GDP and Temperature: Evidence on Cross-Country Response Heterogeneity

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We Revisit the Evidence

- We revisit international evidence on effect of temperature shocks on GDP growth
- Most evidence based on fixed-effects panel data estimation
  - Bansal and Ochoa (2011), Dell, Jones, and Olken (2012), Burke, Miguel, and Hsiang (2015) Leta and Tol (2019), Henseler and Shumacher (2019).
- Consensus findings
  - Higher temperature may hurt growth for all countries.
  - Higher temperature hurts growth for the poor but may have no effect on the rich

Why?

- Panel methods
  - Impose extensive homogeneity in response across countries
  - Time fixed effects induce variable transformations, clouding the interpretation
- What we do instead
  - We employ (individual) local projections to get grwoth impulse response to temperature shock
  - LPs allow unrestricted response heterogeneity across countries
  - LPs allow estimation of longer horizon growth effects
  - We can study the determinants of the heterogeneity

Main Findings

- Global temperature shock causes damage to rich country growth
  - G-7 countries growth declines. All except Canada are significant
- A mixed bag for middle and low income countries
- Positive growth responses more likely for countries that are
  - Poorer
  - Slow growing
  - Less educated
  - Less open to trade,
  - More authoritarian

Data

- Economic capita from World Bank *World Development Indicators*.
  - Per capita GDP are constant 2010 US dollars
  - Maximum span 1960-2017
    - 137 countries with at least 30 consecutive observations
- Temperature are population weighted by year and country
  - Monthly data from weather stations interpolated at 0.5×0.5 lat./lon. grid (Matsuura 2018)
  - Overlay with population data (2000) from *GPWv4* (Gridded Population of the World)

Comment about Panel Regression with Time FE

$$\Delta y_{j,t} = \theta_t + \beta \tau_{j,t} + \epsilon_{j,t}. \tag{1}$$

$$\Delta y_{j,t} - \frac{1}{N}\sum_{j=1}^{N} \Delta y_{j,t} = \beta \left(\tau_{j,t} - \frac{1}{N}\sum_{j=1}^{N} \tau_{j,t} \right) + \left(\epsilon_{j,t} - \frac{1}{N}\sum_{j=1}^{N} \epsilon_{j,t} \right). \tag{2}$$

Global and Idiosyncratic Temperature

- Global (G_t):

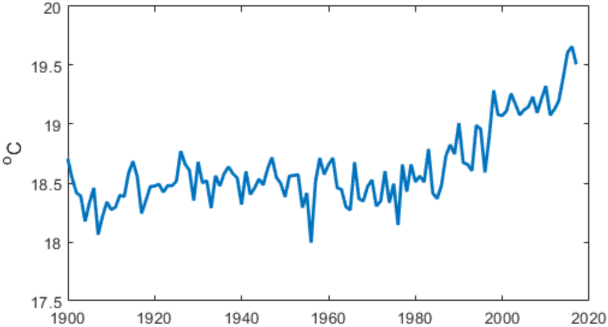
$$G_t = \frac{1}{N} \sum_{j=1}^{N} \tau_{j,t}$$

- Idiosyncratic ($I_{j,t}$)
  - $I_{j,t}$ is residual from regressing $\tau_{j,t}$ on G_t and a constant.

$$I_{j,t} = \tau_{j,t} - \delta_j G_t - \alpha_j$$

Global Temperature

Cross-Sectional Average of Country Annual Temperatures



Empirical Specification (Jordà 2005) LPs

$$ln\left(\frac{y_{j,t+h}}{y_{j,t-1}}\right) = \beta^G_{j,h} G_t + \beta^I_{j,h} I_{j,t} + x^{'}_{j,t}\gamma_{j,h} + \epsilon_{j,t+h}$$

where

- $x^{'}_{j,t}\gamma_{j,h}$ are K lags of GDP growth, L lags of Global temperature, and M lags of Idiosyncratic temperature
- Lags K, L, and M determined by AIC.
- $\beta^G_{j,h}$ / $\beta^I_{j,h}$: percent response in $\Delta y_{j,t}$ from $t-1$ to $t+h$ due to $1°C$ increase in temperature in time t.

Pseudo-Panel Local Projections

Increase estimation precision with little point estimate distortion

- For horizon h, estimate pairwise SSE of estimates relative to remaining countries, $(\beta^G_{1,h} - \beta^G_{j,h})^2 + (\beta^I_{1,h} - \beta^I_{j,h})^2$.
- Create pseudo-panels of groups with lowest SSEs.
- For each group, estimate

$$ln\left(\frac{y_{j,t+h}}{y_{j,t-1}}\right) = \beta^G_h G_t + \beta^I_h I_{j,t} + x^{'}_{j,t}\gamma_{j,h} + \epsilon_{j,t+h}$$

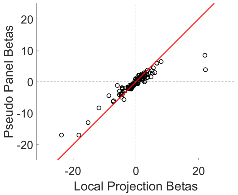
- Constrain β^G_h and β^I_h to be equal in each pseudo-panel.
- Estimate each pseudo-panel by GMM.

Point Estimate Comparison

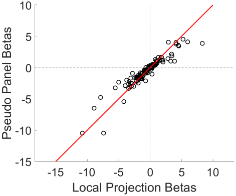
Local Projection vs. Pseudo-Panel Local Projection Betas

A. Global Temperature B. Idiosyncratic Temperature

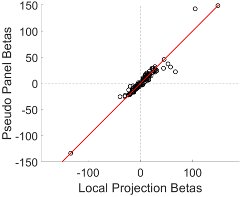
Horizon 0



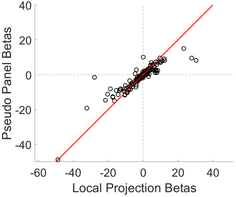
Horizon 0



Horizon 5



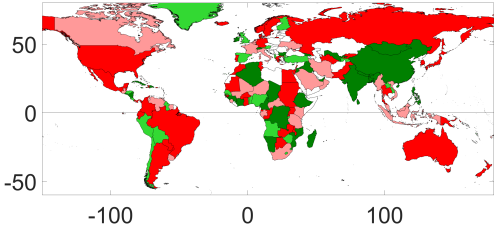
Horizon 5



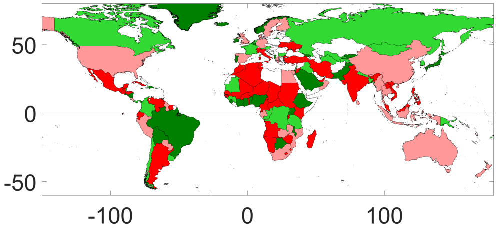
GDP & Temperature

Horizon 0: Pseudo-Panel Betas

Global

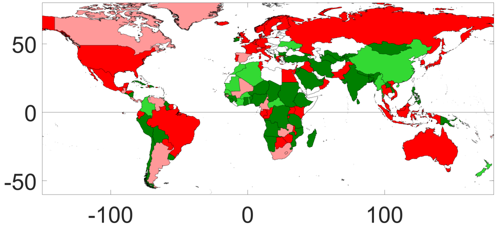


Idiosyncratic



Horizon 5: Pseudo-Panel Betas

Global



Idiosyncratic

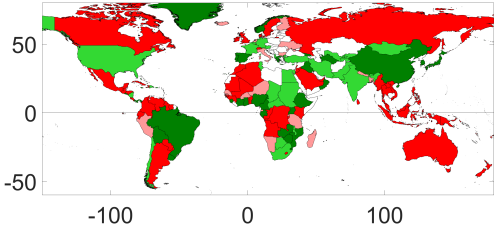
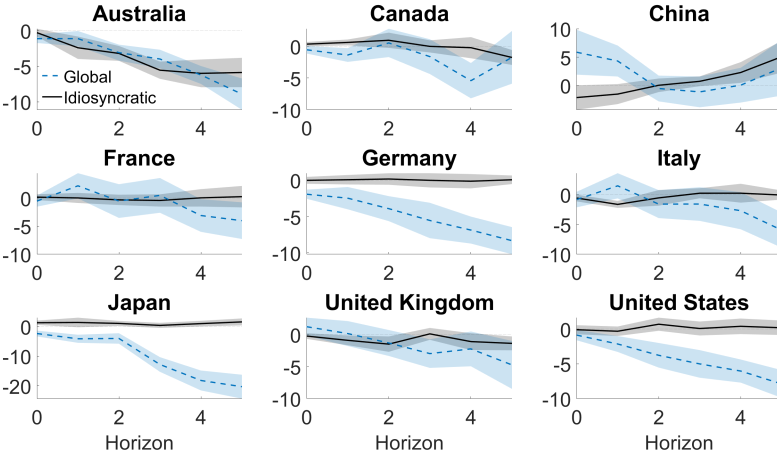


Figure: Global (Dashed) and Idiosyncratic (Solid)

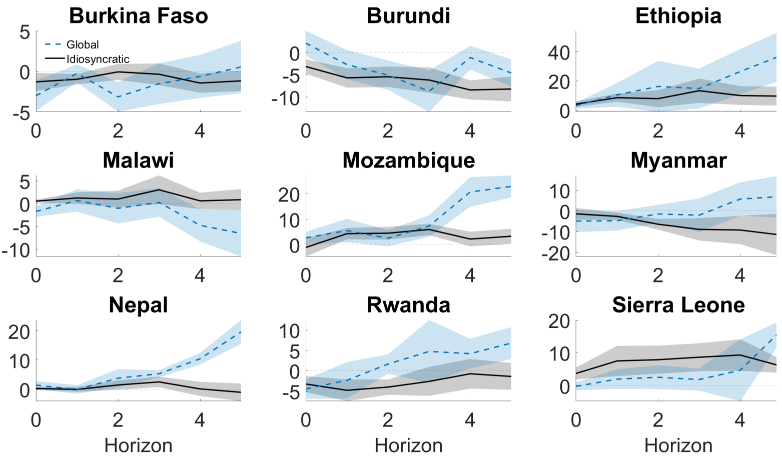
G-7 Plus Australia and China



Notes: Shaded areas are plus and minus 1.96 standard error bands.

Figure: Global (Dashed) and Idiosyncratic (Solid)

Nine Poorest Countries



Modeling Response Heterogeneity

$$\widehat{\beta^{\tau}}_{j,h} = X_j^{'}\gamma_{\tau,h} + u_{\tau,h}$$

- Average log real GDP per capita
- Long term growth
- Openness
- GDP share of Agriculture (labor and crop exposure)
- Democracy
- High School
- Absolute latitude

Table: Cross-Sectional Regression with Global Temperature Local Projection Betas

	Horizon					
	0	1	2	3	4	5
log(GDP Per Capita)	0.133	-1.306	-1.411	**-3.029**	-4.177*	-4.450
	(0.288)	(-1.644)	(-1.308)	(-2.070)	(-1.935)	(-1.452)
L.T. Growth	0.261	**-1.511**	**-2.548**	**-4.258**	**-6.138**	**-7.122**
	(0.768)	(-2.569)	(-3.193)	(-3.931)	(-3.841)	(-3.138)
Openness	0.011	**0.037**	**0.052**	**0.070**	**0.103**	**0.132**
	(1.304)	(2.619)	(2.720)	(2.731)	(2.694)	(2.435)
High School	0.013	**0.075**	**0.131**	**0.236**	**0.382**	**0.483**
	(0.903)	(2.953)	(3.824)	(5.049)	(5.555)	(4.945)
Democracy	-0.029	-0.030	-0.141*	**-0.225**	**-0.458**	**-0.720**
	(-0.823)	(-0.483)	(-1.685)	(-1.972)	(-2.725)	(-3.019)
Agricultural Share	0.028	0.034	0.094	0.065	0.157	0.378
	(0.628)	(0.441)	(0.892)	(0.458)	(0.746)	(1.268)
Latitude	**-0.029**	-0.043*	-0.047	-0.048	-0.055	-0.033
	(-2.026)	(-1.728)	(-1.375)	(-1.036)	(-0.813)	(-0.338)
Temperature	0.029	-0.031	-0.048	0.009	-0.135	-0.422
	(0.553)	(-0.352)	(-0.397)	(0.057)	(-0.556)	(-1.223)
R-Square	0.080	0.244	0.315	0.394	0.429	0.398
Observations	122	122	122	122	122	122

Modeling Response Heterogeneity: Global

$$\widehat{\beta}_{j,h} = X_j^{'}\gamma + u_h$$

- Average log real GDP per capita
- Long term growth (-)
- Openness (+)
- GDP share of Agriculture (labor and crop exposure)
- Democracy (-)
- High School (+)
- Absolute latitude