INTERNATIONAL MONETARY FUND

Eye of the Storm: The Impact of Climate Shocks on Inflation and Growth

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WP/23/87

2023
APR

WORKING PAPER

WP/23/87

IMF Working Paper

European Department

Eye of the Storm: The Impact of Climate Shocks on Inflation and Growth

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Authorized for distribution by Bernardin Akitoby

April 2023

Abstract

What is the impact of climate change on inflation and growth dynamics? This is not a simple question to answer as climate shocks tend to be ubiquitous, but with opposing effects simultaneously on demand and supply. The extent of which climate-related shocks affect inflation and economic growth also depends on long-run scarring in the economy and the country's fiscal and institutional capacity to support recovery. In this paper, we use the local projection method to empirically investigate how climate shocks, as measured by climate-induced natural disasters, influence inflation and economic growth in a large panel of countries over the period 1970–2020. The results shows that both inflation and real GDP growth respond significantly but also differently in terms of direction and magnitude to different types of disasters caused by climate change. We split the full sample of countries into income groups—advanced economies and developing countries—and find a striking contrast in the impact of climate shocks on inflation and growth according to income level, state of the economy, and fiscal space when the shock hits.

JEL Classification Numbers:	E31; E32; E62; N10
Keywords:	Climate change; natural disasters; inflation; growth; local projections; panel data
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[1] The authors would like to thank Helge Berger, Romain Duval, Gianluigi Ferrucci, Zeina Hasna, Florence Jaumotte, Emanuele Massetti, Christine Richmond, Axel Schimmelpfennig, Glebs Starovoits, Alice Tianbo Zhang, and the participants of a seminar at the European Department of the International Monetary Fund (IMF) for helpful comments and suggestions.

I. INTRODUCTION

Climate change is a multifaceted and evolving phenomenon and a major source of uncertainty for the global economy and financial markets.[2] The global surface temperature has already jumped more than 1.1 degrees Celsius (°C) compared with the preindustrial average, escalating the frequency and severity of weather-related natural disasters. Projections show that accelerating climate change will elevate the risk of droughts, extreme temperatures, and severe storms and cause greater damage to the environment, lives, and livelihoods, as the global mean temperature increases by as much as 4°C over the next century (Stern 2007; IPCC 2007, 2014, 2019; 2021). Every country will experience the consequences of climate change, but the extent of vulnerability depends on the size and composition of economies, the resilience of institutions and physical infrastructure, and the capacity for mitigation and adaption to climate change.

What is the impact of climate change on inflation and growth dynamics? This is not a simple question to answer as climate shocks tend to be ubiquitous, but with opposing effects simultaneously on demand and supply. The magnitude and pattern of the impact on inflation and growth also depends on long-run scarring in the economy and the country's fiscal and institutional capacity to support recovery. In this paper, we use the local projection (LP) method proposed by Jordà (2005) to investigate how climate shocks—measured by a binary variable for the occurrence of a climate-induced natural disaster or the number of deaths caused by such an event per population in a given year—influence alternative measures of inflation and economic growth in a large panel of 173 countries during the period 1970–2020. We also explore the possibility of nonlinear effects of large-scale climate shocks on inflation and real GDP growth by looking at two dimensions: (i) the position of a given economy in the business cycle and (ii) the level of public debt as a proxy of fiscal space when a weather-related disaster occurs.

Using data on 173 countries over the period from 1970 to 2020, the empirical analysis shows that inflation and growth respond significantly to disasters caused by climate change, but the impact varies in terms of direction and magnitude. While extreme temperatures result in lower inflation, droughts and storms lead to higher levels of inflation. We also develop a more granular analysis by focusing on alternative measures of inflation and identify that the impact of weather-related shocks on core and food inflation shows significant variation in magnitude and pattern across country groups. With regards to economic growth, we find that the initial response is negative to all types of climate shocks, but the magnitude and pattern of response show variation over the long run. When we split the sample of countries by income group, we observe a striking contrast in the impact of climate shocks on inflation and growth in advanced and developing countries. Finally, we find that the impact of climate disasters on inflation and growth varies in a nonlinear fashion depending on the state of the economy and the level of fiscal space when the shock hits. These results suggest that climate-induced natural disaster have differential and opposing effects on inflation and growth through multiple channels, such as (i) increasing or lowering agricultural production and food prices (ii) dampening economic activity and lowering labor productivity, (iii)

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[2] Climate refers to a distribution of weather outcomes for a given location, and climate change describes environmental shifts in the distribution of weather outcomes toward extremes.

reducing wealth and income and thereby consumption and investment; (iv) affecting transportation infrastructure and distribution costs. Furthermore, these transmission channels vary significantly with the level of economic development and diversification across countries.

Empirical findings presented in this paper should be treated as a lower bound on the impact of weather-related disasters in the wake of accelerating climate change. Accordingly, there are several important implications for economic policy. First, this will make inflation and growth dynamics more volatile, with potential feedback effects across all sectors of the economy. Second, the differing patterns in how inflation and growth response to climate shocks will lead to greater heterogeneity in the level of inflation and income growth experienced by different segments of the society within a country. In other words, households whose consumption basket consists of goods and services that are more likely to experience an increase in inflation and loss of income in the aftermath of natural disasters will be more adversely affected compared to households whose consumption is proportionately less dependent on such products and income is not subject to a negative shock. These results, in our view, reflect demographic and structural differences and weaker fiscal and institutional capacity in developing counties to adapt to and mitigate the consequences of climate shocks. Looking forward, it is also important for policymakers to consider how the green transition away from fossil fuels, as an important part of climate change mitigation efforts, will affect inflation and growth dynamics.

The remainder of this paper is organized as follows. Section II provides an overview of the related literature. Section III describes the data used in the empirical analysis. Section IV introduces the salient features of our econometric strategy. Section V presents the empirical results, including a series of robustness checks. Finally, Section VI offers concluding remarks with policy implications.

II. A BRIEF OVERVIEW OF THE LITERATURE

We pull together different strands of the literature on inflation, growth and climate change. First, inflation is shown to be determined by a range of factors including policy preferences (Rogoff, 1985) macroeconomic developments such as the level of income, trade and financial openness, and fiscal deficits (Végh, 1989; Romer, 1993; Campillo and Miron, 1997; Lane 1997; Galí and Gertler, 1999; Gruben and McLeod, 2002; Catao and Terrones, 2005; Clark and McCracken, 2006; Gupta, 2008, Badinger, 2009; Binici *et al*., 2022), labor market institutions (Cukierman and Lippi, 1999), exchange rate regimes (Levy-Yeyati and Sturzenegger, 2001; Husain *et al*., 2005), and institutional and political features (Cukierman, 1992; Aisen and Veiga, 2007). There is also a broad collection of studies focusing on the relationship between central bank independence and inflation. Building on Kydland and Prescott (1977) and Barro and Gordon (1993), this strand of the literature demonstrates that greater central bank independence brings about low and stable inflation, but not always in a consistent and statistically significant way (Cukierman *et al*., 1992; Alesina and Summers, 1993; Campillo and Miron, 1997; Lougani and Sheets, 1997; Cottarelli *et al*., 1998; Posen, 1998; Arnone *et al*., 2006; Brumm, 2006; Walsh, 2008; Cevik and Zhu, 2020).

Second, there is significant variation in economic growth across countries and over time, driven by a plethora of cultural, demographic, economic, financial, institutional, political and social factors. Neoclassical and endogenous growth theories explain these differences in growth performance mainly by the accumulation of physical and human capital and technological advancements (Solow, 1956; Romer, 1986, 1990; Lucas, 1988). Using cross-country analysis, Easterly and Wetzel (1989), Barro (1991; 2003), Barro and Sala-i-Martin (1992), Mankiw *et al.* (1992), Easterly and Rebelo (1993), King and Levine (1993), Islam (1995), Knack and Keefer (1995), Easterly and Levine, (1997), Sachs and Warner (1997), Burnside and Dollar (2000), Acemoglu *et al.*(2002), Sala-i-Martin *et al.*(2004), among others, show that the differences in income growth rates are systematically related to a set of quantifiable variables, including the initial level of real GDP per capita, the amount of human capital in terms of educational attainments and health conditions, public and private investment, the extent of international openness and terms-of-trade shocks, along with the influence of geography, institutions and politics. Other studies reach similar results, even with different samples and methodologies (Ciccone and Jarocinski, 2010).

Third, there is a fast-developing literature on the economic and financial effects of climate change.[3] Starting with Nordhaus (1991; 1992) and Cline (1992), aggregate damage functions are widely used to analyze the climate-economy nexus. While the identification of macroeconomic effects of annual variation in climatic conditions is a difficult empirical undertaking, Gallup *et al.* (1999), Nordhaus (2006), and Dell *et al.* (2012) observe that higher temperatures result in a significant reduction in economic growth in developing countries. Burke *et al.* (2015) corroborate this finding and determine that higher temperatures would have a greater damage in countries that are concentrated in geographic areas with hotter climates. Using large datasets, Acevedo *et al.* (2018), Burke and Tanutama (2019), Kahn *et al.* (2021), and Akyapi, Bellon, and Massetti (2022) show that the long-term economic impact of weather anomalies, such as persistent changes in the temperature above or below the historical norm, is not homogenous across countries and that economic growth responds nonlinearly to extreme temperature. Furthermore, Cevik and Jalles (2023) find that an increase in climate change vulnerability is positively associated with rising income inequality, especially in developing countries due largely to weaker capacity for climate change adaptation and mitigation.

It is also well documented that increasing frequency and severity of climate-related natural disasters affect economic development (Loyaza *et al.*, 2012; Noy, 2009; Raddatz, 2009; Skidmore and Toya, 2002; Rasmussen, 2004), reduce the accumulation of human capital (Cuaresma, 2010) and worsen external balances (Gassebner *et al.*, 2010). More recently, Cevik and Jalles (2020; 2021; 2022) show that climate change vulnerability has significant effects on government bond yields and spreads, the probability of sovereign debt default and sovereign credit ratings, especially in developing countries. Similarly, Bansal *et al.* (2016) and IMF (2020) find that risks associated with climate change—as proxied by temperature increases—have a negative effect on asset valuations, while Bernstein *et al.* (2019) show that real estate exposed to the risk of sea level rise is priced at a discount relative to otherwise similar unexposed houses. Focusing on the U.S., Painter (2020) finds that counties more likely to be affected by climate change pay more in

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[3] Tol (2018) provides a recent overview of this expanding literature.

underwriting fees and initial yields to issue long-term municipal bonds compared to counties unlikely to be affected by climate change.

With regards to the impact of climate change on consumer price inflation, there is a small but growing literature. A few studies look at the impact of natural hazards on prices (Parker, 2018; Heinen *et al*., 2019), while there is almost no research on the effect of extreme weather events including temperature deviations, apart from studies focusing on specific sectors of activity (De Winne and Peersman, 2018; 2021). In a recent paper, Faccia *et al*. (2021) investigate how extreme temperatures affect various measures of inflation in 48 advanced and emerging economies during the period 1951–1980 and find that higher temperatures played a non-negligible role in driving price developments, especially for emerging market economies. Similarly, Kabundi *et al*. (2022) analyze how climate shocks affect consumer prices and find that the impact depends on the type and intensity of shocks, country income level, and monetary policy regime.

III. DATA OVERVIEW

We construct a panel dataset of annual observations covering 173 countries over the period 1970–2020. Our dependent variables are consumer price inflation and economic growth. Inflation is computed on an annual basis as the year-on-year percentage change in the CPI as follows:

$$\pi_{c,t} = \left(\frac{CPI_{c,t}}{CPI_{c,t-12}}\right) * 100$$

where $\pi_{c,t}$ denotes inflation in country *c* at time *t* based on headline CPI, core CPI and food component of the CPI, drawn from the World Bank's global database of inflation (Ha *et al*., 2021). We measure economic growth using the annual rate of change in real GDP, which is obtained from the World Bank's World Development Indicators database.

The main explanatory variables of interest are climate shocks as measured by the occurrence of weather-related natural disasters from the Emergency Events Database (EM-DAT). The EM-DAT database on natural disasters—compiled by the Centre for Research on the Epidemiology of Disasters (CRED) at the Université Catholique de Louvain in Belgium— provides data on the occurrence and effects of over 22,000 large-scale natural disasters across the world since 1900 and offers information on different categories from which we focus on climate-induced events including droughts, extreme temperatures, and storms.[4] The EM-DAT defines droughts as "an extended period of unusually low precipitation that produces a shortage of water for people, animals and plants", extreme temperatures as "a general term for temperature variations above (extreme heat) or below (extreme cold) normal conditions", and storms as meteorological events including extra-tropical, tropical and convective storms. These shocks take the value of 1 when a climate-related disaster occurs in a country in a given year and zero otherwise. However, to

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[4] The difference between extreme temperatures and droughts is that the former is the result of a short-lived meteorological hazard, while the latter is the result of a long-lived climatological hazard.

develop a more granular analysis, we also use the intensity of climate-related natural disasters as measured by the number of deaths scaled by population.

Following the literature as summarized in Botzen *et al.* (2019), we introduce a number of control variables in our regression analysis, including real GDP per capita, the output gap, trade openness (defined as the sum of exports and imports over GDP), money supply growth, urbanization, the terms-of-trade index, the output gap[5], broad money growth, and the financial openness index developed by Chinn and Ito (2006).[6] We obtain the data series from the IMF World Economic Outlook, the World Bank´s World Development Indicators and the Chinn-Ito databases. Appendix Table A1 reports summary statistics across all countries in the sample.

IV. ECONOMETRIC METHODOLOGY

In this paper, we apply the LP method to estimate the impact of climate shocks on inflation and economic growth and derive impulse response functions (IRFs) in a panel setting. This approach estimates a sequence of regressions of the dependent variable shifted several periods ahead instead of recursive use of the initial set of estimated coefficients. As a result, the LP technique does not constrain the shape of IRFs and therefore become less sensitive to potential misspecification compared to conventional VAR models (Auerbach and Gorodnichenko, 2013; Jordà and Taylor, 2016). Since it is especially useful in estimating nonlinear dynamic responses, the LP framework is widely adopted in the recent literature to analyze the effects of monetary policy shocks (Jeenas, 2018) and fiscal policy shocks (Ramey and Zubairy, 2018; Romer and Romer, 2019). Accordingly, we define the baseline specification in the following form:

$$y_{t+k,i} - y_{t-1,i} = \alpha_i + \tau_t + \beta_k CS_{i,t} + \theta X_{i,t} + \varepsilon_{i,t} \tag{1}$$

where y is a measure of consumer price inflation or economic growth, which are winsorized at 5th and 95th percentiles to mitigate the effects of extreme outliers; the coefficients α_i and τ_t are country and time fixed effects, respectively, accounting for cross-country heterogeneity and global shocks; β_k denotes the cumulative response of inflation or growth in each k year after the climate shock; and $CS_{i,t}$ denotes the climate shock variable, which is measured by either a binary variable or the number of deaths scaled by population and treated as an exogenous event that cannot be anticipated nor correlated with past changes in economic activity. Large-scale climate events featured in our analysis are considered to be country-wide shocks for two reasons: either because the shock itself is widespread or because economic relationships related to trade and/or market integration eventually propagate the shock throughout the country. $X_{i,t}$ is a set a of

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[5] The output gap for each country is obtained by applying the Hodrick-Prescott (HP) filter. Alternatively, and for robustness, the output gap is also obtained using the approach of Hamilton (2018) to decompose time series´ trend and cycle.

[6] The Chinn-Ito index is normalized between 0 and 1, with higher values indicating that a country is more open to cross-border capital transactions.

control variables including up to two lags of climate shocks, of the relevant dependent variable and two lags of the output gap obtained via the HP filter.[7]

This equation is estimated for three different measures of inflation—headline CPI, core CPI, and food prices—and real GDP growth. In terms of the main variable of interest ($CS_{i,t}$), we consider three alternative climate shocks: drought, extreme temperatures, and storms. Equation (1) is estimated using the Ordinary Least Squares (OLS) method with Spatial Correlation Consistent (SCC) standard errors as proposed by Driscoll and Kraay (1998).[8] Impulse response functions (IRFs) are then obtained by plotting the estimated β_k for $k = 0,1, \ldots ,5$ with 90 (68) percent confidence bands computed using the standard errors associated with the estimated coefficients β_k over a five-year period.[9] According to Sims and Zha (1999), "the conventional pointwise bands common in the literature should be supplemented with measures of shape uncertainty." Hence, for characterizing the likelihood shape, bands that correspond to a 68 percent posterior probability—or one standard deviation shock—provide a more precise estimate of the true probability.[10]

We also explore whether initial macro-fiscal conditions at the time of the shock influence the impact of climate shocks on inflation and growth. The LP estimation of nonlinear effects is similar to the smooth transition autoregressive (STAR) model proposed by Granger and Terasvirta (1993).[11] Accordingly, the augmented LP model takes the following form:

$$y_{i,t+k} - y_{i,t-1} = \alpha_i + \tau_t + \beta_k^L F(z_{i,t}) CS_{i,t} + \beta_k^H (1 - F(z_{i,t})) CS_{i,t} + \theta X_{i,t} + \varepsilon_{i,t} \qquad (2)$$

$$\text{with} \quad F(z_{it}) = \frac{\exp(-\gamma z_{it})}{1+\exp(-\gamma z_{it})}, \quad \gamma > 0$$

in which z_{it} the state of the economy as measured by the output gap or the public debt-to-GDP ratio that is normalized to have zero mean and unit variance.[12] The coefficients β_L^k and β_H^k capture the impact of climate shocks at each horizon k in cases of recessions ($F(z_{it}) \approx 1$ when z goes to minus infinity) and expansions ($1 - F(z_{it}) \approx 1$ when z goes to plus infinity), respectively.

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[7] Alternatively, we also employed the output gap obtained via Hamilton (2018) approach and results hardly change.

[8] This is a nonparametric technique assuming the error structure to be heteroskedastic, autocorrelated up to some lag, and possibly correlated across countries.

[9] Another advantage of the LP method compared to vector autoregression (autoregressive distributed lag) specifications is that the computation of confidence bands does not require Monte Carlo simulations or asymptotic approximations. One limitation, however, is that confidence bands at longer horizons tend to be wider than those estimated in vector autoregression specifications.

[10] Other papers that have employed one standard deviation bands include Giordano *et al.* (2007), Romer and Romer (2010) and Bachmann and Sims (2012), among others.

[11] Using such a STAR function in such empirical setups is not new. Auerbach and Gorodnichenko (2013) and Abiad *et al.* (2016) employed a similar approach to look at nonlinear effects of monetary and fiscal shocks.

[12] The weights assigned to each regime vary between 0 and 1 according to the weighting function $F(.)$, so that $F(z_{it})$ can be interpreted as the probability of being in a given space state.

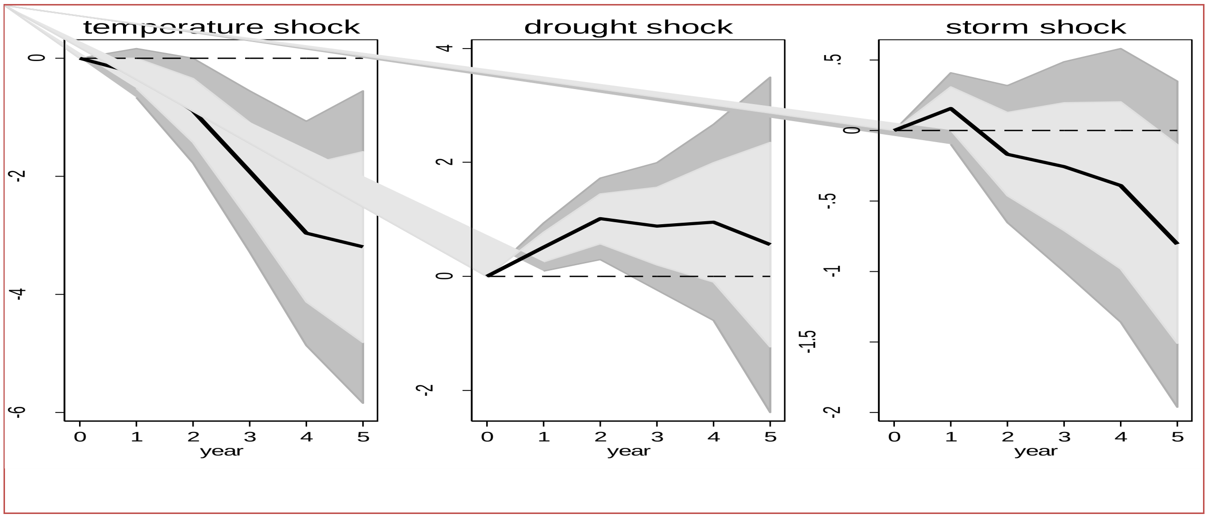
We choose $\gamma = 1.5$.[13] This approach permits a direct test of whether the effect of climate shocks varies across different regimes such as recessions and expansions and allows the effect of climate shocks to change smoothly between recessions and expansions by considering a continuum of states to compute IRFs, thus making the response more stable and precise. We use fiscal space as an alternative conditioning variable to assess whether a government's fiscal capacity to respond to a climate shock affects its inflationary impact.

V. EMPIRICAL RESULTS

A. Climate Shocks and Inflation

The starting point of our empirical analysis is the estimation of the impact of climate shocks on inflation in the whole sample of 173 countries over the period 1970-2020. Figure 1 presents the IRFs of headline inflation to three types of climate-related natural disaster shocks, together with 90 percent confidence intervals. We find that headline inflation responds significantly but also differently in terms of direction and magnitude to climate shocks as measured by a binary variable for the occurrence of a large-scale weather-related natural disaster in a given year. While extreme temperatures result in lower inflation, droughts and storms lead to higher inflation. In the case of a temperature shock, we find that headline inflation declines significantly below its initial level in the first year and over the long run.[14] This fall reaches its trough after about 4 years

Figure 1. Baseline Impact of Climate Shocks on Headline Inflation: Global Sample



Note: The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, and the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level.

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[13] Our results hardly change when using alternative values of the parameter γ, between 1 and 4. We also attempted using alternatively the output gap computed via the Hamilton (2018) approach, which yields qualitatively similar results.

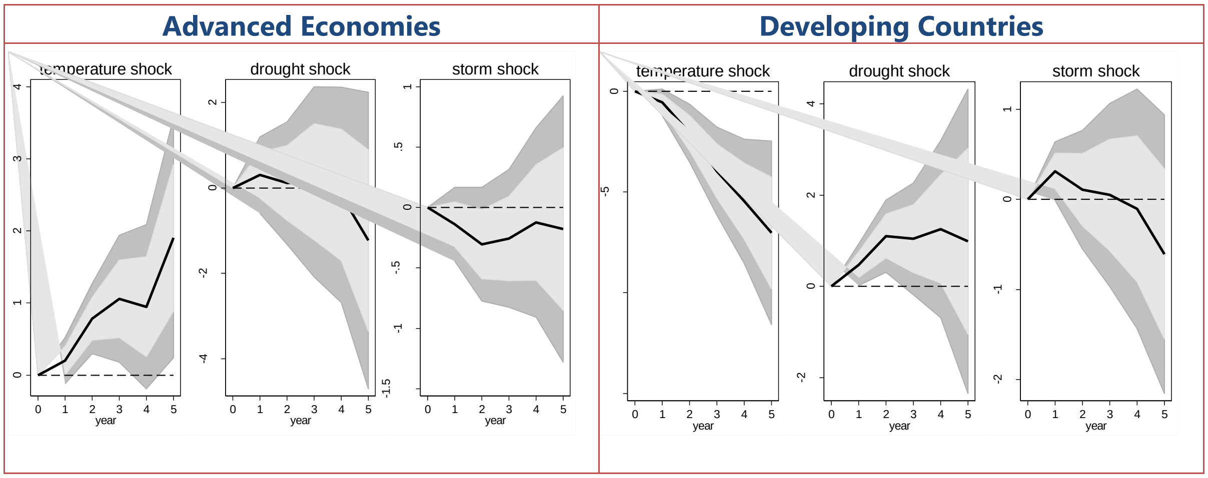
[14] These results are broadly consistent with those reported in other studies, such as Parker (2018) and Kabundi *et al.* (2022).

since the shock, at which point headline inflation is 3.5 percentage points lower than if the temperature shock had not happened. A drought shock, on the other hand, results in an immediate increase in headline inflation above its initial level, which lasts over the long term and amounts to about 1.5 percentage points compared to if the shock had not occurred. The impact pattern of storms, however, is different than other weather-related disasters. We find that headline inflation increases by about 0.2 percentage points in the first year after the storm shock, but then ends up 1 percentage points lower over the long term if the shock had not happened. Table A2 in the Appendix shows all the coefficient estimates, associated standard errors and basic diagnostic statistics behind the IRFs depicted in Figure 1.

We split the full sample of countries into income groups—advanced economies and developing countries—and present these IRFs in Figure 2. This disaggregation reveals a striking contrast in the impact of climate shocks on headline inflation in economies with varying levels of economic development. While a temperature shock leads to sustained increase in headline inflation in advanced economies, it has the opposite effect in developing countries. In the case of a drought shock, we find that headline inflation increases above its initial level across in the first year and over the long run, but this effect is small and dissipates fast in advanced economies compared to developing countries where it is long-lasting. Likewise, the initial impact of a storm shock is different in advanced economies (lower headline inflation) compared to developing countries (higher headline inflation) but does not persist over the long run in both income groups. These results may reflect structural and demographic differences and weaker fiscal and institutional capacity in developing counties to adapt to and mitigate the consequences of climate shocks.

We develop a more granular analysis by focusing on alternative measures of inflation and present these IRFs of core and food inflation to climate shocks for the sub-samples of advanced economic and developing countries in Figure 3. The impact of weather-related shocks on core

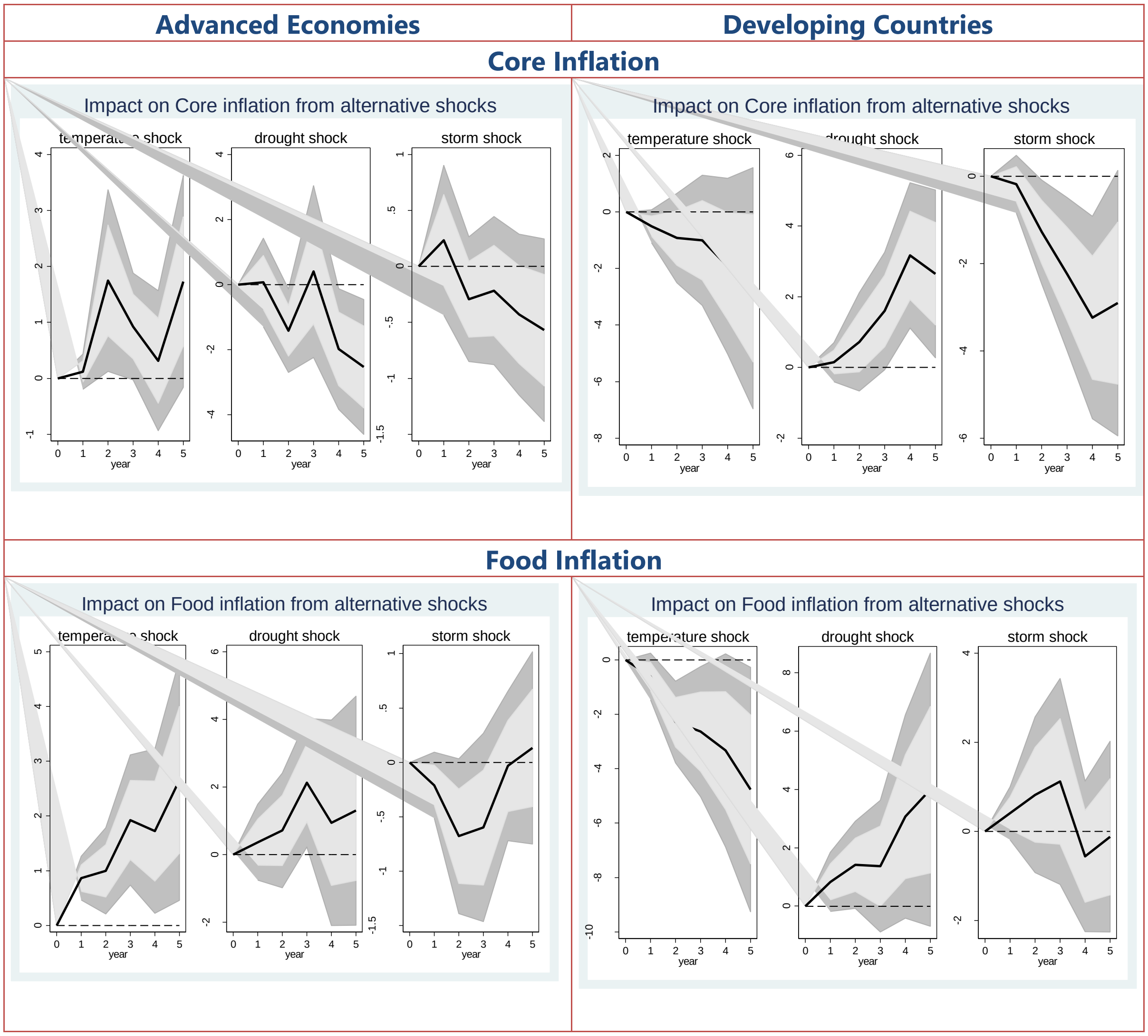
Figure 2. Impact of Climate Shocks on Headline Inflation: Income Group



The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level.

and food inflation shows significant variation in magnitude and pattern across country groups. Extreme temperatures lead to higher and more volatile core and food inflation in advanced economies, whereas it has the opposite and sustained impact in developing countries. A drought shock appears to be disinflationary with a volatile pattern in advanced economies but exhibits a sustained inflationary effect in developing countries. The inflationary impact of droughts on food prices, however, is similar across all country groups, albeit significantly greater in developing countries. Finally, a storm shock leads to a small immediate increase in core inflation in advanced economies, but this effect dissipates over the long run, whereas we observe a downward adjustment in core inflation in the first year after a storm shock that remains intact over the long

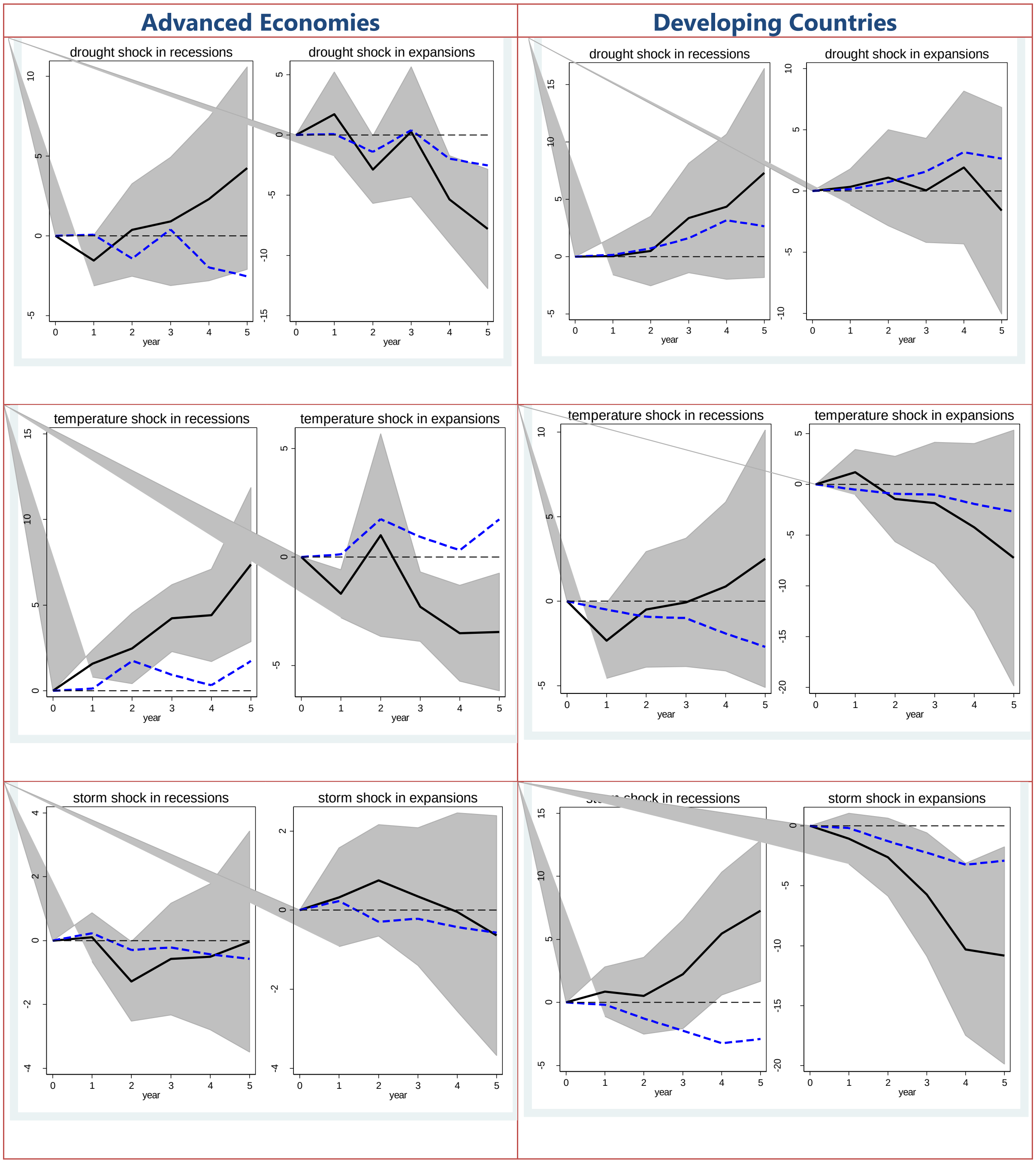
Figure 3. Impact of Climate Shocks on Inflation: Core and Food Inflation



Note: The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level.

run in the case of developing countries. The impact of storms on food inflation, on the other hand, exhibits an opposite pattern in advanced economies (declining) and developing countries (increasing), but converges to insignificance over the long run in both country groups.

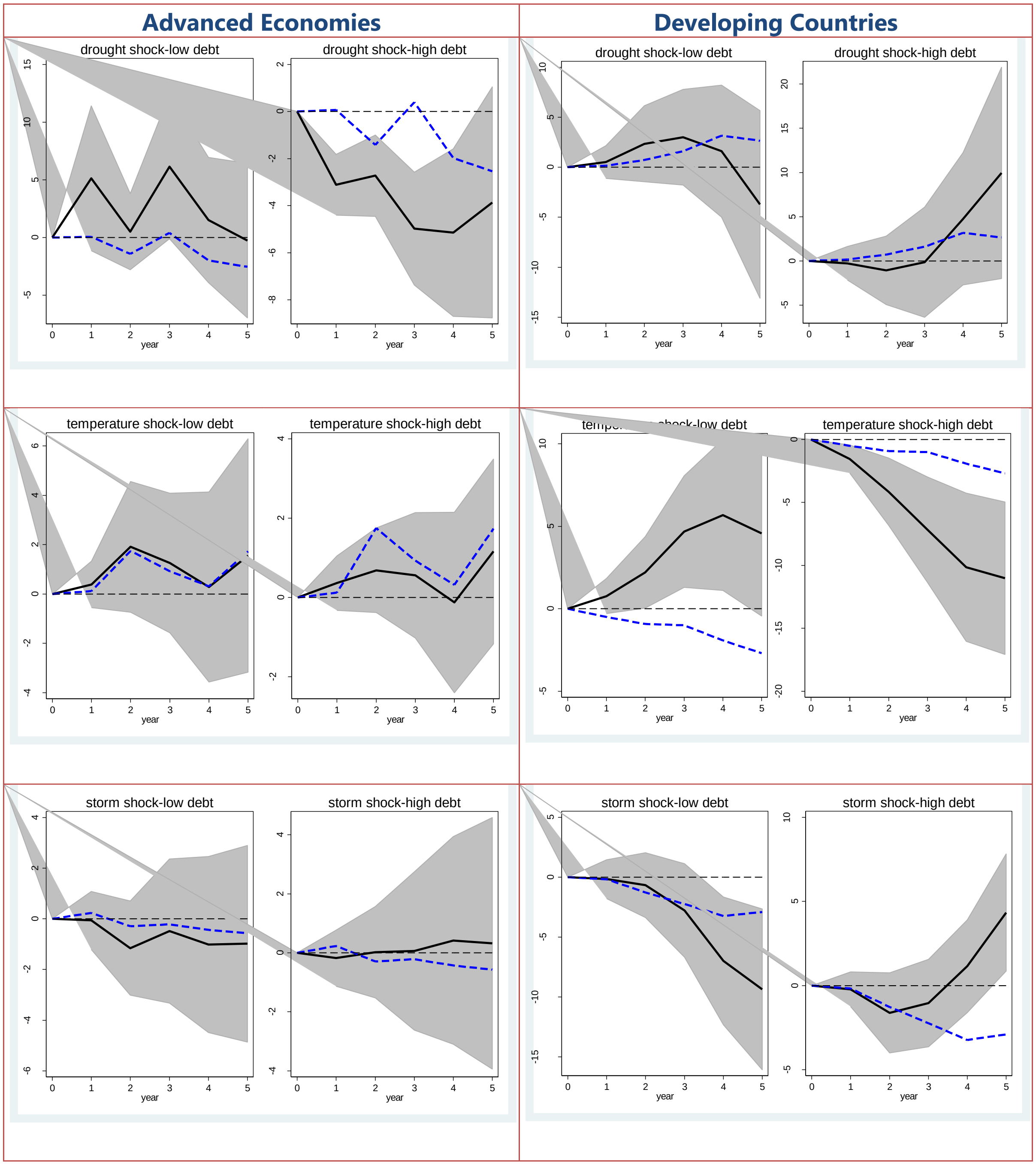
Figure 4. Impact of Climate Shocks on Core Inflation: Role of the Business Cycle



Note: The charts present IRFs based on Equation [2]. x-axis in years; t=0 is the year of the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock; the dark and light grey area denotes 90 and 68-percent confidence bands, respectively, based on standard errors clustered at country level; the dotted blue line denotes the unconditional baseline result obtained from Equation [1].

We also explore the possibility of nonlinear effects of climate shocks on inflation by looking at two particular dimensions: (i) the position of a given economy in the business cycle at the time the climate shock hits; and (ii) the level of public debt as a proxy of fiscal space to cushion the impact of climate shocks. First, as presented in Figure 4, we find that the state of the economy

Figure 5. Impact of Climate Shocks on Core Inflation: Role of the Fiscal Space

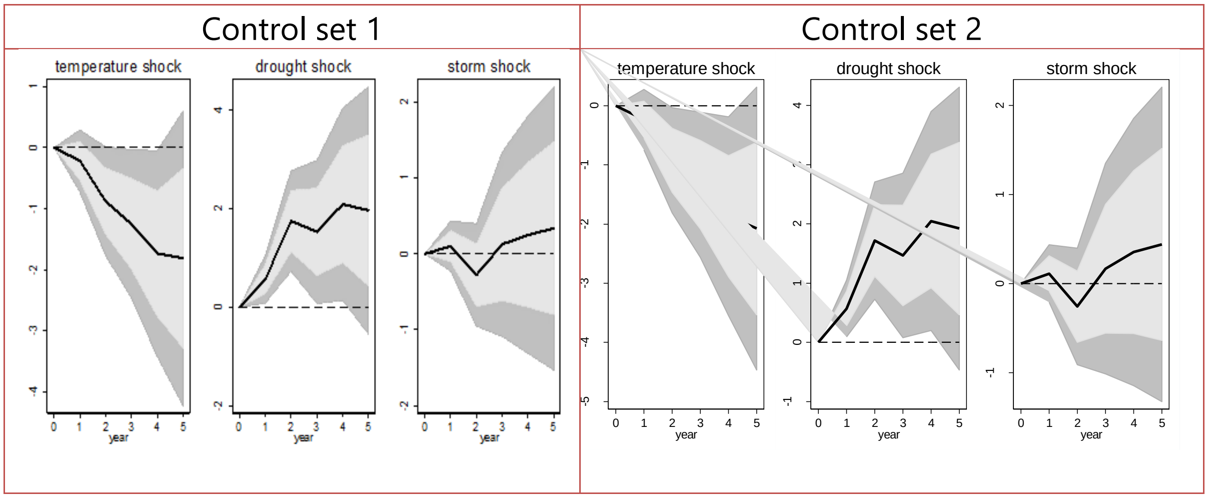


Note: The charts present IRFs based on Equation [2]. x-axis in years; t=0 is the year of the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock; the dark and light grey area denotes 90 and 68-percent confidence bands, respectively, based on standard errors clustered at the country level; the dotted blue line denotes the unconditional baseline result obtained from Equation [1].

plays an important role in shaping the impact of weather-related disasters on core inflation, but magnitude and long-run pattern depend on the exact nature of the shock. Second, as presented in Figure 5, we find that climate shocks have a differentiated effect on core inflation depending on the level of fiscal space as measured by low levels of public debt as a ratio of GDP. The inflationary impact of weather-related disasters in lower in countries with greater fiscal space compared to countries that are fiscally constrained.

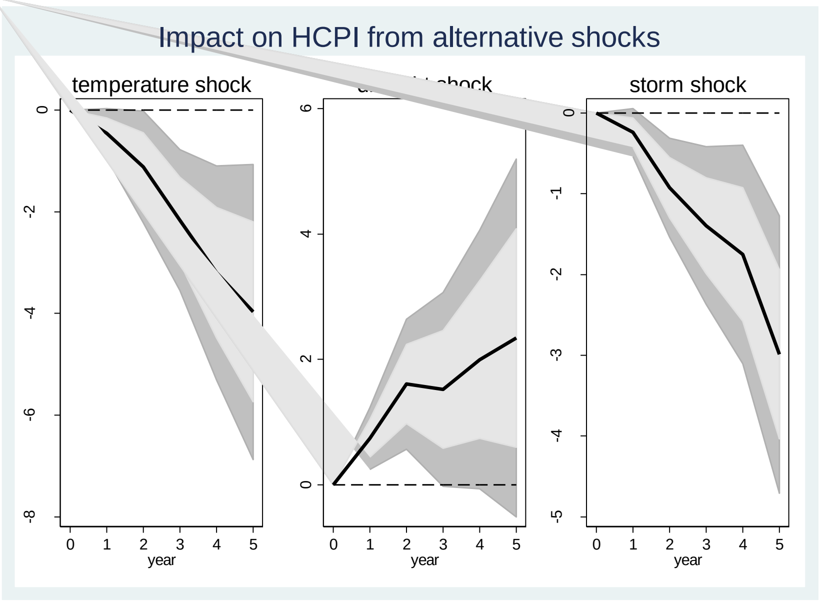
We conduct several sensitivity checks to ensure the robustness of our baseline results. First, we control for the potential omitted variable bias by including up to two lags of additional variables that could contribute to inflation dynamics, such as a measure of financial openness, the terms-of-trade index, urbanization, and money supply growth. Second, we estimate the models by excluding country fixed effects, which could bias the results since the error term may have a non-zero expected value due to the interaction of fixed effects and country specific developments (Teulings and Zubanov, 2014). Third, we split the sample into two periods (1970–1995 and 1996–2020) to examine whether the inflationary impact of climate shocks has become more pronounced over time. These estimations, presented in Figure 6-8, yield similar results with no significant qualitative change. Finally, to develop a more granular analysis, we estimate a measure of disaster intensity (the number of deaths scaled by population) and find that the impact of climate shocks on inflation becomes more pronounced and turns positive even in the case of extreme temperatures (Figure 9).

Figure 6. Impact of Climate Shocks on Headline Inflation: Additional Controls



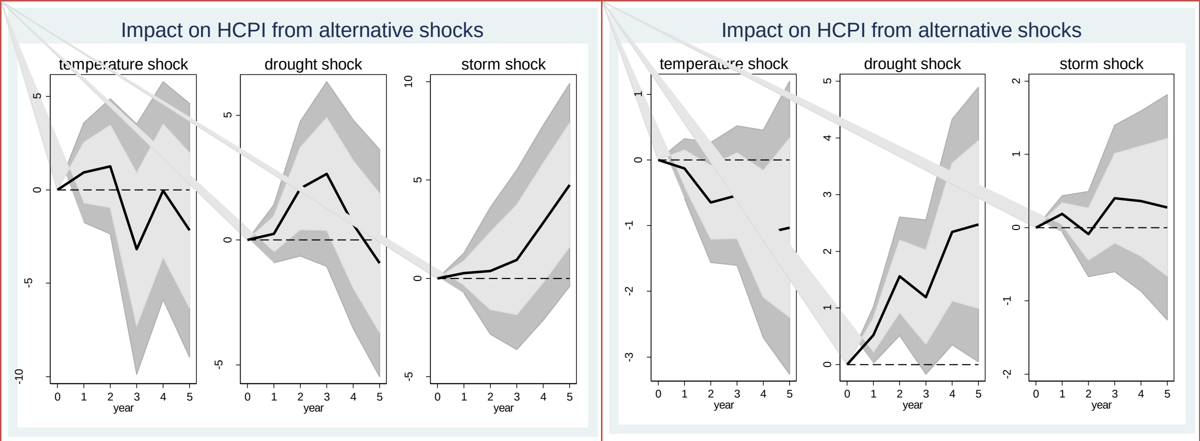
Note: The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level. Control set 1 includes in addition to the output gap (also included in the baseline), trade openness and the log of real GDP per capita. Control 2 includes control 1 variables plus broad money growth, financial openness, urbanization, terms of trade.

Figure 7. Impact of Climate Shocks on Headline Inflation: Excluding Country Fixed Effects



Note: The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level.

Figure 8. Impact of Climate Shocks on Headline Inflation: Sub-Period Estimations

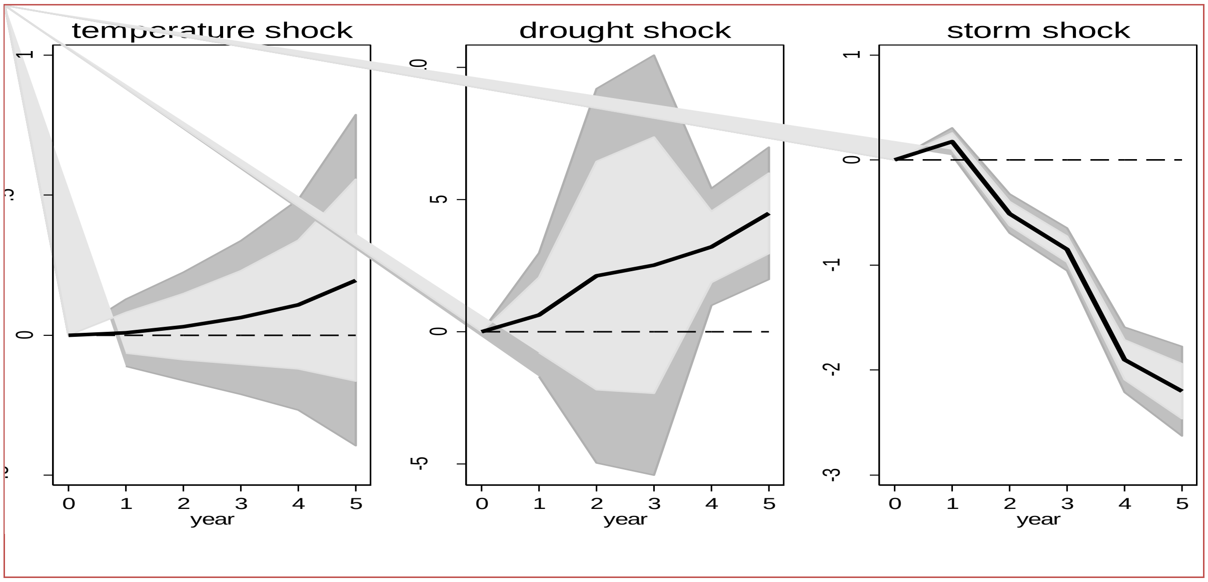


1970-1995

1996-2020

Note: The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level.

Figure 9. Impact of Climate Shocks on Headline Inflation: Disaster Intensity



Note: The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level.

B. Climate Shocks and Growth

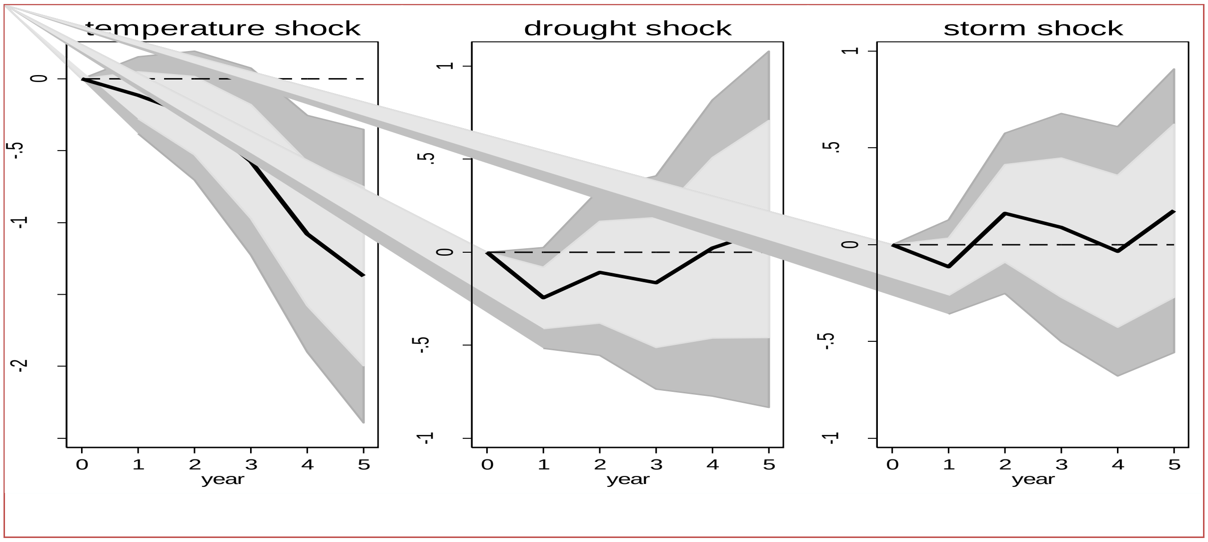
Figure 10 presents the IRFs of real GDP growth to three types of weather-related natural disasters, together with 90 percent confidence intervals. We find that the initial growth response to all types of climate shocks is negative, but the magnitude and pattern of response show variation over the long run. While a temperature shock appears to lead to a lasting reduction in real GDP growth, the impact of droughts and storms is more volatile and less persistent over the long run. In the case of a temperature shock, the growth deceleration reaches at through after 5 years since the shock, at which point real GDP growth is about 1.5 percentage points lower than if the temperature shock had not happened. Both droughts and storms cause a steeper fall in growth in the first year after the shock, but the magnitude of the impact is volatile and less persistent over time. Table A3 in the Appendix shows all the coefficient estimates, associated standard errors and basic diagnostic statistics behind the IRFs depicted in Figure 10.

To better discern the growth impact of climate shocks, we split the full sample of countries into income groups—advanced economies and developing countries—and present these IRFs in Figure 11. This disaggregation confirms reveals a striking contrast in the impact of climate shocks on real GDP growth in countries at different levels of development. While weather-related natural disasters lead to a significant and persistent decline in economic growth in developing countries, there is no such impact in advanced economies. Nevertheless, when we use the intensity of climate shocks (measured by the number of deaths scaled by population) instead of a dummy variable for disasters, the growth impact is significantly negative for all types of climate shocks across all countries in our sample (Figure 12).

We also explore the nonlinear effects of weather-related natural disasters on economic growth by taking into account the state of the economy and the level of public debt as a proxy of fiscal space at the time the climate shock hits. These results, presented in Figure 13-14, show that both the state of the economy and available fiscal space play critical roles in determining how climate shocks affect economic growth in terms of magnitude and persistence over the long run, which also varies with the level of income across countries.

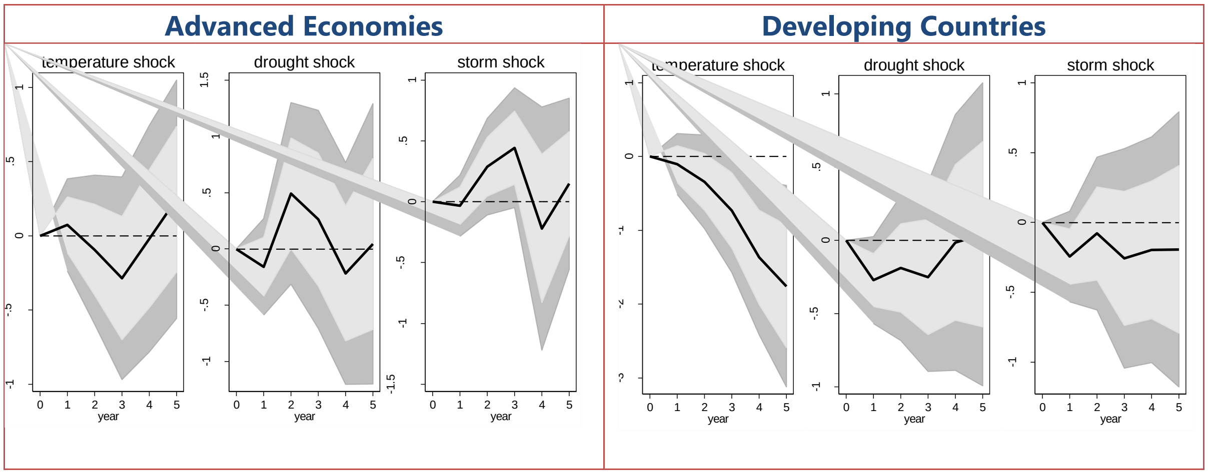
These results, in our view, reflect demographic and structural differences and weaker fiscal and institutional capacity in developing counties to adapt to and mitigate the consequences of climate shocks. In particular, we should also note that the overall impact of weather-related natural disasters on real GDP growth is likely to conceal significant differences across sectors, as shown by the varying growth response in advanced and developing economies.

Figure 10. Impact of Climate Shocks on Growth: Global Sample



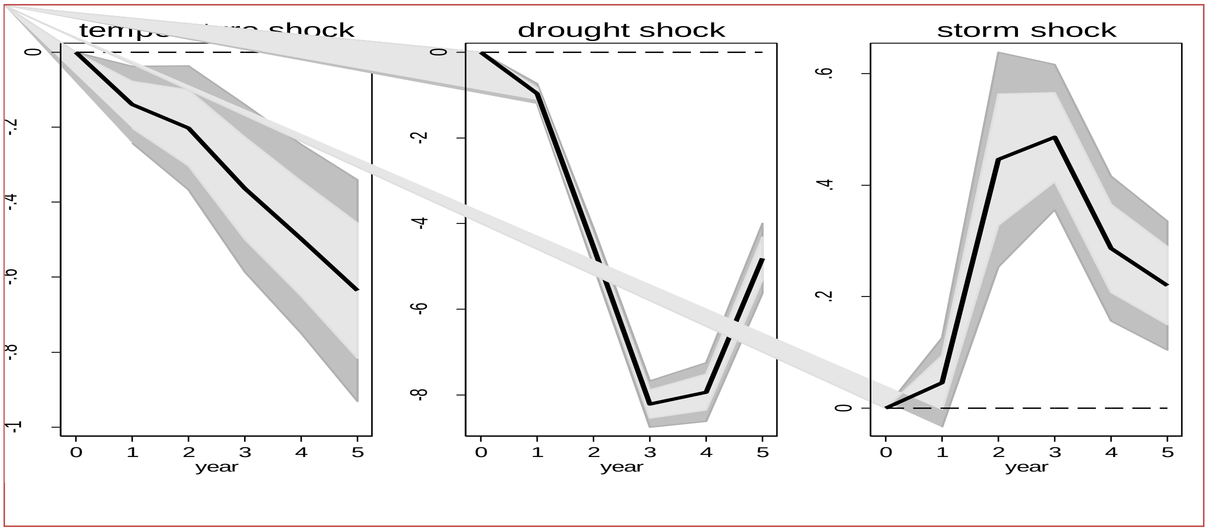
Note: The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level.

Figure 11. Impact of Climate Shocks on Growth: Income Group



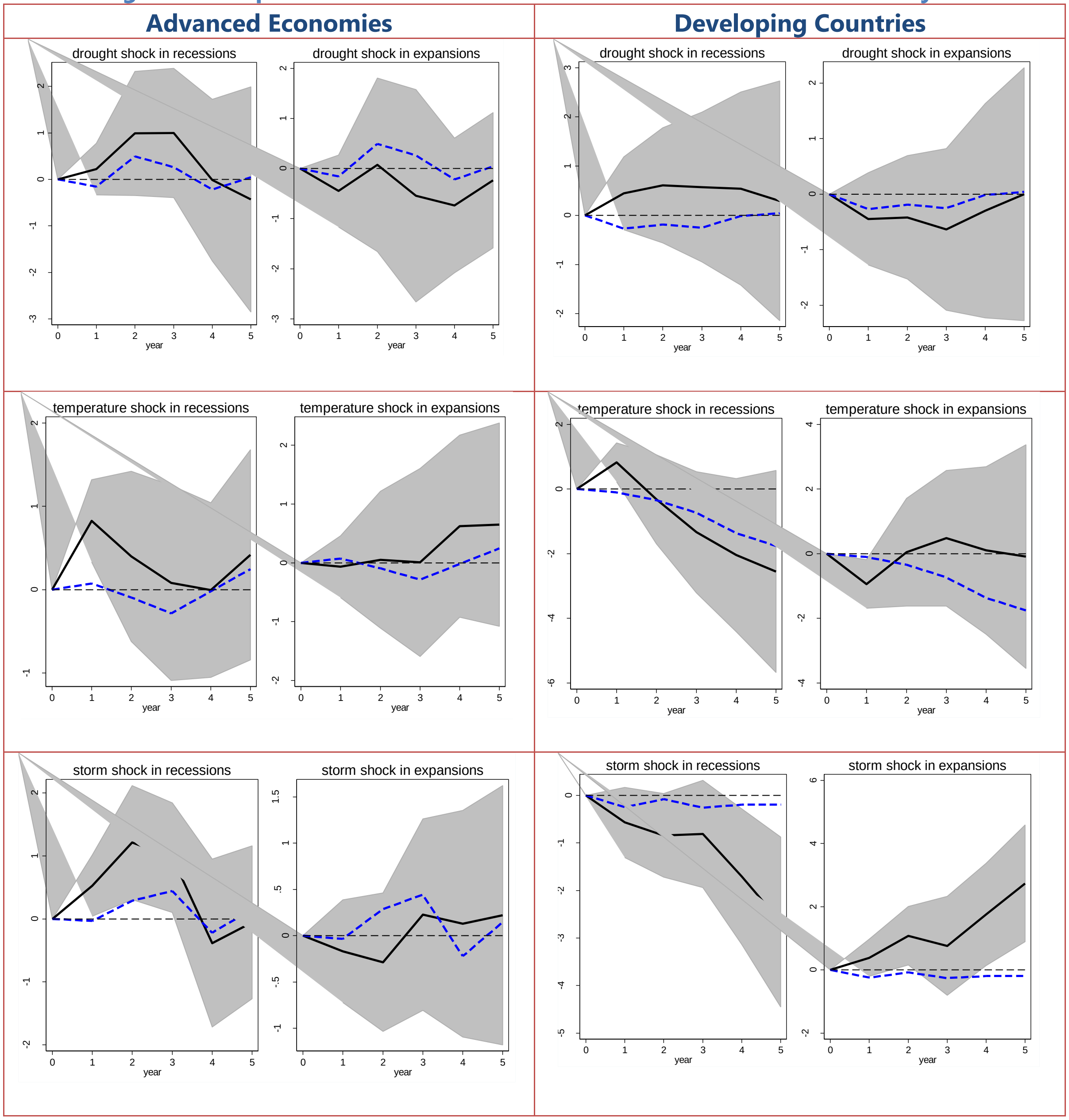
Note: The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level.

Figure 12. Impact of Climate Shocks on Growth: Disaster Intensity



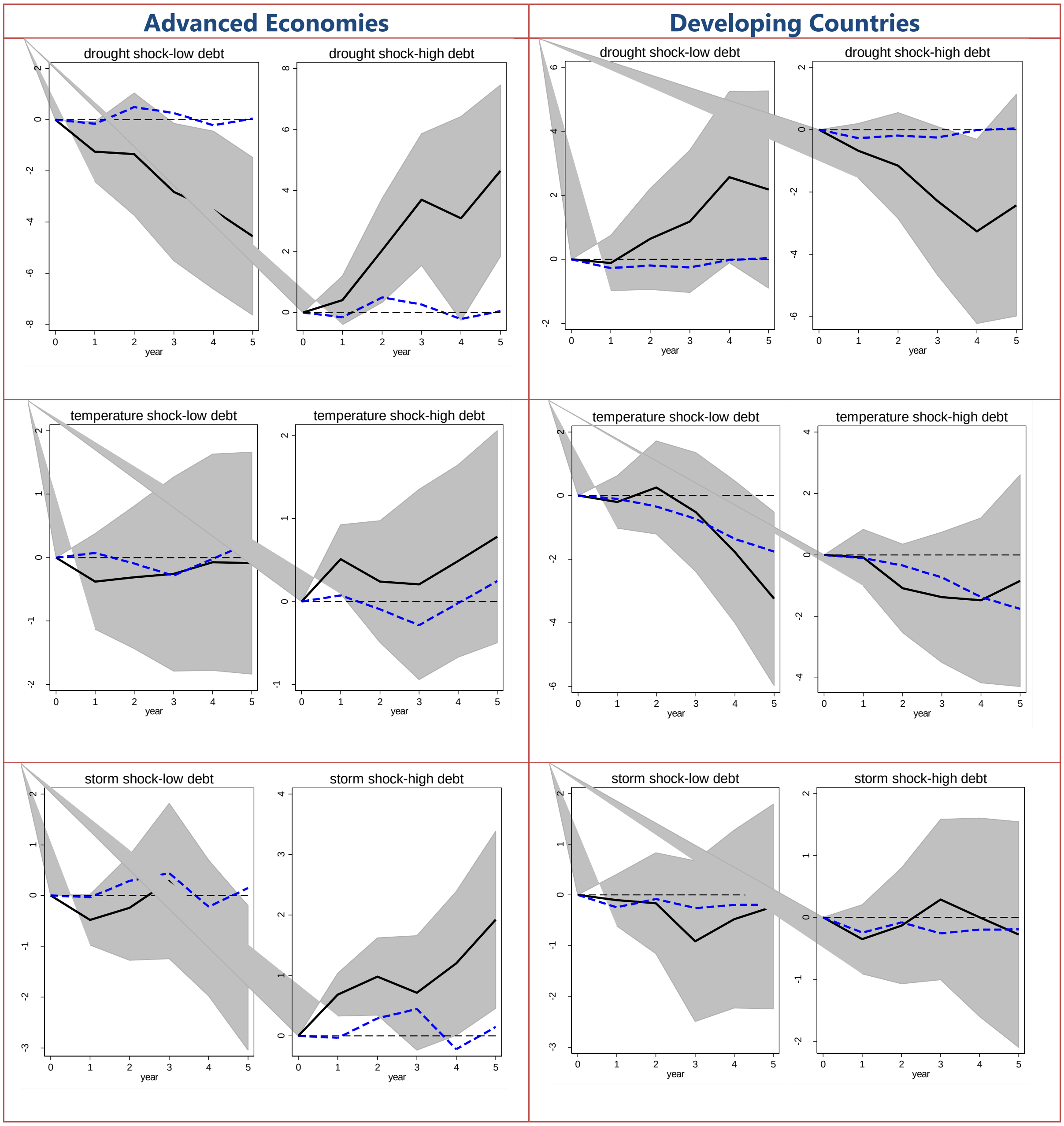
Note: The charts show IRFs using the LP method. x-axis in years; t=0 is the year preceding the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock, the dark grey area denotes 90-percent confidence bands and the light grey area denotes 68-percent confidence bands based on standard errors clustered at the country level.

Figure 13. Impact of Climate Shocks on Growth: Role of the Business Cycle



Note: The charts present IRFs based on Equation [2]. x-axis in years; t=0 is the year of the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock; the dark and light grey area denotes 90 and 68-percent confidence bands respectively based on standard errors clustered at country level; the dotted blue line denotes the unconditional baseline result obtained from Equation [1].

Figure 14. Impact of Climate Shocks on Growth: Role of Fiscal Space



Note: The charts present IRFs based on Equation [2]. x-axis in years; t=0 is the year of the climate shock; t=1 is the first year of impact. The solid black line denotes the response to a climate shock; the dark and light grey area denotes 90 and 68-percent confidence bands respectively based on standard errors clustered at country level; the dotted blue line denotes the unconditional baseline result obtained from Equation [1].

VI. CONCLUSION

Climate change is the defining challenge of our time. In this paper, we empirically investigate the impact of weather-related natural disasters on consumer price inflation and economic growth, using a large panel of 173 countries during the period 1970–2020. The analysis based on the LP method shows that inflation and growth respond significantly but also differently in terms of direction and magnitude to climate shocks.

- Temperature shocks result in lower inflation, but droughts and storms lead to higher inflation. We split the full sample of countries into income groups—advanced economies and developing countries—and find a striking contrast in the impact of climate-induced natural disasters on headline inflation according to the level of economic development. We also develop a more granular analysis by focusing on alternative measures of inflation and identify that the impact of weather-related shocks on core and food inflation shows significant variation in magnitude and pattern across country groups. Finally, we find that the inflationary impact of climate disasters varies in a nonlinear fashion depending on the state of the economy and the level of fiscal space when the shock hits.

- All types of climate shocks have a negative impact on economic growth, but the magnitude and pattern of response show variation over the long run. While a temperature shock appears to lead to a lasting reduction in real GDP growth, the impact of droughts and storms is more volatile and less persistent. To better discern the growth impact of climate shocks, we split the full sample of countries into income groups and find a striking contrast in the impact of climate shocks on real GDP growth in countries at different levels of development. While weather-related natural disasters lead to a significant and persistent decline in economic growth in developing countries, there is no such impact in advanced economies. We also explore the nonlinear effects of weather-related natural disasters on economic growth and observe that both the state of the economy and available fiscal space play critical roles in determining how climate shocks affect growth in terms of magnitude and persistence over the long run, which also varies with the level of income across countries.

Overall, the empirical analysis presented in this paper indicates that climate-induced natural disasters have differential and opposing effects on inflation and growth through multiple channels, such as (i) increasing or lowering agricultural production and food prices (ii) dampening economic activity and lowering labor productivity, (iii) reducing wealth and income and thereby consumption and investment; (iv) affecting transportation infrastructure and distribution costs. Furthermore, these transmission channels vary significantly with the level of economic development and diversification across countries. These results, in our view, also reflect demographic and structural differences and weaker fiscal and institutional capacity in developing counties to adapt to and mitigate the consequences of climate shocks. Accordingly, there are several important implications for economic policy in the wake of accelerating climate change. First, this will make inflation and growth dynamics more volatile, with potential feedback effects across all sectors of the economy. Second, the differing patterns of inflation and growth response to climate shocks will lead to greater heterogeneity in the level of inflation and income growth experienced by different segments of the society within a country. In other words, households whose consumption basket consists of goods and services that are more likely to experience an increase in inflation and loss of income in the aftermath of natural disasters will be more adversely affected compared to households whose consumption is proportionately less dependent on such products and income is not subject to a negative shock. Looking forward, it is also important for policymakers to consider how the green transition away from fossil fuels, as an important part of climate change mitigation efforts, will affect inflation and growth dynamics.

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APPENDIX

Table A1. Summary Statistics

Variable	observations	mean	Standard deviation	minimum	maximum
Real GDP growth (not in percent)	6890	0.032	0.057	-1.02	0.802
Inflation rate (headline) (not in percent)	6129	0.99	0.25	-0.370	5.223
Public debt (% GDP)	5865	57.19	47.17	0.002	677.18
Real GDP per capita (log)	6959	11.14	2.37	5.45	18.68
Output gap (% potential GDP)	7033	-0.46	36.09	-2122.07	827.09
Trade openness (% GDP)	6491	77.10	48.54	0.021	442.62
Urban (%)	7417	49.80	23.64	3.82	100
Financial openness index	6297	0.441	0.356	0	1
Terms of trade	4976	4.692	0.294	3.06	6.58
Broad money growth (%)	6031	33.28	274.82	-99.86	12513.14
Temperature natural disaster	7945	0.0614	0.24	0	1
Drought natural disaster	7945	0.081	0.27	0	1
Storm natural disaster	7945	0.223	0.42	0	1

Table A2. Coefficient Estimates underlying Figure 1

Horizon k	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Shock type	Extreme temperature					Drought					Storm				
shock	-0.0025	-0.0089*	-0.0192**	-0.0297**	-0.0320**	0.0051**	0.0101**	0.0088	0.0095	0.0056	0.0016	-0.0017	-0.0026	-0.0039	-0.0081
	(0.003)	(0.005)	(0.008)	(0.012)	(0.016)	(0.003)	(0.004)	(0.007)	(0.010)	(0.018)	(0.002)	(0.003)	(0.005)	(0.006)	(0.007)
L.shock	-0.0053**	-0.0099*	-0.0194**	-0.0230*	-0.0337*	0.0015	0.0004	-0.0008	-0.0069	-0.0065	-0.0023	-0.0024	-0.0048	-0.0075	-0.0074
	(0.002)	(0.005)	(0.009)	(0.013)	(0.020)	(0.002)	(0.004)	(0.006)	(0.011)	(0.016)	(0.002)	(0.004)	(0.005)	(0.008)	(0.010)
L2.shock	-0.0004	-0.0035	-0.0058	-0.0040	-0.0152	-0.0031	0.0012	-0.0003	0.0034	-0.0069	0.0006	0.0028	0.0053	0.0078	0.0102
	(0.002)	(0.005)	(0.008)	(0.014)	(0.014)	(0.002)	(0.004)	(0.006)	(0.009)	(0.013)	(0.002)	(0.004)	(0.008)	(0.009)	(0.010)
L.hcpi1	0.1478***	0.3018***	0.4690***	0.6594***	0.7925***	0.1476***	0.3014***	0.4688***	0.6595***	0.7932***	0.1480***	0.3020***	0.4696***	0.6600***	0.7936***
	(0.030)	(0.047)	(0.090)	(0.147)	(0.197)	(0.030)	(0.048)	(0.090)	(0.147)	(0.198)	(0.030)	(0.047)	(0.090)	(0.147)	(0.197)
L2.hcpi1	0.0114	0.0335	0.0687	0.0884	0.0975	0.0115	0.0338	0.0688	0.0888	0.0981	0.0112	0.0332	0.0682	0.0883	0.0974
	(0.010)	(0.025)	(0.056)	(0.079)	(0.104)	(0.010)	(0.025)	(0.055)	(0.080)	(0.105)	(0.010)	(0.025)	(0.055)	(0.079)	(0.105)
L.output gap	0.0000	0.0000	0.0000	0.0000*	0.0000	0.0000	0.0000	0.0000	0.0000*	0.0000	-0.0000	0.0000	0.0000	0.0000*	0.0000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L2. output gap	0.0000*	0.0000***	0.0000*	0.0000	0.0000	0.0000*	0.0000***	0.0000*	0.0000	0.0000	0.0000**	0.0000***	0.0000**	0.0000*	0.0000*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	5,180	5,054	4,916	4,763	4,606	5,180	5,054	4,916	4,763	4,606	5,180	5,054	4,916	4,763	4,606
R-squared	0.3686	0.3604	0.3510	0.3436	0.3062	0.3689	0.3601	0.3497	0.3424	0.3049	0.3683	0.3597	0.3497	0.3425	0.3051
Number of countries	172	172	172	172	171	172	172	172	172	171	172	172	172	172	171

Note: LP estimation of equation [1]. Headline inflation as dependent variable. Standard errors in parenthesis. *, **, *** denote statistical significance at the 10, 5 and 1 percent levels, respectively. Constant omitted for reasons of parsimony.

Table A3. Coefficient Estimates underlying Figure 10

Horizon k	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
Shock type	Extreme temperature					Drought					Storm				
shock	-0.0011	-0.0026	-0.0057	-0.0108**	-0.0137**	-0.0025	-0.0011	-0.0016	0.0002	0.0012	-0.0011	0.0016	0.0009	-0.0003	0.0018
	(0.002)	(0.003)	(0.004)	(0.005)	(0.006)	(0.002)	(0.003)	(0.003)	(0.005)	(0.006)	(0.001)	(0.003)	(0.004)	(0.004)	(0.004)
L.shock	-0.0014	-0.0058**	-0.0101***	-0.0130***	-0.0161***	0.0038**	0.0030	0.0063	0.0050	0.0037	0.0029**	0.0024	0.0024	0.0024	0.0022
	(0.001)	(0.003)	(0.004)	(0.005)	(0.006)	(0.002)	(0.003)	(0.004)	(0.006)	(0.007)	(0.001)	(0.003)	(0.003)	(0.004)	(0.004)
L2.shock	-0.0040***	-0.0077***	-0.0106***	-0.0139***	-0.0142***	-0.0004	0.0018	0.0005	-0.0004	0.0025	-0.0016	-0.0017	-0.0021	-0.0026	-0.0013
	(0.001)	(0.003)	(0.003)	(0.005)	(0.005)	(0.002)	(0.003)	(0.004)	(0.006)	(0.007)	(0.001)	(0.002)	(0.003)	(0.004)	(0.004)
L.gdp1	0.1814***	0.2004***	0.2391***	0.2348***	0.2636***	0.1819***	0.2011***	0.2408***	0.2373***	0.2660***	0.1823***	0.2013***	0.2410***	0.2378***	0.2663***
	(0.043)	(0.059)	(0.070)	(0.073)	(0.073)	(0.043)	(0.059)	(0.070)	(0.073)	(0.073)	(0.043)	(0.059)	(0.070)	(0.073)	(0.073)
L2.gdp1	0.0331	0.0930*	0.0802	0.0834	0.0048	0.0334	0.0941*	0.0816	0.0848	0.0064	0.0333	0.0933*	0.0811	0.0846	0.0054
	(0.025)	(0.053)	(0.069)	(0.070)	(0.049)	(0.026)	(0.053)	(0.069)	(0.070)	(0.049)	(0.026)	(0.053)	(0.069)	(0.070)	(0.049)
L.output gap	-0.0000	-0.0000	-0.0000	-0.0001*	-0.0001*	-0.0000	-0.0000	-0.0000	-0.0001*	-0.0001*	-0.0000	-0.0000	-0.0000	-0.0001*	-0.0001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
L2. output gap	-0.0000**	-0.0000	-0.0000	-0.0001*	-0.0001	-0.0000**	-0.0000	-0.0000	-0.0001	-0.0001	-0.0000**	-0.0000	-0.0000	-0.0001*	-0.0001
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	5,105	5,011	4,884	4,739	4,586	5,105	5,011	4,884	4,739	4,586	5,105	5,011	4,884	4,739	4,586
R-squared	0.1668	0.1490	0.1394	0.1296	0.1175	0.1671	0.1479	0.1378	0.1271	0.1148	0.1670	0.1481	0.1376	0.1271	0.1148
Number of countries	173	173	173	173	172	173	173	173	173	172	173	173	173	173	172

Note: LP estimation of equation [1]. Headline inflation as dependent variable. Standard errors in parenthesis. *, **, *** denote statistical significance at the 10, 5 and 1 percent levels, respectively. Constant omitted for reasons of parsimony.