Understanding aggregate economic impacts of climate

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With thanks to co-authors S. Hsiang, T. Miguel, N. Diffenbaugh, M. Zahid

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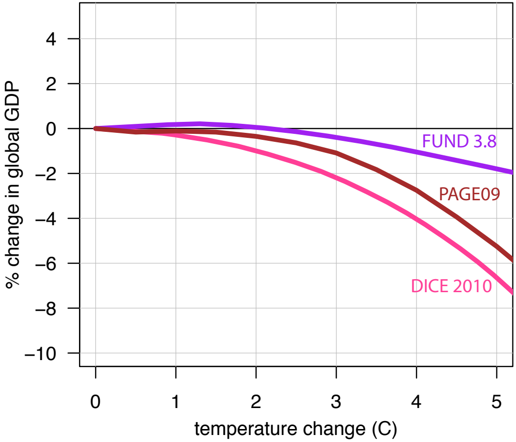
Historical guidance from IAMs on aggregate climate damages



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

So why are we so worried?

Consider: a 2% effect on GDP by 2100.

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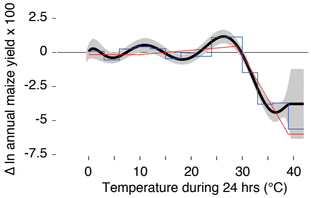
Not everyone is on board:

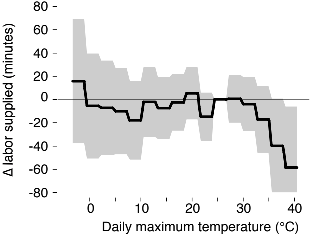
- Pindyck (JEL, 2013): *"The damage functions used in most IAMs are completely made up, with no theoretical or empirical foundation."*
- Revesz, Arrow, Goulder et al (*Nature*, 2014): *"The models should be revised more frequently to accommodate scientific developments."*

Some relevant scientific developments

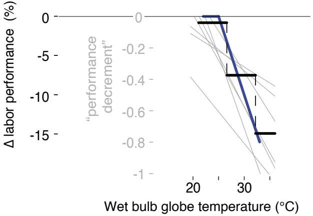
Agriculture
Schlenker and Roberts 2009



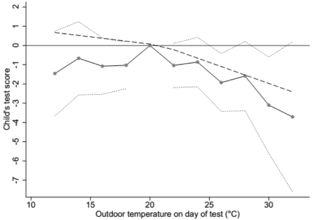
Labor supply
Graff Zivin and Niedell 2014



Ergonomics
Hsiang 2010



Test scores
Graff Zivin et al 2015



How to improve damage functions?

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)

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Estimate: using annual panel data at country level

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

What this does

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

Data: Annual WDI growth data for 190 countries, ERA5 temp/precip, 1960-2019

Growth or level effects?

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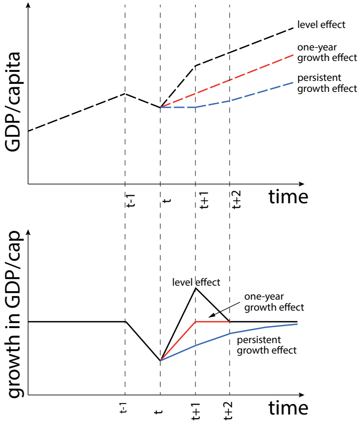
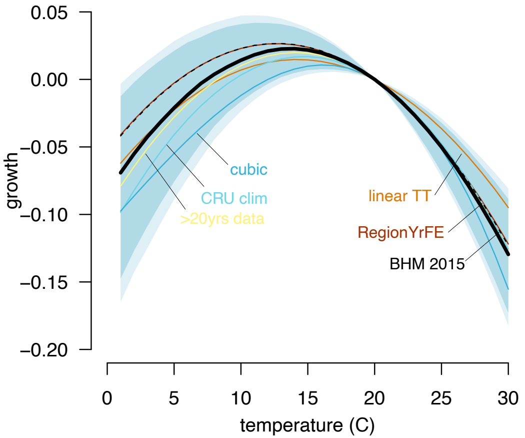
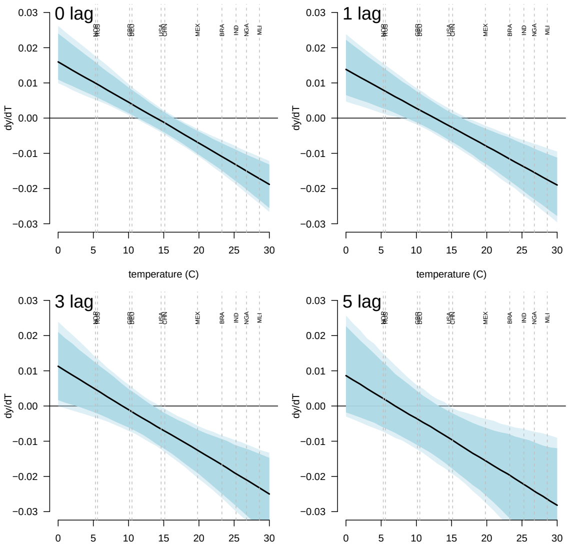
To understand, add lags of temperature (Dell et al 2012).



Global non-linear response



Marginal effects with increasing lags indicate growth effects



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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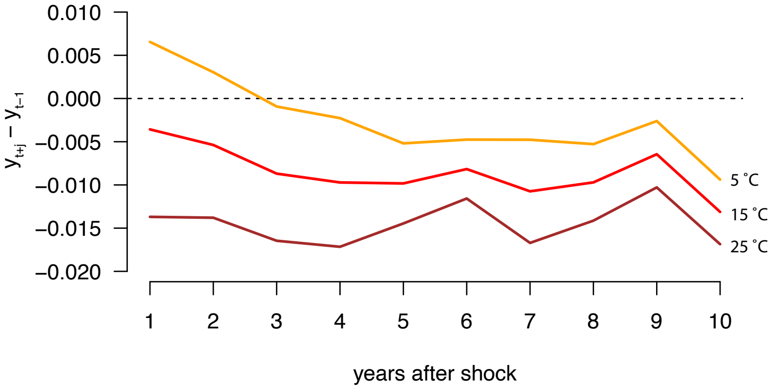

Differences over space or time?

Conventional wisdom(s), common among economists:

1. Wealth insulates you from the effects of climate
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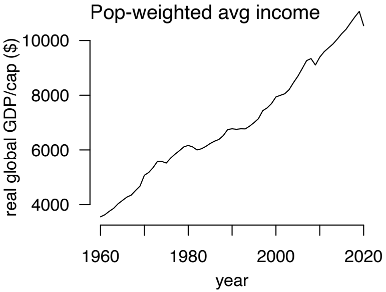
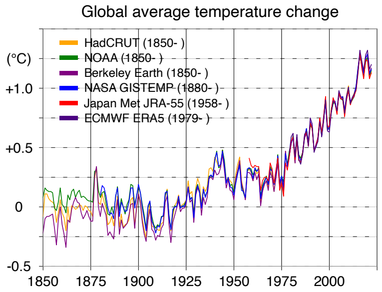
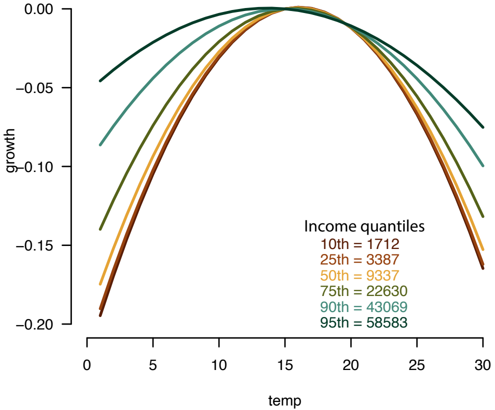
2. We've become less sensitive to climate over time: richer, lots of experience with temperature, lots of science on impacts





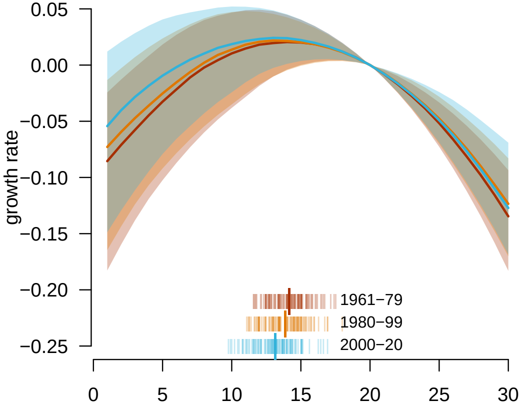
Differences over space or time?

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



Differences over space or time?

No change in sensitivity over time:



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 CMIP 6
3. η_{it}: 'Shared Socioeconomic Pathways" (SSP3), or fixed (e.g 2%)

Can calculate various quantities: SCC, total aggregate damages

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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

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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

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Many researcher degrees of freedom:

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

SCC = $275

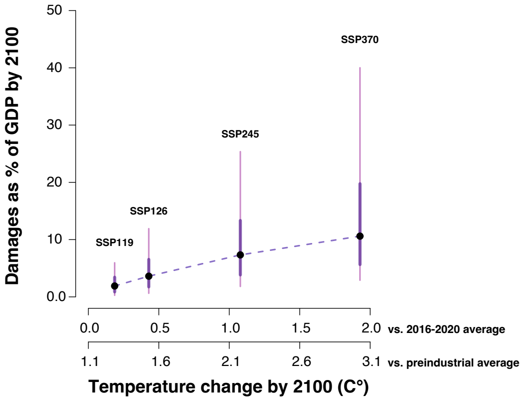
Social cost of carbon

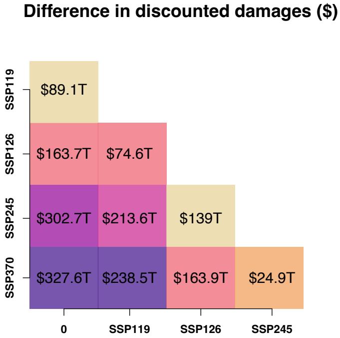
Can get much higher numbers under less conservative choices:

SCENARIO	DISCOUNT RATE				TIME HORIZON	POST-2100 GROWTH	REGRESSION MODEL
	DISCOUNT RATE AT 1%	DISCOUNT RATE AT 2%	DISCOUNT RATE AT 3%	RAMSEY DISCOUNT (0.2%,1.24)			
Growth at 2100 rate	$2,910	$680	$242	$1,459	through 2300	SSP 2100 growth rate	0-lag BHM model
Growth at 1%	$4,276	$854	$270	$2,008	through 2300	1% growth rate	0-lag BHM model
Growth at 2%	$14,482	$1,966	$422	$1,626	through 2300	2% growth rate	0-lag BHM model
Growth at 2100 + clamping	$2,577	$591	$206	$1,296	through 2300	SSP 2100 clamped rate	0-lag BHM model
Growth at 2100 + 5lag BHM	$15,111	$3,301	$1,153	$8,059	through 2300	SSP 2100 rates	5-lag BHM model
Growth at 2100 + 5lag BHM + No impacts > 2100	$1,617	$975	$612	$1,421	through 2100	SSP 2100 rates	5-lag BHM model
No growth effects > 2100	$1,607	$482	$203	$907	through 2300	SSP 2100 rates	0-lag BHM model
No impacts > 2100	$346	$203	$124	$275	through 2100		0-lag BHM model

Aggregate global damages

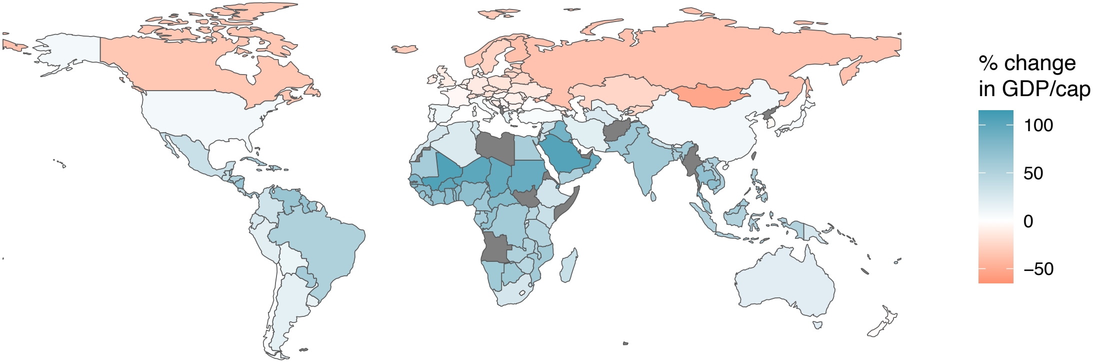
Again under conservative assumptions (2100, no-lag model):





Country-level benefits of aggressive mitigation

Benefits of limiting warming to 1.5C vs 3C by 2100



Conclusions

1. Non-linear effect of temperature on production historically
   - Growth effects, at least out a decade
   - Limited evidence of adaptation

2. High likelihood of losses under future climate change
   - under current "business as usual", even odds of losses greater than ~10% of GDP

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