Understanding the aggregate economic impacts of climate change

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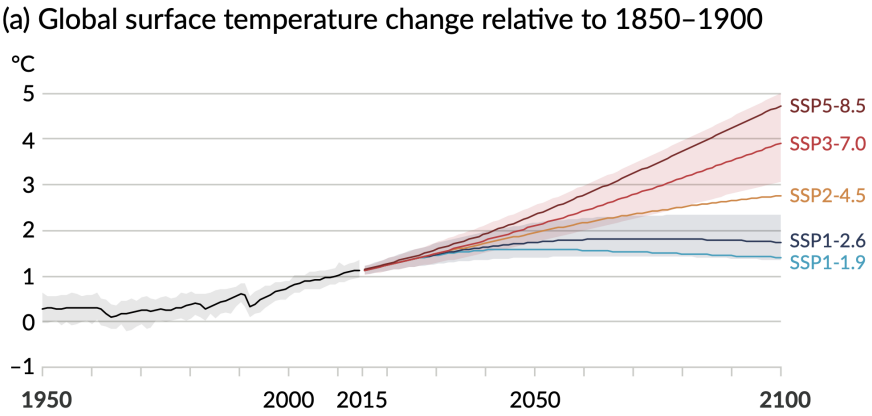
With thanks to co-authors Sol Hsiang, Ted Miguel, Noah Diffenbaugh, Mustafa Zahid

BIS CCA Research Conference | Bogota Colombia, Dec 2 2024

The magnitude of the challenge



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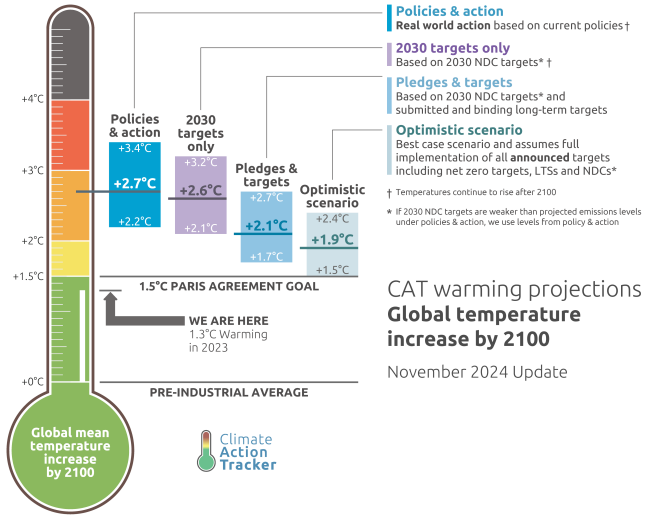
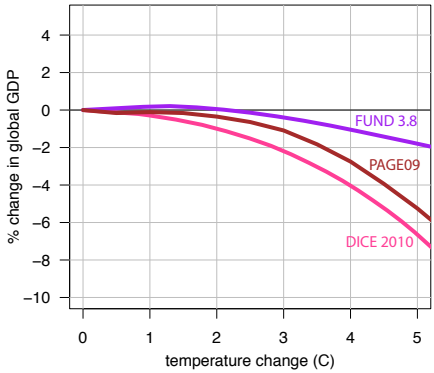


Implications for aggregate climate damages

Historical guidance from integrated assessment models (IAMs):



Stylized facts: minimal damages below 2-3C, accelerating after that

So why are we so worried?

Consider: a 2% effect on GDP by 2100.

An economy growing at 1%/year is 110% richer in 75 years.

With climate change: "only" 106% richer.

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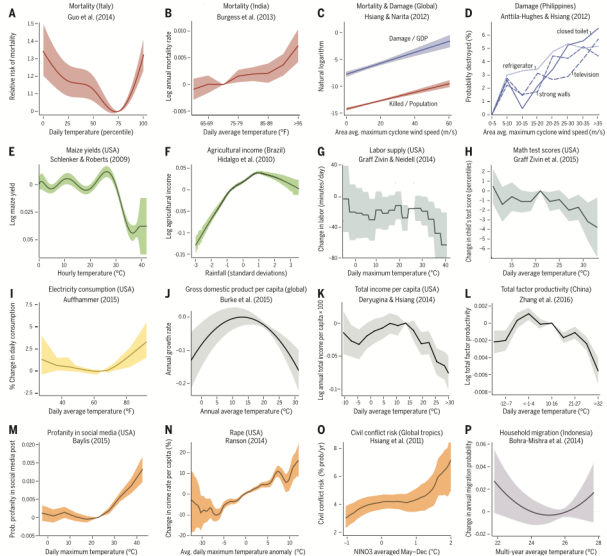
Not everyone is on board:

- 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."*

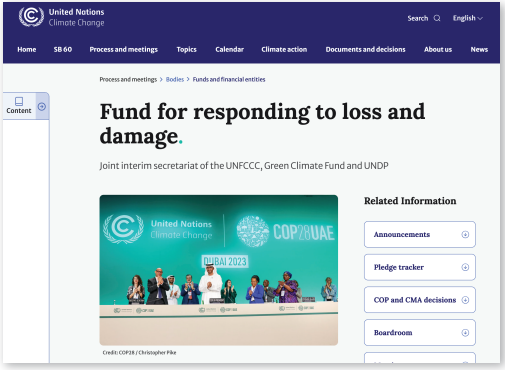
Some relevant scientific developments from micro data



Hsiang and Carleton 2016 *Science*

Getting this right clearly matters

1. Understanding the scale of mitigation needed
2. Understanding how and where to adapt, intervene
3. Understanding the scale of residual damages



How to improve aggregate damage estimates?

Option 1: bottom up

- Uses trusted micro-data, econometrics
- Almost always sectorally focused, so requires (a) explicitly enumerating measurement of affected sectors, and (b) integration of many partial equilibrium estimates over sectors and across space

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Option 2: top down

- Study aggregates (e.g. GDP)
- Adding up is done for you, many costs/benefits of adaptation (e.g. sectoral reallocation) are embedded
- Will miss stuff not in GDP (e.g. mortality VSL, ecosystem loss, etc)

Lots of recent progress on bottom-up

EPA

Report on the Social Cost of Greenhouse Gases:

Estimates Incorporating Recent Scientific Advances

November 2023

National Center for Environmental Economics
Office of Policy

Climate Change Division
Office of Air and Radiation

U.S. Environmental Protection Agency
Washington, DC 20460

Table 3.1.4: Impact Category Disaggregation of Social Cost of Carbon ($SC\text{-}CO_2$) for 2030 under a 2.0% Near-Term Ramsey Discount Rate (in 2020 dollars per metric ton of CO_2)

	Damage Module		
Impact category	DSCIM	GIVE	Meta-Analysis
Health	$179	$104	-
Energy	-$4	$10	-
Labor productivity	$47	-	-
Agriculture	$4	$103	-
Coastal	$3	$2	-
Total	$233	$219	$238

Today: top-down, using micro-econometric approach

Goal: using aggregate data, identify *causal* effect of temperature on economic output

Difficulty: lots of variation in temperature possibly correlated with other determinants of output

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Standard approach: use panel variation at subnational, national, or global scale

$$\Delta Y_{it} = g(T_{it}) + \lambda P_{it} + \mu_i + \gamma_t + \theta_i t + \varepsilon_{it} \tag{1}$$

Guidance from micro literature:

- effect will probably vary as a function of average temperature
- effect could vary as a function of income as well

Data: annual GDP data merged with temperature/rainfall, 1960-2019

Growth or level effects?

Will run regressions with growth as dependent variable – but really growth effects?

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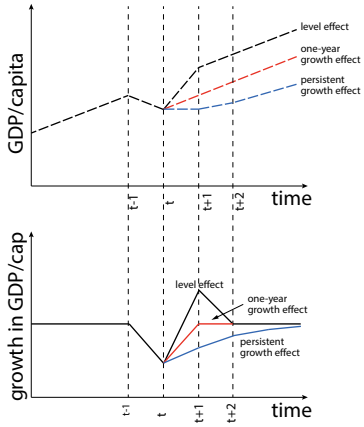
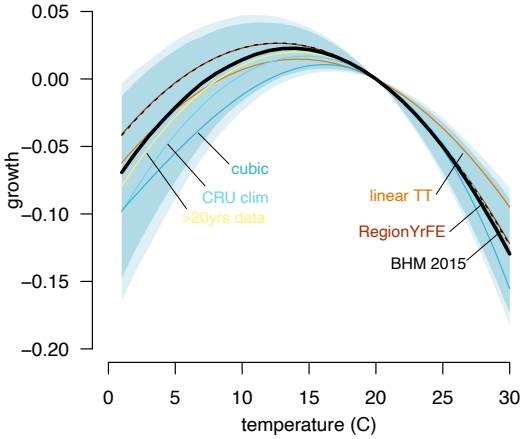
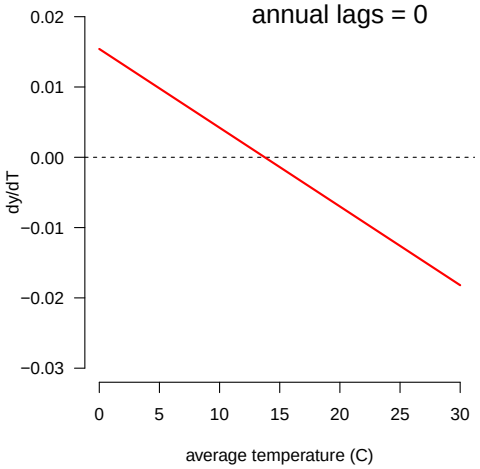
To understand, add lags of temperature (Dell et al 2012).



National data: non-linear response of GDP growth to temperature



Effects are increasingly negative with more lags



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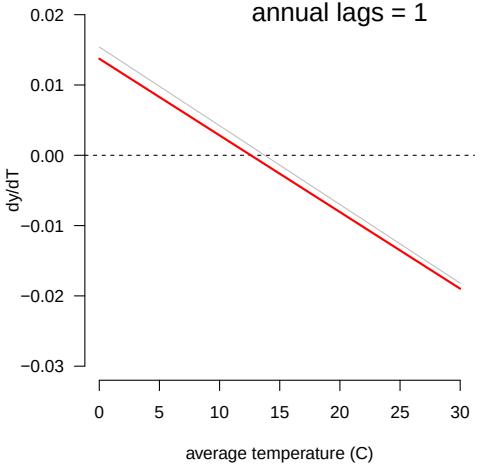

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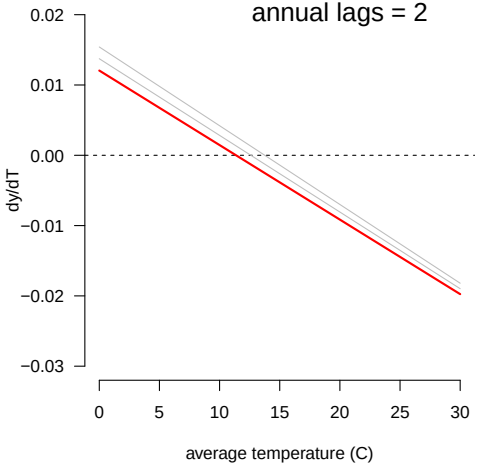

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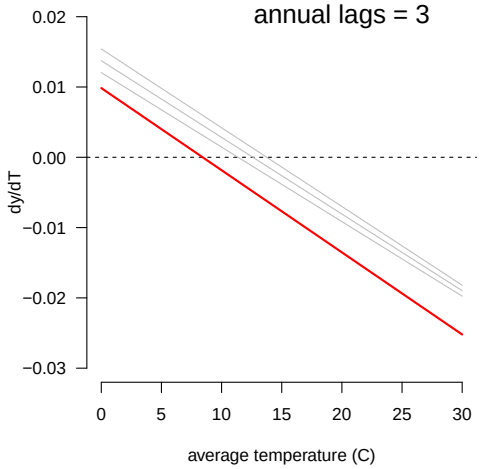

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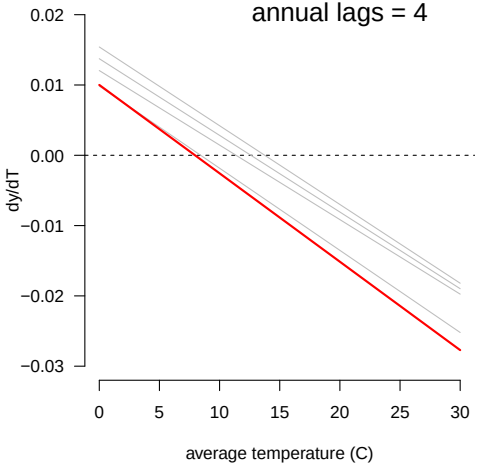

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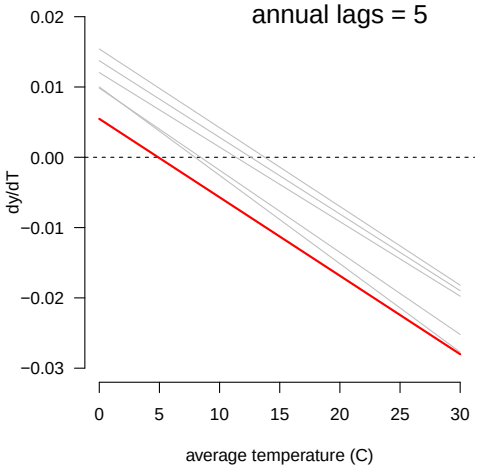

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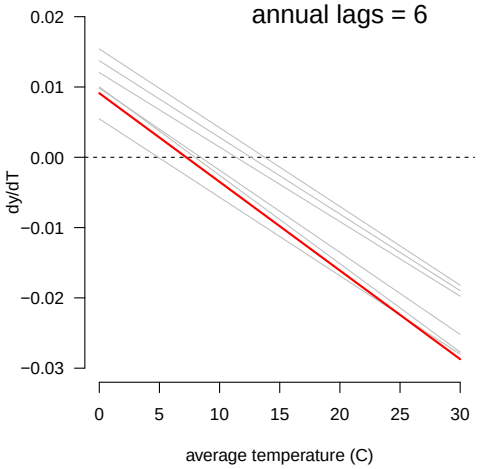

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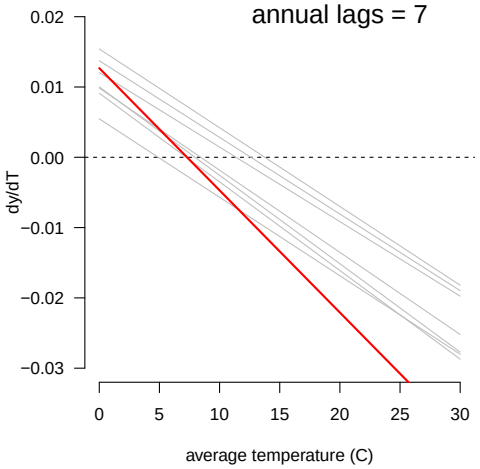

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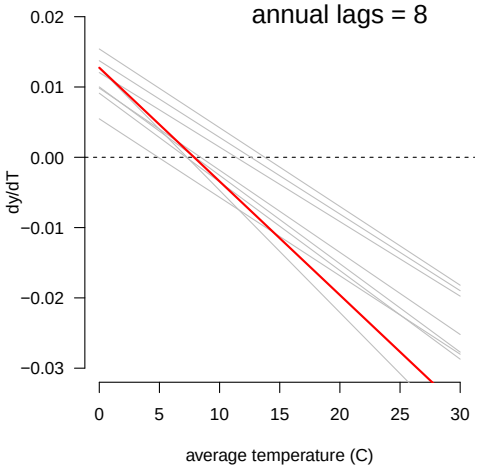

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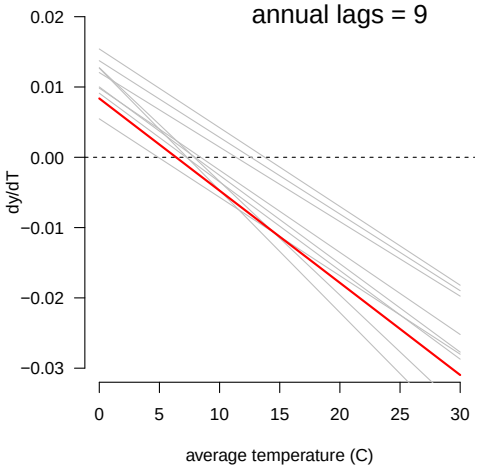

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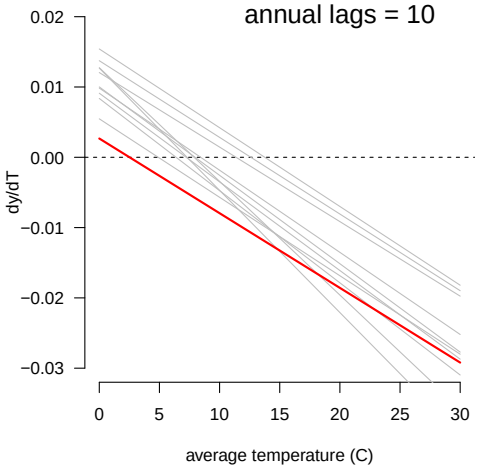
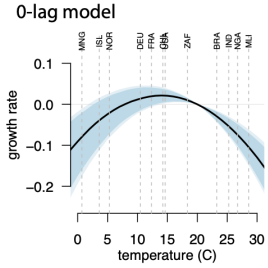
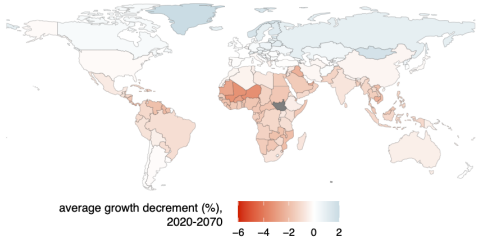
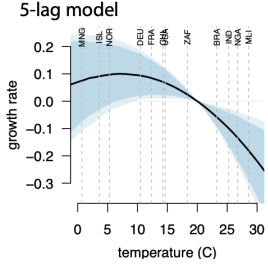
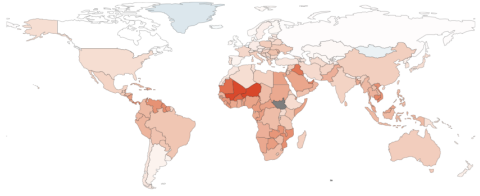


Implied average growth effects, next 50 years









Compare: impulse response

Following Jordà (2005), we use local projections to estimate impulse response:

$$log(y_{i,t+j}) - log(y_{i,t-1}) = \rho \Delta y_{i,t-1} + \beta_1 T_{it} + \beta_2 T_{it} * \bar{T}_i + FE + \varepsilon_{it}$$

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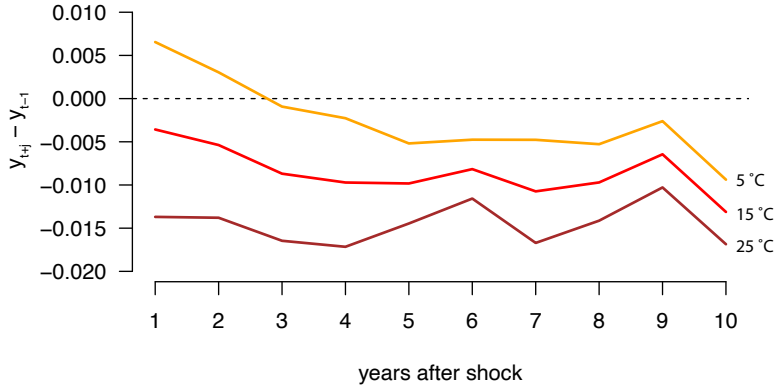

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Conventional wisdom(s), common among economists:

1. Wealth insulates you from the effects of climate
   - explicitly built into some IAMs (e.g. FUND)

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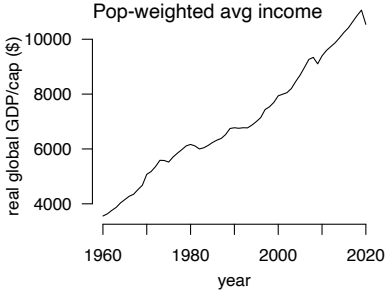
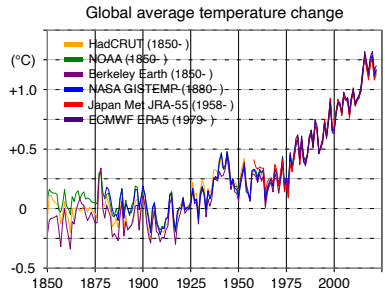
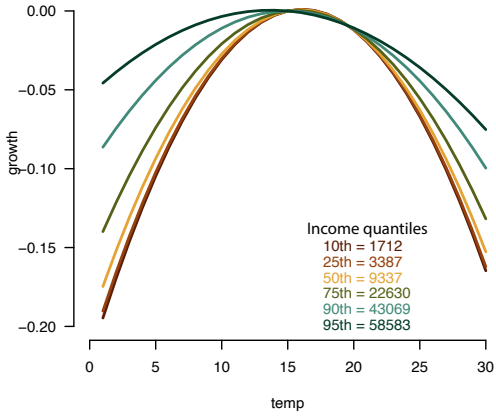
2. We've become less sensitive to climate over time: richer, lots of experience with temperature, lots of science on impacts





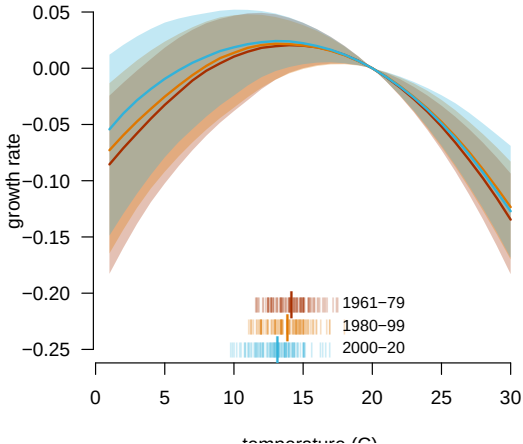
Differences over space or time?

Wealthier countries are a bit flatter, but not significantly different:



Differences over space or time?

No change in sensitivity over time:



Related work showing limited adaptation:

Are We Adapting to Climate Change?
Marshall Burke, Mustafa Zahid, Mariana C. M. Martins, Christopher W. Callahan, Richard Lee, Tumenkhusel Avirmed, Sam Heft-Neal, Mathew Kiang, Solomon M. Hsiang, and David Lobell
NBER Working Paper No. 32985
September 2024
JEL No. O13, Q5

ABSTRACT

We study whether the sensitivity of economic, health, and livelihood outcomes to climate extremes has declined over the last half century, consistent with adaptation. Understanding whether such adaptation is already occurring is central to anticipating future climate damages, to calibrating the level of ambition needed for emissions mitigation efforts, and to understanding additional investments in adaptation that could be required to avoid additional damages. Using comprehensive panel data across diverse geographies and outcomes, including data on mortality, agricultural productivity, crime, conflict, economic output, and damages from flooding and tropical cyclones, we find limited systematic evidence of adaptation to date. Across 21 outcomes we study, six show a statistically significant declining sensitivity to a changing climate, five show an increasing sensitivity, and the remainder show no statistically significant change. Our results do not imply that specific documented adaptation efforts are ineffective or certain locations have not adapted, but instead that the net effects of existing actions have largely not been successful in meaningfully reducing climate impacts in aggregate. To avoid ongoing and future damages from warming, our results suggest a need to identify promising adaptation strategies and understand how they can be scaled.

Differences over space or time?

Conventional wisdom(s), evaluated:

1. **Wealth insulates you from the effects of climate.**
   - **No strong evidence**: flatter response for richer countries, but statistically indistinguishable from poorer

2. **We've become less sensitive over time.**
   - **No**, not for this outcome anyway.

Implications for climate change

We can (heroically) run the world forward:

$$GDPcap_{it} = GDPcap_{it-1} * (1 + \eta_{it} + \delta_{it})$$

$$\delta_{it} = g(T_{it}^{+}) - g(\bar{T})$$

1. $g(.)$: from historical response function(s)
   - allowing rich and poor to respond differently, or not
   - allowing for persistent effects, or not
   - bootstrapping to incorporate uncertainty
2. T_{it}^{+}: from IPCC CMIP 6
3. η_{it}: 'Shared Socioeconomic Pathways" (SSP3), or fixed (e.g 2%)

Can calculate various quantities: SCC, total aggregate damages

Implications for climate change

Things you might worry about with this exercise

1. $g(.)$ is a SR response function, LR response will look different

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2. Spillovers. $g(.)$ estimated off within-country variation, but countries trade and future shocks will be correlated
   - But: past temperature shocks are highly correlated among trading partners too, so $g(.)$ arguably picks up reduced form effect of covariate shocks

Social cost of carbon

$$SCC = \sum_{t=2020}^{\tilde{t}} \sum_{i} \frac{1}{(1+\delta)^t} \frac{\Delta D_{it}}{\Delta T_{it}} \frac{\Delta T_{it}}{\Delta T_t} \frac{\Delta T_t}{\Delta CO2_{2020}}$$

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Many researcher degrees of freedom:

- δ
- end year $\tilde{t}$
- secular growth rate
- regression model

Social cost of carbon

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Many researcher degrees of freedom:

- $\delta =$ Ramsey (calibrated to 2%)
- end year $\tilde{t} = 2100$
- secular growth rate = SSP3 ($\sim$1% by 2100)
- regression model = no lags five lags

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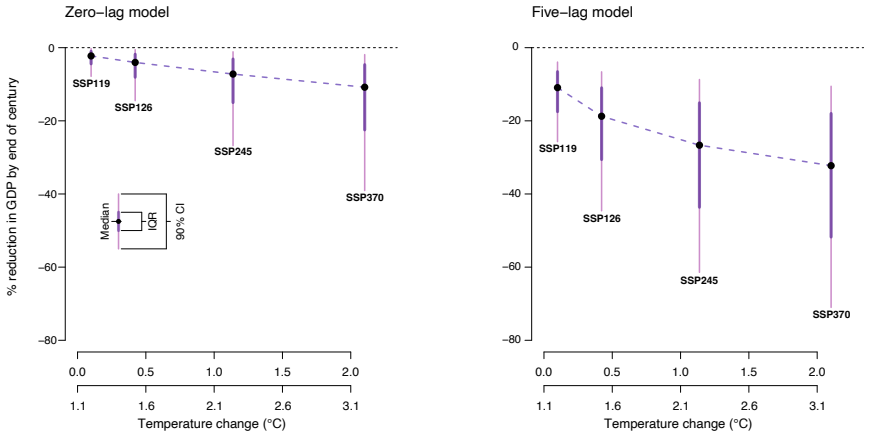
SCC = \$275 \$1300

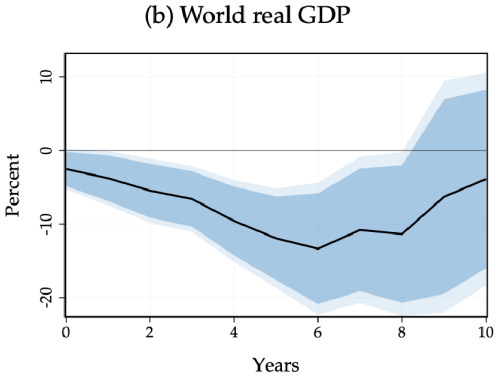
Aggregate global damages by 2100

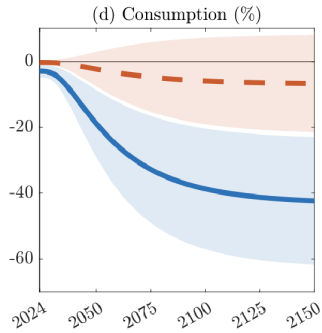
By 2100:



Recent papers find something similar

Bilal and Kanzig 2024:

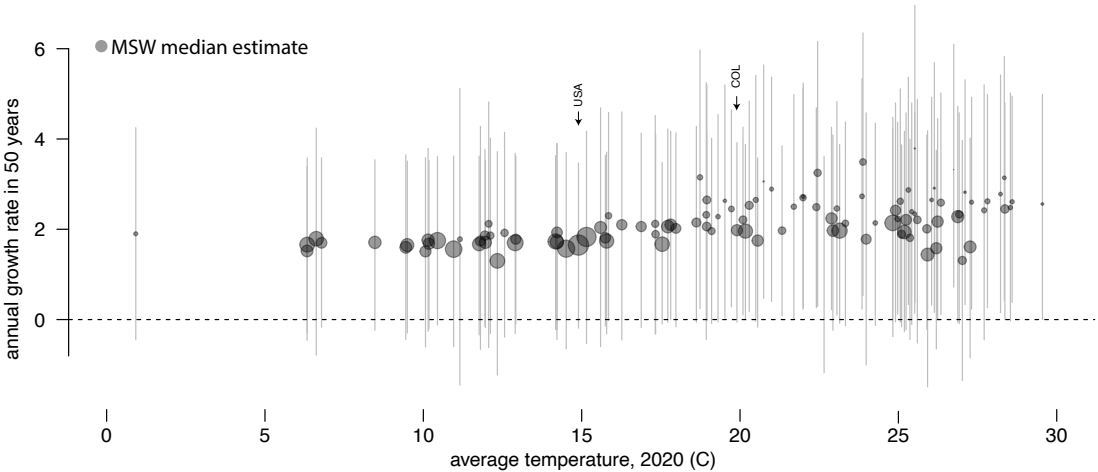




SCC = $1367

Growth impacts in 2100 relative to no-climate-change background

Muller Stock Watson 2022: estimates of plausible future growth rates without climate change



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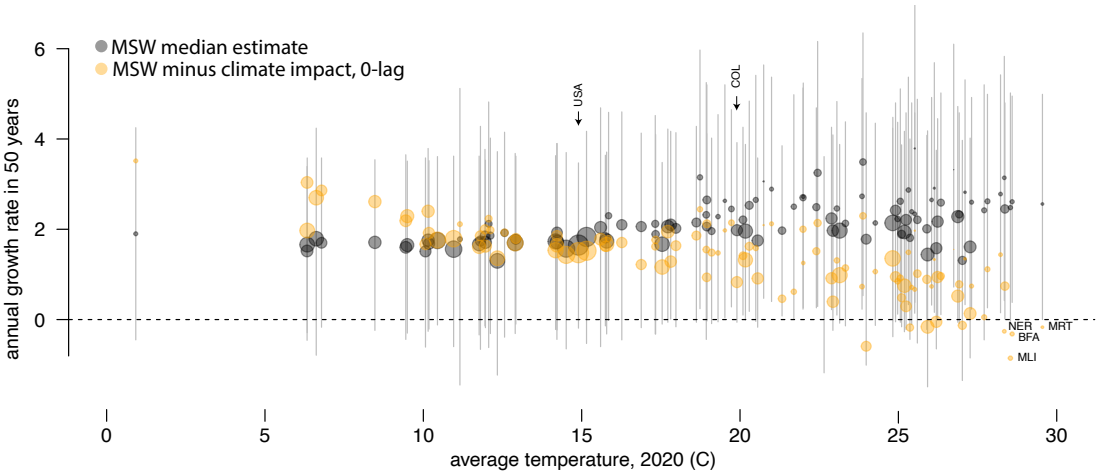

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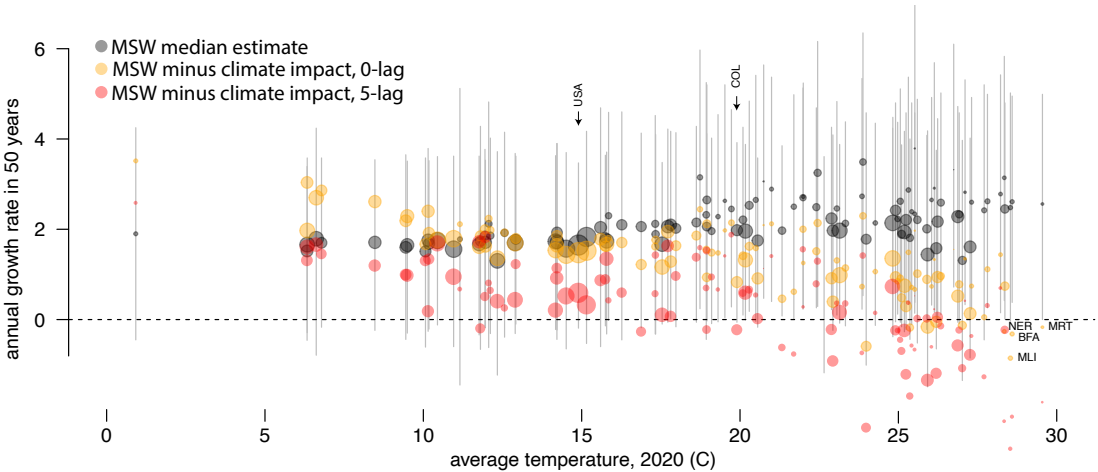

Conclusions

1. Non-linear effect of temperature on production historically
   - Growth effects, or very very persistent level effects
   - Limited evidence of adaptation

2. High likelihood of losses under future climate change
   - under current "business as usual", even odds of global losses greater than $\sim$10% of GDP, probably much larger
   - damages even larger in most LMICs

3. Damage estimates are much higher than historical damage functions in IAMs, somewhat higher than bottom-up SCCs
   - this despite fact that many of these estimates are only through temperature, only on GDP