Empirical evidence on the aggregate impacts of warming

Marshall Burke
Dept. of Earth System Science, Stanford University
National Bureau of Economic Research

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[*with thanks to Sol Hsiang, Ted Miguel, Noah Diffenbaugh, Matt Davis, Vincent Tanutama*]

We know a lot at the “micro” level

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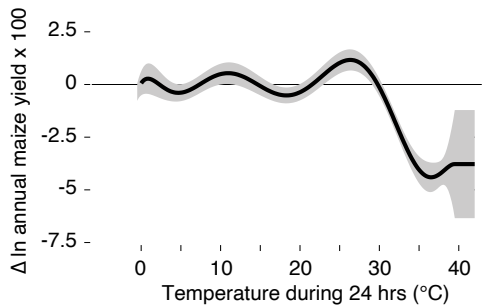
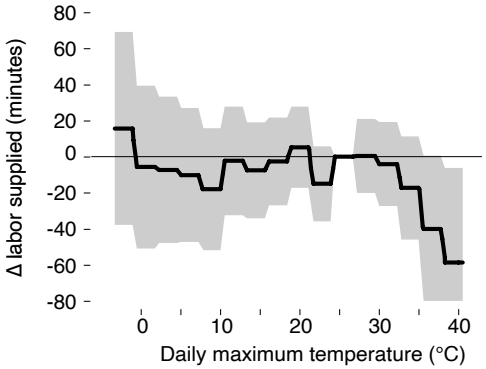
Agriculture

Schlenker and Roberts 2009



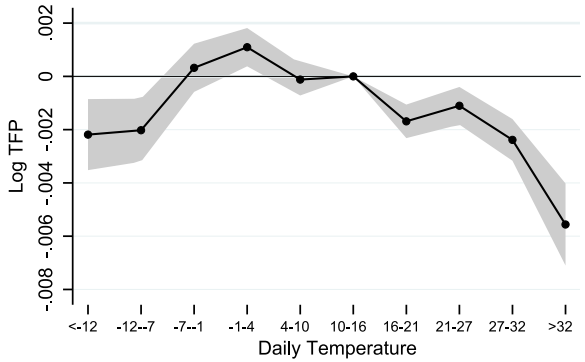
Labor supply

Graff Zivin and Niedell 2014



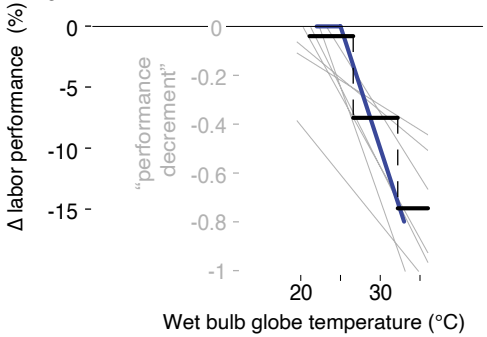
Plant-level TFP

Zhang Meng Deschenes Zhang 2017



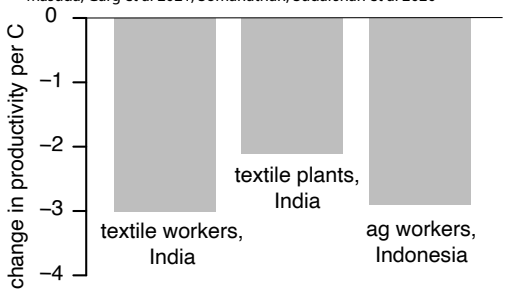
Ergonomics

Hsiang 2010



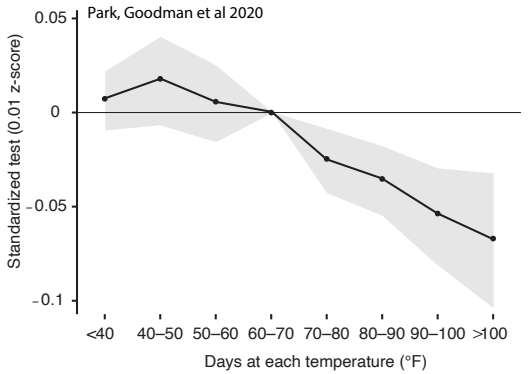
Labor productivity

Masuda, Garg et al 2021; Somanathan, Sudarshan et al 2020



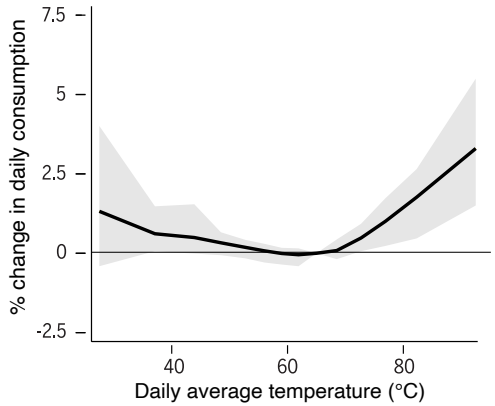
Test scores

Park, Goodman et al 2020



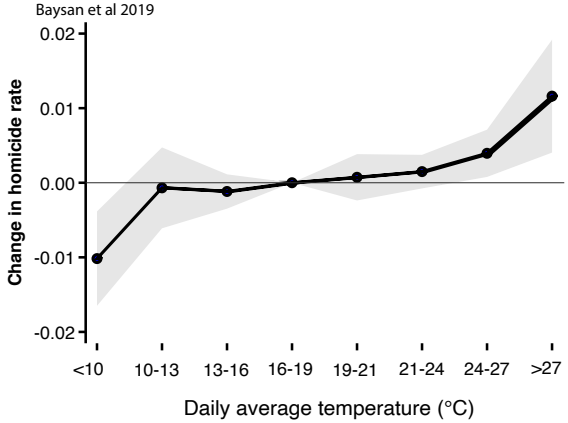
Electricity consumption

Auffhammer 2015



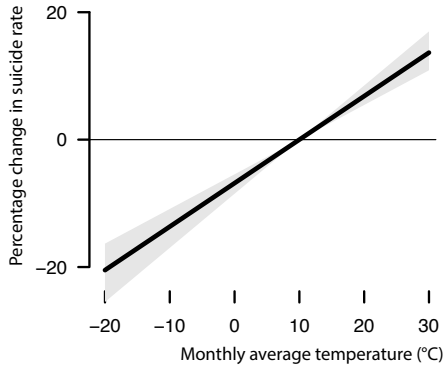
Homicide

Baysan et al 2019



Suicide

Burke et al 2018



But how do these effects aggregate?

Two approaches to generate an aggregate "damage function"

1. **Bottom up**: convert micro estimates to $, add them up somehow

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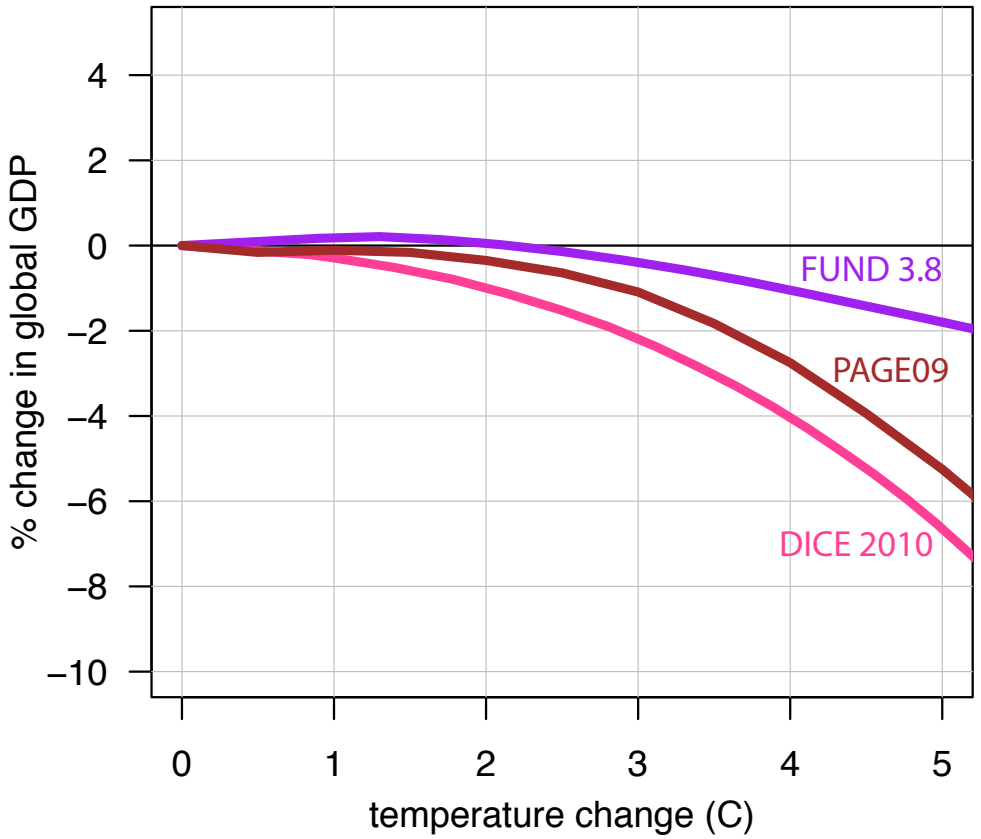
Two approaches to generate an aggregate "damage function"

1. **Bottom up**: convert micro estimates to $, add them up somehow
2. **Top down**: let economy do adding up for you, study effect on economic aggregates (e.g. GDP)

Damage functions we have known



- Pindyck (JEL, 2013): *"The damage functions used in most IAMs are completely made up, with no theoretical or empirical foundation."*
- Revesz, Arrow, Goulder et al (*Nature*, 2014): *"The models should be revised more frequently to accommodate scientific developments."*

Burke et al *Nature* (2015, 2018)

Approach: study effect of temperature on aggregate economic outcomes using country-level data (165 countries, 50 years).

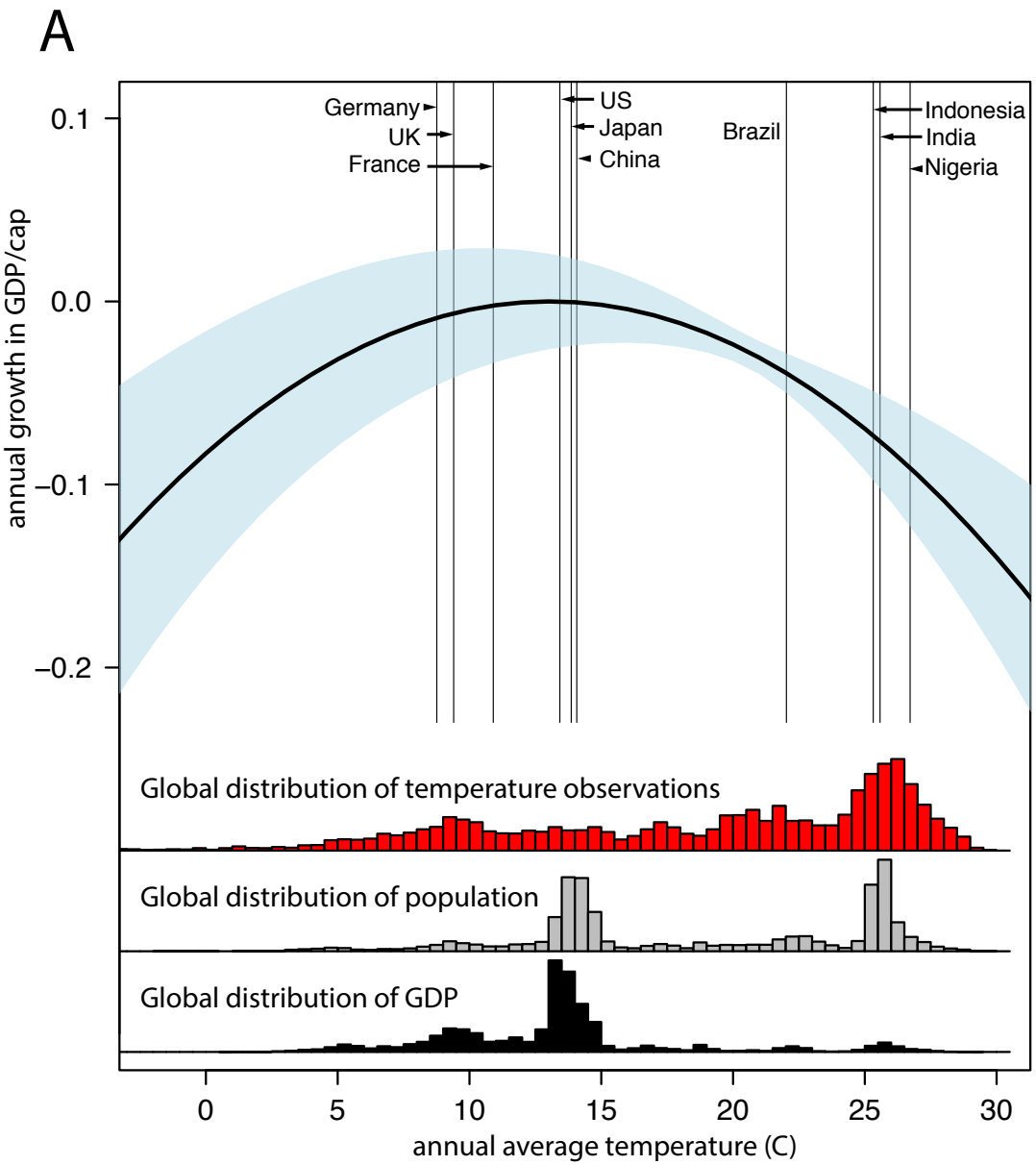
Estimate:

$$\Delta Y_{it} = g(T_{it}) + \lambda_1 P_{it} + \lambda_2 P_{it}^2 + \mu_i + \gamma_t + \theta_i t + \theta_{i2} t^2 + \varepsilon_{it} \qquad (1)$$

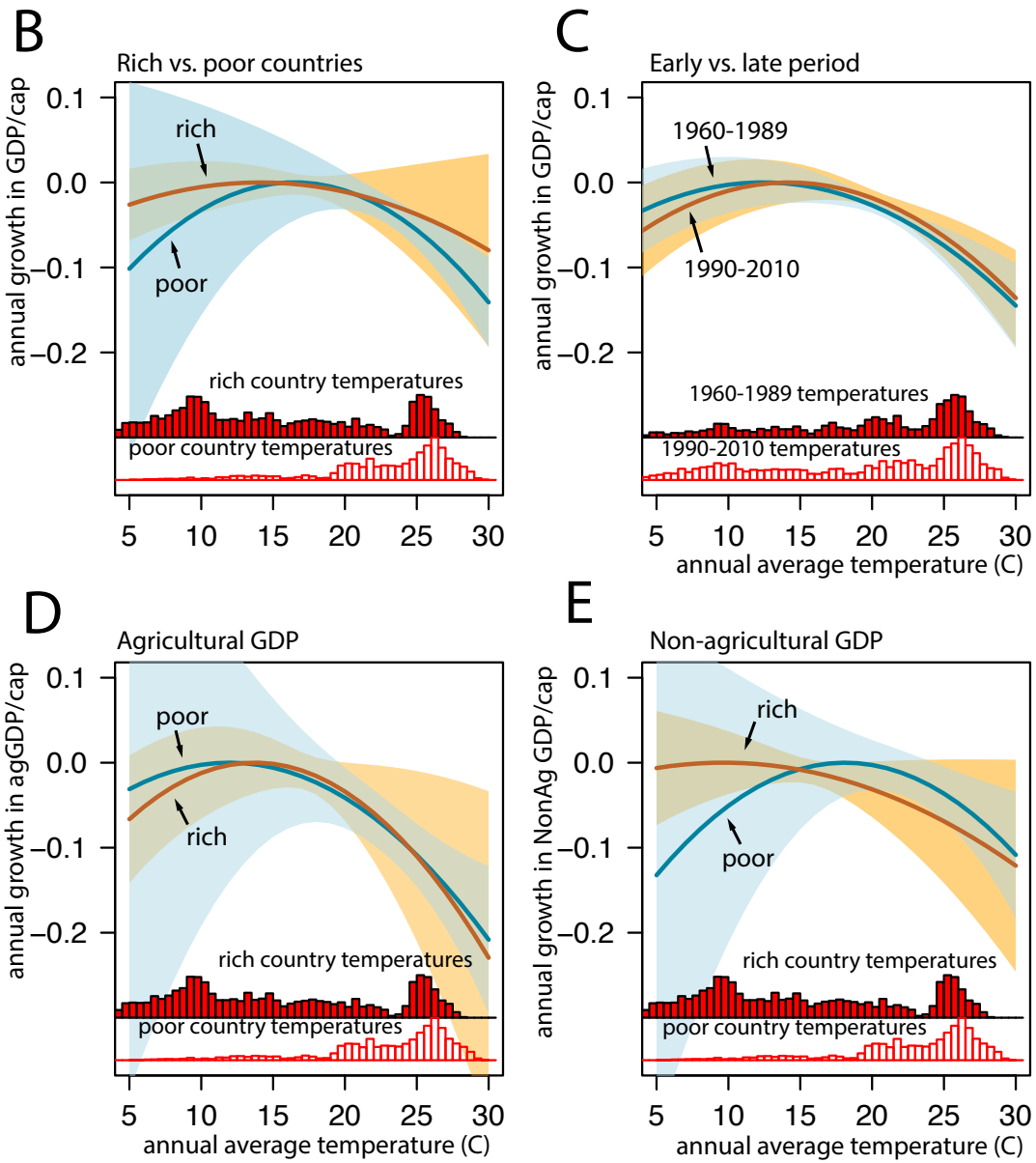
What this does

- uses within-country variation over time, detrended
- allows within-county effect to vary as a function of average temperature

Last half-century: global non-linear response

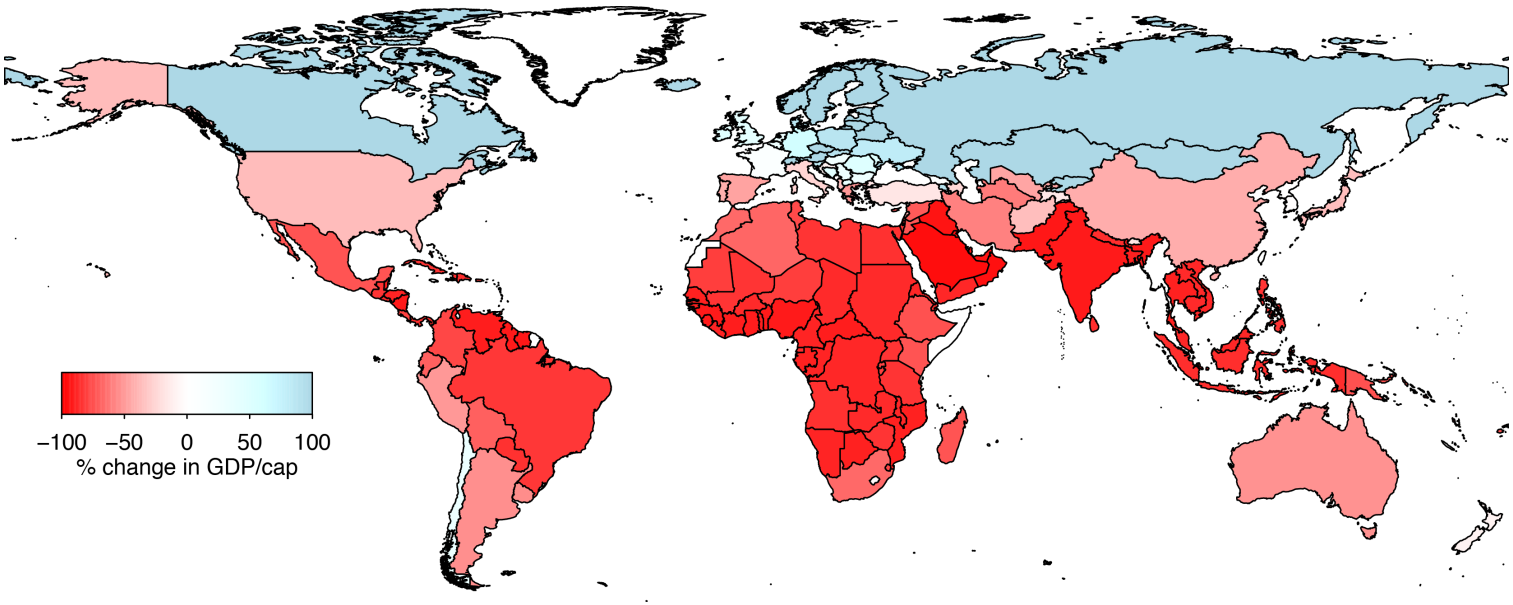


Differences over space or time?



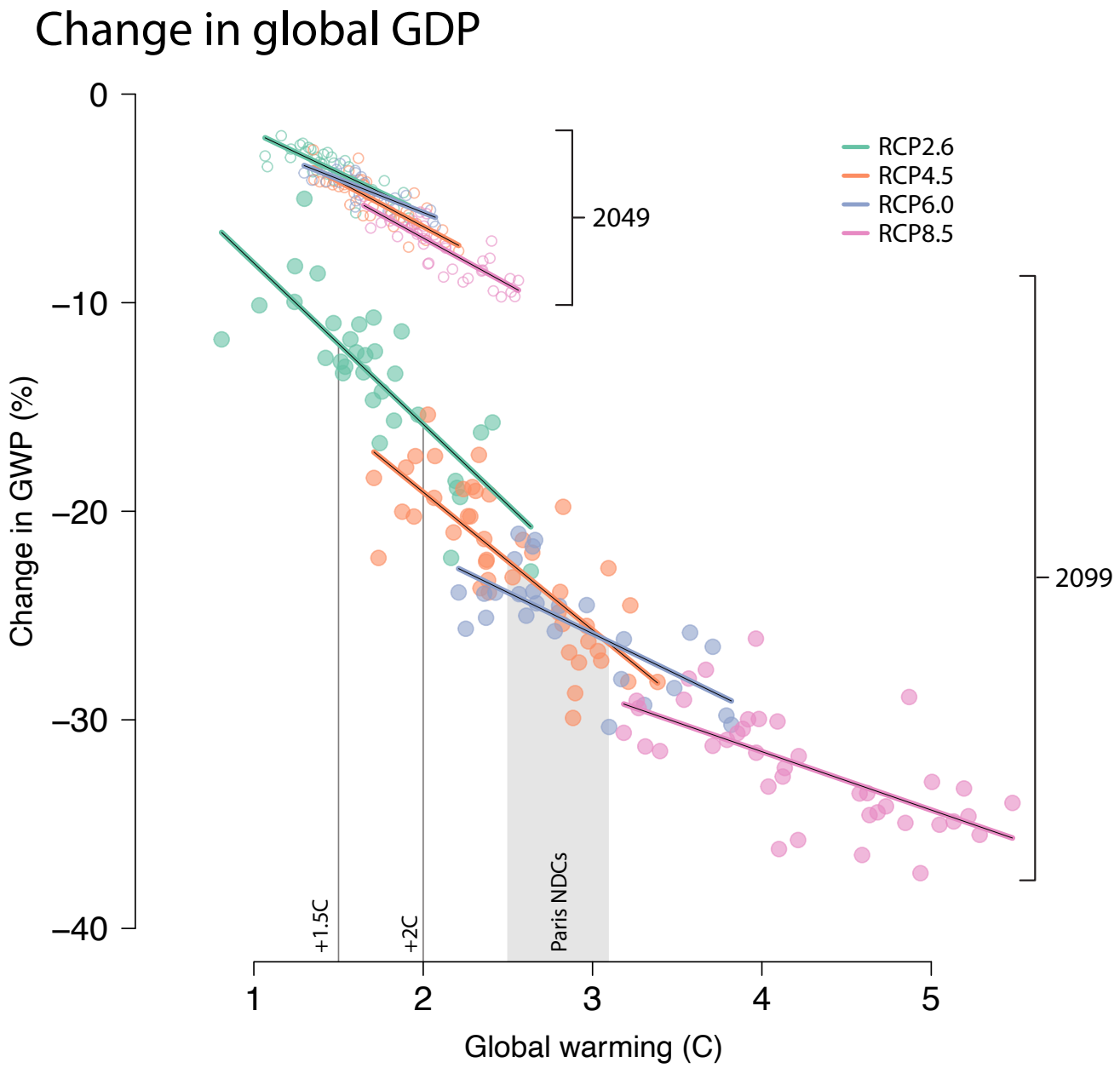
Country-level damages under high warming

Change in GDP/cap by 2100, relative to world without climate change



>75% of countries are worse off in relative terms

Now heroically run the world forward



Can this be right??

Estimates are 5-10x larger that IAM damage estimates.

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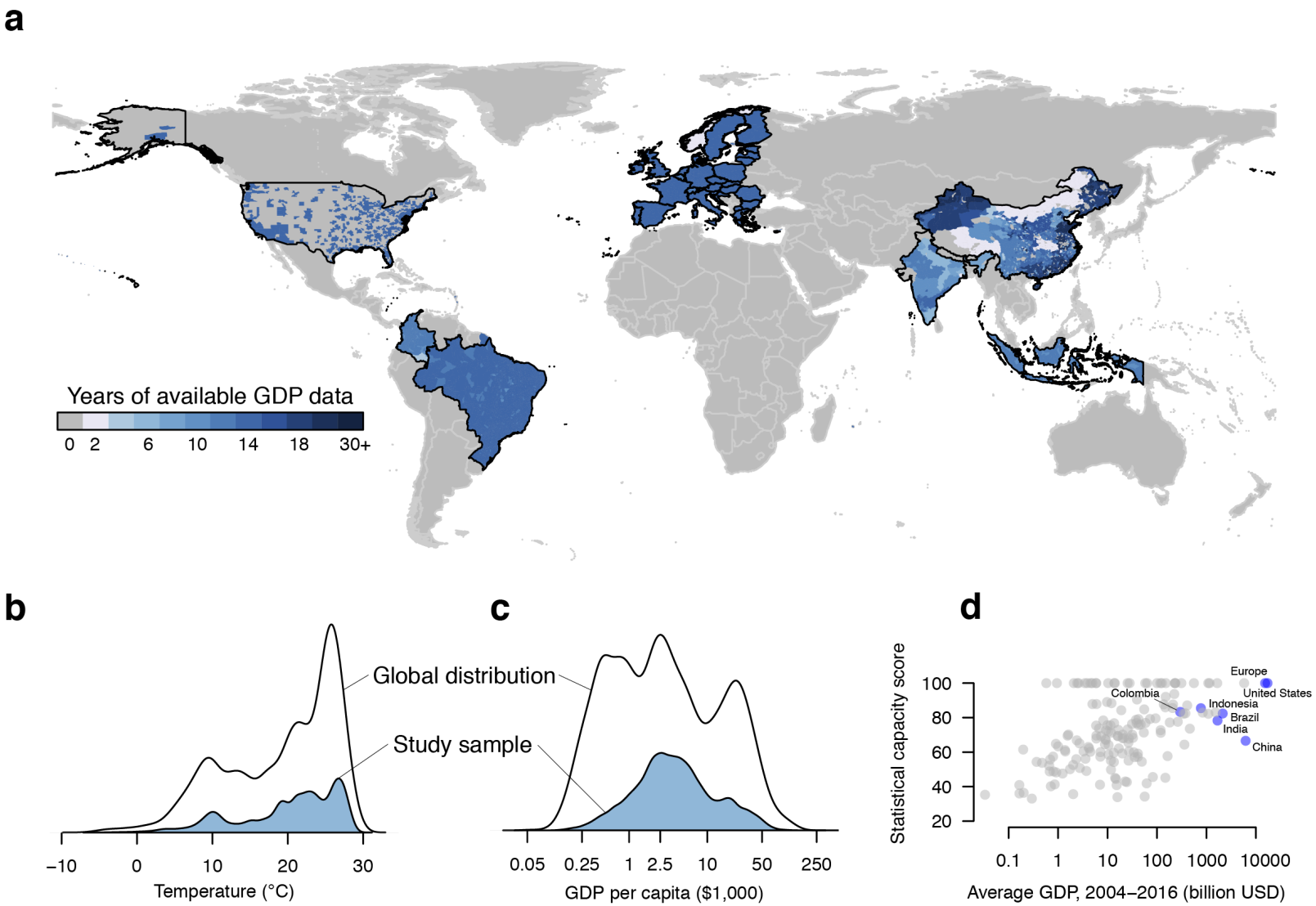
Some common complaints:

- Not convinced growth rates are affected
- We can't trust national accounts data from lots of places
- Effects could differ within countries as well as between them

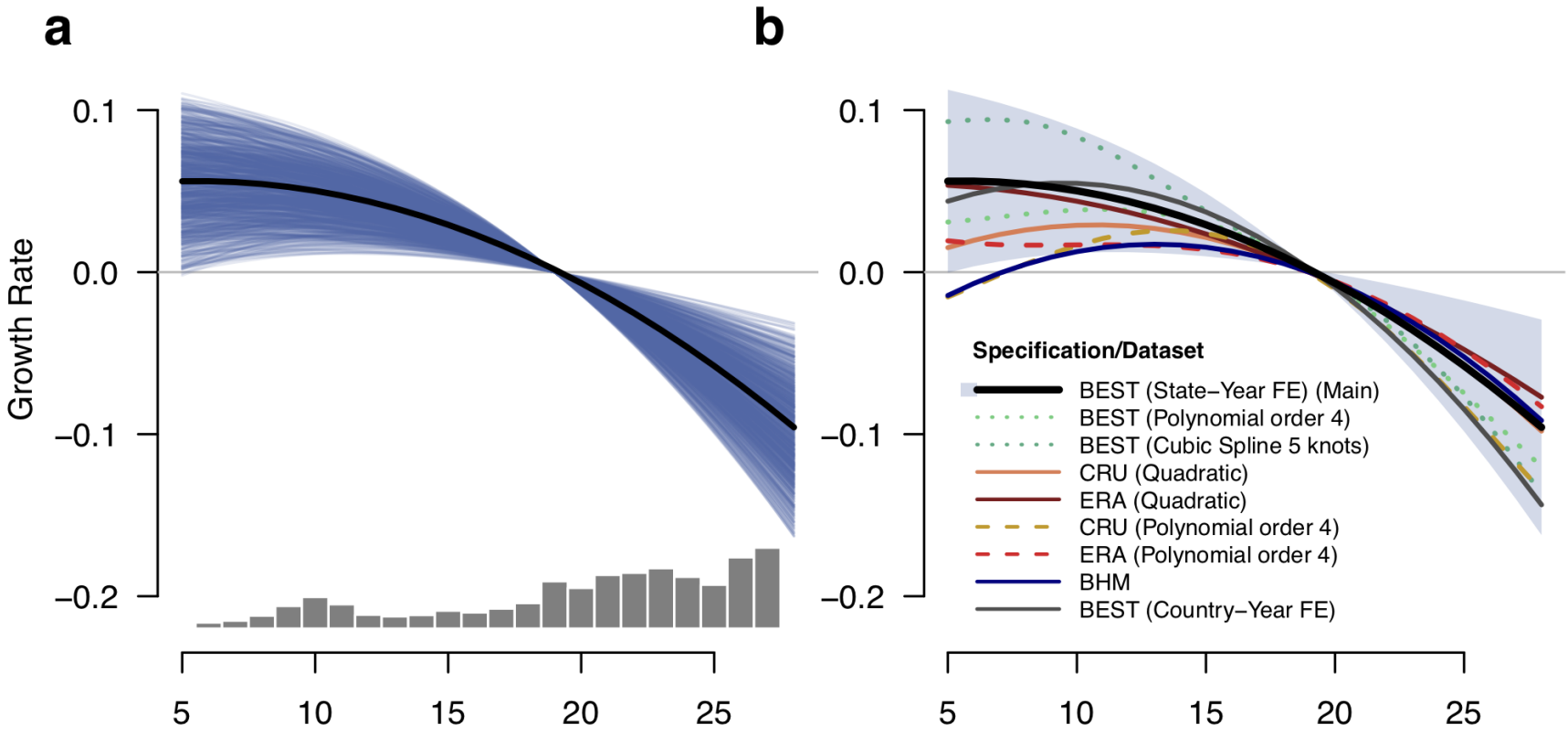
Let's try it with subnational output data



11,669 districts, n=162,256 total district-year obs

Pooled response, all districts

$$y_{isjt} = f(T_{isjt}, P_{isjt}) + \alpha_i + \eta_{st} + \varepsilon_{isjt}$$



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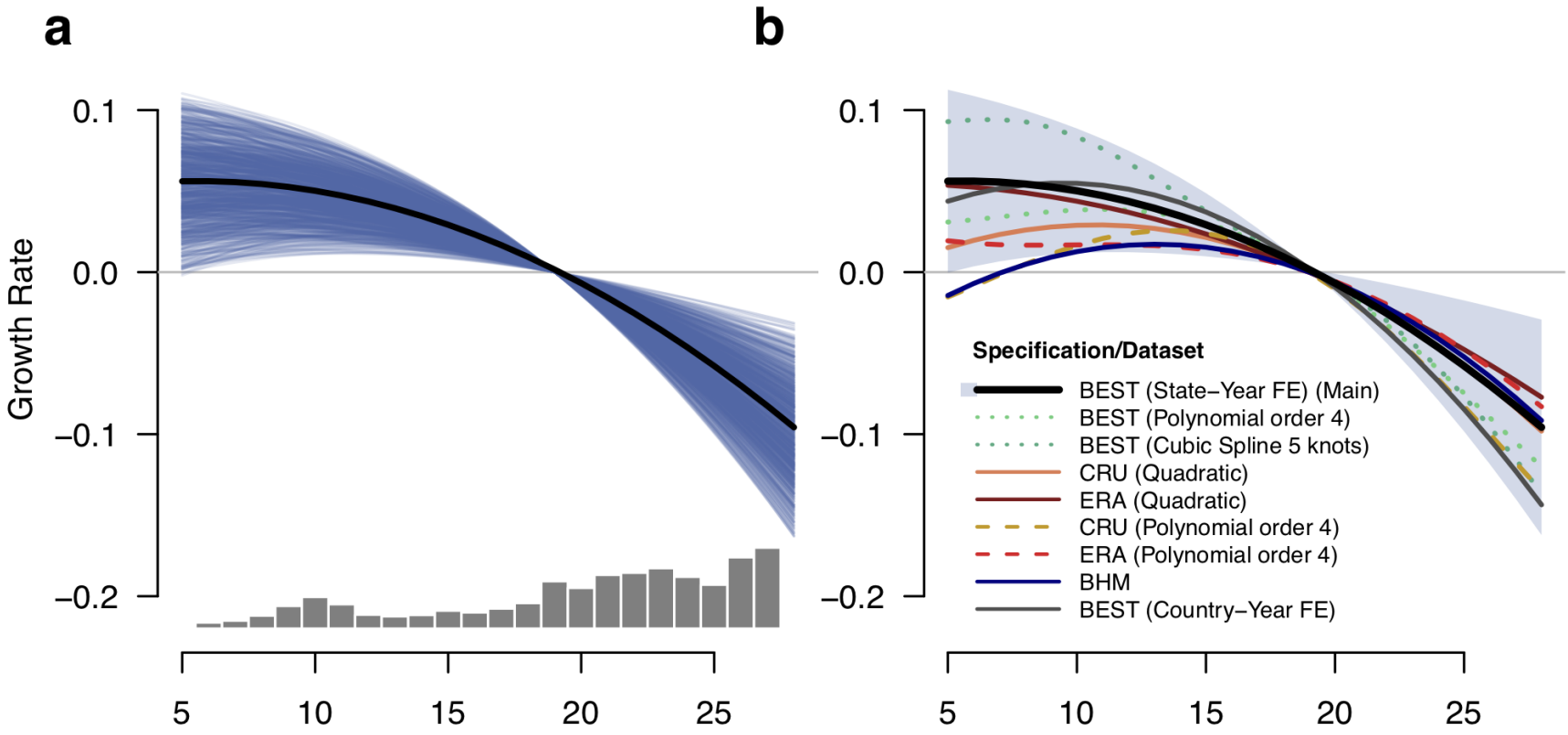
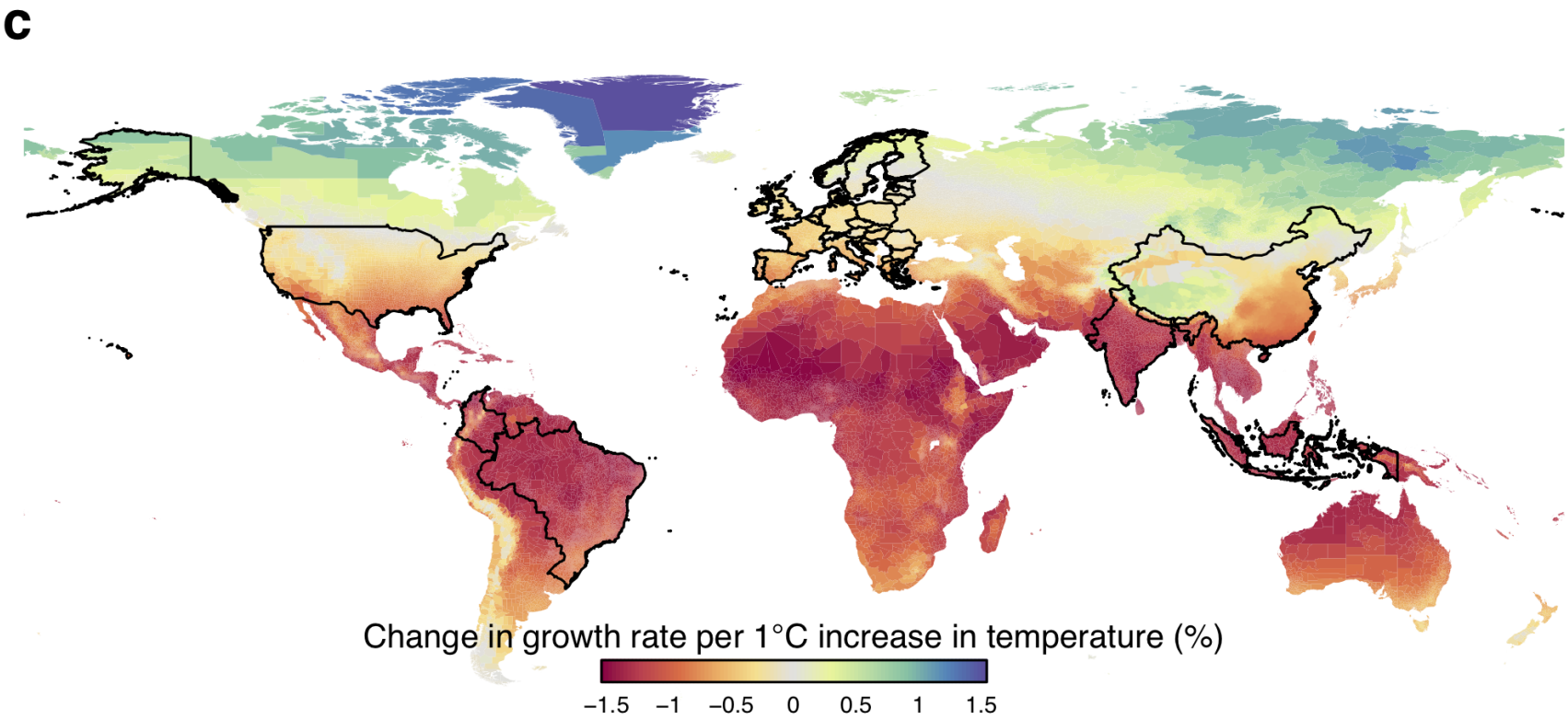


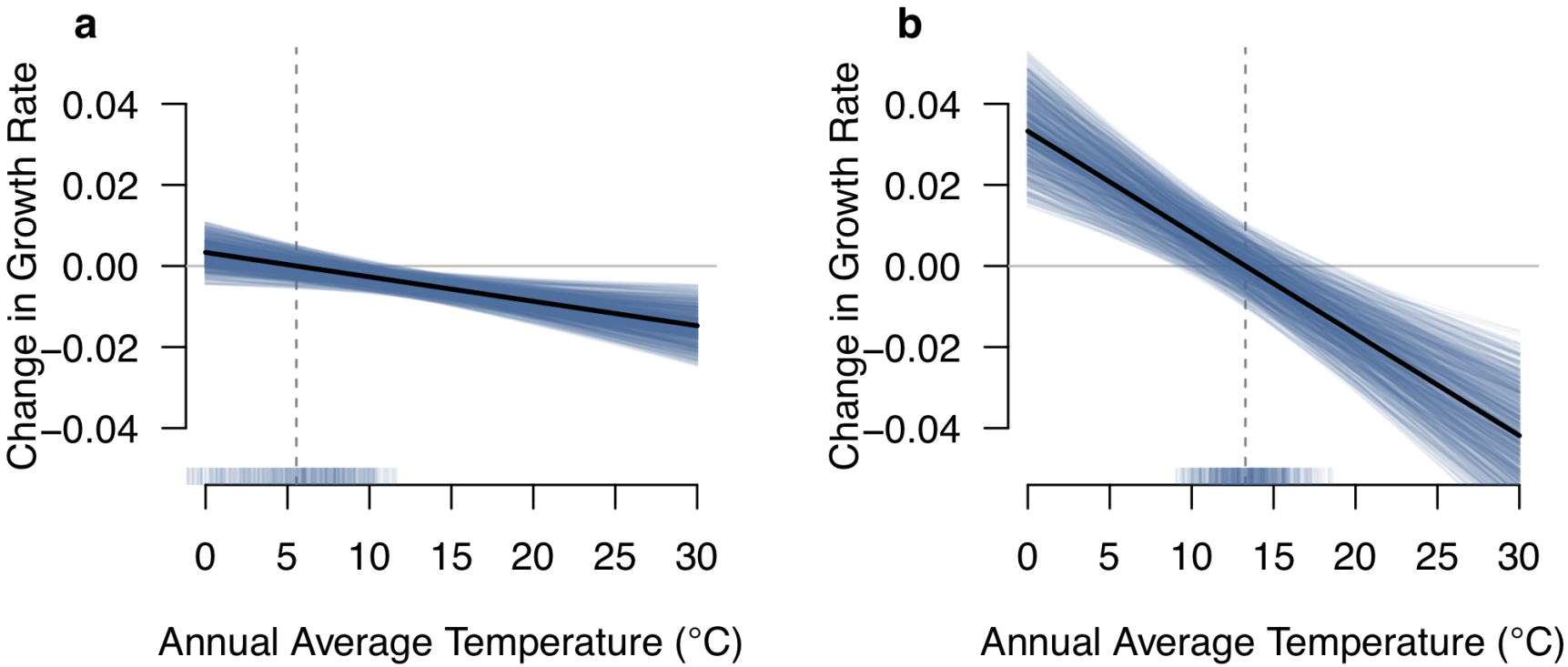
Estimated optimum is ∼5C (compare 13C in Burke et al 2015, 2018).

Implies that most of world harmed by warming



Growth effects?

Since DJO 2012, estimate distributed lag models, add up lags.
(Can also estimate a "long difference")



Will development save us?

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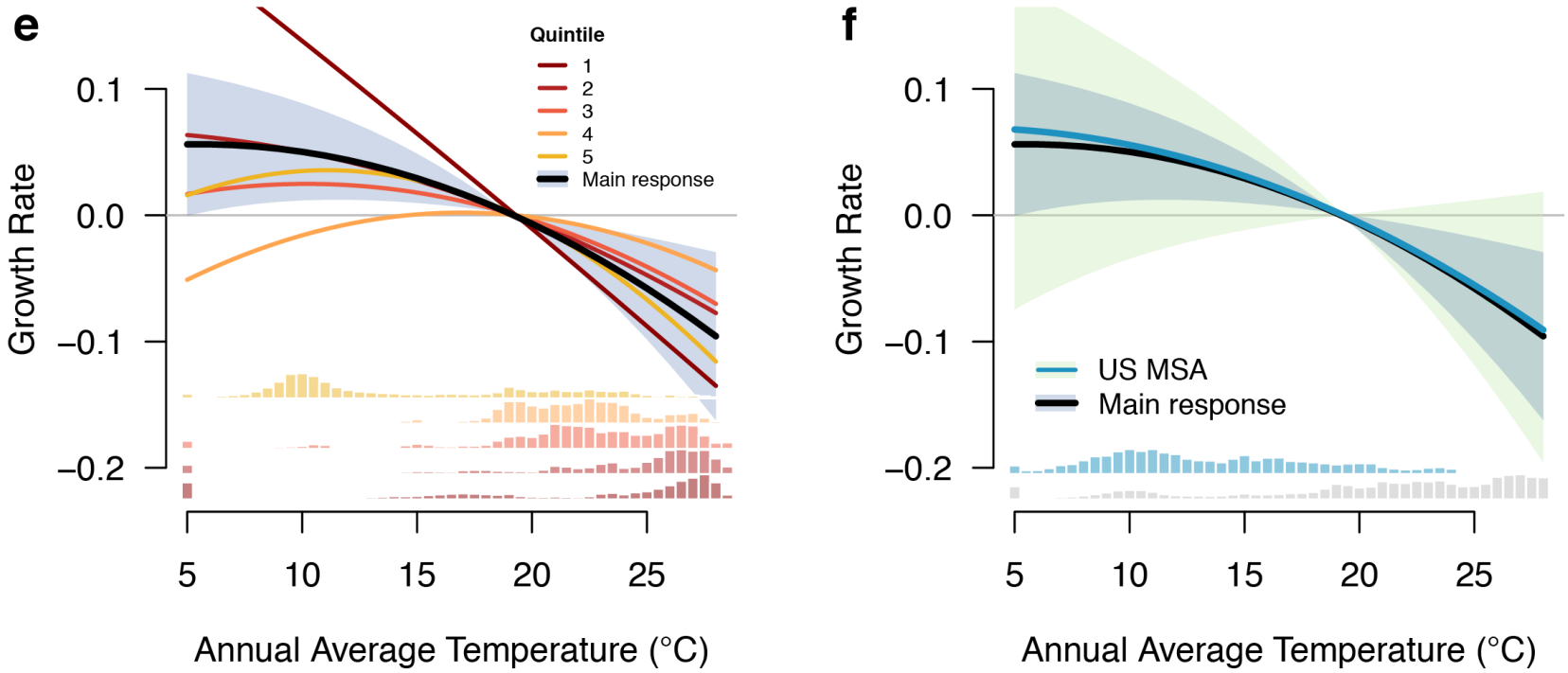
No strong evidence for differential effects by income, at a given temperature



Conclusions

1. **Non-linear effect of temperature on historical output**
   - No strong evidence that structure of economy mitigates these effects
   - No strong evidence of adaptation over time
   - No strong evidence that wealth insulates us
   - Similar response in national and subnational data, and strong evidence for growth effects
2. **High likelihood of substantial losses under future climate change**
   - Loss estimates are much larger than in existing damage functions, 5-10x
   - This is just from taking historical aggregate data seriously
3. **We ignore or downplay large aggregate impacts at our peril**, even if we can't fully explain or understand them.
   - They are robustly "in" the data
   - Micro-founded estimates that do not match macro "moments" should be treated with care