Growth at Risk From Climate Change

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Views are those of the author, and do not reflect those of the Federal Reserve or its staff

Motivation

- Climate change is among the central economic and social challenges of the 21st century.

- Rising temperatures, shifts in precipitation, more frequent and severe extreme weather events and natural disasters, and sea level rise – among other changes induced by climate change – may depress economic activity

- These changes may also alter risks to economic activity

Contribution

- Examine risks to economic activity associated with climate change in a large panel of countries
- Illustrate the Growth at Risk from climate change under alternative Representative Concentration Pathways (RCPs)
- Growth at Risk is large in low income or “hot” countries—severe economic contractions may be more likely in the future owing to climate change

Previous literature

- Impact of climate change on growth has been examined in
  - Integrated assessment models (e.g., Nordhaus DICE model)
  - Reduced form regressions (e.g., Dell, Jones, and Olken, 2012; Burke, Hsiang, and Miguel, 2015; Kalkuhl and Wenz, 2020; Newell, Prest, and Sexton, 2021)
- Reduced-form approach has used weather to proxy for effects of climate change, which may/may not be a good guide to the effects of climate (Dell, Olken, and Jones, 2014; Hsiang, 2016)
  - This work has focused on average expected effects → least squares regressions
- Previous work on risks limited (e.g., risks of different climate pathways, as in Lemoine and Kapnick, 2016; Kahn et al, 2018; & NGFS)
- Macroeconomic research on risks growing (Adrian et al, 2019; Kiley; forthcoming)

Growth at Risk approach

- Quantile regressions linking growth and weather

$$\Delta y(t,j) = a_j + A_D D + F\big(T(t,j)\big).$$

- What can a quantile regression tell us?
  - The approach can inform an assessment of how the distribution of economic growth may shift with a change in weather (climate)
  - A median regression provides a sense of the shift in the central tendency of growth (like least squares, potentially with less influence from outliers)?
  - Exploring other quantiles can inform whether
    - Growth may become more volatile
    - Or more negatively skewed (i.e., larger or more frequent growth disasters)

Growth at Risk approach--specifications

- (A) -- Quadratic in temperature:

$$F\big(T(t,j)\big) = a_{1,0}T(t,j) + a_{1,1}T(t,j)^2.$$

- (B) -- (A) with temperature change interactions:

$$F\big(T(t,j)\big) = a_{1,0}T(t,j) + a_{1,1}T(t,j)^2 + a_{2,0}\Delta T(t,j) + a_{2,1}T(t,j)\Delta T(t,j).$$

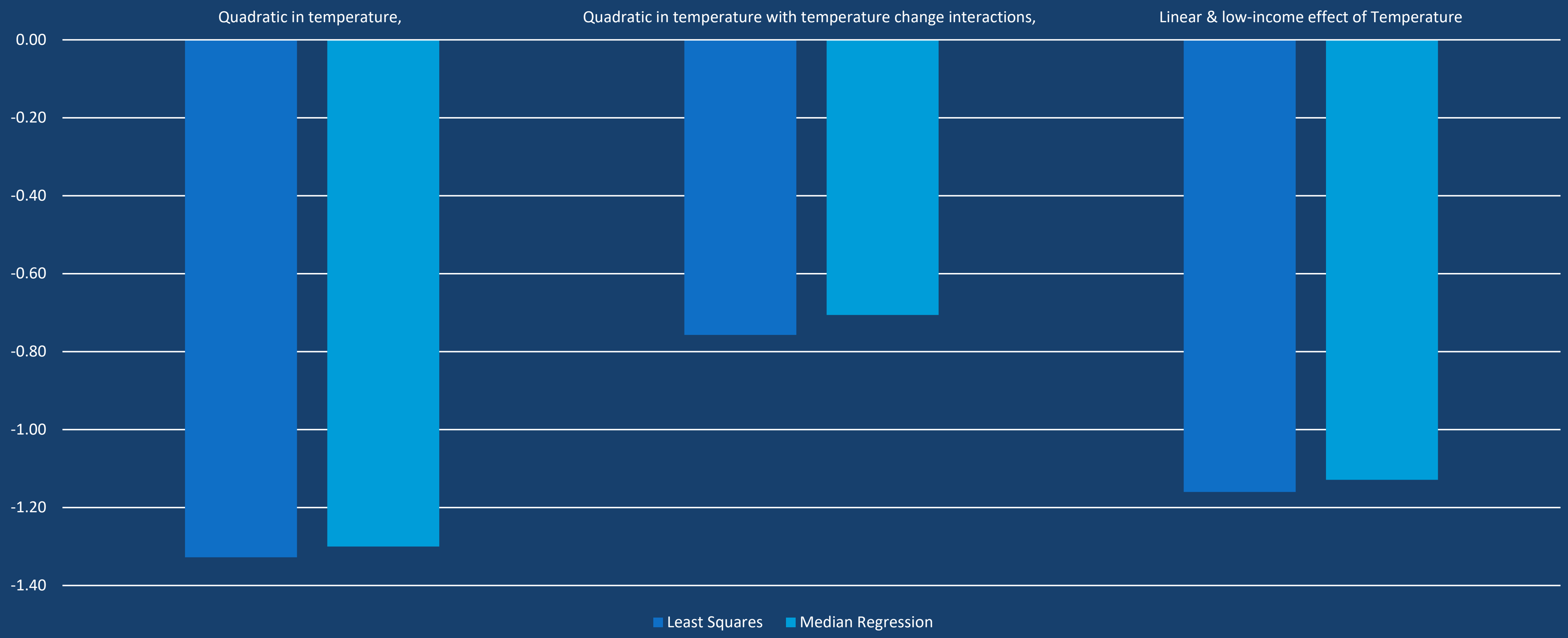
- (C) -- Linear & low-income effect of temperature:

$$F\big(T(t,j)\big) = a_{1,0}T(t,j) + a_{1,1}T(t,j)I_{low\ income}$$

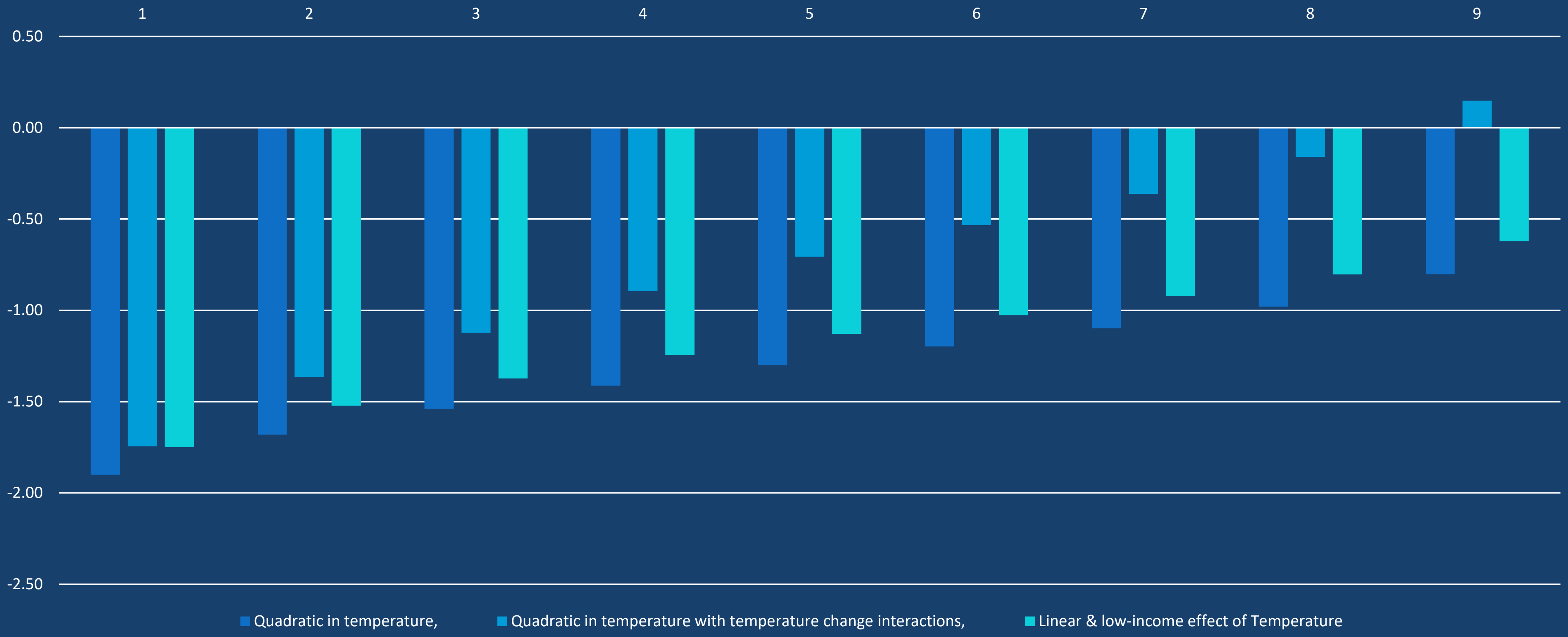
Data

- From Burke, Davis, and Diffenbaugh (2018)
- 124 countries, 1960-2010
- Focus on growth of real GDP per capita
- Temperature variables use detailed data, aggregated to country level using population weights

Temperature → central tendency of growth



Quantile regressions: Temperature → growth (columns refer to growth decile) (table)



Temperature → growth distribution
Robustness checks

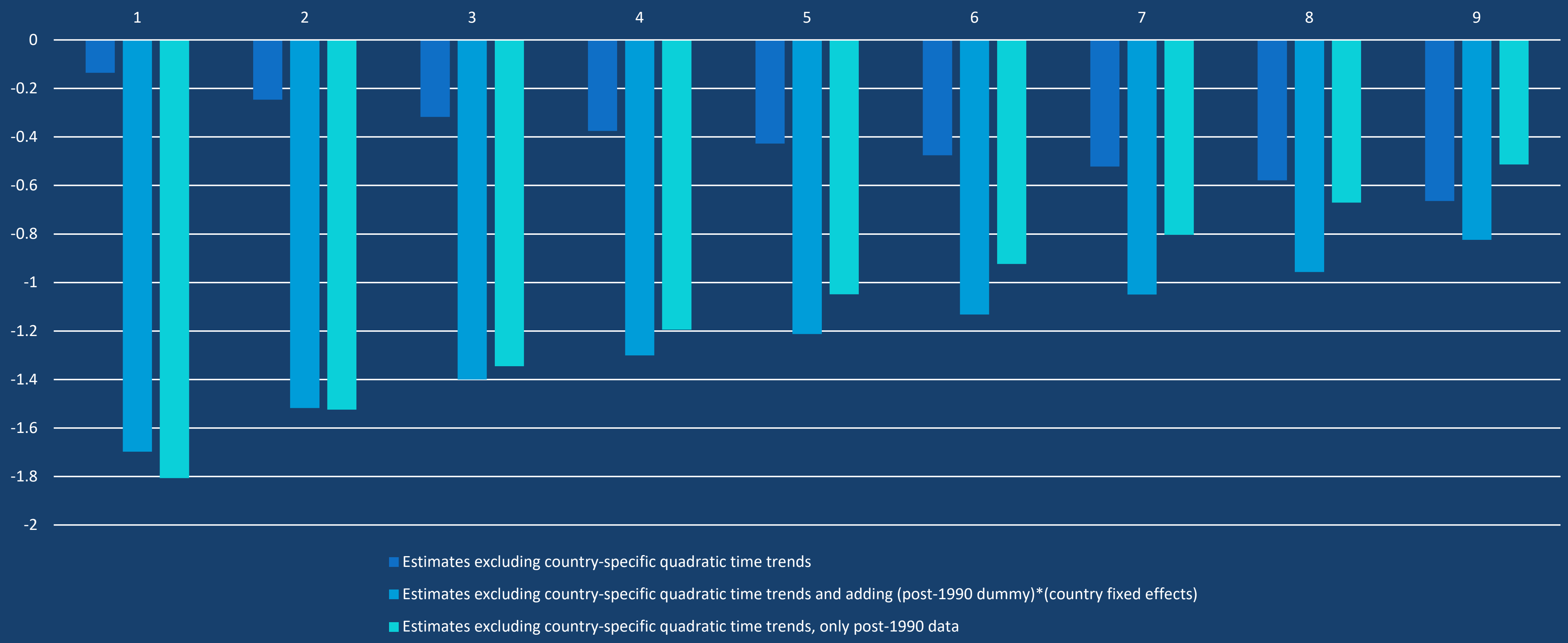
- Are effects implausibly large when extrapolated N years into future?
  - >1pp effect of 1 degree increase in temp.→ >50 percent decline in GDP (relative to baseline) after 50 years
  - Regressions focus on business cycle movements—may be inappropriate to extrapolate
  - Regressions with detrended GDP bound cumulative effect at a lower level—and yield similar results for risk of growth disasters

- Other key robustness issues (Newell, Prest, and Sexton, 2020)
  - Sensitivity of results to treatment of low frequency components of growth
  - Effects on nonagricultural vs agricultural GDP

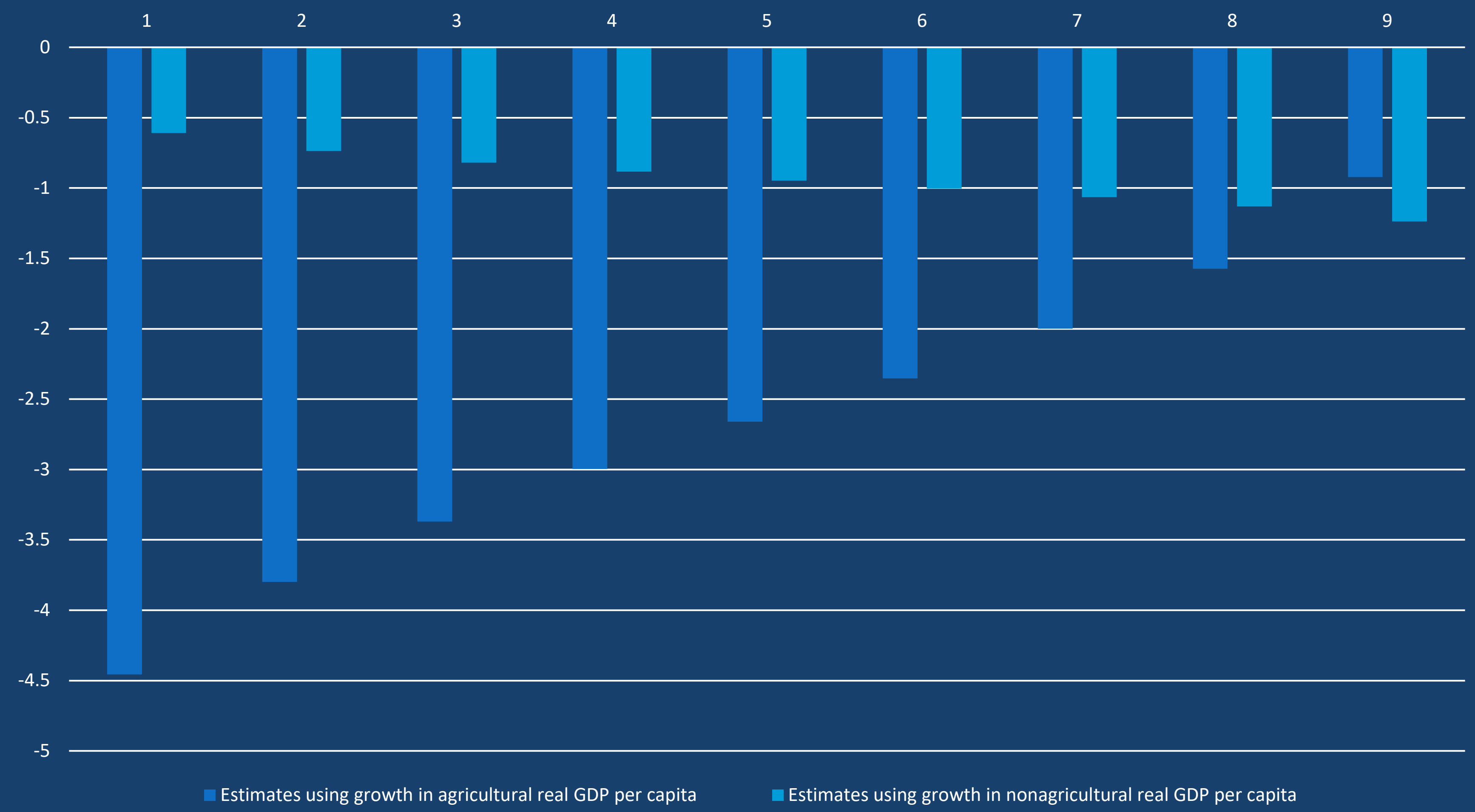
Temperature → growth distribution
Sensitivity to low frequency trends

- Treatment of low frequency components of growth
  - Baseline: Quadratic time trends (from Burke, Hsiang, and Miguel, 2015)
- Newell, Prest, Sexton (2020)—results not robust to excluding trends
- Consider three alternative versions
  - No trends
  - No trends, with country-specific post-1990 dummy to capture low frequency
  - No trends, only post-1990 data

Temperature → growth distribution
Sensitivity to low frequency trends (table)



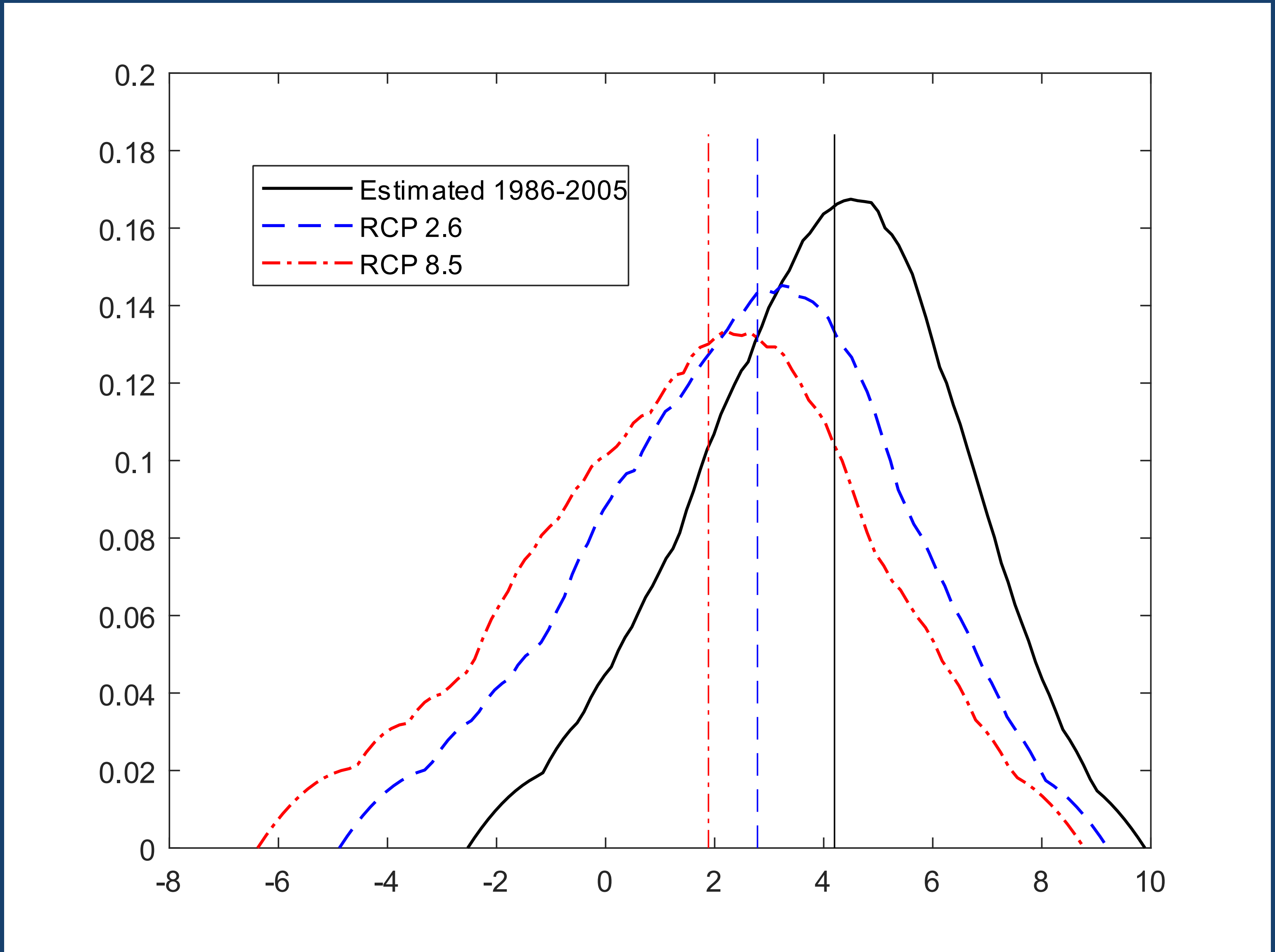
Temperature → growth distribution Agricultural vs nonagricultural GDP



Implications for Growth at Risk (G@R)-- Examples

- USA – high income and moderate temperature→G@R low
- Brazil – high income and relatively high temperature→G@R may be low or high, depending on whether temperature or income specification is the best guide
- India and Nigeria – low income and high temperature→G@R high
- Relative agricultural intensity of each suggests similar implications when considering the agricultural vs. nonagricultural GDP results

Growth at Risk in India



Conclusions

- Growth at Risk from climate change is potentially very large
- Effect of climate on growth much larger for downside risks – climate change may make severe contractions in economic activity more likely
- Reduced form regressions may not account for adaptations, etc., and additional work is needed

Appendix

Baseline Quantile regressions (columns refer to growth decile) (return)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Quadratic in temperature									
Effect in hot countries									
$a_{1,0} + 2 * a_{1,1} * 25.64$	-1.900	-1.681	-1.540	-1.412	-1.300	-1.198	-1.098	-0.980	-0.802
Standard error	0.730	0.566	0.467	0.396	0.347	0.320	0.314	0.337	0.413
p-value	0.012	0.003	0.001	0.000	0.000	0.000	0.000	0.004	0.052
Quadratic in temperature with temperature change interactions									
Effect in hot countries									
$a_{1,0} + 2 * a_{1,1} * 25.64$	-1.745	-1.366	-1.122	-0.893	-0.706	-0.534	-0.362	-0.159	0.149
Standard error	0.941	0.708	0.580	0.488	0.423	0.388	0.384	0.415	0.521
p-value	0.064	0.054	0.053	0.067	0.095	0.169	0.345	0.702	0.775
Linear & low-income effect of Temperature									
Effect in poor countries									
$a_{1,0} + a_{1,1}$	-1.749	-1.522	-1.373	-1.245	-1.129	-1.027	-0.922	-0.803	-0.622
Standard error	1.026	0.786	0.631	0.510	0.408	0.332	0.281	0.273	0.365
p-value	0.088	0.053	0.030	0.015	0.006	0.002	0.001	0.003	0.089

Some robustness results (columns refer to growth decile) (return)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Estimates excluding country-specific quadratic time trends									
Effect in hot countries									
$a_{1,0} + 2 * a_{1,1} * 25.64$	-0.135	-0.246	-0.317	-0.375	-0.427	-0.475	-0.522	-0.579	-0.664
Standard error	0.528	0.403	0.341	0.306	0.292	0.296	0.315	0.354	0.438
p-value	0.799	0.542	0.352	0.221	0.144	0.108	0.098	0.102	0.129
Estimates excluding country-specific quadratic time trends and adding (post-1990 dummy)*(country fixed effects)									
Effect in hot countries									
$a_{1,0} + 2 * a_{1,1} * 25.64$	-1.698	-1.518	-1.4	-1.301	-1.213	-1.132	-1.05	-0.957	-0.824
Standard error	0.652	0.530	0.464	0.422	0.394	0.382	0.384	0.402	0.453
p-value	0.012	0.004	0.003	0.002	0.002	0.003	0.006	0.017	0.069
Estimates excluding country-specific quadratic time trends, only post-1990 data									
Effect in hot countries									
$a_{1,0} + 2 * a_{1,1} * 25.64$	-1.807	-1.524	-1.345	-1.195	-1.049	-0.924	-0.803	-0.671	-0.513
Standard error	1.223	1.008	0.891	0.816	0.759	0.722	0.703	0.699	0.728
p-value	0.179	0.131	0.131	0.143	0.167	0.201	0.253	0.338	0.481

Long-run effect with detrended real GDP

$$\Delta y^{detrended}(t,j) = a_j + A_D D + \mathrm{b} \cdot y^{detrended}(t-1,j) + F\big(T(t,j)\big).$$

- Long run effect on real GDP

$$\frac{F\big(T(t,j)\big)}{1+b}$$

(return)