Drying Development

Assessing the Impact of Droughts on Economic Growth Accounting for Adaptation

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Recent studies suggest **climate change** and **extreme events** pose serious challenges to economic development:

- **temperature** (see, e.g., Dell et al. 2010; Burke et al. 2015; Deryugina and Hsiang 2017)
- **tropical cyclones** (see, e.g., Hsiang and Jina 2014)
- **earthquakes, storms, heat, extreme precipitation (high/low) conditions,..** (see, e.g., Felbermayr and Gröschl 2014)

- Essential to understand: (Botzen et al. 2019; Carleton and Hsiang 2016)
  - potential short-run, long-run, and heterogeneous **economic consequences** of global warming and extreme weather events
  - factors contributing to **adaptation** to climatic hazards
- Recent advances in climate econometrics: Accounting for ***adaptation*** (e.g. Carleton et al. 2018; Deryugina and Hsiang 2017)
- **This study**: ***Assesses the impact of droughts on economic growth accounting for adaptation***

Droughts and Economic Growth: Related Literature

	Dependent Variable	Drought Measure	Climatic Data	Evaluated at	Accounts for Adaptation
Fomby et al. 2009; Raddatz 2009; Loayza et al. 2012; etc.	GDP growth	Reported damages (EMDAT)	-	Local level	No
Felbermayr & Gröschl 2014	GDP growth	Climatic	Precip.	Country level	No
Berlemann & Wenzel 2016	GDP growth	Climatic	Precip.		No
Berlemann & Wenzel 2018	GDP growth	Climatic	Precip. PET	Country level	No
Felbermayr et al. 2018	Nighttime Lights	Climatic	Precip. PET	0.5 degree cells	No
This Study	**GDP growth**	**Climatic**	**Precip. PET**	**0.25 degree cells**	**Yes**

Contribution of this study:

- identifies grid cell-year **drought events on 0.25°x 0.25°global grid** based on Standardized Precipitation Evapotranspiration Index (SPEI) and criteria from hydrology (e.g. Spinoni et al. 2019)
- **accounts for adaptation** by recovering local nonlinear responses conditional on development levels and underlying average drought exposure
- bridges the gap between recent advances in climate econometrics (see, e.g., Hsiang 2016) and empirical natural disasters literature

- Identify the sensitivity of economic growth to droughts by exploiting random year-to-year variation in the distribution of annual drought severity (i.e. exploit within unit variation over time)
- Account for adaptation by recovering non-linear local responses
- Conditional on underlying drought climates and initial development levels of countries (i.e. exploit cross-sectional variation)

- Non-linearities allow for differential responses along the distribution of drought severity
  - Flattening of the response function at certain points indicates adaptation (see, e.g., Hsiang 2016 and Deryugina and Hsiang 2017)
- Conditioning on income and average exposure allows for differential response of poor/rich and high/low exposure countries (see, e.g., Carleton et al. 2018)
  - **Does higher income reduce the sensitivity to droughts?** (e.g. due to higher spending on adaptation measures [see, e.g., Fankhauser and McDermott 2014])
  - **Does higher drought exposure reduce the sensitivity to droughts?** (e.g. benefits of adaptation increase with average exposure level [see, e.g., Hsiang and Narita 2012])

$$growth_{it} = f(\boldsymbol{DS_{it}}, \boldsymbol{DS_{it-1}}) + g(\boldsymbol{T_{it}}, \boldsymbol{T_{it-1}}) + h(\boldsymbol{R_{it}}, \boldsymbol{R_{it-1}}) + \alpha_i + \delta_{drt} + \theta_i \times t + \epsilon_{it}, \tag{1}$$

where i denotes country, t year, d development level, r region, and c cell.

- $\boldsymbol{DS}$: country-level vector of p-order polynomials of cell-year drought severity:

$$\boldsymbol{DS_{it}} = \left[\sum_{c \in i} w_{ci} \left(DS_{ct}\right), \sum_{c \in i} w_{ci} \left(DS_{ct}^2\right), \ldots, \sum_{c \in i} w_{ci} \left(DS_{ct}^p\right)\right]$$

  - time-invariant area weights w_{ci} for aggregation across cells within countries
- same for temperature $\boldsymbol{T_{it}}$ and precipitation $\boldsymbol{R_{it}}$

Nonparametric controls:

- α_i: country-specific fixed effects
  - control for all time-invariant country-specific characteristics
- δ_{dtr}: development level x region x year fixed effects
  - account for all time-varying trends/shocks to development level-specific GDP growth rates within each (world) region
- $\theta_i \times t$: country-specific time trends
  - control for country-specific trends in societal/economic and climatic factors

Dependent variable: growth rate of inflation-adjusted GDP per capita

- Focus on $f(\boldsymbol{DS_{it}})$: captures average treatment effect over all countries

- As in (1) but allow for *differential response* in rich and poor countries:

$$growth_{it} = f_{\underline{\boldsymbol{d}}}(\boldsymbol{DS_{it}}, \boldsymbol{DS_{it-1}}) + g_d(\boldsymbol{T_{it}}, \boldsymbol{T_{it-1}}) + h_d(\boldsymbol{R_{it}}, \boldsymbol{R_{it-1}}) + \alpha_i + \delta_{drt} + \theta_i \times t + \epsilon_{it}, \tag{2}$$

- $f_d(\boldsymbol{DS_{it}})$ captures development level specific effect of droughts on economic growth
  - i.e. distinguish between rich and poor countries to account for differences in drought sensitivity due to, e.g., differential spending on adaptation

- As in (2) but replace $f_d(\boldsymbol{DS_{it}}, \boldsymbol{DS_{it-1}})$ by $f_d(\boldsymbol{DS_{it}}, \boldsymbol{DS_{it-1}}|DSMEAN_i)$
- $f_d(\boldsymbol{DS_{it}}|\boldsymbol{DSMEAN_i})$ captures heterogeneity in drought sensitivity due to differential drought climates (and development levels)

- Climatic data
  - Princeton Global Forcing (PGFv3) reanalysis data: monthly precipitation and min/max monthly temperature at 0.25°x0.25°from 1948-2016
- Economic Data
  - World Development Indicators (WDI) (World Bank, 2019): inflation adjusted as well as inflation and PPP adjusted gross domestic product (GDP) for 1960-2018
- Global coverage: 192 countries over 1960-2016

- Drought magnitude = severity of cell-year drought events based on SPEI:
  - drought event in cell c and year t starts when SPEI falls below -1 for at least two consecutive months
  - drought event ends when SPEI returns to positive value
  - SPEI of non drought months are set to 0
  - severity of cell-year drought event is the negative sum of monthly SPEI values belonging to a drought event:

$$DS_{ct} = -\left(\sum_{m \in t} SPEI_{c,m}\right)$$

Table: **Drought-growth response function.** Regression estimates are from a fourth-order polynomial in annual drought severity. Point estimates indicate the effect of a year with drought severity shown, relative to a year with 0 drought severity. Standard errors are robust to spatial (1000km) and serial correlation. 1% (***), 5% (**), and 10% (*)

	Growth rate		
	(1)	**(2)**	(3)
1-in-100-year event	-0.0120^{**}	$\mathbf{-0.0122^{**}}$	-0.0114^{**}
	(0.0052)	**(0.0052)**	(0.0049)
1-in-50-year event	-0.0116^{***}	$\mathbf{-0.0113^{**}}$	-0.0095^{**}
	(0.0044)	**(0.0046)**	(0.0044)
1-in-20-year event	-0.0092^{***}	$\mathbf{-0.0086^{**}}$	-0.0067^{**}
	(0.0032)	**(0.0034)**	(0.0033)
1-in-10-year event	-0.0065^{**}	$\mathbf{-0.0061^{**}}$	-0.0049^{*}
	(0.0027)	**(0.0028)**	(0.0029)
Adjusted R^2	0.2006	**0.2153**	0.1956
Observations	8,409	**8,349**	8,349
Country FE	Yes	**Yes**	Yes
Region x Year FE	Yes	-	-
Poor x Region x Year FE	-	**Yes**	Yes
Country-specific linear trend	Yes	**Yes**	-

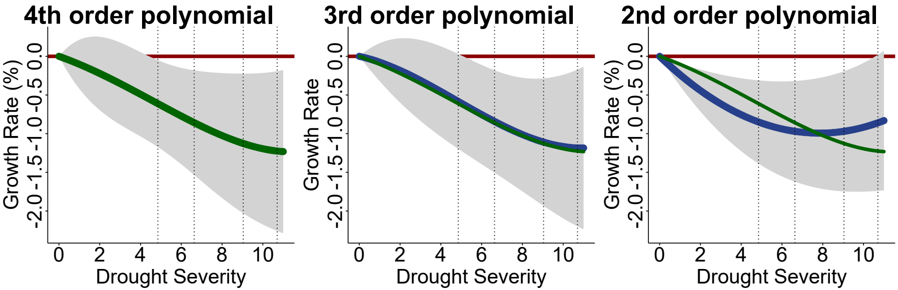


Figure: Robustness of the all development levels growth-drought relationship with the fourth-order polynomial as the main specification in green. Vertical lines represent global 1-in-10, 1-in-20, 1-in-50, and 1-in-100 country-year drought events (from left to right).

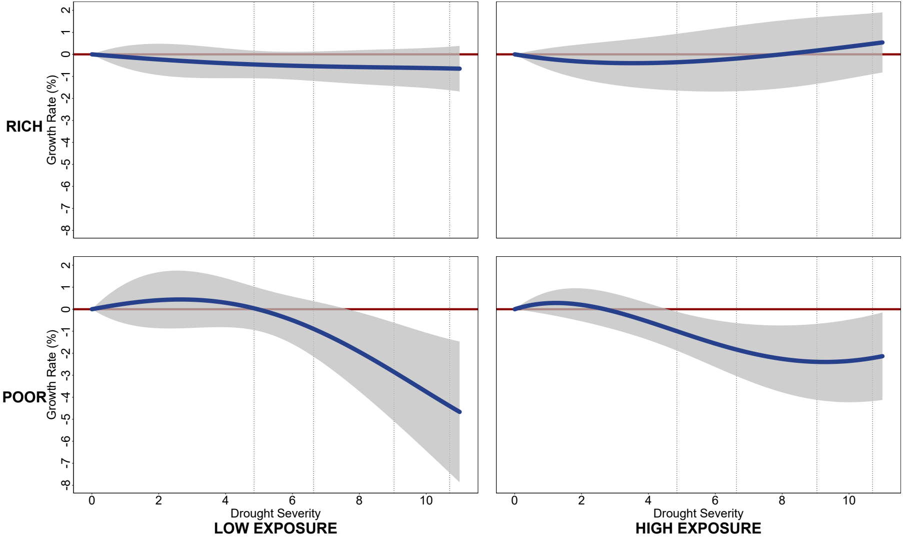
Table: Drought-growth response function with development level heterogeneity.

Regression estimates are from a fourth-order polynomial in annual drought severity. Point estimates indicate the effect of a year with drought severity shown, relative to a year with 0 drought severity. Standard errors are robust to spatial (1000km) and serial correlation. 1% (***), 5% (**), and 10% (*)

	Growth rate		
	(1)	**(2)**	(3)
Panel A: rich			
1-in-100-year event	0.0012	**0.0001**	−0.0005
	(0.0048)	**(0.0050)**	(0.0050)
1-in-50-year event	−0.0001	**−0.0005**	0.0008
	(0.0044)	**(0.0048)**	(0.0046)
1-in-20-year event	−0.0031	**−0.0026**	−0.0004
	(0.0039)	**(0.0043)**	(0.0041)
1-in-10-year event	−0.0052	**−0.0044**	−0.0028
	(0.0035)	**(0.0038)**	(0.0037)
Panel B: poor			
1-in-100-year event	−0.0258***	**−0.0245*****	−0.0231***
	(0.0083)	**(0.0087)**	(0.0084)
1-in-50-year event	−0.0255***	**−0.0242*****	−0.0235***
	(0.0070)	**(0.0074)**	(0.0072)

1-in-20-year event	-0.0172^{***}	$\mathbf{-0.0166}^{***}$	-0.0161^{***}
	(0.0048)	**(0.0050)**	(0.0049)
1-in-10-year event	-0.0076^{*}	$\mathbf{-0.0079}^{**}$	-0.0071^{*}
	(0.0039)	**(0.0039)**	(0.0040)
Adjusted R^2	0.2126	**0.2211**	0.2016
Observations	8,349	**8,349**	8,349
Country FE	Yes	**Yes**	Yes
Region x Year FE	Yes	-	-
Poor x Year FE	Yes	-	-
Poor x Region x Year FE	-	**Yes**	Yes
Country-specific linear trend	Yes	**Yes**	-

Results: 3. Development level specific response function conditional on average drought exposure



Results: 3. Development level specific response function conditional on average drought exposure

- Drought sensitivity of economic growth significantly higher in poor than in rich countries
  $\rightarrow$ **Higher incomes contribute to adaptation**
- Earlier flattening of response functions in high exposure compared to low exposure countries indicates differential adaptation patterns
  $\rightarrow$ **Higher average exposure to droughts contribute to adaptation**