailored risk management strategies to effectively mitigate against disasters. An understanding and awareness of the economic and fiscal impact of disasters can guide policy development and inform government investment in DRR strategies. This can reduce the likelihood of risks materialising, and limit the costs when they do.

- **Disaster risk financing:** Understanding disaster-related fiscal risk is a key step in designing disaster risk financing strategies, leading to a more cost-effective and timely response. Given the fiscal risks disasters pose, governments want to manage these risks to strengthen fiscal sustainability. Governments can draw on a range of DRF instruments to manage the fiscal risks associated with disasters. If well-designed, these instruments can support the timely delivery of funds in response to disaster, reducing the longer-term effects, and be cost-effective in responding to disaster. A summary of measures and financing strategies used by governments to manage disaster-related fiscal risks is outlined below in Box 1.

- **Investor confidence**: Robust analysis of disaster-related fiscal risks can also help underpin creditworthiness and improve market confidence (IMF, 2016). Quantifying disaster-related fiscal risks is essential for understanding the sustainability of the government's fiscal position. Conducting these assessments improves the government's creditworthiness and strengthens market confidence.

Box 1 Disaster risk financing

**DRF strategies are measures and sources of finance used by governments to finance response, recovery and reconstruction post-disaster.** Disasters vary in both their severity and frequency. A successful DRF strategy therefore often requires a combination of different instruments to provide cost-effective and timely responses. These instruments are categorised as ex-post and ex-ante:

- **Ex-post instruments** are sources that do not require advance planning and are implemented following a disaster. These include budget reallocations, domestic credit, external credit, tax increase and donor assistance. Ex-post instruments can offer the benefit of flexibility, but are unlikely to provide sufficient, timely funding for extreme disasters, which can threaten debt sustainability. In particular, while grant financing from donors is the cheapest source of financing, this can often be driven largely by media coverage, making donor assistance difficult to predict, and can be allocated to specific areas, reducing flexibility (Ghesquiere & Mahul, 2010).

- **Ex-ante instruments** are sources that require proactive planning and include risk transfer mechanisms, reserves, calamity funds, budget contingencies and contingent debt facilities. Whilst ex-ante instruments can allow for faster mobilisation and greater quantities of funding after a disaster than ex-post instruments, this often comes at a higher cost.
- **Risk transfer mechanisms allow risks to be ceded to a third party.** Risk transfer mechanisms allow government to shift the burden of the risk, reducing uncertainty in its fiscal position. These instruments include traditional indemnity insurance and reinsurance, parametric insurance and Alternative Risk Transfer (ART) instruments such as catastrophe (CAT) bonds (see Section 4.2).

**Effective DRF strategies use a risk layering approach, including a mix of ex-ante, ex-post and risk transfer mechanisms.** Risk layering places a heavier reliance on risk transfer instruments for low frequency, high impact events, and covers lower impact events using 'risk retention' instruments such as contingency budgets, which provide limited funding capacity at lower cost. Section 4.2 provides more details on DRF instruments and how effective DRF strategies can help economies recover from disasters.

# 2 Identifying disaster-related fiscal risks in Ethiopia

**This chapter sets out relevant aspects of the Ethiopian context and outlines the key fiscal risks associated with floods, droughts, epidemics and locust upsurge.** Drought and flooding are the two most material climatic risks Ethiopia faces (World Bank, 2019a)**.** The framework set out in this chapter also identifies the fiscal risks associated with epidemics and pests, which incorporate further fiscal impacts and extend the framework to cover a non-climatic hazard. The resulting framework is widely applicable and can incorporate additional risks in the future. Section 2.1 provides an overview of key disaster risks in Ethiopia – and how these give rise to fiscal risks. Section 2.2 presents a theoretical framework to support the MoF identify key disaster-related risks. The following chapter details how these key risks can be quantified and assessed using the accompanying Excel tool.

## 2.1 Disaster-related risks in Ethiopia

**Ethiopia experiences frequent and severe droughts**, which exacerbate food insecurity and result in the loss of productive assets and livelihood opportunities. On average, 1.5 million people are exposed to drought annually (World Bank, 2019a). However, there is significant annual variability. In 2015/16 a failed Belg rain was followed by the deepest El Nino drought on record, which resulted in a humanitarian crisis, with half a million people displaced (OCHA, 2020). Droughts have large-scale impacts due to the importance of rainfed agriculture to the Ethiopian economy. The agricultural sector accounts for around half of Ethiopia's GDP, the majority of exports and two-thirds of the labour force (World Bank, 2020a), is highly reliant on rainfall. Moreover, most agricultural workers in Ethiopia are smallholders who may be less resilient to annual fluctuations in production and more vulnerable to poverty and food insecurity. In addition to agriculture, the hydropower sector is vulnerable to drought (Box 2). Hydropower already supports 90% of the country's electricity use, and there is ambition to increase hydropower PPPs and export capacity (World Bank, 2014).

**Riverine (flash) flooding is another frequent natural disaster in Ethiopia**, particularly in the low-lying river basins. These floods pose significant risks to human health, as well as resulting in displacement and crop and livestock losses. Flooding in 2019 impacted more than 795,400 persons and caused severe damage to infrastructure (including schools, health facilities and water supply schemes) and livelihoods (OCHA, 2020). On average, 250,000 people per year are exposed to flooding (World Bank, 2019a) and 117,000 are displaced (OCHA, 2020). Unlike drought, the most significant fiscal risks of flooding come from the physical impacts, resulting in increased construction costs and economic disruption to sectors reliant on damaged infrastructure. Floods also impact populations in urban areas, particularly in Addis Ababa, which has the country's main transport infrastructure.

Box 2 Drought and hydropower production in Ethiopia

**Ethiopia has long understood the potential for hydropower generation and irrigation on the Nile River as an opportunity for development and growth.** The country has some of the richest water resources on the continent with an estimated exploitable hydropower potential of 45,000 MW (Degefu, He, & Zhao, 2015). The first hydropower dams built in Ethiopia were located on the Nile River and were comparatively small in scale. However, the construction of the Grand Ethiopian Renaissance (GERD) and the Gilgel Gibe III dams marked a shift towards large scale hydropower infrastructure in the country. Once in operation, GERD will be the largest hydroelectric power plan in Africa and the seventh largest in the world with an installed capacity of power of 5,150 MW.[2] Today the country's hydropower generation accounts for approximately 84% of its total electricity production.

[2] Government of Ethiopia (2020).

**Climate change impacts the reliability of hydropower generation as a consistent source of energy production in eastern and southern Africa region.** By 2030, it is expected that 70% of total hydropower capacity will be located in an area subject to high levels of rainfall variability, increasing the risk of concurrent climate-related electricity supply disruption.[3] A World Bank study (2013) on the effects of climate change on Ethiopia developed a hydropower simulation to estimate the climate change impacts on annual power production up to 2050, identifying a critical need for investments into climate-resilient hydropower infrastructure[4]. Ethiopia's vulnerability and dependence on temperamental hydropower is in part due to its location amid eight major river basins. The Nile Basin, which represents 32% of Ethiopia's land area, holds around 40% of its population. The basin is dominated by the Nile's largest river, the Blue Nile, which contributes about 85% of the water that makes up the main Nile.

**The history of droughts in Ethiopia has shown the significant impact of water scarcity on the energy sector.** Just a 5% decrease in annual rainfall can decimate the country's hydropower generation. Previous experiences during prolonged dry periods have led to government rationing, the halting of exports, reduced industrial activity, as well as rolling blackouts (i.e. temporary power outages). In 2018, the prolonged dry period led to a power deficit of nearly 500MW. The drought of 1983/1984 in Ethiopia led to water levels in dams and reservoirs dropping markedly, creating a shortage in water availability and power production (electricity rationing).[5] Similarly, the rainfall failure during the long season in 1991/1992 led to a significant power production decline and water supply and electricity was rationed for cities and towns in Ethiopia.[6]

**A number of variables affect hydropower production in Ethiopia, including rain fall, water availability (run off), reservoir storage, and intersectoral competition for water, such as municipal and industrial water demands.** Under a climate change scenario in which there is increased rainfall and higher average river flow in Ethiopia, the proposed hydropower projects could generate larger volumes of hydropower than the baseline. However, in climate change scenarios in which the frequency and/or impacts of droughts and dry weather events increase, resulting in lower average river flows, energy production in Ethiopia would experience a significant decline compared to baseline conditions. The complexity of the dynamics between predicting weather events and the factors affecting hydropower production and demand means that numerous assumptions must be made in order to model the potential effects of droughts on hydropower generation. For instance, it is assumed in the World bank Study (2013) that, under water scarcity, resources would be allocated first to municipal and industrial demands, followed by irrigation, with hydropower production receiving access to the residual volume of water.

In addition to droughts and floods, Ethiopia is vulnerable to landslides, earthquakes, volcanoes, pests, biological and humanitarian disasters.

- Epidemic risks relate to a variety of pathogens, in particular cholera due to limited progress on water and sanitation access and increased flood risk. An estimated 70 million people in Ethiopia are at risk of cholera, leading to more than 275,000 cases and 10,000 deaths each year. These outbreaks are most common in Addis Ababa, particularly during the rainy season. Ethiopia is also increasingly vulnerable to other waterborne and human-to-human transmissible diseases (Dinede, Abagero, & Tolosa, 2020). According to EM-DAT, a database of international disasters, Ethiopia has had 28 epidemic events between 1970 and 2019, including outbreaks of dysentery, measles, meningococcal disease, poliovirus, yellow fever and others. COVID-19 has shown that epidemics and pandemics can put untenable pressure on public health systems and devastate the economy, increasing the impetus for fiscal preparedness.

[3] Conway,e t al., 2017.
[4] Robinson et al., 2013. World Bank Study.
[5] Alem Mera (2018).
[6] Ibid.

- **The Horn of Africa is currently facing the worst desert locust crisis in 25 years,** potentially putting at risk the 80% of people in Ethiopia who rely on agriculture and livestock for food security. The current invasion affects agricultural production in Southwest Asia and the Middle East in addition to Ethiopia, Kenya and Somalia. The swam in Ethiopia has been consuming more than 1.7m MT of vegetation per day. Due to the regional production effects, there is increasing pressure on food security and food prices. The FAO has requested more than USD 300m to expand rapid control and surveillance operations to maintain the outbreak (FAO, 2020b). While locust invasions have not been a frequent hazard in recent decades, the link to extreme weather means that these events may become a more regular risk.

- **Earthquakes, volcanoes and landslides cause less economic damages than floods and droughts, but still put a significant number of people at risk each year.** Landslides have the potential to cause more than USD 3 million in building damage and put 1,000 people at risk each year. The probability of earthquakes is much lower, but a 1-in-50 year event could put 300,000 people at risk (The World Bank, 2019).

**Due to the effects of climate change, Ethiopia can expect droughts, floods, epidemics, and locust risk to become more frequent and intense.** Continued population growth and rapid urbanisation are likely to increase exposure and risk, particularly to floods and epidemic risks.

## 2.2 Theoretical framework

**This section provides an overview of the theoretical framework which maps how key hazards manifest in fiscal risks and have a knock-on effect on the health of the wider macroeconomy in Ethiopia.** It has the following components, as set out in Figure 3 below.

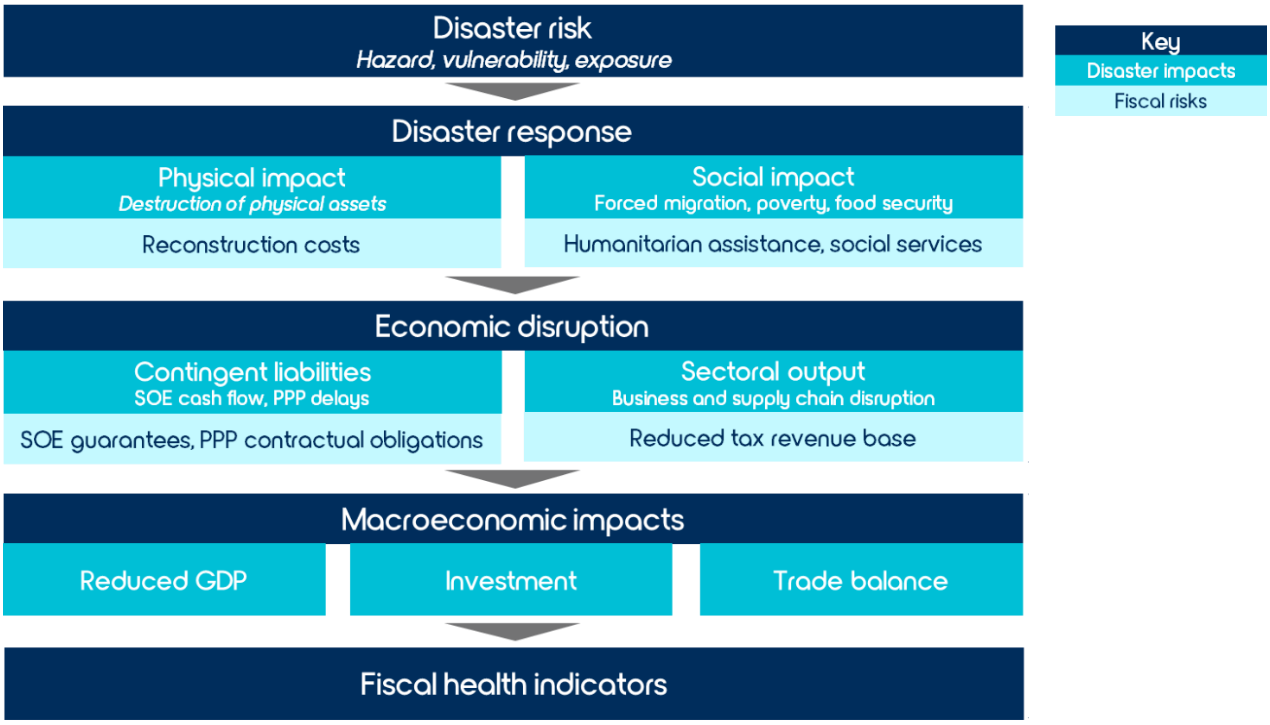
- **Physical and social impacts:** Droughts, floods and locust invasions can destroy property and crops, force displacement, and cause health impacts and food or energy shortages, leading to increased public expenditures. Epidemics can disrupt livelihoods, increasing the proportion of the population requiring social assistance. Waterborne epidemics like cholera can also contaminate food sources and necessitate increased food imports or humanitarian aid.

- **Economic disruption:** Droughts, floods and locust invasions can disrupt exposed sectors of the economy, particularly agriculture. Fiscal risks include reduced tax receipts from productivity losses in key sectors and liabilities from PPPs and SOEs in exposed sectors. Epidemics can cause missed work time and reduced productivity. In the case of highly transmissible diseases like COVID-19, quarantines or restrictions on socialisation can affect tourism and hospitality sectors.

- **Macroeconomic impacts:** The physical, social and economic impacts of disasters can have wider macroeconomic implications in both the short and the long term, impacting GDP, public and private investment in key services and infrastructure and potentially causing a deterioration in Ethiopia's external balance.

- **Fiscal health impacts:** A natural or humanitarian disaster likely increases the amount of public debt and may also decrease GDP. The duration of impacts will depend on the nature of the disaster and the government response. For a natural disaster like drought, the impact on GDP growth may be long term if sufficient and timely action is not taken, and households are forced to sell productive assets such as livestock. The impact of a flood may also be longer term due to the destruction of physical capital. Disasters may make it more costly to finance maturing external debt, increase short-term borrowing, and lead to a deterioration on the current account balance of payments.

Figure 3 Analytical framework overview




Source: Vivid Economics

### 2.2.1 Estimates of fiscal costs of drought

As explained in Section 2.1, droughts are the most impactful and highest cost recurring hazard in Ethiopia. Table 1 presents the key channels through which droughts give rise to disaster response costs for the government and can trigger contingent liabilities. It provides an indicative coding of the likelihood of each risk manifesting in a fiscal impact and the magnitude of that risk in order to prioritise quantification.[7]

Table 1 Fiscal risks associated with droughts

| Impact | Fiscal risk | Likelihood | Severity |
|---|---|---|---|
| Social | Humanitarian aid expenditure | | |
| Physical | Environmental degradation[8] | | |
| Economic disruption | Tax revenue collection | | |
| | SOE liabilities | | |
| | PPP liabilities | | |

Note: Red indicates high risk, amber indicates medium risk, green indicates low risk; RAG coding of risks has been validated with relevant Government ministries.

Source: Vivid Economics

[7] The coding is based on stakeholder interviews and reporting on the experience in Ethiopia of previous droughts, including evidence presented in Section 2.1. The likelihood of risks manifesting may change over time as a result of climate change, and the severity of impacts with vary with the severity of hazards.

[8] Drought can degrade the environment in the long-term by putting stress on wildlife and reducing biodiversity, lower levels in environmental waters, increasing wildfires and eroding soil quality. These longer-term impacts affect the productivity of natural capital and therefore may affect economic growth. These effects are more difficult to quantify and are therefore not included in this framework.

### Social and physical impacts

**Drought has significant impacts on livelihoods and food security, resulting in Government expenditure on humanitarian and food assistance.** Crop and livestock losses from drought result in downstream food shortages and higher food prices, leading to higher incidence and severity of food stress. This puts additional pressure on social security programmes, such as the PSNP which supports chronically food insecure and poor households. With an average of 1.5 million people in Ethiopia affected by drought each year, humanitarian assistance is usually required to meet needs. Over the last decade, approximately 40% of these social assistance needs have been unmet, resulting longer term implications for economic and social indicators, such as food gaps, nutrition, health and education. Since droughts often affecting the same populations each year in drought-prone regions, the use of ad hoc humanitarian financing for predictable social security needs is not a sustainable policy response. Even though the PSNP is shown to deliver a more cost-effective response than humanitarian assistance, the costs of meeting those needs in response to an average annual drought event still amount to USD 940 million (World Bank, 2017).

**Drought can also have impacts on the environment including decreased biodiversity, poorer soil quality, lowered water levels and increased wildfires**. These longer-term impacts affect the productivity of natural capital and therefore may affect economic growth. However, they are less likely to create fiscal stress, are more difficult to quantify and are therefore not included in this framework.

### Economic disruption

**Economic disruption to the agricultural and hydropower sectors can trigger liabilities related to PPPs and SOEs.**

**Agriculture and hydropower are two key sectors in Ethiopia exposed to drought, putting government revenue collection at high risk.** The shocks to these two sectors can cause reductions in government revenue collections and may propagate through the wider economy, reducing productive capacity of other sectors through supply chain impacts.

**The Government may be exposed to hydroelectric and agricultural SOE liabilities if drought reduces cashflow.** Water shortages from droughts limit production of hydroelectric power, which is the primary source of Ethiopia's domestic electricity needs and some of which is already being exported to Sudan and Djibouti (Manson, 2014). Hydropower SOEs Ethiopian Electric Power and Ethiopian Electric Utility had combined losses of ETB 4.6 million in 2018 (PEFA, 2019). Agricultural and agricultural processing SOEs like the Ethiopian Sugar Corporation will also face disruptions and may face challenges in servicing their debt. The Sugar Corporation is highly leveraged (Kamski, 2019).

**Droughts can affect the performance of PPPs in hydropower, increasing the likelihood of project delays or project failures and Government liabilities.** Drought reduces stream flow and therefore affects the storage capacity and generation potential of dams. Accordingly, hydropower projects are particularly vulnerable to droughts and may be delayed. The value of the average hydropower project in the initial pipeline is USD 1.2 billion. Current hydropower PPP project values are USD 7.2 billion (Ministry of Finance, 2019).

### 2.2.2 Estimates of fiscal impacts of floods

**As explained in Section 2.1, floods in Ethiopia damage assets and infrastructure, displacing populations and disrupting livelihoods.** Table 2 presents the key channels through which floods give rise to disaster response costs for the government and can trigger contingent liabilities. It provides an indicative coding of the likelihood of each risk manifesting in a fiscal impact and the magnitude of that risk in order to prioritise quantification.[9]

Table 2 Fiscal risks associated with floods

| Impact | Fiscal risk | Likelihood | Severity |
|---|---|---|---|

[9] The coding is based on stakeholder interviews and reporting on the experience in Ethiopia of previous floods. The likelihood of risks manifesting may change over time as a result of climate change, and the severity of impacts will vary with the severity of hazards.

| | | | |
|---|---|---|---|
| Social | Humanitarian aid expenditure | | |
| Physical | Reconstruction of uninsured or underinsured private housing and public assets; Environmental degradation[10] | | |
| Economic disruption | Tax revenue collection | | |
| | SOE liabilities | | |
| | PPP liabilities | | |

Note: Red indicates high risk, amber indicates medium risk, green indicates low risk; RAG coding of risks has been validated with relevant Government ministries.

Source: Vivid Economics

### Social and physical impacts

**River flooding can destroy private property and livelihoods, resulting in increased expenditure on relief and humanitarian aid.** Immediate relief costs include building temporary shelters, providing medical care and distributing food assistance to populations that rely on pastoral activities for food security.

**Flood damages to public assets can result in increased expenditure on reconstruction costs.** Public assets which are vulnerable include government buildings, healthcare and education facilities, as well as transportation infrastructure. Flooding reconstruction costs USD 200 million on average annually in damages to buildings alone, including public health and education facilities. (World Bank, 2019a).

### Economic disruption

**Damaged capital can cause business disruptions, slow economic growth and hinder disaster recovery.** In Ethiopia, riverine floods tend to be more localised, meaning that the scale of economic disruption is typically smaller than drought losses.

**Flooding impacts on agriculture can affect government revenue receipts.** On average, USD 3.5 million worth of crops are damaged by floods, rising to USD 25 million in crop damages in the most extreme flood years (World Bank, 2019a).

**Flooding may damage infrastructure which is critical for SOEs or PPPs, creating increased Government liabilities.** Flooding may affect production facilities, distribution networks and supply chains, leading to inefficiencies and loss of output for SOEs. The most directly impacted enterprises are those involved in transportation infrastructure, construction, logistics and shipping. Flooding can also lead to increased siltration, or deposition of sediment loads in hydroelectric dams, which may reduce hydropower generation potential and energy output (Mukheibir, 2007). Energy generation and transportation PPP projects may be damaged in the localised area of impact.

### 2.2.3 Estimates of fiscal impacts of epidemics

**As explained in Section 2.1, epidemics in Ethiopia can increase public health expenditure, increase poverty and disrupt economic activity.** Table 3 presents the key channels through which epidemics give rise to disaster response costs for the government and can trigger contingent liabilities. It provides an indicative coding of the likelihood of each risk manifesting in a fiscal impact and the magnitude of that risk in order to prioritise data collection.[11] Unlike climatic disasters, where the duration and intensity of the hazard cannot be controlled,

[10] Flooding can degrade the environment by polluting rivers and habitats, uprooting trees, widening rivers and reducing biodiversity. These longer-term impacts affect the productivity of natural capital and therefore may affect economic growth. These effects are more difficult to quantify and are therefore not included in this framework.

[11] The coding is based on desk-based research and reporting on the experience in Ethiopia of previous floods. The likelihood of risks manifesting may change over time as a result of demographic change, and the severity of impacts will vary with the severity of the outbreak.

public sector responses to epidemics affect not only the economic impacts, but also can play a role in reducing the spread of the disease and the duration of the event. For example, policies such as social distancing measures can reduce the transmission of airborne diseases, and investing in sanitation or hand hygiene facilities can reduce the spread of waterborne diseases.

Table 3 Fiscal risks associated with epidemics

| Impact | Fiscal risk | Likelihood | Severity |
|---|---|---|---|
| Social | Humanitarian aid expenditure<br>Public health expenditure<br>Social assistance | | |
| Physical | n/a | | |
| Economic disruption | Tax revenue collection | | |
| | SOE liabilities | | |

Note: Red indicates high risk, amber indicates medium risk, green indicates low risk; RAG coding of risks will be validated with relevant Government ministries.

Source: Vivid Economics

## Social and physical impacts

**Epidemic management often requires coordinated humanitarian and healthcare expenditure to contain outbreaks.** There are four key areas of increased expenditures during epidemics and pandemics:

- **Surveillance, monitoring and data management**: Managing epidemic outbreaks requires a detailed spatial understanding of infections. COVID-19 has shown that this is particularly important for human-to-human transmissible diseases. Surveillance can also be important in waterborne disease outbreaks to help identify contaminated food and water sources.

- **Healthcare system capacity**: During epidemics, healthcare systems are likely to come under increased pressure. Additional funding for public health systems may be needed to cope with excess demand for services, particularly in countries like Ethiopia which are already stretched. Ethiopia has an estimated 3 hospital beds and less than one physician per 10,000 people (World Bank/WHO, 2016).

- **Community equipment and supplies**: Waterborne epidemics can contaminate water and food supplies, necessitating community dissemination of clean water and food. Additionally, to mitigate the spread of epidemics, additional expenditure on community hygiene and hand-washing facilities may be required. In Ethiopia, just 8% of the population has access to basic hand-washing facilities. Airborne diseases may require further dissemination of supplies to mitigate spread, such as masks and gloves.

- **Treatment and vaccination**: Containing epidemics may require purchasing additional units of existing treatments, such as the cholera vaccine, or funding the development of new treatments.

**Epidemics can increase household expenditures and reduce livelihood opportunities, resulting in increased expenditure on relief and humanitarian aid.** In Ethiopia, 35% of healthcare expenditure is paid by individuals and households rather than by the public sector, external finance or through insurance (World Bank/WHO, 2018), indicating that unexpected health expenditures may be unaffordable for low-income households. The World Health Organization has argued that out of pocket payments above 20% of total health care expenditure can lead to catastrophic health expenditures and impoverishment; Ethiopia has almost double this proportion. Increases in poverty rates can put additional pressure on existing social security programmes, requiring expanded coverage.

## Economic disruption

**Epidemic illnesses can affect economy-wide productivity through both absenteeism and presenteeism, limiting economic growth and tax receipts.** Absenteeism refers to reduced productivity through missed days of work due to illness, while presenteeism refers to workers' reduced cognitive and physical capacity while at work as a result of illness or recovery. Epidemics can affect labour productivity through both mechanisms. For example, on average, cholera can result in up to 6 days of lost work time per ill adult, which may increase if parents need to care for ill children (Oxford Economics, 2010). Diseases like COVID-19, which can have a longer tail of recovery and lead to chronic fatigue, can result in reduced productivity at work even after workers are no longer contagious.

**Epidemics can lead to social distancing measures and reduce confidence in safety, affecting Ethiopia's growing tourism and commercial industries.** Ethiopia receives nearly one million international tourist arrivals each year (World Bank/Wourld Tourism Organization, 2018). Prior to the COVID-19 pandemic, Ethiopia had one of the fastest growing global tourist industries; in 2018, the travel and tourism economy grew nearly 50% and contributed USD 7.4 to the economy, representing almost 10% of GDP. The industry supported 2.2 million jobs, or 8% of total employment (Embassy of the Federal Democratic Republic of Ethiopia, 2019). Epidemics can increase the real or perceived risk of tourist travel and reduce arrivals, even in epidemics which do not lead to travel bans and border closures. Analysis of historical events has shown that pandemics decrease tourism demand, particularly in low-income countries (Karabulut, Bilgin, Demir, & Doker, 2020). Social distancing may also lead to forced closures for commercial activities, affecting tourism, airline and hospitality industry revenues (Delivorias & Scholz, 2020). SOEs related to transportation may be particularly affected, potentially resulting in contingent liabilities.

### 2.2.4 Estimates of fiscal impacts of desert locust invasions

**As explained in Section 2.1, desert locust invasions in Ethiopia can have significant impacts on the agricultural sector and threaten livelihoods and food security.** Table 4 presents the key channels through which desert locust invasions give rise to disaster response costs for the government and can trigger contingent liabilities. It provides an indicative coding of the likelihood of each risk manifesting in a fiscal impact and the magnitude of that risk in order to prioritise quantification.[12] Desert locust invasions create fiscal risks through many of the same channels as droughts, but with lower likelihood and potentially higher severity.

Table 4 Fiscal risks associated with desert locust invasions

| Impact | Fiscal risk | Likelihood | Severity |
| --- | --- | --- | --- |
| Social | Humanitarian aid expenditure | | |
| | Pest monitoring and control | | |
| Physical | Environmental degradation[13] | | |
| Economic disruption | Tax revenue collection | | |

Note: Red indicates high risk, amber indicates medium risk, green indicates low risk; RAG coding of risks will be validated with relevant Government ministries.

Source: Vivid Economics

**Locust invasions have significant impacts on livelihoods and food security, resulting in Government expenditure on humanitarian and food assistance.** Crop losses from locusts result in downstream food shortages and higher food prices, leading to higher incidence and severity of food stress. This puts additional pressure on social security programmes, such as the PSNP which supports chronically food insecure and poor

[12] The coding is based on desk-based research and reporting on the experience in Ethiopia of previous locust events. The likelihood of risks manifesting may change over time as a result of climate change, and the severity of impacts will vary with the severity of hazards.

[13] Drought can degrade the environment in the long-term by putting stress on wildlife and reducing biodiversity, lower levels in environmental waters, increasing wildfires and eroding soil quality. These longer-term impacts affect the productivity of natural capital and therefore may affect economic growth. These effects are more difficult to quantify and are therefore not included in this framework.

households. The last major locust outbreak in West Africa in 2003-5 cost over USD 450 million to end the plague and caused USD 2.5 billion in crop damage.

**In addition to humanitarian expenditure, locust invasions may require additional expenditure on locust response.** Locust response efforts may include monitoring and surveillance systems and locust control measures. In 2020, the World Bank provided more than USD 400 million in financing for locust response efforts in Djibouti, Ethiopia, Kenya, Uganda and the Middle East (World Bank, 2020b).

**Locust response efforts can have negative impacts on people and ecosystems if they are treated with harmful chemical pesticides**. Government and humanitarian responses to locust outbreaks often include pesticide spraying. Chemical insecticides for locust control often kill not only locusts, but other potentially beneficial organisms. Some of these pesticides may be toxic, persist in the environment, and may be applied indiscriminately (FAO, 2020a; Sarkar, 2020). These longer-term impacts affect the productivity of natural capital and human health, and therefore may affect economic growth. However, they are less likely to create fiscal stress, are more difficult to quantify and are therefore not included in this framework.

#### Economic disruption

**Economic disruption to the agricultural sector can trigger liabilities related to SOEs.**

**The agriculture sector is most exposed to the impacts of locust invasions, potentially putting some revenue collection at risk.** Tax revenue collection from smallholders is minimal, therefore the tax revenue implications are likely to be insignificant.

**The Government may be exposed to agricultural SOE liabilities if locust invasions reduce production and cashflow.** As with drought, agricultural processing SOEs like the Ethiopian Sugar Corporation will also face disruptions and may face challenges in servicing their debt. The Sugar Corporation is highly leveraged (Kamski, 2019).

### 2.2.5 Estimates of wider macroeconomic impacts

**The physical, social and economic impacts can have wider macroeconomic implications in both the short and the long term.**

**GDP is likely to be impacted in the wake of a disaster, which may persist if capital is damaged or disaster risk is not sufficiently financed.** Empirical work has shown that globally disasters have both direct and indirect impacts on the economy, with indirect impacts persisting for more intense disasters which impact physical assets. In addition to affecting annual output, disasters can impact economic growth. Using a disaster risk database, a study finds that the most severe natural disasters can reduce GDP growth by 7% (Botzen, Deschenes, & Sanders, 2019). In Ethiopia, GDP growth has been found to be inversely related to rainfall variability (USAID, 2017). Although drought does not impact physical assets, droughts can be more impactful on economic growth than floods because they do not trigger post-disaster economic activity for reconstruction (Benson & Clay, 2004).

**Ethiopia's primary export sector (XX) is exposed to drought, putting pressure on the existing trade deficit and increasing the challenge of financing foreign debt.** Evidence from the World Trade Organization (WTO) suggests that in general, disasters lead to reduced trade flows from both declining imports and exports (Gassebner, Keck, & Teh, 2011) due to reduced economic activity. However, the nature of Ethiopia's disasters mean that drought and flood are more likely to increase the trade deficit. Ethiopia's trade deficit has been widening, with estimates as high as 22% per year (Rekiso, 2020) between 1997 and 2016. Disasters can widen the trade deficit by limiting export capacity and increasing imports. This is particularly salient for Ethiopia since its main export sector is vulnerable to both droughts and floods. Additionally, droughts can increase the demand for imports if there are food shortages and humanitarian relief is insufficient. The FAO estimated that nearly 800,000 tonnes of cereals imports were needed to cover food shortages from poor Belg season rains in 2000 (FAO, 2000).

**Disasters can also impact the Government's ability to invest in providing critical services and infrastructure, restricting long-term economic growth.** In the absence of adequate DRF mechanisms, hazards can force budgetary reallocations to meet reconstruction and humanitarian needs. Budget reallocations can mask the overall fiscal stress of a disaster since they do not increase the budget deficit, but can reduce public resources available for investment in infrastructure and poverty alleviation efforts (Benson & Clay, 2004). OECD research indicates that public investment has long-term implications for growth and labour productivity (Fournier, 2016).

### 2.2.6 Fiscal health impacts

**Summary indicators of fiscal health can provide an indication of the pressure on public finances associated with a macroeconomic shock and increased expenditures.** While there is no single macroeconomic variable which can indicate a good or poor fiscal position, summary indicators of fiscal health can help analyse the pressures caused by shocks to multiple macroeconomic variables. The Excel tool described in the next chapter calculates the impacts of disasters on two summary indicators: the debt-to-GDP ratio and Gross External Financing Requirements (GXFR). The former is a debt-related indicator, and reflects the ratio of debts to economy-wide production. A low debt-to-GDP ratio typically reflects an economy that produces and sells goods and services sufficient to pay back debts without incurring additional debt. The latter is a reserve-related indicator, and reflects external currency needs to cover external debts and the current account balance as a ratio of foreign currency reserves. This can provide an indication of whether a Government holds sufficient foreign currency to meet needs. Both debt- and reserve-related measures are important indicators to analyse, as disasters may put pressure on debt, reserves, and the value of local currency.

# 3 Quantifying risk in the Excel tool

**This chapter describes how the analytical framework outlined in the last section is implemented in the Excel tool.** The tool provides an estimate of the costs of a disaster scenario and the associated impacts on GDP, public investment, trade balance and fiscal health indicators. The tool is ready-to-use and includes flood and drought hazard scenarios that represent varying severities, and is pre-populated with data from the Government of Ethiopia. The tool is flexible to also assess additional scenarios created by users; this requires collecting and processing appropriate data and developing relevant scenarios of hazards, which is described in detail in the Methodology Annex. Section 3.1 provides background to the development of the approach, and Section 3.2 provides a high-level overview of how key impacts are estimated in the tool. A more detailed tool methodology can be found in the Methodology Annex.

## 3.1 Approaches to quantifying disaster-related fiscal risks

**Best-practice international approaches for assessing disaster-related fiscal risks include 'top down' and 'bottom up' methods.**

- **Bottom-up approaches** account for costs associated with the physical impacts of disasters and draw out fiscal implications. They often employ probabilistic or spatial modelling tools to understand events, which are particularly well developed for hazards that result in physical damages to assets. They can include an assessment of the emergency and/or direct losses associated with hazards. This approach is followed by modelling tools including IIASA's Catastrophe Simulation Model (CATSIM) and the Central America Probabilistic Risk Assessment Platform (CAPRA).

- **The top-down approach,** sometimes referred to as a Fiscal Stress Test (FST), is independent of the specific cause of macroeconomic impact. This approach estimates the impact of a simulated macroeconomic shock or a correlated set of macroeconomic shocks on the fiscal position or to indicators of fiscal health such as the debt-to-GDP ratio. This approach is often employed by the financial sector to assess risk, and is increasingly used to assess the risks associated with climate change. FSTs sometimes include specific tests of natural disaster stresses, such as the FST conducted for the Federated States of Micronesia (FSM) shown in Box 5.

**The approach developed for Ethiopia combines elements of both a bottom-up accounting of impacts, and a top-down estimation of a correlated macroeconomic shock, including the effect on Ethiopia's trade balance.** The bottom-up accounting includes estimates of relief, recovery and reconstruction costs and contingent liabilities. The accounting feeds into an estimate of the overall macroeconomic effect, which is used to provide a top-down indication of the impacts on fiscal health. This mixed approach is flexible to account for disasters which impose both direct costs and wider economy-impacts, is fit-for-purpose in Ethiopia, and follows international approaches to disaster risk analysis.

## 3.2 Applying the analytical framework in the tool

**This section provides the background for how the framework is implemented in the tool for a range of hazards.** Refer to the Methodology Annex for details on the model specification and for guidance on updating data or parameters or to the User Guide for insights into the tool's functionality. The accompanying User Manual provides practical guidance on navigating the tool.

### 3.2.1 Hazard scenarios

**The calculations in the tool are underpinned by hazard scenarios.** As detailed in the previous chapter, each disaster type will create unique fiscal risks resulting from increased government expenditures and reduced government revenues based on its severity. The tool is pre-populated with probabilistic hazard scenarios for drought and flood that correspond to hazard scenarios ranging from a 1-in-2 year event, to a 1-in-100 year event.[14] It is easiest to think about these scenarios in terms of probabilities; when we talk about a 1-in-10 year event, we mean that in any given fiscal year, there is a 10% chance of an event of at least that size occurring. Similarly there is a 2% chance of a 1-in-50 year event (a more severe event). In reality these probabilities may change year on year as the occurrence of a severe drought in one year may influence the probability of a similar event the following year. These inter year dependencies as well as external effects such as El Nino may cause some deviation from the probability of an event of a certain severity within a given year. Overall though, these probabilities provide a strong guidance for planning but local information can be used to support more accurate analysis for multiyear scenarios. Table 5 lists the key costs of disasters, relevant to fiscal outcomes, that make up each of the disaster scenarios in the tool.

**Probabilistic modelling can be valuable to support fiscal risk analysis and planning.** Probabilistic modelling can help set an expectation and information on what to prepare for by providing the level of funding required based on the likely frequency and severity of future events. It is likely that preparation for smaller events described by return periods of 1 in 10 years and less will demand a different response than more severe events (1 in 50 or 100), thus allowing the Government to put in place procedures to meet this level of outgoing with the projected timescale and variability. Ahead of a more severe disaster, modelling these costs allows for planning and preparation and to understand the breakdown of the losses that contribute to the event to appropriately tailor the response.

Table 5 Scenario parameters in the tool

| | Drought | Flood | Epidemics | Desert locust invasion |
|---|---|---|---|---|
| Humanitarian assistance | Expanded catchment of newly insecure households or individuals in federal assistance programmes | | | |
| Disaster response | n/a | Combined costs of establishing shelters, providing medical care, and distributing food aid | Combined costs of relief required in different types of epidemics, including healthcare expenditure | Cost of locust response and surveillance |
| Cost of reconstruction | n/a | Damaged public and un- or underinsured private assets | n/a | n/a |
| Food imports | Food imports to meet cereal demand | n/a | n/a | Food imports to meet cereal demand |
| Loss in sector GDP | Agriculture and hydroelectric sector | Agriculture sector | Tourism, retail, and hospitality sector (airborne), agriculture sector (waterborne) | Agriculture sector |
| Productivity losses | n/a | n/a | Worker absenteeism | n/a |

[14] Deterministic hazard scenarios will be developed for locusts and epidemics ahead of the capacity building workshops in July 2021

| | Drought | Flood | Epidemics | Desert locust invasion |
|---|---|---|---|---|
| SOE debt liabilities | Cost of servicing publicly guaranteed SOE debt | Cost of servicing publicly guaranteed SOE debt | n/a | Cost of servicing publicly guaranteed SOE debt |
| PPP contractual obligation liabilities | Hydroelectric project delays or cancellations | Infrastructure project delays or cancellations | Infrastructure project delays or cancellations | n/a |

Note: Epidemic and locust scenario parameters are under development and will be finalised ahead of the capacity building workshops in July 2021.
Source: Vivid Economics

**A simplified hazard scenario could be developed by using historical data and using simple estimating equations.** Table 6 provides a breakdown of simple equations that could be used to estimate key scenario inputs for floods and droughts.

Table 6 Indicative equations for estimating the fiscal risks of floods and droughts

| Hazard scenario input | Simplified estimating equation |
|---|---|
| Humanitarian aid | $\textit{Cost of assistance per household} \times \textit{Additional households receiving food aid}$ |
| Food imports | $\textit{Domestic food demand} - \textit{Reduced agricultural output}$ |
| Reconstruction costs | $\textit{Cost of reconstructing damaged public assets}$ |
| Government revenue losses | $\sum_{i}^{sector} \textit{Sector loss} \times \textit{Sector revneue rate} + \textit{Sector loss} \times \textit{Sector I} - \textit{O multiplier} \times \textit{Sector revneue rate}$ |
| SOE guarantees and PPP contractual obligations | $\textit{Interest payments on exposed guaranteed SOE debts} \times \textit{Probability GoE pays servicing cost}$ |

Note: These are indicative equations intended to guide future analyses.
Source: Vivid Economics

### 3.2.2 Macroeconomic impacts in the Excel tool

Stemming from the magnitude of hazard scenario impacts, the Excel tool estimates the total cost of disasters, and the resulting impacts on GDP, public investment levels and the trade deficit.

- **GDP and tax revenue losses:** The tool captures sector losses, the wider macroeconomic impacts they cause, and ultimate impacts on revenues. Input-output analysis captures wider economic costs, and then are translated to revenue losses using sector-specific revenue rates.
- **Provision of public services and public investment:** Public service delivery and infrastructure investment are both reduced when disasters are financed through budget re-allocations. The tool calculates reductions in public spending, including how this persists over the medium-term horizon following the hazard.

- **Trade balance:** Sector-specific losses are translated into reductions in exports using sector export weights. If a hazard results in particularly severe agricultural disruption, the country may require additional food imports, which will combine with export capacity reductions to result in a larger trade deficit. A trade deficit reduces foreign exchange reserves available to conduct monetary policy and stabilise markets, which may be critical in the wake of a disaster.

### 3.2.3 Fiscal health indicators in the Excel tool

The risk assessment tool estimates the impact of hazards on two summary fiscal health indicators: debt-to-GDP ratio and GEXFR.

- **Debt-to-GDP ratio:** A natural disaster likely increases the amount of public debt and may also decrease GDP. The duration of impacts will depend on the nature of the disaster and the government response. For a natural disaster like drought, the impact on GDP growth may be long term if sufficient and timely action is not taken, and households are forced to sell productive assets such as livestock. The impact of a flood may also be longer term due to the destruction of physical capital. An increase in debt-to-GDP ratio is an indication that the level of debt may be unsustainable.

- **GXFR**: A natural disaster is likely to impact sovereign risk perception, short-term borrowing, and reductions in balance of trade. A high GXFR relative to FOREX indicates that a country is at high risk of falling into debt distress and may struggle to service its debts.

### 3.2.4 Financing mix and recovery modelling

**In the Excel tool, the financing mix affects fiscal health recovery trajectories.** The user can determine the structure of each scenario's relief and recovery package by inputting the amounts drawn from a list of DRF instruments based on country norms or established practice, legal frameworks, or can be used to test ambitious financing policies. Inputted scenarios influence recovery rates based on how they compare to international best practice. Funding scenarios that implement DRF layering effectively will see faster recovery times and full recovery to baseline levels; funding scenarios that fail to use financing strategies effectively or do not allocate sufficient funds to meet humanitarian or reconstruction needs will result in incomplete and slow recovery trajectories. See the Methodology Annex for how this is implemented in the tool.

# 4 Managing disaster-related fiscal risks

**This chapter provides guidance on using the outputs of fiscal risk analysis using the Excel tool to better prepare and plan for climate and humanitarian disasters.** A key next step for the MoF is to implement the methodology in order to quantify risks. Section 4.1 explains the importance of a Fiscal Risk Statement and how it can be used in budgeting, policy, planning and investment decisions, including processes currently in place for identifying, quantifying and managing fiscal risks within the MoF. Section 4.2 details how a cogent funding response strategy can feed into hazard recovery. Section 4.3 describes the role of investing in disaster risk reduction as a means of reducing fiscal risks.

**Box 3 Tool uses and limitations**

The Excel tool is intended to provide a starting point for assessing disaster-related fiscal risks, by providing estimates of the magnitude of costs of events, the probabilities of events, and the relationship between financing strategy and recovery. However, the tool is not a comprehensive assessment and will require complements with local expertise to inform effective policymaking, budget decisions, and developing a disaster risk financing strategy. Tool limitations include:

- The tool provides a simplified macroeconomic model that does not capture all of the interactions between all sectors in the economy. The tool uses simple parameters to estimate the relationships between shocks to key sectors and the wider economy.
- The tool is not able to capture fiscal risks arising from interest and exchange rate shocks as a result of the disasters. The direction and magnitude of these shocks is uncertain and depends on policy responses; therefore the tool does not model the implications for these rates and assumes they remain constant over time.
- The tool does not capture the interactions between hazards. In a given fiscal year, it is possible that multiple hazards will occur at the same time. This may create a multiplier effect on fiscal risks, and make financing recovery and humanitarian assistance more challenging.
- Probabilities of disaster events are based on historical data, and do not account for climate change increasing the risk of hazards. In the long-term, probabilistic scenarios may need to be updated to account for changing climate risk.
- Probabilistic disaster scenarios do not account for changes in risk that result from investments in disaster risk reduction, such as irrigation infrastructure. Scenarios that account for reduced risk can be developed and implemented in the 'user scenarios' section of the tool. Further analysis would need to be conducted to assess the updated probabilities of risk given investments in disaster risk reduction.
- Probabilistic disaster scenarios do not account for multi-year interactions. In reality, the probability of a disaster scenario of a given magnitude may change year on year as the occurrence of a severe drought in one year may influence the probability of a similar event the following year. These inter-year dependencies as well as external effects such as El Nino may cause some deviation from the probability of an event of a certain severity within a given year. Overall though, these probabilities provide a strong guidance for planning but local information can be used to support more accurate analysis for multiyear scenarios
- Costs required for humanitarian assistance are based on historical expenditures, and therefore may not account for previous disasters failing to meet the needs of some populations. Scenarios can be developed to test assumptions around unmet needs; if an assessment is made of unmet

needs as a ratio of historical expenditures, an inflation parameter can be added to the modelled expenditures to capture these additional needs.

- The approach to disaster risk financing and recovery is indicative, and does not necessarily reflect disaster risk financing tools that are available in Ethiopia. The tool does not provide a full-scale macroeconomic model; the recovery trajectories are intended to reflect the trade-offs between disaster risk financing instruments.

## 4.1 Developing a fiscal risk statement

**The fiscal impacts of droughts and flood are currently not systematically analysed by the MoF, information that is available shows that costs are substantial.** The 2019 FRS reports that the 2015/16 El Nino induced drought resulted in additional fiscal support of 18 billion Birr in 2015/16, with electricity export earnings from hydropower reducing by 26.5% (Ministry of Finance, 2019). The Public Expenditure and Financial Accountability Assessment also noted that the same drought resulted in budget reallocation and revenue shortfalls relative to target (Federal Government of Ethiopia, 2019). A World Bank study found that a 1-in-5-year drought would result in 13.9 million people needing assistance with a financial costs of USD 1.1 billion (assuming support delivered through the Productive Safety Net Programme, PSNP), while a 1-in-10-year drought would require assistance for 16.1 million beneficiaries at a cost of USD 1.28 billion (World Bank, 2017). The same report found that while sufficient financial resources are available to cover needs associated with the average annual impact of drought, there is a financing gap in the instance of more severe droughts. For example, a 1-in-5 year drought would be associated with a financial gap of USD 72.9 million.

**In its recent report, the IMF noted ongoing issues with weak goods exports, foreign exchange shortages, a high debt-to-GDP ratio and high inflation (IMF, 2020).** Agricultural products (coffee and oilseeds) account for the bulk of Ethiopia's goods exports, which represent less than 8% of GDP (World Bank/OECD, 2019). Given the vulnerability of these goods to hydrological conditions, drought and flood can severely exacerbate external imbalances. More generally, the vulnerability of Ethiopia's position increases the risk that droughts and flooding could threaten fiscal sustainability. The announced Homegrown Economic Reform Plan aims to address internal and external balances, debt vulnerabilities, higher inflation and low foreign exchange reserves.

**The MoF has made an important first step in managing these fiscal risks through developing the 2019 FRS.** The 2019 FRS identifies a number of key fiscal risks, including the risk droughts pose due to their impact on the agricultural and hydropower sectors. The Statement shows a good understanding of risks relating to drought and some preliminary quantification of these risks. However, the MoF does not at present systematically quantify disaster-related fiscal risk. The analysis within the 2019 FRS is limited to the example of the 2015/16 El Nino induced drought, without including a forward-looking assessment of fiscal risk which takes into account different return periods. Furthermore, when the MoF forecasts tax revenue, expenditure, debt and other relevant fiscal indicators, these forecasts do not take into account the risks disasters might pose.

**A comprehensive assessment of disaster-related fiscal risks in a Fiscal Risk Statement (as well as other fiscal risks faced) can improve fiscal policymaking, investment decisions, budget allocations, and risk reduction.** Box 4 provides international examples of the use of quantified fiscal risk information from disasters in planning by governments. Findings from a fiscal risk analysis can be disseminated and integrated into decision making on three levels:

- The framework as it stands gives a narrative basis for understanding the fiscal risks from flood and drought. This can be used by the government in activities to manage its fiscal exposure – for example through negotiating terms of PPPs – and in assigning ownership of sources of risk across government, which can improve incentives to manage risks (IMF, 2008).

- Once risks have been quantified and entered into the FRS, the analysis can be used to prioritise risk management activities and to develop a DRF strategy. The objective of the latter is to ensure sufficient funding is available to cover post-disaster needs at low cost and that this funding is efficiently disbursed towards relief, recovery and reconstruction.
- By publishing information on fiscal risks and planned mitigation in the FRS, the government can foster investor confidence in the stability of its fiscal position, reducing its cost of borrowing.

Box 4 Examples of best practice in FRS design

- **The Philippines FRS is a best practice example of detailed inclusion of natural disasters as contingent liabilities in a disclosure of fiscal risks.** The document includes quantification of the cost of previous disasters, as well as forecasts of future disasters events and the costs they will impose. This guides funding allocation for recovery and rehabilitation activities as part of wider DRF strategies such as financing available through the National Disaster Risk Reduction and Management Fund. The FRS includes a section covering risk mitigation measures, which outlines different risk transfer measures and their funding. This facilitates the inclusion of disaster-related fiscal risk as part of debt sustainability analysis.
- **The Colombian government recognise that the quantification of fiscal risk is part of the first step in managing disaster-related fiscal risk.** The Colombian MoF and Public Credit is responsible for promoting the government's efforts in assessing, reducing and managing the fiscal risk associated with natural disasters. They have identified three priority policy areas for managing fiscal risk with the "identification and understanding of fiscal risk due to natural disaster" as the first objective for fiscal risk management. This understanding and quantification is used to develop financial and actuarial decision making tools, allowing them to design an optimal combination of financial instruments through cost-benefit and dynamic financial analysis (World Bank, 2016).
- **The Mexican government use thorough quantification to aid the design of DRF instruments such as sovereign CAT bonds.** In 2006, Mexico was the first sovereign country to issue a parametric CAT bond. These are financial instruments which offer investors a high interest rate but allow for forgiveness in the event of a natural disaster, meaning they do not have to repay the unpaid value of the bond if a natural disaster occurs. Higher-quality disaster-related fiscal risk quantification has guided improved design and allowed pooling multiple risks across regions (IMF, 2018). Over or under-estimating the size of fiscal risks could lead to significant inefficiencies in the use of this risk transfer instrument by leading to costly misallocations of government investment. Robust quantification gives governments the confidence to invest in these effective ex-ante instruments.

**Risk information can be continually updated, refined and extended.** Figure 4 below describes opportunities to improve the information base used to estimate fiscal risks. Key dimensions of are in increasing the coverage of hazards (likely priority areas being infectious diseases, conflicts, pestilence), developing forecasts of fiscal risks for various return periods, and in more clearly specifying the extent to which post-disaster funding requirements are expected to be met through sources of DRF.

Figure 4 Opportunities to develop the 2019 FRS

| Component | FRS 2019 | Opportunity | Rationale | Example |
|---|---|---|---|---|
| Historical disaster- | 2015/16 El-Niño drought: impact on GDP growth, food inflation | Add further events, covering range of hazards of varying | Greater ability to validate fiscal risk | *Philippines (2020):* This provides accounts of the number of cyclones recorded |

| | | | | |
|---|---|---|---|---|
| related costs | and electricity export earnings. | severity and regional impact. Decompose costs to cover asset damages, lost production. | pathways and quantification. | since 2016, breaking down the costs incurred by the major hazard events by geographic region. They also include data on health emergencies, recording the number deaths in different regions, as well the historic impact of the El-Niño drought.[15] |
| Historical disaster-related expenditure | 2015/16 El-Niño drought: overall estimate of additional fiscal support associated. | Add further events as above.<br><br>Increase granularity of El-Niño drought coverage: relief, recovery, reconstruction costs. | Greater ability to validate fiscal risk pathways and quantification.<br><br>Decomposition of relief, recovery, reconstruction costs useful for DRF strategy, as affects instrument choice. | *Colombia (2018):* This provides a detailed breakdown of specific hazard events, dating back to 1983, describing the size and source of disaster-related financing.[16]<br>*Philippines (2020):* Describes the quantity and source of finance required due to certain historic disaster events. |
| Current mitigation strategies | Statement recognises need for mitigation policies for drought due. No detail of measures. | Prioritisation of mitigation measures and assignment of responsibility.<br><br>Clearer processes for disbursement of post-disaster funding to support mitigation. | Provides clarity for government departments, sharpens risk ownership, guides policy making. | *Mexico (2018):* Provides detailed description of types and values of insurance measures employed, such as CAT bonds. Also describes size of contingency budget the government sets aside for disasters.<br>*Philippines (2020):* Provides a whole section on risk mitigation measures, including their size and sources of funding. Also details which groups are responsible for their implementation.[17] |
| Forecasts of future events | State that droughts occur, on average, every 10 years. | Forward-looking estimates of fiscal risks for hazards under a range of return periods . | Improve accuracy of fiscal risk estimates by accounting for changes in exposure and vulnerability.<br><br>Inform risk layering approach to DRF. | *Philippines (2020):* Provides a discussion of how weather and climate forecasts are used to predict the impacts on different sectors.[18] |

Note: Ethiopia = (Ministry of Finance, 2019), Colombia = (Fouad et al., 2018), Philippines = (Development Budget Coordination Committee, 2020), Mexico = (Pattanayak et al., 2018)
Source: Vivid Economics

[15] https://www.dbm.gov.ph/index.php/dbcc-matters/dbcc-publication/fiscal-risk-statement
[16] https://www.imf.org/~/media/Files/Publications/CR/2018/cr18250-ColombiaFTE.ashx
[17] https://www.dbm.gov.ph/index.php/dbcc-matters/dbcc-publication/fiscal-risk-statement
[18] https://www.dbm.gov.ph/index.php/dbcc-matters/dbcc-publication/fiscal-risk-statement

#### 4.1.1 Updating and improving the fiscal risk assessment

**The fiscal risk assessment should be regularly updated, extended and improved to develop a more complete understanding of the magnitude of fiscal risks associated with disasters in Ethiopia.** These updates should be reviewed on a regular schedule to improve fiscal risk assessment. The IMF cites New Zealand, Australia, the UK, the US and South Africa as best practice examples of institutionalisation of fiscal risks with regular review and update. Australia reports on fiscal risks as part of the annual budget, the UK publishes an in-depth fiscal risk report every two years, and South Africa has a fiscal risk committee which meets quarterly (IMF, 2016). Accordingly, it will be important for Ethiopia to establish an appropriate schedule for regularly reviewing and updating the analysis.

**The disaster risk quantification can be updated to reflect a changing climate, economic and policy environment.**

- **Updating scenarios to reflect current understanding of climate risk:** Climate change may increase the frequency and severity of both floods and droughts. Heavier rainfall events could lead to more flooding and flood damages, while uncertain El Nino conditions could affect rainfall during key agricultural seasons (Simane et al., 2016). Accordingly, as knowledge on climate change impacts evolves, drought and flood scenarios should be updated to reflect uncertainties and changing risks.

- **Updating national data to reflect changes in the economy:** National data and scenario inputs into the framework are based on the structure of the economy. These can be updated to reflect changing economic conditions. For example, this could include changes in the size of key sectors, such as a diversification away from agricultural production.

- **Updating impacts to reflect policy changes:** Scenario outputs in the framework reflect both the scenario assumptions as well as the policy environment, including financing mix and adaptation policies. An updated fiscal risk assessment should include a revised policy environment if there are changes in DRM strategy, such as increased reliance on ex-ante DRF mechanisms and reduced reliance on Official Development Assistance (ODA). This could also include updating risk mitigation strategies in SOEs and PPPs. These strategies could mitigate government liabilities in the case of disasters.

**The framework can also be expanded to include additional hazards.** While drought, flood, epidemics, and locusts are currently the most salient disasters to assess, Ethiopia is also vulnerable to other climate hazards. These include earthquakes, landslides and volcanoes which are present in Ethiopia but currently affect a much smaller number of people (World Bank, 2019a). Figure 5 outlines a four-step process for expanding the analytical framework to include additional fiscal hazards. This process is analogous to the methodology taken for developing the drought and flood framework and accompanying tool.

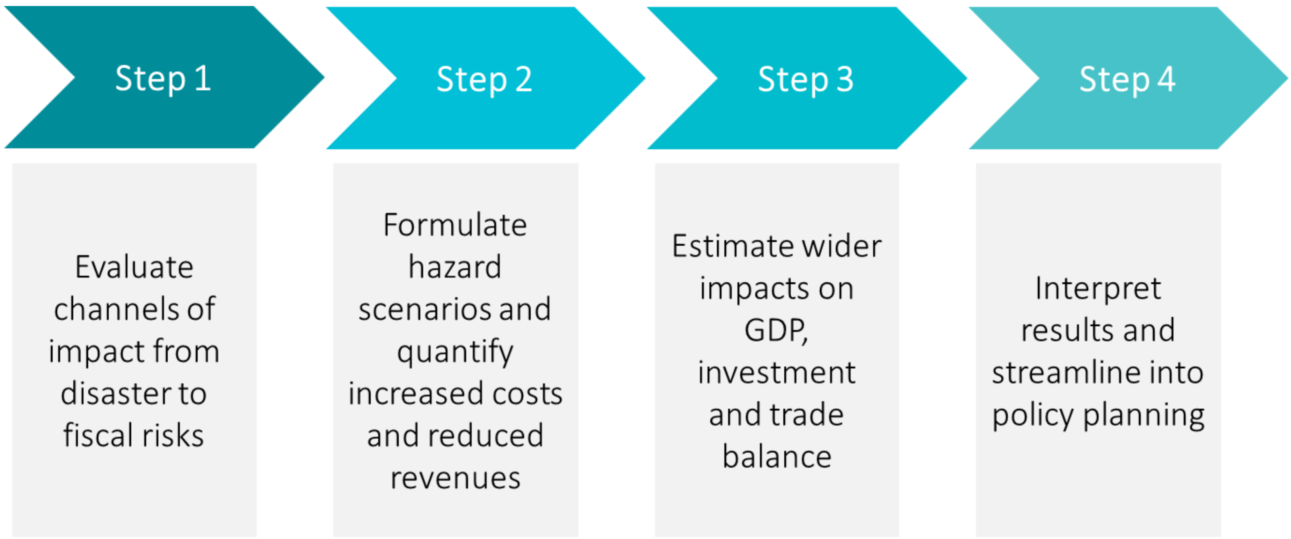
- **Step 1:** develop a qualitative understanding of how a hazard impacts fiscal position. This will account for the expenditures and liabilities associated with disaster impacts by reviewing historical data and international assessments of the hazard, in order to develop a RAG coding of the likelihood and magnitude of key fiscal risks. This stage involves mapping channels of impact from the economic costs of the disaster to the wider macroeconomy, including reviewing impacts on sector output and trade balance.

- **Step 2:** develop simple equations for estimating the cost of these risks under different scenarios of hazard risk. These equations can build on data which can be collected nationally and should be flexible to include scenario assumptions which can be sourced from historical examples or forward-looking modelling. This will identify which fiscal risks can lead to reduced revenues and increased expenditures.

- **Step 3:** estimate how these risks translate to GDP, public services and investment and the trade balance. This stage should develop a series of simple equations which estimate how the reduced costs and increased expenditures affect the Government's ability to invest in public services, how the lost sectoral output translates into overall GDP and exports, how imports may change (for example to address food shortages or repair infrastructure). These equations can build on the approaches taken for estimating the impacts of flood and drought.

- **Step 4:** The final stage uses the fiscal costs calculated and fiscal health indicators to develop policies to plan for and mitigate risks. These can include policy levers identified in the flood and drought frameworks or additional policies to test which can mitigate the impact of disasters or Government exposure to risk.

Figure 5 Process for developing analytical framework for assessing hazard fiscal risks



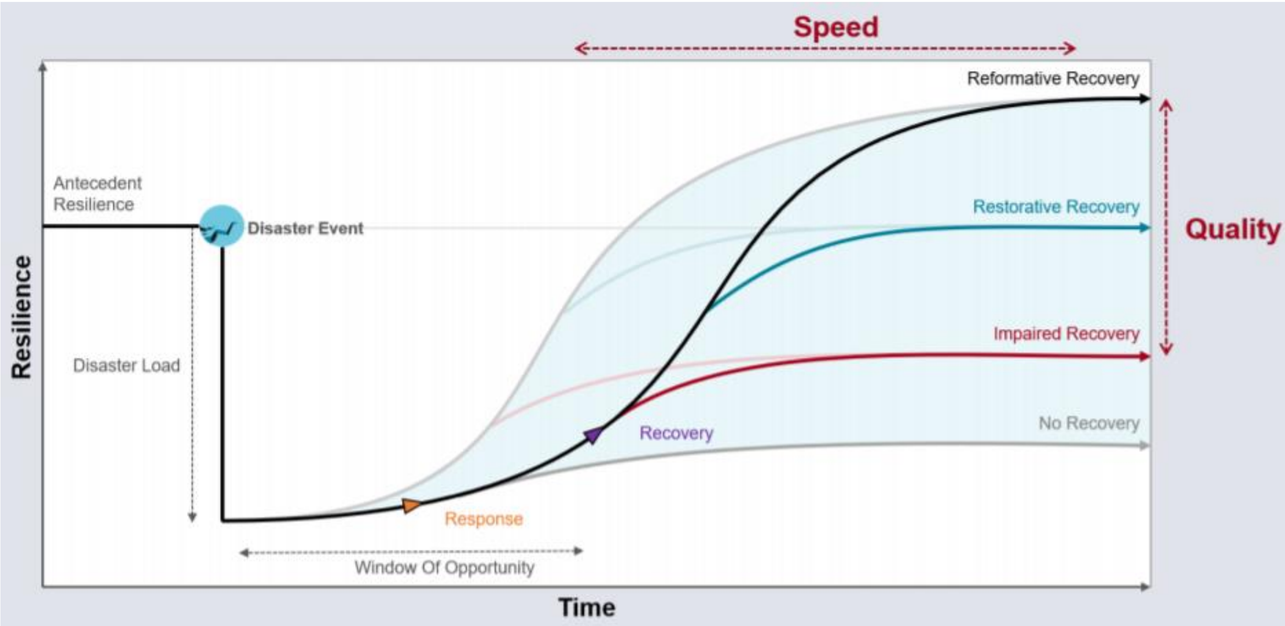

Source: Vivid Economics

## 4.2 Disaster risk financing

**Disaster-related fiscal risk analysis can inform an effective DRF strategy that helps reduce the impacts of a disaster and encourage economic and social recovery.** DRF strategies are measures and sources of finance used by governments to finance response, recovery and reconstruction post-disaster. A successful DRF strategy incorporates the information collected in the identification and quantification of risk and makes informed decisions regarding how to manage and allocate risk.

**An effective financing strategy can facilitate the restoration of humanitarian outcomes and normal business operations, reduce disaster mortalities and bolster long-term growth** (Mechler, Hochrainer, & Pflug, 2006). For example, a financing strategy that allows aid to be quickly distributed to affected households may prevent panic sales of livestock or other productive assets, preventing a deepening of household losses and a quicker and more complete recovery. A financing strategy that draws on the least expensive instruments minimises opportunity costs, meaning more funds are available to finance much-needed economic development and humanitarian assistance spending. Conversely, a financing mix that draws on instruments that are either expensive to hold or can get tied up in bureaucratic appeals or political bargaining risk deepening losses and extending the period of time to full recovery. Figure 6 illustrates the difference between speed and quality of recovery.

Figure 6 Speed and quality of disaster recovery




Source: https://axaxl.com/-/media/axaxl/files/optimizing-disaster-recovery.pdf

**Selecting the appropriate mix of funding instruments involves balancing the trade-offs.** Financing instruments may be mobilised at different speeds, require outlays of expenditure, or divert funds from key services. Table 7 summarises different DRF mechanisms, their advantages and relative the trade-offs. Traditional approaches, such as relying on budget reallocations or donor assistance, may divert funds from the provision of key services or public investment and can harm economic growth and poverty objectives in the long-term. Financing disasters through raising new debt can avoid the opportunity costs of reallocation, but additional debt financing can be expensive and put additional pressure on governments with existing debt burdens (Schnarwiler & Reto, 2008). There is also a risk of relying too heavily on humanitarian aid for disaster relief, as the quantity may be uncertain and may not be deployed quickly enough for time-sensitive relief (Schnarwiler & Reto, 2008). Existing programmes such as the PSNP, which are set up to provide a safety net to vulnerable populations, can be cost-effective and allocate funding quickly to households in need. While more advanced risk-transfer instruments like indemnity-based insurance, parametric insurance, and alternative risk transfer (ART) mechanisms can pay out quickly and protect sovereign fiscal resilience, they are expensive to hold as insurers have to maintain very high risk capital provisions to ensure payouts can be met.

Table 7 Trade-offs between DRF instruments

| DRF instrument | Description | Pros | Cons |
|---|---|---|---|
| Reserves | *Ex-ante.* Reserves are similar to budget contingencies, but with less fungibility and more formality governing how funds are accessed. | Can be mobilised quickly; relatively fungible; no repayment costs.* | High opportunity cost associated with idle reserves. Are usually small given competing demands. |
| Budget reallocation | *Ex-post.* Funds reallocated from other projects. | No cost of repayment; fungible. | Can divert funds from key priorities, stalling economic growth or poverty reduction measures. Budget |

| DRF instrument | Description | Pros | Cons |
|---|---|---|---|
| | | | reallocations can get tied up in political negotiations or bureaucratic processes. |
| Contingent debt facility (e.g., CAT-DDO) | *Ex-ante.* Loans that are arranged in advance of a disaster with agreement that they will be made available once a trigger is met. CAT-DDO is a World Bank issued loan of up to USD$500 million or 0.25% of GDP that is available to IBRD-eligible countries after a natural disaster. | The instrument is intended to provide immediate liquidity while other sources of funding are mobilised. International financial institutions offer these instruments at accessible rates. | Cost of repayment. |
| Donor support | *Ex-post.* Grant financing from donors. | Least expensive source of funds. | Driven by media coverage; lengthy disbursement process; often replaces existing assistance programmes; funds are inflexible; concerns over country sovereignty and self sufficiency; non-fungible. |
| Budget contingency | *Ex-ante.* A risk mechanisms where a certain proportion of revenues within a budget are set aside for contingencies (usually 2-5% of annual budget). | Fungible and quick to pay out. | Not earmarked for disaster relief or reconstruction, so funds may already be exhausted (or too little in the first instance) once a hazard occurs. |
| Domestic credit | *Ex-post.* Domestic bond issue. | Fungible. | Implications for debt sustainability. |
| External credit | *Ex-post.* Emergency loans or external bond issue. | Second least expensive source of funds behind donor support. | Additional debt can strain existing debt loads and may be expensive to repay. Emergency loans may take time to negotiate. |
| Parametric insurance | *Risk transfer.* Insurance mechanism where payouts are based on automatic triggers related to hazard severity. | Can pay out very quickly given automatic trigger mechanisms. | Very expensive to hold; cost of premium payments. Trigger needs to be well-designed. |
| Alternative risk transfer (ART) | *Risk transfer.* CAT bonds or weather derivatives. CAT bonds are short-term | Can be indemnity-based or parametric, making them flexible. | Very expensive to hold; cost of premia payments and/or interest rates. |

| DRF instrument | Description | Pros | Cons |
|---|---|---|---|
| | bonds that transfer natural catastrophe risk to investors. | | |

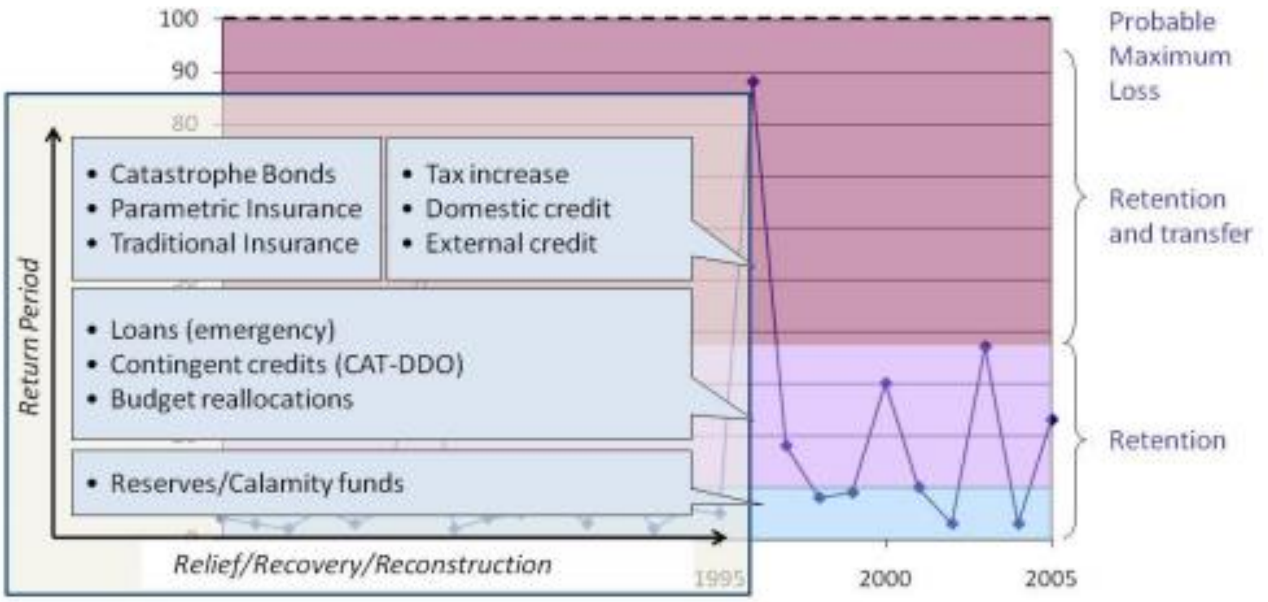
Note: *Although reserves need to be replenished.
Source: Vivid Economics

**An effective DRF strategy should fund relief and recovery efforts cost effectively, deliver aid quickly, and account for the full cost of the hazard.** Specifically, an appropriate financing mix should:

- *layer mechanisms in order of increasing cost.* To minimise opportunity costs, the strategy draws first from the least expensive mechanisms available, increasing through the layers of other DRF mechanism pre-planned as required.
- *ensure financing mix is designed such that funds are delivered swiftly.* Especially for financing relief efforts, it is important to minimise bureaucratic and political hold-ups in allocation and distribution of funds. How funds will be pushed out to support the response effort should be agreed ex-ante.
- *allocate enough funds to cover the full cost of the disaster.* Governments may not distribute adequate funds to cover the entire cost of the disaster, either by underestimating needs or because the needed funds cannot be accessed. Not meeting the full cost will impact on the speed of economic recovery.

**To balance these competing considerations, best practice calls for a layering of financial instruments where the lowest-cost instruments are drawn down first.** In practice, this means that more expensive mechanisms should be tapped into only once low-cost mechanisms like reserves and budget contingencies have been exhausted. A layering approach would recommend ex ante instruments to underpin credible management plans, with the timing of funding matched to requirements across relief, recovery and reconstruction phases, with ex post instruments providing additional flexibility to tailor a response to specific circumstances. This also means that these mechanisms should fund smaller losses associated with higher frequency hazards whereas more expensive options should help cover the cost of higher severity, lower frequency events. The layering concept is illustrated in Figure 7, which demonstrates how hazards of lower return periods can be financed through reserves, calamity funds, emergency loans, contingent credits, and budget reallocations, whereas higher-return period disasters should be funded through catastrophe bonds, parametric insurance, traditional indemnity-based insurance, tax increases, and domestic and external credit.

Figure 7 Indicative DRF layering strategy where low-cost instruments are drawn down first




Source: World Bank (2012)

**The probabilistic analysis provided by the Excel tool can support the structuring of DRF strategies to meet the response needs.** Even within certain risk transfer strategies there are a multitude of options. For example, with insurance, a first layer of finance may function as a quota share, meaning for every loss the insurer will cover 50% of the losses for small to medium sized events (e.g., 1 in 10 to 1 in 20 years). However, in the case of rare but large events, an insurance product may need to include a stop loss contract, such that beyond a certain limit the insurer will cover 100% of the losses.

## 4.3 Disaster risk reduction

**Once a disaster-related fiscal risk analysis has been conducted, the MoF can identify strategic areas of disaster risk reduction (DRR) for reducing fiscal risks.** The Appendix provides maps of spatially disaggregated drought risk which can also inform DRR strategies.

**Investment in disaster risk reduction is increasingly recognised as key to reducing the economic, social and fiscal impacts of disasters.** Historically, research on the impacts of natural disasters in Ethiopia have tended to focus the direct costs of disasters (Drechsler, Coll-Black, Tatin-Jaleran, & Clarke, 2017) or the investment needs for effective climate adaptation (Robinson, Strzepek, & Cervigni, 2013). Research is now emerging on the financial cost of DRR inaction in the face of growing natural disaster risks (World Bank, 2014). A 2013 study on estimated adaptation investment needs in Ethiopia under different climate scenarios determined that an annual average of USD 158-258 million was needed for the 2010-2050 period (Robinson et al., 2013).[19] One study estimates that the cost of resilience would have to be about USD 200 per capita per year for 10 years before the modelled costs of resilience begins to approach the cost of humanitarian response (Venton & Majumder, 2013).

**Investing in early response and resilience can lead to significant economic benefits (Shreve & Kelman, 2014).** Investments in building disaster resilience may be poorly incentivised because the benefits are less frequently translated into economic terms and may be realised over a long time period. However, building resilience and early response are far more cost effective than late humanitarian responses. Incorporating DDR into development planning can help avoid losses when disasters strike, including by saving lives, reducing

[19] The study focused on a select number of priority areas for Ethiopia (agriculture, road infrastructures and hydropower.

infrastructure damages, and reducing economic losses. Disaster risk management investments also unlock development potential and can produce significant economic, social, and environmental co-benefits. For example, increased resilience can encourage firms to invest and innovate, which in turn leads to job creation and economic growth. While there is still some uncertainty surrounding the cost of building resilience, an assessment of comparative DRR costs related to droughts in Ethiopia concluded that investment in resilience significantly outweighs the costs (Venton & Majumder, 2013). The net benefits of investments into adaptation were found achieve USD 70-140 billion over the 2010-2050 period.[20] Another 2012 study on the economics of early response and disaster resilience in Kenya and Ethiopia estimated that for every USD 1 spent on resilience, USD 2.9 is gained.[21]

**Despite the benefits, global investments in DRR represent a fraction of development assistance and national budgets**. Research has shown that development assistance tends to be concentrated in a few countries, and that lower-income, drought prone countries receive an inadequate share development assistance relative to their level of risk. At the national level, a recent UNDRR risk-sensitive budget review of 16 African countries concluded that current direct and indirect DRR investments vary widely across countries, ranging from 0.3% to 8.8% of budgets in 2018-2019 (UNDRR, 2020). While the review did not include figures specifically from Ethiopia, the average DRR investment provides an indication of the current level of investments across the African region.

**Despite the increasing attention given to fiscal measures for disaster risk management, there is still limited research of the temporal scale and relationship between DRR investment and disaster mitigation impact, especially in low-income, high disaster risk countries.** Existing best practice indicates as range of measures to support a comprehensive approach for fiscal disaster risk management within an overall public risk management framework:[22]

1. Enhance the understanding of fiscal risks and assessments of the relevance of disaster risk for public finance;
2. Ensure comprehensive tracking of spending on disasters across agencies and disaster phases (response, recovery, mitigation, and preparedness);
3. Protect public finance through risk financing instruments - identify and examine insurance-related instruments and mechanisms protection of the fiscal position;
4. Manage disaster risk through a comprehensive framework, including risk mitigation integration and risk preparedness as they affect development; and
5. Pursue a synergistic, co-benefits based, strategy of concurrently managing disaster risks and promoting development.

[20] See table 5.6. "Net benefits and adaptation project costs, USD billions" (p. 2).
[21] Cabon Venton et al., 2012.
[22] See reports by the World Bank (2016), ODI (2014), Pew Charitable Trusts (2020).

Figure 8 Incorporating disaster risk within a comprehensive risk management framework


Note: Holm-Nielsen, Niels (2013). World Bank.
Source: Vivid Economics

**The most comprehensive international accord to date on disaster risk reduction, the Sendai Framework 2015-2030, calls for increased public and private investments into disaster risk reduction for resilience.** The agreement acknowledges that DRR investment can be a driver of innovation, job creation and economic growth, as well as cost-effective measures to prevent and reduce losses and damage from disasters. Drawing on the lessons and experiences of the predecessor agreement (Basabe, 2013), the Sendai Framework provides a set of common standards and a framework for action. Studies have highlighted several best practices in DRR investments: (i) planned expenditures for DRR should focus on pre-disaster rather than post-disaster activities; (ii) external funding for DRR activities play an important role in complementing efforts by the national government; and (iii) DRR investments at the subnational level plays a key role. UNDP's Ethiopia's Coping with drought and Climate Change Project was shared as an international good practice for building adaptive capacity and reducing vulnerabilities to the adverse effects of drought and climate change (UNDP, 2012):

**Ethiopia's national policy and strategy on disaster risk management (2013) provides general directions and implementation strategies for DRR**. This includes the implementation of a decentralized DRM system, early warning and risk assessment, information management, capacity building, and integration of disaster risk reduction into development plans. In the case of Ethiopia, its vulnerability to droughts and flooding have widespread impacts on the economy, including on agricultural production, infrastructure, and electricity production (as detailed in previous sections). In this context, disaster risk reduction measures can consist of investments in climate-smart agriculture, soil and water management irrigation and drainage infrastructure, expansion of rural roads, upgraded design standards for roads and bridges and the diversification of energy generation.

# 5 Appendix

**The table below provides an overview of best-practice international tools used for assessing disaster-related fiscal risks.** The tools are evaluated against criteria that are relevant to the key risks faced by Ethiopia of flood and drought, and the types of fiscal considerations that would be needed in a fiscal risk statement.

Figure 9 Table of tools and risks quantified

| Tools | | | Fiscal risks assessed | | | **Drought covered?** |
|---|---|---|---|---|---|---|
| Name | | Description | Direct losses | Emergency losses | Macrofiscal losses | |
| CATSIM* | Catastrophe Simulation Model | Model illustrating the trade-offs and choices faced when managing natural disasters. | ● | ● | ● | |
| PCRAFI | Pacific Catastrophe Risk Assessment and Financing Initiative | Initiative providing risk assessment and modelling tools from a historical database. | ● | ● | | |
| PDNA* | Post-Disaster Needs Assessment Tool | Guidelines providing evidence-based resource mobilisation advice. | ● | ● | ○ | |
| R-FONDEN | Loss Estimation for Federal Risk System | Probabilistic catastrophe risk assessment platform for the Mexican government. | ● | | | |
| PFRAM* | PPP Fiscal Risk Assessment Model | Tool that assesses potential fiscal costs and risks arising from PPP projects. | ○ | ○ | ○ | n/a |
| InaSAFE | Indonesia Scenario Assessment for Emergencies | Free software producing natural hazard impact scenarios. | ● | | | ● |
| MnhPRA | Morocco Natural Hazards Probabilistic Risk Analysis | Open-source software combining asset and hazard databases in Morocco, estimating the impact of disasters. | ● | | | ● |
| FST* | Fiscal Stress Test | Fiscal Stress Test models how public finances react to large shocks. | ○ | ○ | ○ | ● |
| CAPRA | Central America Probabilistic Risk Assessment Platform | Initiative aimed at integrating disaster risk information into development policies & programs. | ○ | | | ● |
| GAR | Global Risk Model | Global Risk Model for catastrophe risk assessments. | ● | | | |

Note: *not specific to different types of hazards
● = risk fully assessed; ○ = risk partially assessed or only for certain circumstances

Source: Vivid Economics

Box 5 Federated States of Micronesia Fiscal Stress Test

**A FST shows the short and long-term effects on the FSM's fiscal position.** In 2019, the IDA and the IMF conducted a FST for the FSM as part of a debt sustainability analysis. The analysis is based on baseline macroeconomic assumptions and scenarios of joint macroeconomic shocks, with a specific natural disaster scenario based on FSM's historical experiences. The FST can be divided into three stages:

1. **Scenario design:** How does the physical risk of natural disasters translate into economic impacts
2. **Model risk:** How does the scenario create fiscal risk?
3. **Interpretation:** What tested outcomes are desirable and/or undesirable?

**The natural disaster scenario tested shocks to multiple macroeconomic variables simultaneously.** Key assumptions included a one-off shock of 10 percentage points to the debt-to-GDP ratio, real GDP growth lowered by 5 percentage points and growth lowered by 3.5 percentage points. Shocks related to contingent liabilities were not considered in this analysis.

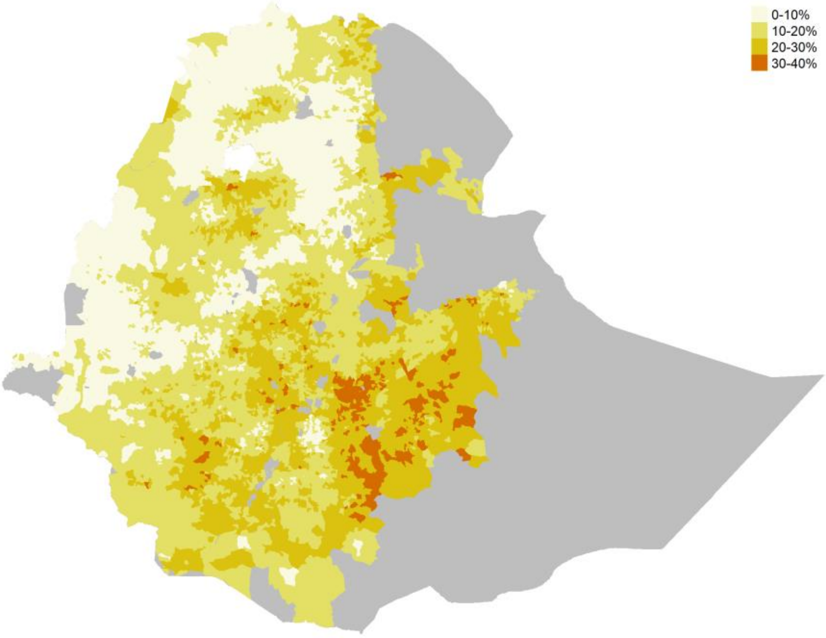
**The natural disaster FST demonstrated the long-term effects on the economy and fiscal health.** The scenario examined endogenous debt dynamics using a simple equation of debt-to-GDP ratio growth. The analysis found that the natural disaster shock would have a long-term effect on debt accumulation with the present value of external-debt-to-GDP ratio rising to 41% in 2029 and 84% in 2039. In the natural disaster scenario, debt breaches the threshold of sustainability in 2027, six years earlier than in the baseline scenario.

Source: (IMF, 2017)

## 5.1 Drought risk maps

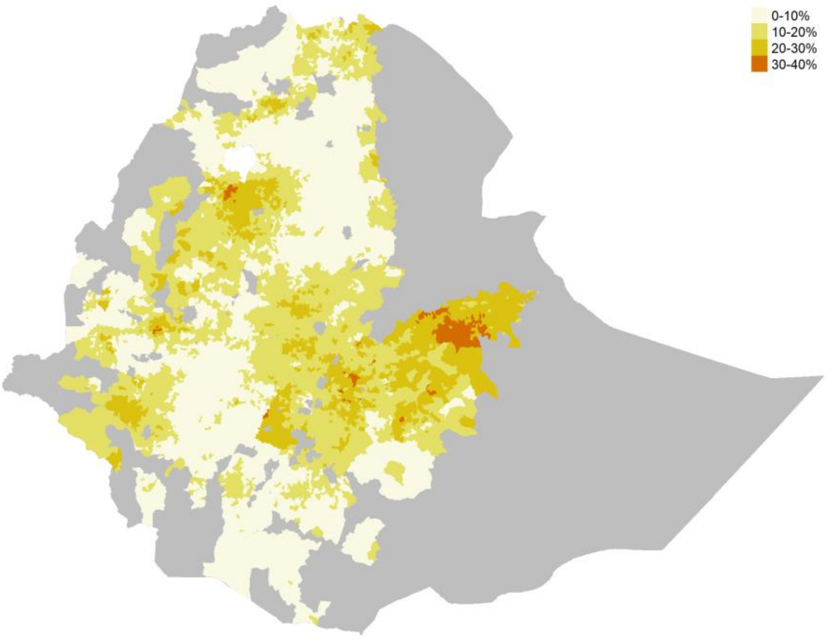
The following maps have been produced by Vivid's agriculture-drought risk model developed for the UK Space Agency. These maps may be used to identify areas where agricultural production is at particular risk of drought based on historical events.

Figure 10 Percentage of years between 1996-2016 in which kebeles experienced drought loss affecting maize yields



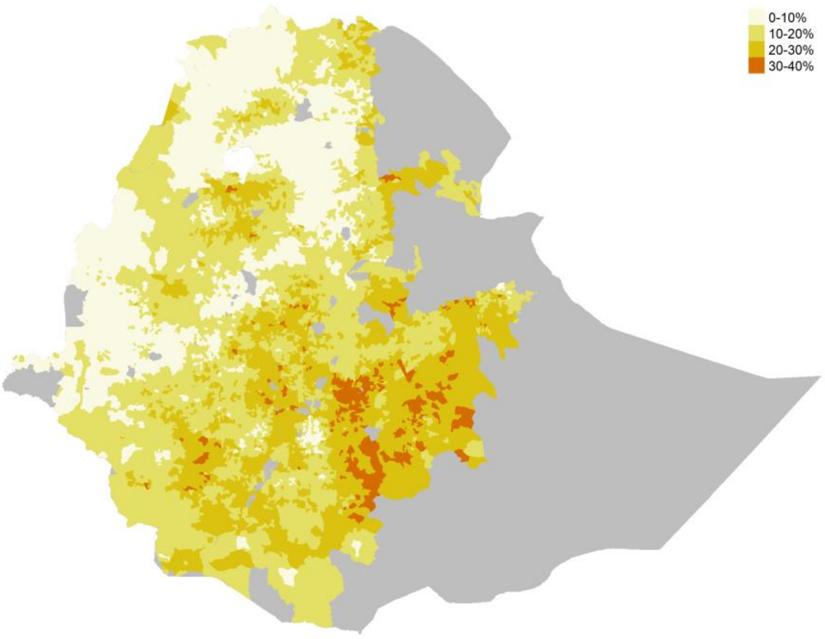

Source: Vivid Economics

Figure 11 Percentage of years between 1996-2016 in which kebeles experienced drought loss affecting maize yields



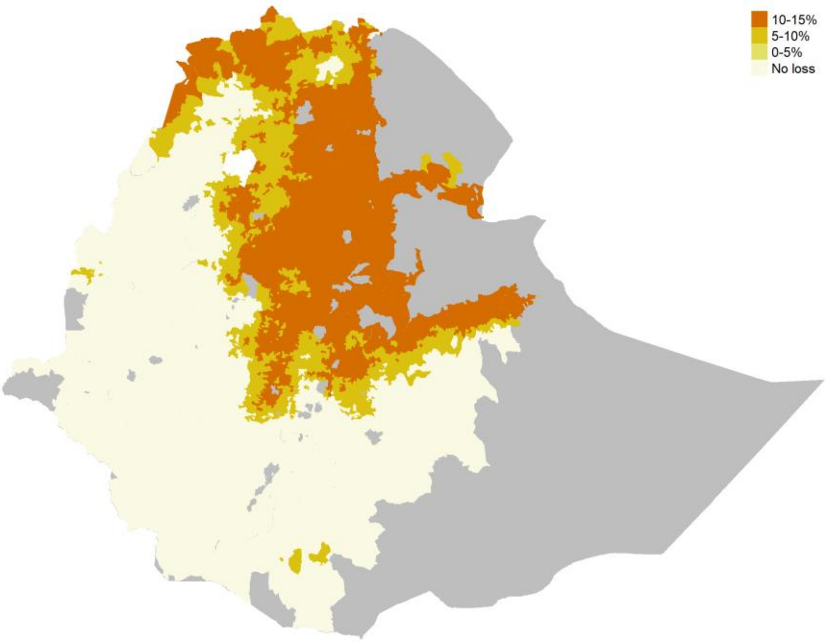

Source: Vivid Economics

Figure 12 Percentage of years between 1996-2016 in which kebeles experienced drought loss affecting sorghum yields



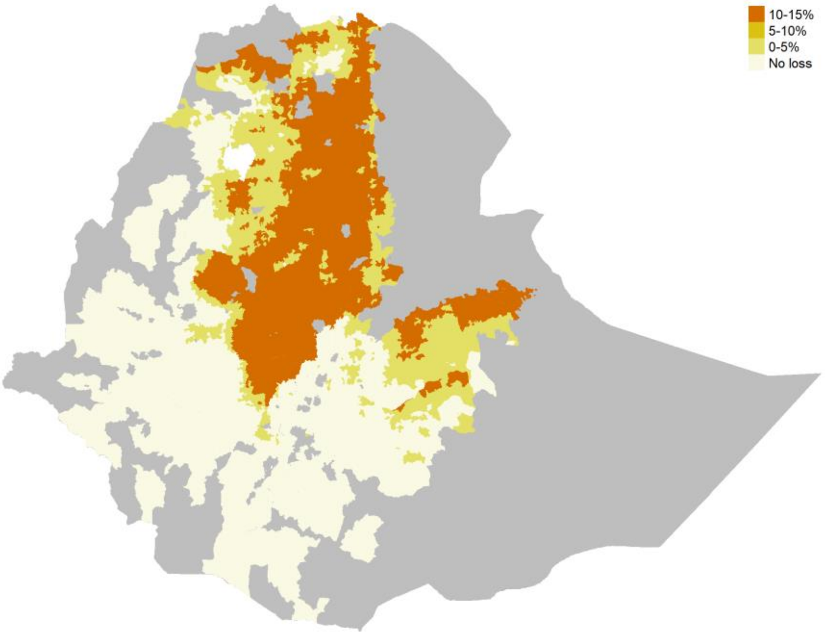

Source: Vivid Economics

Figure 13 Estimated production losses associated with maize during the 2015 drought



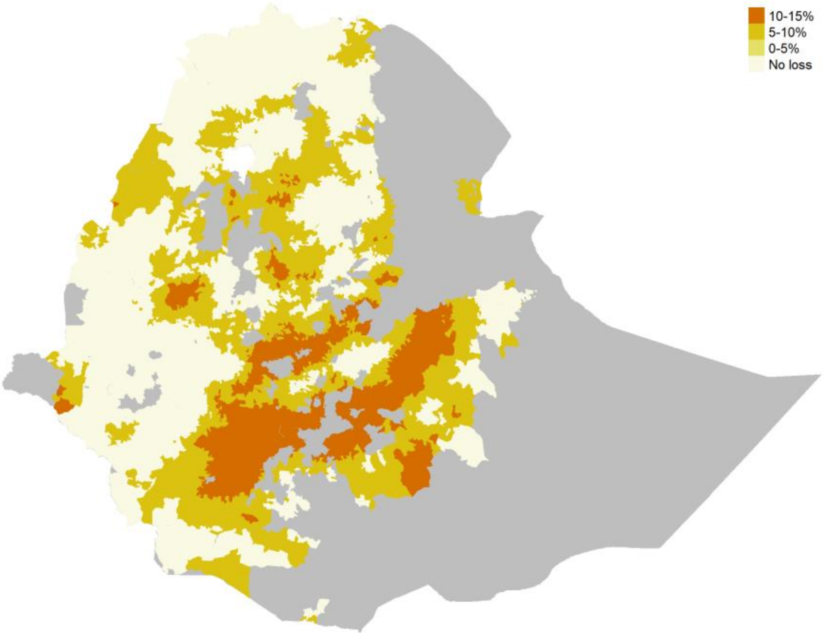

Source: Vivid Economics

Figure 14 Estimated production losses associated with wheat during the 2015 drought




Source: Vivid Economics

Figure 15 Estimated production losses associated with sorghum during the 2009 drought




Source: Vivid Economics

# 6 Methodology Annex

**The methodological annex provides a detailed overview of how the flood and drought scenarios are developed and how fiscal risks and economic recovery are calculated in the tool.** Table 8 outlines the key assumptions in the macroeconomic and probabilistic modelling, which are explained in more detail in the following sections.

Table 8 Assumptions used in the macroeconomic and probabilistic modelling

| # | Assumption | Type |
|---|---|---|
| Macroeconomic modelling | | |
| 1 | Rates (growth rates, revenue rates, exchange rates, interest rates, etc.) are constant over the projected horizon. | Baseline |
| 2 | Disasters do not result in a lower proportion of agricultural and energy sector output being exported. | Hazard |
| 3 | The only sectors which experience lower exports are those directly impacted by disaster (the agricultural and energy sectors). | Hazard |
| 4 | New debt taken on over the horizon has the same principal and interest payment terms as baseline public debt. | Both |
| 5 | Additional public debt taken on to finance disaster response has the same principal and interest payment terms as baseline public debt. | Hazard |
| 6 | Deficits are split between external and domestic public debt in the same proportion as the aggregate baseline stock of public debt. | Both |
| 7 | Foreign exchange reserves following a disaster evolve at the same rate as the baseline. | Both |
| 8 | Food imports recover to baseline levels in the year following the hazard. | Hazard |
| 9 | Food impacts are a function of reduced agricultural production. This does not account for international food aid. | Both |
| 10 | Revenue rate of the agricultural sector is assumed to be negligible (zero). An empirically derived national average is used for non-agricultural sectors. | Both |
| 11 | The trade balance is the only factor which influences the current account deficit. | Both |
| 12 | Best- and worst-case recovery times are informed by the literature at a high level, but recovery times by return period are by assumption. | Hazard |
| 13 | Financing strategies are linked to best- and worst- case recovery times based on a qualitative assessment of how quickly funds are dispersed by different financing mechanisms after a disaster. Strategies that utilise instruments that disburse more quickly are linked to the fastest recovery times, and vice versa. Strategies linked to a 'medium' are assumed to recover at the average of the best- and worst- case scenarios. | Hazard |
| 14 | Disaster risk financing mechanisms only have a direct impact in the year of the hazard; it is assumed they are not drawn on to finance persistent effects in years FY1-FY4. | Hazard |

| # | Assumption | Type |
|---|---|---|
| 15 | Ethiopia has no outstanding contingent debt (e.g., CAT DDOs). | Both |
| 16 | The principal payments for contingent financing (e.g., CAT DDOs) follow external public debt repayment rates. Interest rate payments are set at the World Bank's CAT DDO repayment schedule (LIBOR + 0.5%, with LIBOR at 0.2% as of August 2021). | Both |
| 17 | Debt repayment is factored into government spending when that is calculated as a share of GDP. | Both |
| 18 | The government always pays all interest on debt in the same period it accrues. | Both |
| 19 | Government spending in the medium-term is assumed to rise in proportion with the funding gap. This is to provide for those who suffer lasting effects as a result of a funding gap (e.g., those who had to sell livestock or their main sources of living to survive), which may result in additional spending on social assistance programmes or other public investment needs. However, in thee absence of detailed information on how social security programmes would respond to funding gaps government spending simply responds to | Hazard |
| **Probabilistic modelling** | | |
| 1 | All drought production losses relate to the Meher harvest. Belg harvest relates to on 4.4% of production compared to Meher for grain crops, thus we assume it will not contribute to a material additional fiscal impact beyond that of Meher in case of a severe drought. | Drought |
| 2 | Arable hectarage and crop production vulnerability to drought remain constant over time. | Drought |
| 3 | Yield loss is relative to expected annual aggregate rather than potential yield. | Drought |
| 4 | A weighted scaling factor of 1.43 x modelled crop losses is used to scale up to total crop losses. | Drought |
| 5 | Hydropower production loss is relative to 2018 production levels (approximately 13 billion kWh). | Drought |
| 6 | The proportion of the population exposed at the Awash Basin level can be scaled up to a country-wide exposure, maintaining a consistent aggregation effect. In other words, this assumes the proportion of the population exposed at the Awash Basin level can be applied at the national level. | Flood |
| 7 | For agriculture, we make an analogous assumption that the proportion of exposed cropland at the Awash Basin can be applied to the national coverage of arable land. | Flood |
| 8 | GDP exposure is aggregated and scaled consistently with population exposure. | Flood |
| 9 | Infrastructure exposure for transport, measured in kilometres exposed to road and rail, and also public buildings, measured in number of health and education facilities exposed, are based on the World Bank reported figures from the 2019 disaster risk profile. | Flood |

| # | Assumption | Type |
|---|---|---|
| 10 | Assuming that people do not return to properties immediately following the flood we include a 10% buffer on top of the estimated flood duration to approximate displacement time for humanitarian assistance needs and business interruption time. | Flood |
| 11 | Humanitarian assistance costs USD 2.66 per person for 5 days per month. | Flood |
| 12 | The cost of agricultural production losses is based on the average price of main cereal crops weighted by production volume. | Flood |
| 13 | The reconstruction costs are based on average day centre (including basic surgeries), regional hospital, and general hospital (e.g. city teaching hospital) costs for health facilities whereas for education we use primary and secondary schools and university costs. In the absence of health or education building damage figures for Ethiopia we instead take the average of costs for Kenya and Uganda as a reasonable proxy. | Flood |
| 14 | The translation from replacement costs to depreciated value is done using a conversion factor of 0.60. | Flood |
| 15 | Contents damage is equivalent to building damage. | Flood |
| 16 | Infrastructure, including road and rail, uses the damage function calculated by JRC for Ethiopia updated for to 2019 at 7.39 EUR $m^{-1}$ assuming a road width of 8m, taxing a conservative assumption that exposed roads experience the maximum damage. | Flood |
| **Historical-based modelling** | | |
| 1 | The locust invasion in 2019-2020 affected 197,163 hectares of cropland and 1,350,000 hectares of pasture in Ethiopia. Alternative historical-based scenarios multiply the hectarage affected by a factor of one half or two. | Locust |
| 2 | Modified historical-based scenarios do not affect the scale of damage per hectare for pasture or cropland. | Locust |
| 3 | Cereal losses per hectare are calculated by FAO estimates of cereal loss divided by estimates of total cropland affected. | Locust |
| 4 | Weighted average value of crops is estimated to be 254.7 USD based on the price per tonne of barley, maize, millet, oats, rice, sorghum, and wheat. | Locust |
| 5 | Average value of livestock assets per farm are assumed to be 720 USD, as per the producer price of livestock cited in the IFPRI. | Locust |

| # | Assumption | Type |
|---|---|---|
| 6 | The control costs account for the quantity of pesticides used. Therefore, control costs will adjust based on affected hectarage commensurate to the 2019-2020 infestation, assuming equal shares of pesticide protection per hectare affected by the infestation. | Locust |
| 7 | Given limited data, locust recovery ranges are based on our drought modelling. Both drought and locust have little persistence and predominantly affect agricultural sector, with smallholder farmers incurring the greatest losses. It is worth noting that locust will be more asset damaging, making this estimation more conservative than the drought model. | Locust |

Source: Vivid Economics

## 6.1 Probabilistic scenario modelling

**Probabilistic modelling is a methodology used to characterise a risk, or the likelihood of an event occurring, in terms of its frequency and the severity.** With historic data of sufficient quality and time-span, a probability distribution can be fitted to the data such that it describes the likelihood of events with the same characteristics of the risk. This allows modellers to simulate an event for any frequency – severity combination; for example, the MoF may seek to understand the magnitude of a 1 in 100-year event, which may not be possible based on historical data or physical modelling alone. Alternatively, this can be used to analyse historical events, such as a major drought or flood, to understand how likely it is that such an event will reoccur. We use the probabilistic modelling in this analysis to estimate the severity of potential future events for a range of different probabilities or return periods, i.e. 1 in 10 years or 1 in 100 year event occurrence.

### 6.1.1 Drought scenario modelling

**The purpose of drought modelling is to deliver a quantitative estimate of the impact of drought on an annual, aggregate national level for selected return periods**. The return periods chosen cover a range of more frequent events needed for near term planning and rarer extreme events useful for worst case scenario planning, including; 1 in 10 years, equating to a probability of occurring during a given year of 10%; 1 in 30 years, or a 3.3% probability; and 1 in 50 years, or a 2% probability of occurring.

The drought scenarios model four key impacts of droughts that affect macrofiscal outcomes:

- Agricultural sector losses
- Food imports
- Humanitarian assistance costs
- Hydropower sector losses

#### Crop Yield

The agricultural sector losses, food imports and humanitarian assistance costs are underpinned by a spatial disaggregated model of drought on crop yield developed by Vivid Economics for the UK Space Agency. The agricultural yield model used the data collated by the Agricultural Sample Survey that measured crop yields over a large spatial extent of Ethiopia over a number of years, combined with SPEI, a spatially explicit drought measure that takes into account temperature and precipitation. The response of four main cereal crops (maize, millet, sorghum and wheat) to drought have been characterised in a parametric model.

Models tested included:

- Regional, zonal, woreda and Kebele fixed effects
- Time fixed effects and linear year trends
- Latitude and longitudes as covariates (as a proxy for spatial effects)
- Level and log models
- Additional spatial variables (altitude, distance to roads and electricity grids)
- Additional agricultural inputs, and a drought-irrigation interaction term

The model with the highest predictive power (R^2) for all three crops included Woreda fixed effects, a linear time trend, altitude and some combination of agricultural inputs (varies by crop). Yield is predicted at the Kebele-crop level.

$$\log\left(Yield_{kwt}\right) = \beta_0 + \beta_1 SPEI_{kt} + \beta_2 Year_t + \beta_3 Fert_{kt} + \beta_4 Irrg_{kt} + \beta_5 Chem_{kt} + \beta_6 Altitude_k + \beta_7 Wor_w + \varepsilon_{kwt}$$

Modelling the Probability Distribution of Annual Aggregate Crop Losses

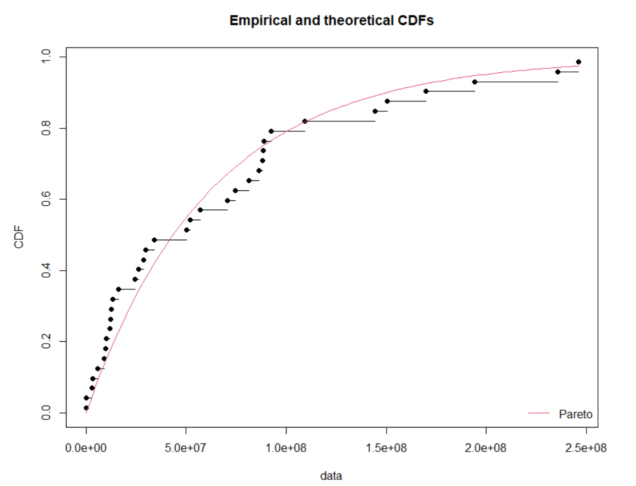
The agricultural model provides an estimation of yield for the Meher harvest based on known climatic and location specific parameters. Using historical drought data over a 36-year period from 1981 to 2016 we model the effects of drought on yield while holding other parameters constant, including arable hectarage, for 2020.

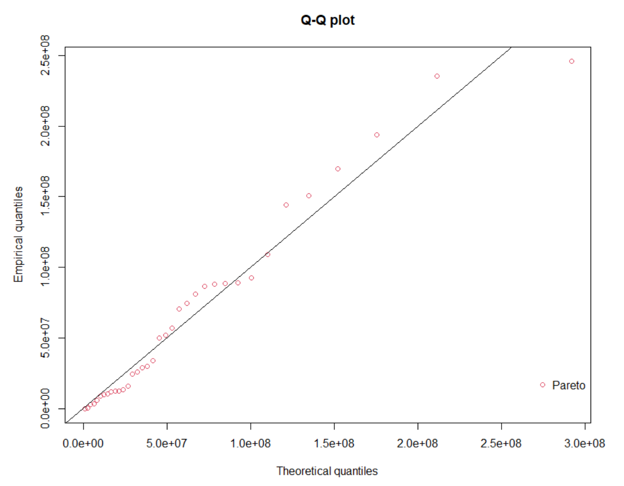
Converting to production loss we are then able to fit the modelled data with a suitable frequency-severity probability distribution applying standard maximum likelihood fitting criteria. Two distribution types were found to give a good fit, Weibull and Pareto. Figure 16 shows the fit of the Pareto distribution that gave the best fit and was used in the later analysis.

In order to compare the losses to a realistic baseline we use a measure of the loss relative to the expected annual aggregate loss rather than the potential yield. This is a more realistic assumption as we do not expect to achieve potential yield during a typical year (i.e. zero losses) but instead expect a degree of loss that is characterised by the mean of the distribution, or the annual aggregate loss.

Figure 16 Pareto distribution used in the analysis

| Shape | Scale |
|---|---|
| 2.223128e+01 | 1.375798e+09 |



Note: The Pareto distribution was selected from which we were able to simulate losses for return period beyond the original historic data set.

Source: Vivid Economics

To scale up the loss across all crops grown in Ethiopia we utilised FAO gross production value data[23] by crop to scale up the loss proportional to the gross production value relative to the modelled crops. In cases where we had information, we weighted the crop production value with the Water Response Yield Function,[24] Ky, as a measure of the crops expected response to drought relative to the four major modelled crops. The final weighted scaling factor of 1.43 x modelled crop losses was used.

### Food Imports

Food imports during period of drought stress were modelled in relation to the historic production losses between 2007 and 2016. The value of imports by end use data was provided by the NBE. The cereal and other food data was normalised against the total imports over time and plotted against the modelled production loss data for the same period. A simple shifted linear regression was used to model the change in food imports with changes in production losses. The model was shifted to start at zero food imports for zero production loss in order to only capture the additional food imports in case of drought.

### Humanitarian Costs

The humanitarian aid estimation leveraged the work done by Drechsler, Coll-Black, Tatin-Jaleran, & Clarke, (2017) quantifying the humanitarian costs of drought in Ethiopia. The report looks at the Productive Safety Nets Project (PSNP) that provides an ongoing financial support to the food insecure in addition to the Humanitarian Requirements Document (HRD) process which works through government appeals for international humanitarian assistance during periods of stress. Drechsler performs a statistical analysis on historical PNSP and HRD beneficiaries numbers between 1995 and 2016 which they fit a probability distribution to allow estimation of combined costs for a range of return periods while comparing the two different funding approaches. For more details on the core case load, contingency PSNP budget, and how the HRD process functions, see Drechsler, Coll-Black, Tatin-Jaleran, & Clarke, (2017).

In order to utilise the results of Drechsler, Coll-Black, Tatin-Jaleran, & Clarke (2017) we need to exclude the ongoing costs provided through PNSP program as we are interested in only the temporal cost of drought in times of stress that is reflected in the HRD response. To account for this we consider that on average, between 2005 - 2016, 6.96 million core caseload beneficiaries received PNSP assistance. We then exclude these from the projected number of beneficiaries for all return period reported. The final humanitarian cost is the remaining number of beneficiaries multiplied by the cost of HRD aid per person annually. The HRD cost is based on the total HRD cost over 9 months in 2017 of USD 598 million distributed to 5.6 million people; giving an annual cost of USD 106.8 per beneficiary.

It is worth to note that HRD funding covers a range of associated needs beyond food support. The breakdown below is take from Drechsler et al. shows the funding use over the period 2005 to 2015.

- Food requirements constituted the largest component of HRD funding, representing on average 72.5% of total HRD funding for the years 2005 to 2015;
- Funding for health and nutrition represented the second-largest component, accounting for an average 10.7% of HRD funding;
- Water and sanitation represented a further 4.6% of HRD funding;

[23] http://www.fao.org/faostat/en/#data/PP
[24] http://www.fao.org/3/i2800e/i2800e00.htm

- Targeted Supplementary Feeding (TSF) accounted for 3.6% of HRD funding; and
- Education accounted for 0.3% of HRD funding.

### Hydropower Impact

The impacts of drought on hydropower are modelled separately, since hydropower production is not directly affected by impacts on the agricultural sector. The Ethiopian Electric Power Cooperation reports that 88% of Ethiopia's electricity is generated by hydropower. However, the effects of drought on hydropower are especially difficult to quantify due to the inherent complexity of the drivers behind changes in river levels. Ethiopia has 12 dams spread across multiple river basins and with a wide variation in catchment size and dam capacity (Degefu et al., 2015).

The risk assessment for the effect of drought on hydropower was a combination of qualitative literature analysis and statistical modelling. We were able to benchmark the potential range of impact drought may have on power generation in Africa as a guide.

van Vliet, Sheffield, Wiberg, & Wood (2016) "quantify the impacts of drought episodes and warm years on hydroelectric and thermoelectric available capacity. They show that hydropower utilisation rates were on average reduced by 5.2% and thermoelectric power by 3.8% during drought years compared to the long-term average for 1981–2010, while during major drought years, hydropower showed declines in the 6.1–6.6% range and thermoelectric power in the 4.7–9% range. Among the global regions considered, they observe the highest interannual variability in utilisation rates of hydropower in Southern Africa (the only region of SSA considered in the study)."

To quantify the impact for a range of return periods we used the historic data on power generation in Ethiopia broken down by source found at US Energy Information Administration[25]. Hydropower is found to reveal evidence for cases where a drop in generation is associated with drought events. To capture this sensitivity we isolate only the decreases in power generation over the 39-year data record assuming that it reflects a natural variability that is influenced by drought. Fitting the data with a standard Pareto distribution we are able to simulate decreases in hydropower generation over the selected range of return periods.

Table 9 Estimated hydropower production loss by return period

| Return Period | % Hydroelectricity Production Loss | Absolute Production Loss (billion kWh) | Comments |
|---|---|---|---|
| 2 | 0.0% | 0.00 | |
| 5 | 1.3% | 0.17 | |
| 10 | 3.2% | 0.41 | |
| 30 | 6.0% | 0.78 | |
| 38 | 6.7% | 0.86 | 2015/16 El Nino drought |
| 50 | 7.4% | 0.95 | |
| 100 | 9.4% | 1.22 | |
| | Total Hydro power 2018*: | 12.88782 | |

Source: US Energy Information Administration

[25] https://www.eia.gov/international/data/country/ETH

The modelled power loss is consistent with the literature search that observed a reduction in power from historic events up to 6.6% between 1981 to 2010, excluding the large El Nino drought of 2015/16. The results are a best estimate as the effect is strongly dependent on many upstream influences.

### 6.1.2 Flood scenario modelling

The purpose of the flood risk assessment is to quantify the annual losses from flood country-wide for a range of return periods. To do this we need to understand how flood impacts the main areas of production, losses due to damages, and associated costs of humanitarian support. To achieve this, we define a flood scenario, in this case flooding of the Awash Basin, to understand and characterise the impacts at the level of woreda which we then aggregate to give exposures for the entire Awash Basin. With the exposures well characterised at the regional level we are then able to scale exposures up to a national level based on assumptions described below. Finally, we apply damage functions to estimate the annual costs of flood to the public sector in Ethiopia for a range of return periods.

Annual costs are derived using modelled exposures along with internationally accepted damage functions. This means that the modelling undertaken here is not based on recorded data on costs and damages, but on the spatial distribution of people and assets and how this relates to the spatial realisation of flood events. While these impacts are not based in historical estimates, the estimates that feed into the fiscal tool are calibrated against publicly available estimates where available.

#### Flood model

The modelling of the exposure to flood in the Awash Basin was developed by Sayers and Partners LLP and Vivid Economics for the UK Space Agency. The fluvial analysis uses a hydrological assessment (based on a combination of CHIRPS and climate models) to drive an innovative hydrodynamic flood hazard model (providing a fast but full 2-D representation of flood flows) that represents the topography, channel network, dams and defences (based on a combination of in-situ and Earth Observation (EO) datasets). The flood extent for different return periods is applied to layers for population, agricultural production, and GDP.

#### Aggregation

The model provides the exposures for the above layers for the Awash Basin scenario already aggregated to the level of woreda. Before calculating losses, we need to first translate the exposure from a single event in the Awash Basin to an annual exposure country-wide for the required return periods. We break down this translation into two parts.

1. Aggregate exposure across woredas to the level of Awash Basin
2. Scale aggregate exposure to an annual country-wide exposure

To simply sum exposures across woredas would likely result in an overestimate. This is because as we do not expect, say for a 1 in 50-year flood, that every woreda would experience a 1 in 50-year level of flooding. It is expected that there will be some spatial diversification such that some woredas experience the full impact while others remain largely undamaged. To account for this, we have aggregated the exposure by woreda using a correlation matrix that allows for a degree of diversification across woredas. The degree of correlation has been calibrated to ensure the resulting aggregate exposure compares favourably to exposures previously reported by the World Bank and others, and lies within the range of past events of similar type and magnitude of flood. In particular, the recent floods in 2020 in the Awash Basin, provide a meaningful example of the real exposure to flood in the region which we can compare to the modelled exposures for comparable return periods. Below is an extract from an article from Flood List, on 23rd September, 2020.

> "The government in Ethiopia reports that unprecedented flooding caused by the overflow of the Awash River has displaced more than 144,000 persons in Afar Regional State. According to state

> disaster officials, the overflow of Kesem, Tendaho, and Koka dams on the Awash River were the cause of displacement of more than 144,000 people. Flooding in the state has affected 240,000 people, demolished 105 schools, 200 rural roads, 6 bridges, and killed over 21,000 domestic animals. Flooding has also damaged around 60,000 hectares of crops and farmland" [26]

A further comparison is provided in Table 10 that suggest based on the modelling the floods in the Awash Basin in 2020 were comparable to a 1 in 10 to a 1 in 30-year impact depending whether you measure by the effect on agriculture or population.

Table 10 Model results compared to figures reported from an actual flood event in the Awash Basin

| | Aggregated Model Exposures | | 2020 Flood Awash Basin | |
|---|---|---|---|---|
| Awash Basin Exposures | 1 in 10 | 1 in 30 | Reported figures | Source |
| Population (#) | 227,656 | 274,105 | 289,025 | *Estimated from Flood Response Plan, Ethiopia, 2020 Kiremt Season Floods*[27] |
| Agriculture Cropland (ha) | 42,163 | 49,143 | 40,000 | *Approximately 40,000 acres of cropland in Afar's Amibara and Nahurka woredas, USAID*[28]*. Upper limit 60,000.* |
| GDP ($US million) | 550 | 616 | | *No data* |
| Education & health buildings (#) | 216 | 267 | 105 schools | *Flood List, 23 September 2020*[29]*; no mention of health facilities (Afar state only)* |
| Infrastructure: roads, railways, and bridges (km) | 683 | 776 | 200 rural road, 6 bridges | *Flood List, 23 September 2020; no mention of road length (Afar state only)* |

Source: Vivid Economics

With confidence in the Awash Basin scenario, we now consider how to scale up to a country-wide effect. To estimate the exposure at a national level we assume that the proportion of exposed population and agriculture can be scaled up from the Awash Basin, maintaining a consistent aggregation effect at a country-wide level. In the case of population, we assume the proportion of the population exposed at the Awash Basin level can be applied at the national level. For agriculture, we make an analogous assumption that the proportion of exposed cropland at the Awash Basin can be applied to the national coverage of arable land.

As for the aggregation at the national level we again benchmark against historic events and previously reported analysis. Below is a summary of aggregate exposures and comparable national level benchmark findings (World Bank, 2019b).

Table 11 Modelled results compared to World Bank analysis

| | Model Results | | World Bank | |
|---|---|---|---|---|
| National Exposure (aggregated) | 1 in 10 | 1 in 50 | 1 in 10 | 1 in 50 |
| Population Exposed | 1,366,006 | 1,761,550 | 1,000,000 | 1,500,000 |

[26] http://floodlist.com/africa/ethiopia-floods-afar-september-2020
[27] https://reliefweb.int/sites/reliefweb.int/files/resources/ethiopia_-_flood_emergency_response_plan_for_2020_kiremt_season_16_sep_2020.pdf
[28] https://www.usaid.gov/sites/default/files/documents/2020.09.30_-_USG_Ethiopia_Complex_Emergency_Fact_Sheet_4.pdf
[29] http://floodlist.com/africa/ethiopia-floods-afar-september-2020

Source: Vivid Economics and World Bank 2019

The World Bank reported a 1 in 10-year annual exposure of one million people, which is comparable to the 2020 Kiremt floods in September 2020 and to the modelled results for a 1 in 10 year shown in Table 10.

> "The most recent figures from the country's National Disaster Risk Management Commission (NDRMC) indicate that close to 1,017,854 people are affected by flooding and 292,863 people are displaced across the country." (Flood List, September 2020) [30]

GDP exposure are aggregated and scaled throughout consistently with population exposure. Infrastructure exposure for transport, measured in kilometres exposed to road and rail, and also public buildings, measured in number of health and education facilities exposed, are based on the World Bank reported figures from the 2019 disaster risk profile.

Table 12 Estimated flood return periods

| National Exposures (aggregated) | Return Period (years) | 5 | 10 | 20 | 30 | 50 | 100 |
|---|---|---|---|---|---|---|---|
| Population Affected | (#) | 1,181,020 | 1,366,006 | 1,527,868 | 1,644,709 | 1,761,550 | 1,968,289 |
| Agricultural (cropland, ha) | (ha) | 208,610 | 232,835 | 254,033 | 271,383 | 288,733 | 321,153 |
| GDP at risk (business interruption) | (US$) | 1,532,935,412 | 1,832,905,705 | 1,924,095,775 | 2,053,623,635 | 2,260,065,458 | 3,193,554,118 |
| # of Education / Health Buildings | (facilities exposed) | 1,114 | 1,298 | 1,470 | 1,603 | 1,762 | 2,090 |
| # of Transport (roads, railways, and bridges) | (kilometres exposed) | 2,594 | 3,000 | 3,355 | 3,612 | 4,000 | 4,469 |

Source: Vivid Economics

### Humanitarian Costs

Population exposed is translated into humanitarian costs by estimating the duration in days for which the population exposed is in need of financial assistance multiplied by the established Productive Safety Nets Project (PNSP) humanitarian cost per day (Drechsler et al., 2017).

The duration of flood per return period has been calculated from statistical analysis of the Dartmouth Flood Observatory database on floods in Ethiopia over a 26-year period spanning 1985 to 2010. The database records the duration of flood in days from which we derived the Occurrence Exceedance Probability (OEP) curves. This allows us to model the duration as a function of return period. Assuming that people do not return to properties immediately following the flood we include a 10% buffer on top of the flood duration itself.

The translation to losses we use the PNSP cost per person of USD 2.66 per day (Drechsler et al., 2017) for 5 days per month. Thus, the estimated humanitarian assistance is estimated as the Exposed Population$_{RP}$ x Flood Duration$_{RP}$ x Cost$_{RP}$ for each calculated return period.

### GDP Losses

GDP losses are calculated based on the business interruption incurred during flood events. As such we can use a similar approach using flood duration as used to calculate the humanitarian costs above. Using the same assumptions around exposure of businesses to flood duration as used for population we use the flood duration as a fraction of the year to apply to the total GDP to estimate the loss due to flood.

As we calculate the impact of flood on agricultural production separately prior to calculating the above impact on GDP we subtract the agricultural GDP at risk.

### Agriculture (arable) Losses

The losses due to flood on agricultural production are estimated by taking the average price of the main cereal crops grown weighted by production volume. We multiply the aggregate area of arable land exposed to flood by the price to give a total loss per return period.

### Public Assets Losses

Public assets include health and education facilities as well as infrastructure including road and rail. The damage function is calculated based on construction costs of hospitals and education facilities in line with the JRC methodology. The reconstruction costs are based on average day centre (including basic surgeries), regional hospital, and general hospital (e.g. city teaching hospital) costs for health facilities whereas for education we use primary and secondary schools and university costs.  In the absence of health or education building damage figures for Ethiopia we instead take the average of costs for Kenya and Uganda as a reasonable proxy taken from Turner & Townsend, 2019. The translation from replacement costs to depreciated value is done using a conversion factor of 0.60, based on World Bank (2000), Frenkel & John (2002), Messner et al. (2007) and Penning-Rowsell et al. In addition, contents damage is included as percentage of building damage here set at 100%. Lastly, the portion that is undamageable and should thus not be included in the maximum damage estimate used in the flood damage assessment is set at 40% consistent with masonry and concrete buildings specified by the JRC methodology.

The maximum damage function is applied to the number of buildings exposed estimated by the World Bank Disaster Risk Profile – Ethiopia to provide an annual loss by return period.

Infrastructure, including road and rail, uses the damage function calculated by JRC for Ethiopia updated for to 2019 at 7.39 EUR $m^{-1}$ assuming a road width of 8m. In this case, assuming poor quality construction of transport infrastructure, with many kilometres of unsurfaced road, we take a conservative assumption that the exposed roads experience the maximum damage. The country-wide annual losses are summarised in Table 13 below for a wide range of return periods.

Table 13 Estimated annual losses by return period

| | Return period (years) | | | | | |
|---|---|---|---|---|---|---|
| Costs (millions USD) | 5 | 10 | 20 | 30 | 50 | 100 |
| Population Assistance | 18.68 | 32.50 | 48.55 | 59.94 | 74.55 | 99.01 |

| | Return period (years) | | | | | |
|---|---|---|---|---|---|---|
| Agricultural (cropland) Losses | 169.61 | 189.30 | 206.54 | 220.64 | 234.75 | 2661.11 |
| GDP Losses (business interruption) | 111.04 | 201.41 | 281.05 | 343.99 | 441.42 | 759.63 |
| Education / Health Buildings Losses | 69.26 | 80.68 | 91.38 | 99.65 | 109.52 | 129.96 |
| Transport (roads, railways, and bridges) Losses | 9.19 | 10.63 | 11.89 | 12.80 | 14.18 | 15.84 |

Source: Vivid Economics

## 6.2 Historical-based scenario modelling

**Deterministic scenarios, based on historical data are used to characterise a risk in the absence of sufficient data to model probabilistically.** Without sufficient historic or forward-looking data, we are unable to reliably generate a probability distribution to estimate the likelihood of a given event. Therefore, the epidemic and locust modules use recent historical disasters as a base scenario and allow users to modify the scale of the event. This will enable users to simulate different fiscal outcomes for different disaster severities without probabilistic frequencies. The tool structure for these modules mirrors the probabilistic scenario modelling, but with flexibility to modify outcomes contingent upon a verified reference point. For example, users can examine possible fiscal outcomes for a locust infestation scaled to one half or twice the hectarage affected relative to the 2019-2020 infestation.

### 6.2.1 Locust scenario modelling

**The purpose of the locust risk assessment is to provide an estimate for the losses incurred from different severities of locust infestation.** With these estimates, the model can quantify the efficacy, costs, and recovery times of different financing approaches for government intervention. Firstly, we quantify the damages from locust swarms. This requires estimates of the area affected by a given infestation, the yield from that area, the value of the yield, and the scale of the damages (i.e., how much of the affected yield can still be used). Given limited available data on these measures, we limited our model to one reference point: the 2019-2020 desert locust infestation.

**The model provides measures on macrofiscal outcomes through declines in production and increases government expenditure that stem from the locust crop damages.** Government expenditure is measured by estimating the number of people requiring emergency aid, multiplied by the cost per beneficiary. One notable omission is food imports are not included in the scenario, with implications for the trade balance and FOREX. Given that the reference historical event occurred during the COVID-19 pandemic, it is not possible disentangle the changes in food imports stemming from the locust upsurge from other economic and social impacts of the pandemic. To include the any estimate would overestimate the costs of government expenditure in future scenarios.

**For production, locust scenario modelling focusses entirely on agricultural losses, which are measured by cereal production losses.** Total cereal production losses are quantified by multiplying hectares of cropland affected, the average cereal loss per hectare, and the average value of different crops. Livestock asset losses are not factored into agricultural GVA losses, since asset losses represent a stock of value, whereas GVA is a flow of annual value produced. In addition, livestock losses will be partially endogenous to the policy response; financing strategies that have quick-to-disburse instruments can prevent households from resorting to extreme coping mechanisms that result in livestock losses. Therefore, the agricultural GVA losses should be considered a conservative lower-bound estimate.

**To create variation in the model, scenarios are scaled by the affected hectarage of 2019-2020 locust infestation by 50 and 200 percent.** The 2019-2020 infestation is estimated to be the worst infestation in 25 years in Ethiopia. The additional scaled estimations, however, have no comparable probabilistic outcome. Instead, these alternative scenarios provide variation in hectarage affected to the recent historical example we used. Other factors, such as share of pastoral damage unusable for grazing and households resorting to emergency coping strategies, remain constant across scenarios.

**The current estimates assume that the locust management response (pesticide application) is constant across scenarios, scaled commensurate with affected hectarage.** The scope of pesticide application against a locust upsurge will greatly affect the severity of pasture and cropland lost. Moreover, pesticide use is often commensurate to the predicted scale of an incoming swarm. The historical-based estimation is limited to one scenario in 2019-2020, when conflict in Yemen and the COVID-19 pandemic affected Ethiopia and neighbouring countries' response, which might underrepresent overall pesticide usage for an event. To avoid bias in our factor effect estimates, which depend on the pesticide application levels relative to a normal year, we assume pesticide intensity is constant across all historical-based scenarios. If further control were to occur, the damage level would decline; given data constraints it is not possible to estimate this relationship.

**Due to limited data, locust recovery period ranges are based on estimates from drought recoveries.** Drought provides an adequate proxy for locust recovery, as both disasters are particularly taxing on agriculture with limited persistence into different seasons. As locust are more likely to lead to asset damages than drought, the 1-in-25 year locust reference scenario is aligned with a 1-in-30 year drought event recovery time period, to reflect that locust upsurges may have longer recoveries than drought.

## 6.3 Fiscal risk analysis

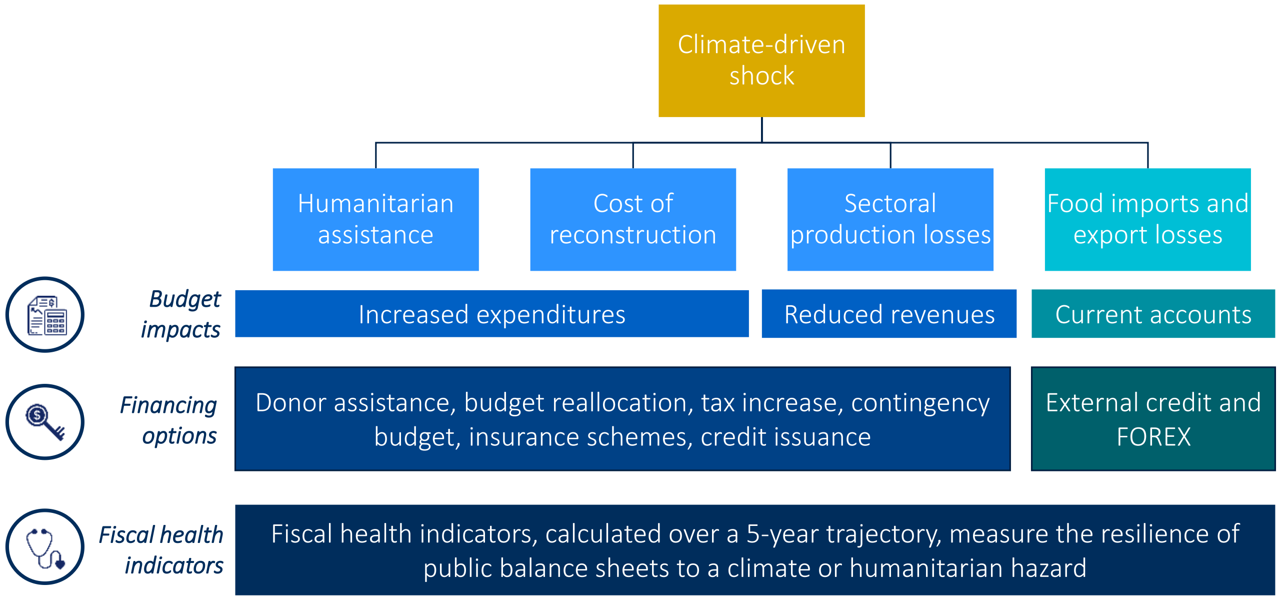
**The fiscal risk analysis is intended to provide the user with a view of both total in-year fiscal impacts associated with each hazard scenario, as well as reserve-related and debt-related trajectories of fiscal health.** The former can form the basis of the natural disasters component of a Fiscal Risk Statement, and the latter can inform longer term fiscal planning and the design of disaster risk financing strategies. This section lays out the structure of the tool and can serve as a reference for advanced users who need to update the tool's input parameters, data, or assumptions. Please refer to the tool manual for guidance on the basic functionality of the tool.

**The tool has undergone Vivid Economics' rigorous model audit process and has been tested with a range of stakeholders.** The audit process requires a trained technical colleague outside of the project team to carry out a comprehensive audit. The auditor creates a detailed report following a defined template, and the researcher is obliged to explain how all concerns raised have been addressed. This ensures the model is robust, error-free, and consistent. In addition to this, the model has been critically reviewed by technical experts at Oxford Policy Management, the World Bank, the Centre for Disaster Preparedness, and the Government Actuary's Department.

### Structure of the tool

**Figure 17 illustrates the schematic structure of the tool**. A climate-driven shock feeds directly to the spending or revenue line items in the first row of boxes, as described in the probabilistic modelling section. The tool first calculates the budget impacts in terms of increased expenditures, reduced revenues, and current account balance impacts. The user inputs funding responses, which help determine recovery rates associated with key macroeconomic indicators, which give a longer-term view of how fiscal risks evolve.

Figure 17 Structure of the fiscal risk Excel tool




Source: Vivid Economics

## Model inputs

**The assessment of flood and drought impacts is underpinned by national data and scenarios of hazard severity.** The tool requires user inputs of two types of data: national data and scenario assumptions (as detailed in Table 14 and Table 15). National data refers to Ethiopia-specific data on indicators such as production in key sectors and revenue rates; these indicators do not vary with hazard severity. Scenario assumptions refer to indicators which reflect the magnitude of a hazard, such as number of households displaced or affected. In the tool, users can use pre-populated hazard and national data, or develop their own assumptions. The scenario data for floods and droughts have already been developed for a range of return periods (see the section on probabilistic modelling for an overview of how these were developed) and the national data has been collected from the Ministry of Finance and the National Bank of Ethiopia. Table 15 shows the national data requirements and the government sources from which the pre-populated sources were collected. If users wish to input their own data, a key component of implementing a framework which provides a robust assessment will be sourcing accurate national data and developing appropriate scenario assumptions. Underlying equations for calculating fiscal risks are detailed in Table 18.

### 6.3.1 Scenario parameters

**User-developed scenarios in the Excel tool can be informed by historical data, forward-looking projections or international experience of drought and flood impacts.** The Excel tool is designed to test up to three user-inputted scenarios of droughts and floods, which can be developed using simple or more complex modelling approaches. Scenarios tested should include a range of magnitudes of flood and drought impacts to improve understanding of the range of possible fiscal outcomes. For example, an 'annual average' scenario could support understanding of the fiscal consequences of relatively high-frequency, low-impact events that the government would typically cover, while a 1-in-20 or a 1-in-100 year hazard scenario (a 5 or 1% annual probability) can provide a magnitude of impact for a more adverse scenario, for which the government may seek risk transfer options (see Box 1). Quantifying both possible outcomes can support fiscal planning and designing appropriate DRF instruments. Table 14 details all of the assumptions which underpin the drought and flood scenarios and vary with the magnitude of hazard, noting Government agencies that can be consulted for developing these scenario assumptions. In the absence of Government data sources, some indicators can be estimated using publicly available data. Several open-access databases, including Sendai DesInventar and EM-DAT, collect natural disaster losses, including number of households displaced, number of buildings damaged, and crop losses associated with individual events. With some processing and assumptions, these can be used to inform scenario design.

Table 14 Hazard scenario inputs

| Key variable | Units | Description | Hazard | Government source |
|---|---|---|---|---|
| Cost of humanitarian assistance | USD | For both drought and flood relief, the average cost of assistance per household based on historical response and the number of additional individuals or households that require government assistance | Both | NDRMC |
| Cost of reconstructing damaged public assets | USD | Under a flood scenario, the total governmental cost of infrastructure repairs | Flood | NDRMC |
| Value of food imports | USD | For a certain severity of drought, food imports may be required if cereal production is reduced enough to threaten self sufficiency. | Drought | NBE |
| Loss in agricultural GDP | USD | Agricultural sector losses, based on lost crops and livestock | Flood, Drought, Locusts | NDRMC |
| Loss in hydroelectric GDP | USD | Energy sector losses, based on reductions in hydroelectric generation | Drought | NDRMC or MOWIE |
| Proportion of exposed SOE liabilities that are triggered | % | Given cash-flow interruptions, the probability the government has to fulfil SOE debt payment obligations | All | TBD |
| Proportion of PPP contractual obligations that are realised | % | Given physical disruptions, the probability PPP projects face interruptions or delays in contracted services | All | TBD |

Source: Vivid Economics

### 6.3.2 Macroeconomic indicators

**Collecting appropriate data for the Excel tool may require cross-ministry collaboration.** Table 15 details all of the national data required to implement the framework for flood and drought scenarios. The format of the data collected will have implications for how it is processed. For example, the revenue rate may be available as described in Table 15 or may require further calculations based on historical revenue receipts and GDP. Some data categories may need to be collected from multiple sources. For example, cost of assistance per household may capture multiple sources of government expenditure, such as medical care, food aid or temporary shelter assistance. These could be sourced separately and combined to a single cost-per-household, or where analysis exist, an average cost across all forms of expenditure could be calculated. The following checks should be carried out to ensure data is in the correct format to be processed by the tool:

- Data are in standard units (not thousands or millions)

- Data are in U.S. dollars
- Calendar is Gregorian
- Data is at the same level: General, Federal, or Regional (this analysis uses General)

Table 15 National data requirements

| Data | Units | Description | Government sources |
|---|---|---|---|
| Exchange rate | ETB per USD | Annual value | NBE |
| Effective revenue rate | % of GDP | For each Birr generated, proportion captured in total government revenue | MoF |
| Liabilities to creditors and other stakeholders on SOEs | USD | Interest rates or payments on exposed SOEs (agricultural/hydroelectric firms for drought; agricultural/infrastructure firms for flood) | MoF |
| Exposed project contractual obligations | USD | Project contractual obligations for exposed projects (hydroelectric projects for drought; hydroelectric/infrastructure for flood) | MoF (PPP Board) |
| Agricultural sector exports | % of agricultural output | Proportion of agricultural output that is exported | MoR |
| Hydroelectric sector exports | % of hydroelectric output | Proportion of hydroelectric output that is exported | MoR |
| Public debt schedules (external and domestic)* | USD (stocks), % (payment terms) | Public and publicly guaranteed debt stock, principal, and interest payments | MoF |
| Primary deficit | USD | The total budget deficit excluding interest payments prior to the disaster | MoF |
| Government spending | USD | Government expenditure totals | MoF |
| Nominal GDP* | USD | Domestic production in the base year, as well as forecasts carried out within the Ministry (if available) | NBE |
| Nominal GDP growth rate | % | Average annual increase/decrease in nominal GDP | NBE |
| Foreign reserves and anticipated growth | USD (reserves), % (growth) | Foreign currency deposits held by the Bank of Ethiopia and Ministry-derived forecasts (or enabling time series) | NBE |
| Current account balance* | USD | Trade balance, as well as international transfers. | NBE |

Notes: All data requirements should use most recent year or estimate available. Starred data would be useful to have forecasted, although the tool only needs base year data to carry out its forecasting.

Source: Vivid Economics

### 6.3.3 Financing responses and fiscal health

**The tool is populated with six disaster risk financing strategies users can test to assess the implications for fiscal outcomes.** The six financing strategies represent a range of instruments deployed within a given strategy, to illustrate the key trade-offs between different strategies. Table 7 in the main body of the report describes some of these trade-offs, and Table 17 DRF instrument indicative costs and time to disburseTable 17 below provides a high-level overview of the costs and disbursement times of a range of instruments. Instruments are split into two types, ex-ante, and ex-post, and then further sub-divided into instruments that are fixed and variable. Fixed instruments have a known limit (e.g., the government has $USD 50 million in reserves). Variable instruments can flex in the amount of funding provided, depending on the cost of the disaster. For example, parametric insurance payouts would be higher in the event of a more significant disaster. Each strategy is also linked to a recovery speed, reflecting the mix of instruments and disbursal times. The six strategies the user can select from are as follows:

Table 16 Six illustrative DRF strategies from which users can select

| Strategy | Description | Instrument mix (USD) |
|---|---|---|
| Reserves | Some ex-post risk retention | • 50m in budget contingencies, 75m in budget reallocations |
| Reserves + aid | Some ex-post risk retention and some risk transfer via aid | • 50m in budget contingencies, 75m in budget reallocations<br>• 40% of remaining costs financed through donor support |
| Debt-led | Significant ex-post and ex-ante risk retention | • 75m in budget reallocations<br>• 25% of remaining costs financed through domestic credit, 25% through external credit |
| Debt + aid | Significant ex-post and ex-ante risk retention, with some risk transfer via aid | • 75m in budget reallocations<br>• 25% of remaining costs financed through domestic credit, 25% through external credit, 20% though donor support |
| Mixed | Some ex-post and ex-ante risk retention, with some risk transfer | • 75m in budget reallocations<br>• 20% of remaining costs financed through contingent debt facilities, 40% through insurance |
| Insurance-led | Substantial risk transfer | • 60% of costs financed through insurance, 40% through alternative risk transfer |

Note: The financing strategies are intended to illustrated trade-offs between instruments and are not intended to reflect a real mix of feasible strategies for Ethiopia. Further analysis is required to develop and test a set of strategies that are feasible and fit for purpose in Ethiopia.

Source: Vivid Economics

**The tool is built flexibly so that users can adjust these strategies as needed.** Users can select the amount or share they wish to fund through each instrument with the tool automatically calculating the size of the funding gap. Some instruments have a known cap. For fixed instruments, the user can choose the exact level of financing in the strategy. Once these funding sources are drawn down, the user then can input the share of the remaining costs covered by other instruments. The user must then also select the ‘speed’ of the strategy, which should reflect the mix of instruments deployed, and how likely they are to disburse funds quickly and lead to a slow or fast recovery time.

Table 17 DRF instrument indicative costs and time to disburse

| DRF instrument | Cost | Time |
|---|---|---|
| Reserves | | |
| Budget reallocations | | |
| Contingent debt facility (e.g., CAT DDO) | | |
| Parametric insurance | | |
| ART (e.g., CAT bonds, weather derivatives) | | |
| Donor support (relief) | | |
| Donor support (recovery & reconstruction) | | |
| Domestic credit (bond issue) | | |
| Budget contingencies | | |
| External credit (e.g., emergency loans, bond issue) | | |
| Traditional (indemnity based) insurance | | |
| Funding gap | | |

Note: The cost multiplier is the ratio between the opportunity cost of the financial product and the expected payout. Cost multipliers are indicative and only to facilitate comparison between instruments. Time to disbursement also depends on a country's individual legal and administrative processes.

Source: Vivid Economics; adapted from https://www.preventionweb.net/files/15924_54291.pdf

### 6.3.4 Model outputs

**The tool estimates the immediate fiscal risks associated with hazard scenarios or probabilistic return periods.** Table 18 describes how these are estimated.

Table 18 Equations for estimating the macroeconomic impacts of floods and droughts

| Components of the analytical framework | Simplified estimating equation |
|---|---|
| Disaster response | $Humanitarian\ assistance\ +\ Food\ imports\ +\ Cost\ of\ reconstruction$ |
| Contingent liabilities | *Not currently calculated* |
| *SOE guarantees* | $Interest\ payments\ on\ exposed\ guaranteed\ SOE\ debts\ \times\ Probability\ GoE\ pays\ servicing\ cost$ |
| *PPP contractual obligations* | $Exposed\ project\ values\ \times\ Probability\ of\ project\ failure$ |
| Macroeconomic impact | |
| *GDP loss* | $\sum_{i}^{sector} Sector\ loss + Sector\ loss\ \times Sector\ I - O\ multiplier$ |

| Components of the analytical framework | Simplified estimating equation |
|---|---|
| *Tax revenue loss* | $\sum_i^{sector} Sector\ loss\ \times Sector\ revenue\ rate + Sector\ loss\ \times Sector\ I - O\ multiplier\ \times Sector\ revenue\ rate$ |
| *Increase in imports* | $Increase\ in\ food\ imports$ |
| *Decrease in exports* | $\sum_i^{sector} Sector\ loss\ \times Sector\ export\ share$ |
| *Current account (trade) balance* | $Exports - Imports$ |

Note: Input parameters represent impacts which are additional to a "normal" year.
Placeholders are included for risk of default on guaranteed SOE loans and PPP contractual obligations being realised.
See the below for how macroeconomic multipliers are calculated.

Source: Vivid Economics

**To model how sector shocks propagate through the economy, the tool translates a supply-side shock from the probabilistic modelling to a change in exogenous demand, for which we derive a multiplier impact.** A standard 58-sector social accounting matrix (SAM) for Ethiopia was simplified to represent just three sectors: agriculture, energy, and other. The social accounting matrix used for this analysis was the Nexus Project SAM developed by the Economic and Policy Analysis Unit and the International Food Policy Research Institute. These steps can be replicated following the steps below, so the tool is flexible to the actual SAM used if newer tables become available. The multipliers used in the modelling are presented in Table 19. The following steps were followed to derive the macroeconomic multipliers:

- Aggregate the 58-sector standard SAM to represent a simple 3-sector economy by summing rows and columns.
- Calculate the coefficient matrix by dividing each column by its total.
- Create an identity matrix and subtract the coefficient matrix.
- Invert the (identity – coefficient) matrix.
- Create an exogenous demand shock matrix.
- Multiply the inverted coefficient matrix and the exogenous demand shock matrix to derive the table of multiplier effects.

Table 19 Macroeconomic multipliers used to calculate indirect economic impacts

| | Agriculture | Other | Energy |
|---|---|---|---|
| **Agriculture** | 1.76 | 0.63 | 0.73 |
| **Other** | 1.05 | 1.49 | 1.36 |
| **Energy** | 0.02 | 0.02 | 1.02 |

Source: Vivid Economics

**All hazard scenario trajectories are calculated based on a "no-hazard" counterfactual, or baseline.** With input baseline macroeconomic indicators and relevant growth rates, the tool will automatically calculate a simple forecast of the main indicators, upon which the hazard recovery calculations are based. Refer to Table 8 for the assumptions used in the baseline macroeconomic forecast. Otherwise, the user may choose to input forecasts for the indicators for which they are available.

**The user-selected financing strategy determines the quality of post-disaster social and economic recovery.** The tool distinguishes between social and business recovery. Business recovery is characterised by business interruptions and is proxied in the tool by the GDP recovery rate; social recovery is characterised by household impacts and is proxied in the tool by government expenditure. If the financing strategy leaves a funding gap (or some portion of the hazard cost unmet), "restorative recovery," as labelled in Figure 6 is not reached, as damages that give rise to unmet need is assumed to permanently depress economic and social outcomes. Scenarios that leave a funding gap can expect to see an "impaired recovery" trajectory instead and will settle at a lower level of GDP than the no-disaster baseline. Leaving a funding gap is strongly disincentivised in the tool, as leaving losses unaddressed will result in the lower economic and social outcomes. GDP will not fully recover, and lasting social consequences will require the government to increase regular spending to support affected people through welfare programmes.

**In addition to recovery level, the financing strategy affects the speed of recovery.** The number of years to recovery is determined by a qualitative assessment of how fast funds can be disbursed to tackle the disaster and the disaster severity.[31] For example, government reserves are easily mobilised whereas issuing new government debt is a comparatively slower emergency revenue source. Similarly, larger disasters will see longer recovery periods than smaller disasters for a given financing mix. Scenarios are classified as either fast, medium or slow. Fast recoveries achieve the best-case timeframe to arrive at the level of recovery linked to the funding level. Slow recoveries follow the worst-case timeframe, and medium speed recoveries fall within the middle. **Error! Reference source not found.** summarises the relative weighting used in the tool.

[31] Full recovery here an all-encompassing term including reformative, restorative, and impaired recovery trajectories, as illustrated in Figure 6

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