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Hanging Out to Dry? Long-Term Macroeconomic Effects of Drought in Fragile and Conflict-Affected States

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ABSTRACT: Using a comprehensive drought measure and a panel autoregressive distributed lag model, the paper finds that worsening drought conditions can result in long-term scarring of real GDP per capita growth and affect long-term price stability in Fragile and Conflict-Affected States (FCS), more so than in other countries, leaving them further behind. Lower crop productivity and slower investment are key channels through which drought impacts economic growth in FCS. In a high emissions scenario, drought conditions will cut 0.4 percentage points of FCS' growth of real GDP per capita every year over the next 40 years and increase average inflation by 2 percentage points. Drought will also increase hunger in FCS, from alreay high levels. The confluence of lower food production and higher prices in a high emissions scenario would push 50 million more people in FCS into hunger. The macroeconomic effects of drought in FCS countries are amplified by their low copying capacity due to high public debt, low social spending, insufficient trade openness, high water insecurity, and weak governance.

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WORKING PAPERS

Hanging Out to Dry? Long-Term Macroeconomic Effects of Drought in Fragile and Conflict-Affected States

Prepared by Kalin Tintchev and Laura Jaramillo[1]

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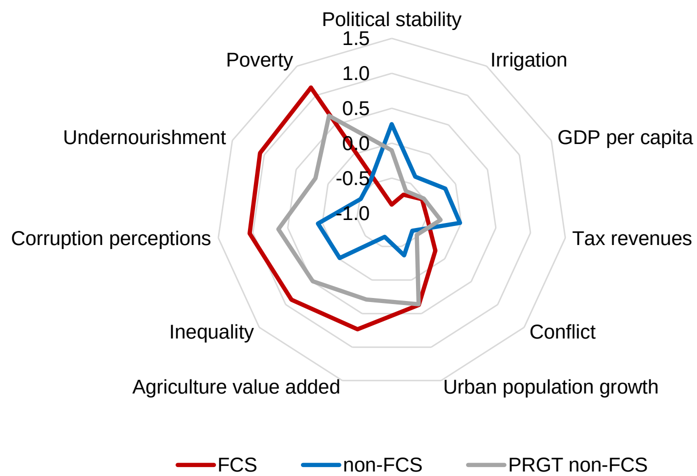
Contents

I. Introduction

A scarce natural resource, water is vital to economic growth and human well-being. Approximately half of the world's population is already suffering from reduced water availability for at least part of the year (Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report, 2022). Climate change has led to increased disruptions to the global water cycle over the last two decades. Droughts and floods—two of the most devastating manifestations of climate change—have affected three billion people with staggering economic toll (Word Bank 2021). Since 2000, droughts have increased both in number and duration and are set to worsen further and aggravate water scarcity (IPCC, 2008; INFCCC, 2012; WMO, 2021; Zaveri and others, 2023). By 2040, around a third of global cropland will likely be exposed to severe drought every year (Aberg, 2022).

Figure 1. Different Structural Characteristics Across FCS and Non-FCS

(Median across country group; variables are standardized)



Source: Jaramillo and others (2023)

Notes: Political stability (Worldwide Governance Indicators), percent of cultivated areas equipped for irrigation (Food and Agriculture Organization of the United Nations, AQUASTAT), GDP per capita (current US$, WDI), tax revenues to GDP (IMF, World Economic Outlook database), number of conflict years since 1980 (Uppsala Conflict Data Program), urban population growth (WDI), agriculture valued added to GDP (WDI), Gini coefficient (Standardized World Income Inequality Database), Corruption Perceptions Index (Transparency International), prevalence of undernourished population (WDI), and poverty headcount ratio at $2.15 a day (2011 purchasing power parity, WDI). FCS = fragile and conflict-affected states; PRGT = Poverty Reduction and Growth Trust.

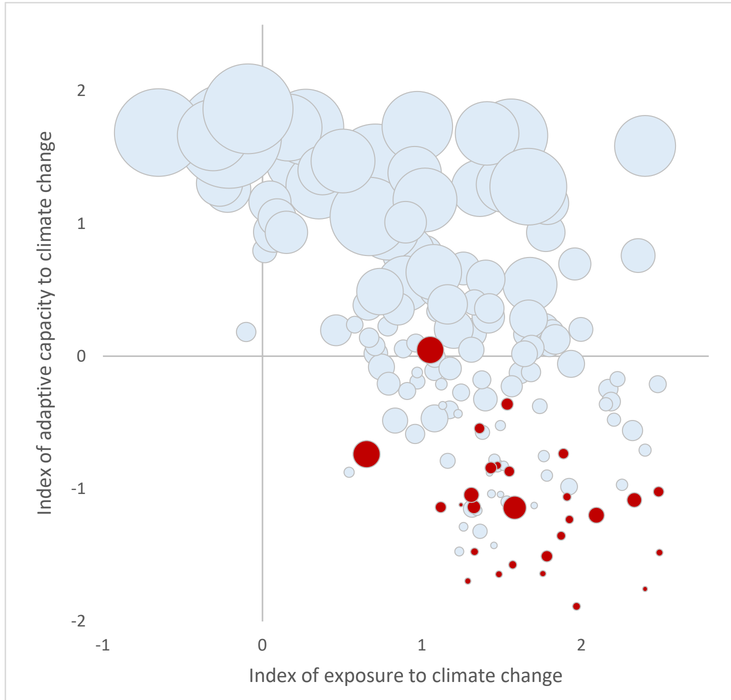
Worsening drought conditions exacerbate macroeconomic challenges in fragile and conflict-affected states (FCS). FCS are a heterogenous group of countries that face a complex set of challenges, including—and to varying degrees—high levels of institutional and social fragility and violent conflict. Relatedly, FCS have lower per capita income and growth rates, higher poverty and undernourishment, and higher inequality than other countries (Figure 1). At the same time, and as illustrated by Figure 2, FCS are highly exposed to climate change and must bear the immense burden of climate adaptation without having the means or capacity to adapt (Jaramillo and others, 2023). Climate change-driven water scarcity appears to have increased most rapidly in FCS (Karlsson, 2023) where more than one third of the population lacks access to safe drinking water (WHO, 2017). Freshwater shortages are a frequent cause of disease and food crises in FCS, where more than 80 percent of the population is found to be acutely food-insecure (World Bank, 2021). Droughts can have especially severe economic consequences in FCS given their heavy reliance on rain-fed agriculture and widespread structural vulnerabilities that amplify their susceptibility to climate shocks.

Against this backdrop, this paper employs econometric analysis to investigate the long-term scarring effects of worsening drought conditions on macroeconomic outcomes in FCS. The paper exploits a comprehensive drought measure and covers a large set of FCS with different climate characteristics and income levels. In addition to economic growth, the paper considers a range of other macroeconomic variables to address two interrelated questions: (i) How are long-term macroeconomic outcomes in FCS affected by worsening drought conditions and through which channels? (ii) How can structural policies help address the long-term macroeconomic consequences of drought in FCS?

This paper relates to the emerging literature on the macroeconomic impact of climate change with a focus on FCS. While a number of influential studies have highlighted the vulnerability of developing countries to climate change, especially countries with low incomes (Dell and others, 2012) and hot climates (Burke and others, 2015; Mejia and others, 2018), the literature on the climate challenges facing FCS is still developing. A recent IMF study (Jaramillo and others, 2023) shows in FCS, climate vulnerability and underlying fragilities—namely conflict, heavy dependence on rainfed agriculture, and weak capacity and policy buffers—exacerbate each other, amplifying the negative impact on people and economies both in the short term and the long term. Other recent IMF studies have highlighted the adverse effects of climate change on economic growth in fragile states in sub-Saharan Africa (IMF, 2020; Maino and Emrullahu, 2022).

Figure 2. Exposure versus Adaptive Capacity to Climate Change

(Bubble size represents GDP per capita of the country)



Source: Jaramillo and others (2023)
Note: The exposure index in this note measures exogenous climate change vulnerabilities based on the physical characteristics of extreme weather events and the projected impact of climate change on temperature and rainfall. It is the average of standardized values of the Notre Dame Global Adaptation Initiative exposure subindex, INFORM Risk Index natural hazard exposure subindex, UN Development Program's Human Climate Horizons projected increase in human deaths, and the World Risk Index climate exposure subindex. The adaptive capacity index in this note measures climate change vulnerabilities due to socioeconomic, infrastructure, and institutional characteristics. It combines the World Risk Index coping and adaptive capacity subindices and INFORM Risk Index's coping capacity subindex. FCS = fragile and conflict-affected states.

The microeconomic effects of water supply shocks on economic activity are well documented in the climate literature but their macroeconomic impacts have proved more elusive. Several macroeconomic studies based on aggregate data have found no robust and significant relationship between average precipitation and real GDP growth in the short-to-medium term (Dell and others, 2012; Burke and others, 2015) nor in the long term (Kahn and others, 2019). However, recent papers find evidence of significant short-term growth effects of water supply shocks based on high-resolution geospatial (subnational) data (Damania and others, 2020; Fuje and others, 2023) and the computation of water supply shock thresholds using daily observations (Akyapi and others, 2022; Kotz and others, 2022) and alternative measures of "green water" availability (Ross, 2020; Zaveri and others, 2023).[2] An important takeaway from this literature is that to capture the

[2] Green water is water stored in soil and biomass that is crucial for climate resilience, especially in the agricultural sector.

macroeconomic impact of drought, a more comprehensive measure of drought is needed than precipitation alone.

We extend the existing literature along several dimensions. To the authors' best knowledge, this is the first paper focused specifically on FCS countries (i) to examine how climate change-driven shifts in drought conditions affect long-term macroeconomic outcomes in FCS; (ii) to document evidence of the longer-term scarring effects of drought on per-capita GDP growth and inflation and underlying transmission through productivity and investment channels; (iii) to utilize a comprehensive measure of drought conditions—the deviation of the Standardized Precipitation Evapotranspiration index (SPEI) index from long-run historical trend—that reflects the net soil moisture resulting from precipitation, evaporation and transpiration; and (iv) to investigate how long-term scarring is amplified by FCS' structural vulnerabilities and the role of macroeconomic policies in alleviating the longer-term impacts of drought in FCS.

The empirical results show that droughts impact long-term macroeconomic outcomes in FCS countries. Worsening droughts can result in long-term scarring of real GDP per capita growth and affect longer-term price stability in FCS countries, more so than other countries. Drought conditions cut 0.4 percentage points from per capita GDP growth every year by 2060 and 1.4 percentage points over the 2061-2100 period in a high emissions scenario (RCP 8.5).[3] Lower crop productivity and slower investment growth are key channels through which drought affects economic growth in FCS. Drought-induced macroeconomic impacts in FCS countries are amplified by high public debt, low social spending, insufficient trade openness, high water insecurity, and weak governance. GDP per capita growth in FCS with dry climates and low incomes appear particularly vulnerable to worsening drought conditions.

The results highlight the risks posed to FCS' food security by worsening drought conditions. Food production in FCS is found to be two times more sensitive to drought conditions than other countries. Moreover, worsening drought conditions lead to persistent upward pressure on inflation in FCS, where food represents a large share of consumption and governments face import constraints and productivity challenges. Inflation in FCS appears seven times more sensitive to droughts than other countries. In a high emissions scenario, drought conditions will increase average inflation by 2 percentage points. Importantly, the empirical results indicate that persistent drought conditions would increase the share of undernourished population from an already high level. The confluence of lower food production and higher food prices in the high emissions scenario would push 2 percent more of FCS' population—about 50 million more people—into hunger by 2060.

Addressing climate challenges in FCS countries requires further progress with global climate mitigation, scaling up concessional adaptation funding, and addressing structural vulnerabilities. FCS' economies account for a small share of global greenhouse gas emissions but are facing significant climate challenges exacerbated by low copying and adaptive capacities and limited policy buffers. In this context, advancing the global transition to greener economies is critical to slow climate change and reduce FCS' exposure to climate risks. Access to affordable climate adaptation funding and resolute structural reforms

[3] It is important to note that there is considerable uncertainty around the global emissions trajectory as well as long-term climate and macroeconomic modeling. Predicting future emissions is inherently extremely uncertain, including because of the rapid rate of technological progress. For illustrative purposes, this note draws on models in the Intergovernmental Panel on Climate Change Sixth Assessment Report for a high emissions scenario (Representative Concentration Pathway (RCP) 8.5) and a low emissions scenario (RCP 2.6). RCP 8.5 is on the higher end of the range of possible baseline scenarios that assumes absence of global mitigation efforts in the context of high economic growth and thus high emissions.

is critical to help FCS countries avoid large potential drought-induced income losses over the next decades.

The paper is structured as follows. Section II examines FCS' exposure to drought risk. Section III outlines the methodology, Section IV presents key results and scenarios, and Section V carries out robustness tests. Section VI discusses policy implications and Section VII concludes.

II. Exposure to Drought Risk

The analysis in the paper is based on a comprehensive measure of drought conditions that captures the effects of climate change. The multi-scalar Standardized Precipitation Evapotranspiration index (SPEI) (Vicente-Serrano and others, 2010) gauges the impact of rising temperatures not only on water supply (precipitation) but also atmospheric water demand, namely evaporation from soil and transpiration from plants. The SPEI reflects the net soil moisture resulting from precipitation, evaporation and transpiration and is well suited to study the effects of rising temperatures on "green" water availability—water used by plants—which is a critical production factor in FCS' agriculture-based economies (see Annex II).

The climate literature suggests that global warming increases drought severity. Rising temperatures are found to intensify evapotranspiration (Rebetez and others, 2006) and plant mortality (Adams and others, 2009). This appears to have contributed to a decline in world agricultural production (Lobell and others, 2011). Temperature variability has considerably increased over the past decades and global warming is expected to have a major impact on drought conditions over the 21st century. Recent scientific projections suggest that climate change is gradually worsening global drought conditions. Without decisive global mitigation action, droughts would become more frequent and severe, especially in the 2050s and beyond as indicated by multiple, well-known climate models (IPCC Sixth Assessment Report 2022; Housfather, 2019). The frequency of concurrent droughts and heatwaves is also projected to increase across multiple regions. Dai (2013) shows that global aridity has risen substantially since the 1970s as global warming has increased atmospheric moisture demand and altered atmospheric circulation patterns. Aridity is likely to increase in the 21st century over most of Africa, southern Europe and the Middle East, most of the Americas, Australia and Southeast Asia. The frequency of long-term drought (longer than 6 months) is set to increase considerably in the high emissions scenario (RCP 8.5) in most regions (Lu and others, 2019). The global multi-model ensemble mean in the spatial extent of severe drought is projected to increase from 11 percent for the period of 1976-2005 to 33 percent under RCP 8.5 for the period of 2071-2100.

FCS tend to be located in semi-arid climates that leave them vulnerable to droughts.[4] The SPEI data indicate that FCS have experienced more severe and variable drought conditions than non-FCS over the past decade (Figures 3 and 4). FCS' median SPEI value has broadly remained in negative territory since 2008. This has added to water demand pressures from development, population growth, and urbanization (FAO and World Bank 2018).[5] FCS' vulnerability to droughts is compounded by high water insecurity and poor water infrastructure. FCS' semi-arid climates would become even drier as rising temperatures dry out soil and vegetation and alter the water cycle by reducing the surface available for evapotranspiration.

[4] Of the world's 17 most water-scarce countries, 12 countries are located in the Middle East and North Africa (Karlsson, 2023).

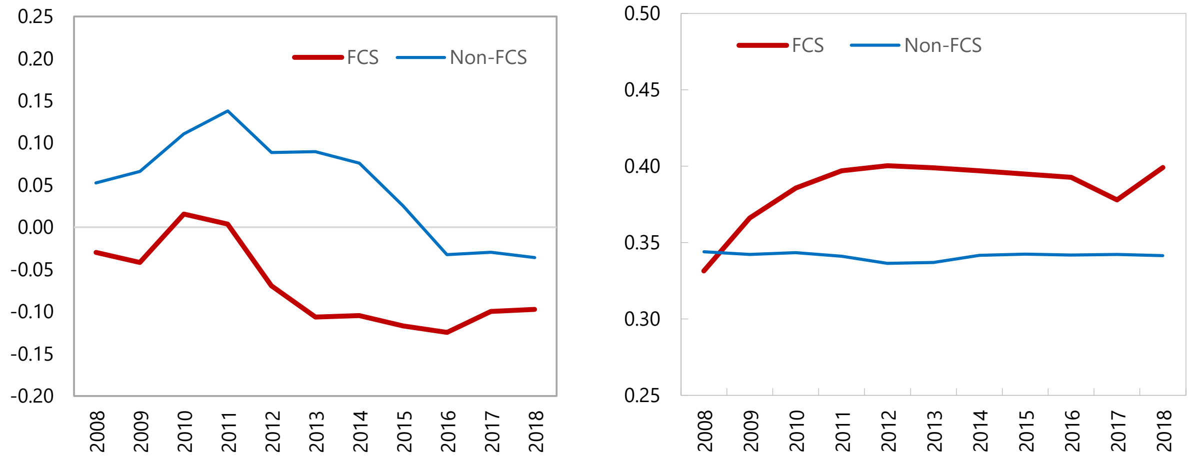
[5] The economic risks from flooding, although increasing in all world regions, appear to be greatest in North America, Europe and Asia (OECD, 2016).

In a high emissions scenario (RCP 8.5), drought conditions are projected to worsen considerably more in FCS than in non-FCS with similar income levels (Figure 4).

Figure 3. Drought Conditions and Water Insecurity, 2008-2018

Drought Conditions (SPEI) *(median)*

Water Insecurity Index *(median)*

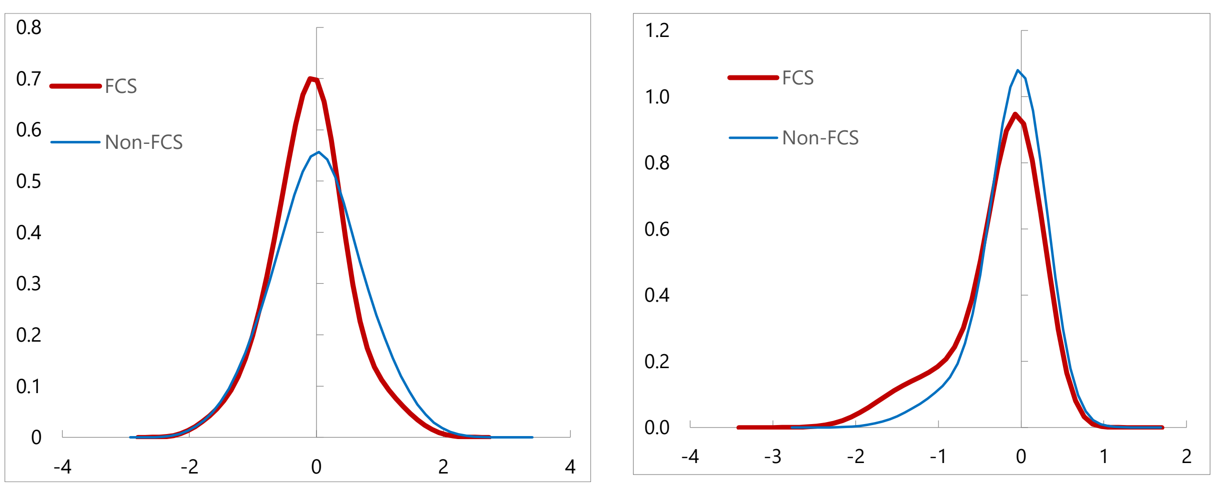


Sources: The global SPEI database, University of Notre Dame ND-Gain database, and IMF staff calculations.
Note: LHS: Five-year moving SPEI average. Negative (positive) SPEI values broadly indicate drought (non-drought) conditions.
RHS: The water insecurity index varies from 0 to 1 with higher values indicating higher water insecurity.

Figure 4. FCS: Exposure to Drought Conditions

Distribution of Drought Conditions Based on the SPEI Level, 2000-2018

Distribution of Drought Conditions Based on Deviations of SPEI from the Historical Average, 2024-2100 *(High emissions scenario)*



Sources: Global SPEI database and IMF staff estimates.
Note: Historical distributions over the 2000-2018 period derived from SPEI levels using Epanechnikov kernel. The FCS sample excludes island states. The non-FCS sample includes countries with income per capita below 3,000 USD over the estimation period.

Sources: World Bank Climate Change Knowledge Portal; IMF staff estimates.
Note: Distribution of SPEI projections expressed as deviations from the average values in the 1950-2005 period based on the IPCC high emissions scenario (RCP 8.5) using Epanechnikov kernel. The FCS sample excludes island states. The non-FCS sample includes countries with income per capita below 3,000 USD over the estimation period.

Drought conditions can affect long-term macroeconomic outcomes in FCS through multiple channels.

- Investment and productivity. The neoclassical growth literature has highlighted the importance of productivity for long-term growth (Sollow,1956). In this vein, the climate literature has modeled the long-term growth effects of climate change as negative productivity or investment shocks (Dell and others, 2012; Burke and others, 2015; Kahn and others, 2019). Droughts can have a profound impact on FCS economies facing conflict and instability with limited resources and human capacity, with long-term ramifications for growth, inflation, consumption, imports, investment, and food security.

- Agriculture.[6] Water is an essential factor of production and FCS' reliance on agriculture for growth and employment leaves them especially vulnerable to water shortages. In 2021, the value added of the agriculture rector represented 22 percent of GDP in FCS, compared to 6 percent in non-FCS. In 2019, 43 percent of employment in FCS was in agriculture, compared to 14 percent for non-FCS. Among economic sectors, agriculture consumes the largest percentage of water, averaging 70 percent of global water use (Norins, 2011). Deadly heatwaves, prolonged dry spells, and severe droughts kill plants and forests, burn crops, and degrade land and pastures, increasing desertification and shrinking the pool of productive land. Extreme floods and storms damage river basins and irrigation systems. Chronic water scarcity, exacerbated by weak irrigation systems and inefficient water management can have lasting effects on crop productivity and long-term growth. Drought can also affect long-term growth through its adverse effects on employment and migration.

- Disease. Droughts endanger human lives in FCS countries (Mbaye and Signé, 2022). Droughts facilitate the transmission of vector-borne diseases (dengue, malaria, chikungunya, West Nile fever, and zika) in FCS' semi-arid and tropical climates (Rawal and others, 2016). Polluted water and poor sanitation play an important role in the transmission of cholera, hepatitis and typhoid. Risks of infectious outbreaks are highest in FCS where there is limited access to reliable health services, adequate housing, and safe drinking water. Climate change is projected to lead to 250,000 additional deaths per year from malnutrition, infectious outbreaks, and heat stress between 2030 and 2050 (Howeth, 2020).

- Inflation and food insecurity. Worsening drought conditions increase the risks of inflation and food insecurity over the long run. Drought impacts inflation both through supply and demand-side channels (Cantelmo, 2022). Supply-side effects are likely to dominate in FCS countries as a permanent shift in drought conditions over the longer run would entail lasting output and productivity losses. Water shortages disrupt food production and lower crop productivity in countries with underdeveloped agriculture sectors (Letseku and Grové 2022; Molden and others, 2010; FAO, 2021). FCS are disproportionately exposed to malnutrition risk and drought-induced spikes in food prices are likely to exacerbate hunger and poverty.[7]

[6] Although agriculture is the most affected sector, other water- and agriculture-dependent sectors—including industry and energy (hydropower generation), tourism, recreation, public water supply and water transportation—are also vulnerable to droughts (Damania and others, 2020).

[7] Climate-induced shocks to the food system now occur every two and a half years in Africa, making it more difficult for countries to recover from these persistent shocks (World Bank, 2022).

III. Empirical Strategy

The paper focuses on the empirical link between drought conditions and longer-term macroeconomic outcomes in FCS. The analysis examines the impact of drought on economic welfare, measured by per-capita real GDP growth, and underlying channels of transmission through productivity, investment, and price channels. It also sheds light on structural FCS characteristics that amplify their vulnerability to drought and related macroeconomic policies that can build resilience against climate change. The paper focuses on the permanent long-term effects of drought on GDP growth as opposed to its effects on the level of output. Level effects are driven by transitory weather shocks whereas growth effects reflect climate change-driven shifts in average climate conditions (Dell and others, 2012; Kahn and others, 2019).

Our identification strategy combines two approaches proposes in the literature. To disentangle “level effects” from “growth effects”, the paper follows the model and identification approach in Dell and others, (2012) where weather shocks produce a growth effect through their impact on long-term productivity growth. We replace the level temperature variable in the Dell model with a measure of climate change based on deviations of drought conditions from their pre-climate change average. Our approach is akin to Kahn and others (2019) who proxy climate change using deviations from a long-term moving average. The approach is based on the premise that climate change manifestations are country-specific, with some countries being more exposed to climate change than others due to their climatic characteristics, location, and geography.[8]

The model assumes a simple economy where output is produced using labor *L* and level of productivity *A*. Drought conditions, defined as negative deviations of drought from its historical pre-climate change average, affect both the level of output and the growth rate of labor productivity:

$$Y_{it} = e^{\beta(D_{it}-D'_i)} A_{it} L_{it} \tag{1}$$

$$\frac{\Delta A_{it}}{A_{it}} = g_i + \gamma(D_{it} - D'_i) \tag{2}$$

where Y_{it} is real GDP, A_{it} is labor productivity, L_{it} is labor, D_{it} is annual soil moisture; the variables are indexed by country and time period; D'_i denotes the historical pre-climate change average of soil moisture in country *i*, and g_i denotes long-term productivity growth in country *i.*

Log-differencing equation (1) and substituting productivity growth with equation (2) yields a dynamic expression for per-capita real GDP growth:

$$\Delta y_{it} = g_i + \gamma(D_{it} - D'_i) + \beta(D_{it} - D_{it-1}) \tag{3}$$

In equation (3), the β coefficient captures the transitory effect of drought conditions on GDP growth while the γ coefficient gauges their permanent GDP growth effect. Solving this difference equation and adding *L* lags results in the following autoregressive distributed lag (ARDL) panel model specification:

[8] Empirical regularities suggest that countries that are closer to the north and south poles are warming faster than other countries (Kahn and others, 2019).

$$\Delta y_{it} = \alpha_i + \sum_{j=0}^{l} \theta_j \Delta y_{it-j} + \sum_{j=0}^{l} \gamma_j \text{`}D_{it-j} + \epsilon_{it} \qquad (4)$$

where Δy_{it} is the growth rate of real GDP per capita in country *i* and year *t*, $\text{`}D_{it-j}$ is the annual deviation of drought from its pre-climate change average D'_i in country *i*.

In equilibrium, per-capita GDP growth equals its steady state value $\Delta y_i{}^*$. Climate change represents a permanent departure of drought conditions from their pre-climate change average. Accordingly, we model climate change as an equilibrium phenomenon, assuming that drought conditions deviate permanently in the steady state from their pre-climate change average by a negative (non-zero) constant $D^*{}_i$.

$$\Delta y_i{}^* = \frac{\alpha_i}{1 - \sum_j^l \theta_j} + \frac{\sum_j^l \gamma_j}{1 - \sum_j^l \theta_j} D^*{}_i \qquad (5)$$

where $D^*{}_i < 0$ if climate change and $D^*{}_i = 0$ otherwise.

In line with Dell and others (2012), the long-run growth effect of drought conditions is defined in (5) as the summation of the drought effects on growth at different lags $\sum_j^l \gamma_j$ divided by the speed of adjustment to equilibrium $1 - \sum_j^l \theta_j$. Positive values of this expression would ensure that the impact of worsening drought conditions on long-term growth is negative and increasing in the magnitude of climate change.[9]

The baseline model is expanded to examine FCS-specific effects of drought conditions on growth of real GDP per capita. The FCS-specific drought effects are captured by a time-varying FCS dummy interacted with the drought variable[10]. Following Kahn and others (2019) we proxy climate change using the deviations of the climate variable (drought conditions) from its long-term trend.[11]

$$\Delta y_{it} = \sum_{j=1}^{l} \theta_j \Delta y_{it-j} + \sum_{j=0}^{l} Z_j \text{`}D_{it-j} + \sum_{j=0}^{l} \mu_j \text{`}D_{it-j} * FCS_{it-j} + \sum_{j=0}^{l} \Phi_j FCS_{it-j} + \lambda f_i + \varepsilon_{it} \qquad (6)$$

We control for time-invariant country-specific effects and estimate equation (6) using the Hausman Taylor instrumental variable random effects estimator (Hausman and Taylor, 1981) to address the potential correlation between the time invariant control f_i (the average primary balance to GDP ratio) and the error term which would create a bias in the estimation of the coefficients of the lagged dependent variable.

The effect of drought conditions on long-term growth in FCS is equal to expression (7) below. A rejection of the joint null hypothesis that the numerator and denominator of this expression are equal to zero together with a rejection of the null hypothesis that the denominator is equal to zero is interpreted as evidence of the existence of a long-term growth effect of drought in FCS countries.

[9] The transitory β term effects cancel out in the derivation of equation (5). See Dell and others (2012).

[10] Estimating the model with fixed effects in first differences would zero out the fixed effect and result in a demeaning of the variables, turning the drought variable into a zero-mean shock. Therefore, we use the Hausman Taylor instrumental variable estimator with random effects where fixed effects can still be added as country-specific time-invariant variables.

[11] Using deviations from average pre-climate change conditions shortens the sample period considerably and therefore we use the long-term drought trend estimated via the Hodrick-Prescott filter. As climate change intensified mainly over the last decade and our sample covers more than four decades, the HP trend is still a reasonable proxy of average pre-climate change conditions.

$$\frac{\sum_j^l Z_j + \sum_j^l \mu_j}{1 - \sum_j^l \theta_j} = \frac{\sum_j^l B_j}{A} \quad (7)$$

Next, the paper explores the channels through which drought affects per-capita real GDP growth in FCS countries over the long term. Equation (6) is estimated using as dependent variables the crop yield, investment growth, food production, and measures of dependence on food imports, and undernourishment.[12]

Lastly, the paper investigates which structural characteristics may amplify the impact of drought conditions on per-capita GDP growth in FCS using interactions of macroeconomic variables with drought and the FCS dummy:

$$\Delta y_{it} = \sum_{j=1}^{l} \theta_j \Delta y_{it-j} + \sum_{j=0}^{l} Z_j' D_{it-j} + \sum_{j=0}^{l} \mu_j' D_{it-j} * FCS_{it-j} + \sum_{j=0}^{l} \Phi_j FCS_{it-j} + \psi' D_{it} * FCS_{it} * S_{it} + \Omega S_{it} + \lambda f_i + \varepsilon_{it} \quad (8)$$

where S_{it} is a dummy taking unity if structural variables' values are above the historical mean for FCS.[13]

The analysis examines potential amplification effects from a variety of structural factors, including public debt, social spending, trade openness, water insecurity and governance. Separate models are estimated for each structural variable, considering the ratios of public debt to GDP, social expenditure to GDP, and trade to GDP, and the indexes of water insecurity, regulatory quality, and control of corruption. The amplification effect on growth of GDP per capita in FCS in response to a unit change in drought conditions is captured by the coefficient ψ divided by the speed of adjustment $1 - \sum_j^l \theta_j$.

The panel ARDL model defined by equation (6) is estimated on a sample of 159 developing and developed countries over the 1975-2018 period using three annual lags for all variables. To disentangle the effects of drought and non-drought conditions, the model is fit separately on negative (drought) and positive (non-drought) deviations of the SPEI from its long-run historical trend (estimated using the Hodrick-Prescott filter).[14] Annex Table 1 details the FCS sample and Annex Table 2 describes the data.

IV. Results

Drought conditions are found to significantly affect macroeconomic outcomes in fragile states over the long term (Table 1). Across the various specifications, the estimated long-term (cumulative) sensitivities of macroeconomic variables to drought conditions in FCS are statistically significant and have the expected sign. The results show that worsening drought conditions reduce food production and lower the long-term growth rates of real GDP per capita. Lower crop productivity and slower investment growth are key

[12] The long-term effects of drought on these variables are again gauged by expression (7). See Annex Table 2 for definitions.

[13] The regulatory quality and control of corruption indexes are included as continuous variables, with negative (positive) values broadly indicating below (above) average regulatory quality and control of corruption.

[14] SPEI variable is rescaled for ease of interpretation, as described in Annex Table 2.

channels through which drought conditions affect long-term economic growth.[15] FCS show significantly higher sensitivity to drought than the rest of the world possibly due to weak fundamentals, insufficient policy buffers, and poor copying and adaptive capacities.[16]

- Real GDP per capita growth, investment, crop productivity. The point estimates indicate that the long-term growth rates of real GDP per capita, investment, and crop productivity would be lower by 0.42-0.50 percentage points every year in a high emissions scenario (RCP 8.5). Average food production would be lower by about 20 percent.

- Inflation and undernourishment. Worsening drought conditions are associated with higher long-run inflation and food insecurity in FCS, where food represents a large share of consumption.[17] In a high emissions scenario, average inflation would be higher by 2 percentage points. Food production in FCS appears two times more sensitive to droughts than in the rest of the world in the context of inadequate water infrastructure and poor water management capacity. The share of food imports in total imports would also increase. Importantly, the empirical results show that drought conditions increase the share of undernourished persons in the total population, from an already high level.

Table 1. Long-Term Impacts of Drought on Macroeconomic Outcomes

	Long-run coefficients 1/		Average Impact 2/	
Dependent variable	**Non-FCS**	**FCS**	**2024-2060**	**2061-2100**
Real GDP growth (p.c.)	0.0034 (0.0057)	0.0360** (0.0181)	-0.42 pp	-1.39 pp
Investment growth	0.0030 (0.0059)	0.0396* (0.0214)	-0.46 pp	-1.53 pp
Crop yield	-0.0011 (0.0047)	0.0434*** (0.0155)	-0.50 pp	-1.67 pp
Food production	0.0080*** (0.0018)	0.0174*** (0.0050)	-20 percent	-67 percent
Inflation	-0.0246 (0.0202)	-0.1840*** (0.0619)	2 pp	7.12 pp
Undernourishment ratio	0.0019 (0.0020)	-0.0122** (0.0058)	0.14 pp	0.47 pp
Food import ratio	0.0006 (0.0014)	-0.0118** (0.0058)	0.14 pp	0.45 pp

Sources: Authors' estimates.
1/ Long-run cumulative sensitivities to negative SPEI deviations from its long-term trend (higher aridity) calculated as the sum of the SPEI coefficients at different lags divided by 1 minus the coefficients of the lagged dependent variable (see Section III equation (7)).
2/ Impact on the variables' long-run values of the average deterioration in drought projected in the high emissions scenario. Please note that the definition of the SPEI variable in Annex Table 2 differs from the standard SPEI definition.
FCS = fragile and conflict-affected states; pp = percentage point. Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

[15] Total factor productivity was not considered in the analysis due to data limitations.

[16] FCS countries fare significantly worse than non-FCS countries along the structural vulnerability dimensions, which are found to amplify the long-term effects of worsening drought conditions.

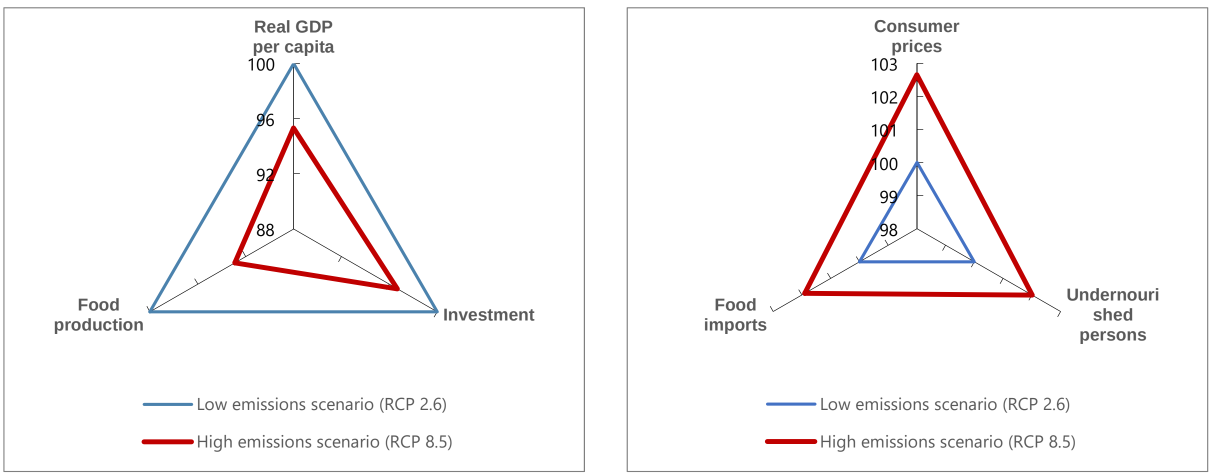
[17] Data from the U.S. Department of Agriculture Economic Research Service show that food represents 42 percent of total consumer expenditure for the median FCS, compared to 23 percent in other countries.

The autoregressive distributed lag model is used to dynamically forecast the impacts of drought conditions on FCS under high emissions (RCP 8.5) and low emissions (RCP 2.6) scenarios (Figure 5). In 2060, the level of FCS' per-capita real GDP in the high emissions scenario is estimated to be by about 5 percent lower relative to the low emissions scenario, while the level of investment would be lower by 3.5 percent. Food production would be lower by 7 percent, food imports would be higher by 2 percent, and consumer prices would be higher by about 3 percent. The confluence of lower food production and higher food prices would push 2 more percent of FCS' growing population—about 50 million people—into hunger by 2060.[18]

Figure 5. FCS: Comparison of Macroeconomic Losses in Climate Scenarios, 2060

(Projections in levels in percent of the projections in the low emissions scenario)

Real GDP per capita, Food Production, Investment | **Consumer prices, Food Imports, Undernourished Persons**



Source: World Bank Climate Change Knowledge Portal and authors' estimates

These estimates are consistent with other findings in the climate literature. Zaveri and others (2023) show that moderate to extreme droughts reduce short-term GDP per capita growth between 0.4 and 0.9 percentage points, on average, with low- and middle-income countries in dry areas sustaining the highest losses. Russ (2020) find that economic growth is more sensitive to changes in water runoff than rainfall, with runoff of 1 standard deviation reducing GDP growth by 0.4–0.6 percentage points in the short term. IMF (2020) points to a significant impact of droughts on medium-term GDP growth in Sub-Saharan Africa. Using data for 20 fragile states in sub-Saharan Africa between 1980 and 2019, Maino and Emrullaho (2022) show evidence of a long-run relationship between real GDP per capita, temperature anomalies, and technology. Kotz and others (2023) show that future warming could cause global increases in annual food and headline inflation of 0.9-3.2 and 0.3-1.2 percentage points per-year by 2035, respectively. Faccia and others (2021) find that higher temperatures play a non-negligible role in driving price developments, especially for emerging market economies.

[18] Based on the UN population growth forecast.

Our findings on growth are in line with other studies that utilize the SPEI index. Berlemann and Wenzel (2018) assert that rainfall shortages have a negative long-term impact on economic growth primarily for the group of less developed and poor countries while rainfall surpluses have no significant growth effect. Using the SPEI, Zappalà (2023), Albert and others (2023), and Mohammed and others (2022) find a negative impact of drought on agriculture. Kabundi and others (2022) and Jirophat and others (2022) show that droughts have a positive impact on inflation, reflecting rising food prices.

The results show that weak macroeconomic policies can amplify FCS vulnerability to climate change. (Table 2). The extended model (8) (see section III) is used to analyze how policies can address the long-term effects of drought in FCS (Table 2). Drought-related real GDP per capita losses in FCS countries appear to be amplified by high public debt, low social spending, insufficient trade openness, high water insecurity, weak regulatory quality, and weak control of corruption.

- Public debt. All other things being equal, per-capita GDP growth would be 0.32 percentage points lower per year in FCS with debt levels above 60 percent of GDP compared to FCS with debt levels below that threshold in response to the mean change in drought conditions projected in the high emissions scenario up to 2060. High debt burdens constrain FCS' ability to mobilize resources to cope with the adverse consequences of climate change and provide adequate social protection to those affected by climate shocks.[19]

- Social spending. FCS with social spending below 1 percent of GDP would see annual real GDP per capita growth drop by 0.35 percentage points more than FCS with higher social spending. Protecting a country's human capital through continued access to quality health and education programs is indispensable for FCS to promote inclusive growth and poverty reduction.

- Trade openness. FCS with higher-than-average trade openness would see higher annual real GDP per capita by 0.29 percentage points. Insufficient trade openness hampers FCS' ability to import food to smooth consumption.

- Water insecurity. FCS with an above average water insecurity score would see lower annual real GDP per capita by 0.3 percentage points. Water scarcity compounds the adverse effects of drought on agricultural production.

- Regulatory quality. FCS with a below average regulatory quality would see real GDP per capita growth drop by 0.29 percentage points more compared to FCS with above average regulatory quality. Regulatory gaps make it easier to evade rules and regulations which could facilitate environmental damage and resource overuse.

- Corruption. FCS with below average control of corruption would experience GDP per capita growth that is lower by nearly 0.5 percentage points per year compared to FCS with above average control of corruption. Weak control over corruption leads to misdirected and poor-quality climate investments, inadequate responses to climate change, and misuse of revenues needed to invest in climate resilience.

[19] These results are in line with other studies that find that countries with greater fiscal space are better positioned to deal with the adverse consequences of climate change and strengthen their adaptive capacity (Bellon and Massetti 2022).

Table 2. Amplifiers of Drought's Impact on Growth of Real GDP per capita in FCS

Interaction variable	Interaction coefficient	Amplification Effect [3] High-emission scenario 2024-2060	Amplification Effect [3] High-emission scenario 2061-2100
Public debt to GDP[1]	0.0274** (0.014)	-0.32 pp	-1.06 pp
Social expenditure to GDP[1]	-0.0299** (0.0146)	0.35 pp	1.16 pp
Trade openness[1]	-0.0255* (0.015)	0.29 pp	0.99 pp
Water insecurity[1]	0.0258* (0.014)	-0.30 pp	-0.10 pp
Regulatory quality[2]	-0.0251*** (0.108)	0.29 pp	0.97 pp
Control of corruption[2]	-0.0429*** (0.014)	0.49 pp	1.66 pp

Sources: Authors' estimates.
1/ Binary variables taking unity for values above historical mean interacted with negative SPEI deviations from trend and the FCS dummy. Positive (negative) coefficients indicate negative (positive) amplification effects.
2/ Continuous variables; positive (negative) values indicate above (below) average institutional quality.
3/ Amplification of a unit increase in drought conditions on growth in FCS with higher-than-average structural weaknesses.
FCS = fragile and conflict-affected states; pp = percentage point. Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

The macroeconomic effects of changes in the SPEI are not symmetric, as there is limited evidence of long-term economic effects of excessive soil moisture (Table 3). The analysis found limited long-term impact of positive SPEI deviations from its historical trend, which would generally be associated with heavy rainfall, floods, and storms. The long-term effects of such extreme events appear to be primarily reflected in lower inflation, likely driven by a demand contraction (Cantelmo, 2022). Possible explanations of why positive and rising SPEI levels would not impair long-term growth include that: (i) floods and storms are more localized events and shorter in duration than droughts; (ii) reconstruction efforts following floods and storms would offset losses in economic activity; and (iii) there are benefits of flooding for recessional agriculture in FCS.[20] These results are broadly in line with other studies that suggest that droughts have a significantly stronger impact on medium-term growth in sub-Saharan Africa than floods (IMF, 2020).

[20] Farmers practicing recessional agriculture plant in the flooded areas once the waters recede, using it as a form of irrigation.

Table 3. Long-Term Macroeconomic Impacts of Excess Soil Moisture

	Long-run coefficients [1/]	
Dependent variable	**Non-FCS**	**FCS**
Real GDP growth (p.c.)	-0.0102	-0.0119
	(0.0064)	(0.0199)
Investment growth	-0.0011	-0.0182
	(0.0059)	(0.0226)
Crop yield	-0.0000	0.0099
	(0.0037)	(0.0113)
Food production	-0.0002	-0.0036
	(0.0015)	(0.0047)
Inflation	-0.0047	-0.1285***
	(0.0174)	(0.0557)
Undernourishment ratio	0.0003	0.0004
	(0.0015)	(0.0048)
Food import ratio	0.0012	0.0269***
	(0.0012)	(0.0058)

Sources: Authors' estimates.
1/ Long-run cumulative sensitivities to positive SPEI deviations from its long-term trend (higher soil moisture) calculated as the sum of the SPEI coefficients at different lags divided by 1 minus the coefficients of the lagged dependent variable (see Section III equation (7)). The definition of the SPEI variable differs from the standard SPEI definition (Annex Table 2).
FCS = fragile and conflict-affected states; pp = percentage point. Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

V. Robustness Tests

The empirical findings above are supported by a series of robustness tests.

- Alternative samples and sample periods (Table 4). The estimates remain significant when the period is shortened to 1982-2018 (Model 1) and when the sample is restricted to countries with real incomes below US$10,000 and US$1,000, respectively (Models 2 and 3). The higher sensitivity to drought in the latter sample suggests that the poorest FCS countries may be most vulnerable to drought. FCS' sensitivity to droughts appears to increase when the model is fitted only on countries experiencing dry conditions in the previous year (annual SPEI values below 0.5 in the previous year) (Model 4). This finding suggests that FCS with already dry climates would be especially vulnerable to a further worsening of drought conditions.

- Alternative definitions of the FCS group in the pre-2006 period (Table 5). Given that the World Bank's FCS classification starts in 2006, the composition of the FCS group prior to 2006 is inevitably based on assumptions. In the baseline analysis, the paper conservatively considers for the pre-2006 period only countries consistently classified as FCS during 2006-2018 (Model 1). In the robustness analysis, two alternative FCS specifications are tested: (i) a broad FCS definition that includes prior to 2006 all countries classified as FCS more than once during 2006-2018 (Model 2); and (ii) a narrow FCS definition that includes throughout the estimation period only countries consistently classified as FCS during 2006-2018 (Model 3). The estimates overall retain their sign and level of significance across the alternative FCS specifications.

Table 4. Robustness Tests: Alternative Sample Definitions

	Long-run coefficients [1/]			
Dependent variable	**(1)**	**(2)**	**(3)**	**(4)**
Real GDP growth (p.c.)	0.0285***	0.0382***	0.0499*	0.0449**
	(0.0098)	(0.0195)	(0.0268)	(0.0198)
Investment growth	0.0198*	0.0395*	0.0262	0.0396*
	(0.0119)	(0.0224)	(0.0307)	(0.0214)
Crop yield	0.0130*	0.0341***	0.0349	0.0385**
	(0.0079)	(0.0115)	(0.0128)	(0.0155)
Food production	0.0114***	0.0221***	0.0347***	0.0206***
	(0.0029)	(0.0072)	(0.0150)	(0.0065)
Inflation	-0.1231***	-0.1616***	-0.1853***	-0.1739***
	(0.0357)	(0.0607)	(0.0744)	(0.0662)
Undernourishment ratio	-0.0085**	-0.0117*	-0.0200	-0.0121**
	(0.0042)	(0.0067)	(0.0135)	(0.0058)
Food import ratio	0.0012	-0.0111*	-0.0061	-0.0143**
	(0.0034)	(0.0068)	(0.0145)	(0.0063)

Sources: Authors' estimates.
1/ Long-run cumulative sensitivities to negative SPEI deviations from its long-term trend (higher aridity) calculated as the sum of the SPEI coefficients at different lags divided by 1 minus the coefficients of the lagged dependent variable (see Section III equation (7)).
Note: Model 1 covers the period 1982-2018 only; Model 2 countries with income per capita lower than US$10,000; Model 3 countries with income per capita lower than US$1,000; and Model 4 only countries experiencing non-humid conditions in the previous year (SPEI<0.5). FCS = fragile and conflict-affected states; pp = percentage point. Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

Table 5. Robustness Tests: Alternative FCS Group Specifications

	Long-run coefficients [1/]		
Dependent variable	**(1)**	**(2)**	**(3)**
Real GDP growth (p.c.)	0.0360**	0.0225**	0.028 5**
	(0.0181)	(0.0102)	(0.0098)
Investment growth	0.0396*	0.0232*	0.0198*
	(0.0214)	(0.0128)	(0.0119)
Crop yield	0.0434***	0.0127	0.013*
	(0.0155)	(0.0083)	(0.0079)
Food production	0.0174***	0.0097***	0.0114***
	(0.0050)	(0.0026)	(0.0029)
Inflation	-0.1840***	-0.1435***	-0.1231***
	(0.0619)	(0.0378)	(0.0357)
Undernourishment ratio	-0.0122**	-0.0097*	-0.0085**
	(0.0058)	(0.0057)	(0.0042)
Food import ratio	-0.0118**	0.0029	0.0012
	(0.0058)	(0.0041)	(0.0034)

Sources: Authors' estimates.
1/ Long-run cumulative sensitivities to negative SPEI deviations from its long-term trend (higher aridity) calculated as the sum of the SPEI coefficients at different lags divided by 1 minus the coefficients of the lagged dependent variable (see Section III equation (7)).
Note: Model 1 includes in the FCS group prior to FY06 only countries consistently classified as FCS during FY06-FY18; Model 2 includes as FCS prior to FY06 all countries classified as FCS at least once during FY06-FY18; Model 3 includes as FCS in the entire sample period only countries classified consistently as FCS during FY06-FY18. FCS = fragile and conflict-affected states; pp = percentage point. Standard errors in parentheses. ***p < 0.01, **p < 0.05, *p < 0.1.

VI. Building Long-Term Resilience to Drought

Climate adaptation calls for substantial investment in climate-resilient infrastructure and adequate safety nets, which require structural reforms and international financial assistance (Jaramillo and others, 2023). Key structural reforms include:

- Creating fiscal space to make room for climate adaptation spending**.** Given FCS's limited fiscal space, structural fiscal policies need to aim at broadening the revenue base and rationalizing non-productive expenditures (Duenwald and others, 2022). Fiscal prudence can keep investment affordable through careful selection and execution of projects (Aligishiev, Bellon, and Massetti, 2022). Reducing FCS' debt burdens, including through international aid, could help create fiscal policy space to build climate resilience over the longer run. Debt-for-climate swaps could be useful in countries with limited access to debt restructuring and debt relief (Georgieva and others, 2022).

- Investing in climate-smart agriculture and water management to build resilience in agricultural production and reduce water- and food insecurity. Addressing water scarcity can mitigate the impact of drought on per-capita real GDP growth. Consequently, investing in climate-smart agricultural practices and technologies would enhance resilience to drought and increase agriculture productivity. This includes improved irrigation, drainage systems, and water management (FAO 2021). The use of organic fertilizer and mulch, water-efficient sprinkler and drip irrigation systems, and drought-resilient seeds and crops can increase productivity and help withstand worsening drought conditions (IMF 2020). Establishing early warning and weather advisory systems is also critical to raise public awareness of inclement weather conditions (Mbaye and Signe, 2022). Increasing the maintenance of investment is also essential.

- Scaling up social assistance to communities that are highly exposed to climate shocks. Climate change hits the poorest hardest and risks increasing hunger in FCS. Social spending can mitigate the welfare losses entailed by worsening drought conditions. This could be achieved through targeted social assistance programs dedicated to building resilience to climate risks, including programs to diversify livelihoods in drought-prone areas.

- Improving regulations and reducing the perceptions of corruption, which are critical to facilitate climate adaptation and secure access to climate financing from development partners. As discussed above, countries with weak governance and low-quality regulations see a more severe impact of drought on long-term growth. Governance reforms have low cost but can be instrumental in attracting climate financing and channeling it to its most effective use. Importantly, transparency and accountability are key to building investor trust in FCS' climate policies.

- Promoting trade openness and diversification that can help smooth consumption following drought-induced shocks to food production and prices. Food imports from countries less affected by drought conditions can help FCS protect vulnerable populations from hunger. In addition, international trade can improve access to drought-resilient crops and technologies (Xu and Monteiro, 2022) and act as a substitute for climate-related labor migration (Conte and others, 2021). However, FCS' capacity to substitute imports for domestic food production may be constrained by low external and fiscal buffers.

Scaling up international concessional climate financing for FCS countries is critical. At present, FCS countries appear to receive less climate funding per capita than non-FCS and the climate projects sponsored are also smaller than in other countries (Aberg, 2022). To be affordable, climate financing needs to be granted on highly concessional terms given FCS' limited fiscal space and elevated debt burdens.

VII. Conclusion

Unmitigated drought conditions risk further entrenching fragility and poverty in FCS countries. Worsening droughts can result in long-term scarring of real GDP per capita growth and affect longer-term price stability in FCS countries, more so than other countries, leaving them further behind. Lower crop productivity and slower investment are key channels through which drought impacts economic growth in FCS. In a high emissions scenario, drought conditions will cut 0.4 percentage points of FCS' growth of real GDP per capita every year over the next 40 years and increase average inflation by 2 percentage points. Droughts will also increase food insecurity and hunger from already high levels. The confluence of lower food production and higher prices in a high emissions scenario would push 50 million more people in FCS into hunger by 2060.

Adaptation requires substantial investment in climate-resilient infrastructure and adequate safety nets, which requires structural reforms and international financial assistance. The results show that the macroeconomic effects of drought in FCS countries are amplified by high public debt, low social spending, insufficient trade openness, high water insecurity, and weak governance. Fiscal reforms to improve revenue mobilization and expenditure management can create policy space for climate adaptation and social protection of vulnerable communities. Improving the agricultural sector's resilience to drought is critical to tackle food insecurity together with more diversified trade to smooth drought-induced consumption shocks. Importantly, governance and institutional reforms to make FCS' climate policies more effective and trustworthy are essential to broaden access to external climate financing. Sizeable and sustained international support for climate adaptation, including financing and capacity development support, is urgent.

Annex 1. Definitions and Data

The analysis covers the evolving universe of FCS countries (Table 1). The definition of FCS is based on the World Bank Classification of Fragile and Conflict-Affected Situations. A total of 62 countries have been classified as FCS at least once from FY2006 to FY2018, of which 17 countries over the entire period. Countries included in the time-varying FCS dummy are marked with asterisk in Table 1. Excluded from the dummy are countries classified as FCS only once over the 2006-2018 period as well as small island states with a population of less than 150,000 people. A few FCS countries are missing from the sample due to data availability. Given that the World Bank classification of FCS starts in 2006, the composition of the FCS sample prior to 2006 is inevitably based on assumptions. The main analysis conservatively includes as FCS in the pre-2006 period only countries consistently classified as FCS between 2006 and 2018. The robustness analysis broadens the FCS group included in the pre-2006 period to cover all countries classified as FCS more than once during 2006-2018. To reduce sample variability, another robustness test includes in the overall FCS sample only countries consistently classified as FCS between 2006 and 2018.

Annex Table 1. List of Fragile and Conflict Affected States, FY2006–FY2020

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Grand Total
Afghanistan*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Albania	√															**1**
Angola*	√	√	√	√	√	√	√	√								**10**
Armenia															√	**1**
Azerbaijan															√	**1**
Bosnia and Herzegovina*	√	√	√	√	√	√	√	√	√							**11**
Burkina Faso*													√	√	√	**3**
Burundi*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Cambodia*	√	√														**4**
Cameroon*		√	√										√	√	√	**5**
Central African Republic*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Chad*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Colombia	√															**1**
Comoros*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Congo, Dem. Rep.*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Congo, Rep.*	√	√	√	√	√	√	√				√	√	√	√	√	**14**
Cote d'Ivoire*	√	√	√	√	√	√	√	√	√	√	√	√				**14**
Croatia	√															**1**
Djibouti*	√	√	√							√	√	√				**8**
Eritrea*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Ethiopia															√	**1**
Gambia, The*	√	√	√						√	√	√	√	√	√		**11**
Georgia*			√	√	√											**3**
Guinea*	√	√	√	√	√	√										**8**
Guinea-Bissau*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Haiti*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Iraq*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Kiribati	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**15**
Kosovo	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Lao PDR*	√	√												√		**5**
Lebanon*	√								√	√	√	√	√	√	√	**8**
Liberia*	√	√	√	√	√	√	√	√	√	√	√	√	√	√		**16**
Libya*						√	√	√	√	√	√	√	√	√	√	**10**
Madagascar*							√	√	√	√						**4**
Malawi*							√									**1**
Mali*							√	√	√	√	√	√	√	√	√	**9**
Marshall Islands					√	√	√	√	√	√	√	√	√	√	√	**11**
Micronesia, Fed. Sts.					√	√	√	√	√	√	√	√	√	√	√	**11**
Mozambique*											√	√		√	√	**4**
Myanmar*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Nepal*			√	√	√	√	√									**5**
Niger*													√	√	√	**3**
Nigeria*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Papua New Guinea*	√		√							√	√	√	√	√	√	**10**
Sao Tome and Principe*	√	√	√	√												**6**
Sierra Leone*	√	√	√	√	√	√	√	√	√	√	√					**13**
Solomon Islands*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Somalia*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
South Sudan*						√	√	√	√	√	√	√	√	√	√	**10**
Sudan*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Syrian Arab Republic*						√	√	√	√	√	√	√	√	√	√	**10**
Tajikistan*		√	√	√												**4**
Timor-Leste	√	√	√	√	√	√	√	√	√			√	√	√	√	**15**
Togo*	√	√	√	√	√	√	√	√	√	√	√	√				**14**
Tonga	√	√	√													**5**
Tuvalu						√	√	√	√	√	√	√	√	√	√	**10**
Uzbekistan*	√	√														**4**
Vanuatu*	√															**3**
Venezuela, RB*													√	√	√	**3**
West Bank and Gaza	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Yemen, Rep.		√	√	√	√	√	√	√	√	√	√	√	√	√	√	**14**
Zimbabwe*	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	**17**
Grand Total	**41**	**38**	**38**	**33**	**33**	**36**	**38**	**35**	**36**	**36**	**37**	**37**	**37**	**39**	**39**	

Note: Countries included as FCS in the sample are marked with asterisks.

Source: World Bank Classification of Fragile and Conflict-Affected Situations

Annex Table 2. Variable Definitions and Sources

Variables	Definition/transformation/source
Dependent variables	
Real per capita GDP growth	Annual percent change in real Gross Domestic Product per capita (IMF WEO)
Inflation	Annual percent change in end-year consumer price index (IMF WEO). The variable is winsorized to exclude extreme inflation and deflation (above 100 percent).
Investment growth	Log difference of capital stock at constant 2017 national prices multiplied by 100 (Penn World Table)
Crop yield	Log difference of cereal crop production index smoothed using the Hodrick-Prescott filter; multiplied by 100 (World Bank WDI)
Food production	Natural logarithm of food production index (World Bank WDI). Food production index covers food crops that are considered edible and that contain nutrients. The index shows the relative level of the aggregate volume of food production for each year in comparison with the base period 2014–2016.
Undernourishment ratio	Annual difference in undernourished people as a percentage of the total population (World Bank WDI)
Food import ratio	Annual difference in food imports as a percentage of total imports (WB WDI)
Independent variables	
Drought	Drought conditions = (SPEI – SPEI long-term trend) *100 < 0 where SPEI is the Standardized Evapotranspiration Index and the trend is estimated using the Hodrick-Prescott filter (Global SPEI database)
Primary balance to GDP	Average annual difference in the general government primary balance as a percentage of nominal GDP (World Bank WDI)
Public debt to GDP	Government gross debt as a percentage of nominal GDP (IMF WEO)
Water insecurity index	Water security score on the ND-GAIN Global Adaptation Index measuring vulnerability to water stress scaled between 0 (low) and 1 (high) (ND-GAIN database). Water stress is determined based on a number of indicators, including fresh-water withdrawal rate, access to reliable drinking water, water dependency ratio, dam capacity.
Social expenditure to GDP	General government expense on social programs to nominal GDP (IMF WEO)
Trade to GDP	The sum of exports and imports as a percentage of nominal GDP (IMF WEO)
Regulatory quality index	Change in the regulatory quality index (World Bank WGI). Regulatory Quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.
Control of corruption index	Change in the control of corruption index (World Bank WGI). Control of Corruption captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.
Categorical variables	
Public debt	The variable takes unity if public debt to GDP exceeds 60 percent (the FCS average)
Social expenditure	The variable takes unity if average social expenditure exceeds 1 percent of GDP (the FCS average)
Trade openness	The variable takes unity if the sum of imports and exports exceeds 73 percent of GDP (the FCS average)
Water insecurity	The variable takes unity if the water insecurity score exceeds 0.37 (the FCS average)

Annex 2. Measuring Drought Conditions

Drought is defined as a prolonged period of abnormally dry weather due to a lack of precipitation, resulting in serious hydrological imbalance and moisture deficiency (Mpelasoka et al., 2008). Drought is caused by imbalances between water supply and atmospheric water demand. Although precipitation is a major driver of water supply, temperature is also an important factor that affects atmospheric water demand through its impact on evapotranspiration (evaporation from soil and transpiration from plants).

Some measures of drought are based on precipitation data alone. The Standardized Precipitation Index (SPI) proposed by McKee and others (1993) depends on precipitation as a single input variable and assumes that the variability of precipitation is much higher than that of other drought determinants. The SPI has been endorsed by the World Meteorological Organization (WMO) to be used by national meteorological and hydrological services to characterize droughts (Hayes et al., 2011).

The Palmer Drought Severity Index (PDSI) (Palmer, 1965) is based on a physical water-balance model that uses both precipitation and surface temperature as inputs. The index measures the cumulative effect of antecedent and current moisture supply and demand. The PDSI has been widely used to gauge drought conditions in the United States. However, unlike the SPI, the PDSI has been standardized using limited data from the central U.S. and has more limited spatial comparability due to its fixed calibration parameters. Other shortcomings are the fixed time scale (between 9 and 12 months) and its autoregressive characteristics, which cause index values to be affected by drought conditions up to four years in the past (Guttman 1998).

This paper employs the multi-scalar Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano and others, 2010) which is well suited to capture the effects of warming temperatures on drought conditions. Like the PDSI, the SPEI considers precipitation and also the effects of temperature on atmospheric water demand. However, the SPEI is based on a simple water balance equation and avoids most of PDSI's shortcomings. Its advantage over the PDSI is that it relies on multiple time scales which ensure identification of different drought types and their impacts in the context of global warming.[1]

The literature has found that the SPEI tends to perform better than other drought indexes. Comparisons between the SPI and SPEI indexes indicate that the SPEI performs better than the SPI on most occasions (Tefera and others, 2020). Tirivarombo and others (2018) compare time series plots (1960–2015) of the two indices and show that both are able to capture the temporal variation of droughts. However, the SPEI can identify more droughts in the severe to moderate categories, with extended duration and increased intensity. Gurrapu and others (2014) find that although there is no significant difference between the SPI and SPEI indices in their representation of past droughts, the SPEI is better for gauging the effects of rising temperatures on drought conditions. Zhao and others (2017) find using data for China that the PSDI can be qualified as a mid- and long timescale drought-monitoring index whereas the SPEI can conveniently monitor both short- and long-term drought using selected timescales. Guttman (1998) highlights the advantages of the SPI over the PSDI due to its reliance on different time scales which are important for the analysis of water availability and water use.

[1] SPEI is standardized to vary between +5 and – 5 and classifies soil moisture conditions as follows: non-drought (SPEI> -0.5), mild drought (-1< SPEI <-0.5), moderate drought (-1.5<SPEI< -1), severe drought (-2< SPEI< -1.5), and extreme drought (SPEI < -2).

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