Discussion:
Climate, Economic Growth and Conflict

2024 Nobel Symposium in Development Economics
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Motivation: climate change.

- Focus in this discussion on two key questions:

(#1) What is the impact of climate / climate change on **economic growth**?

(#2) What is the impact of climate / climate change on **violent conflict**?

- Major progress in evidence over the last 20 years. Starting point circa 2000:
- Model-based simulations predicted global warming would have **at most a trivial (-3%) effect** on long-run global GDP (Nordhaus 1991, 1992, 1993).

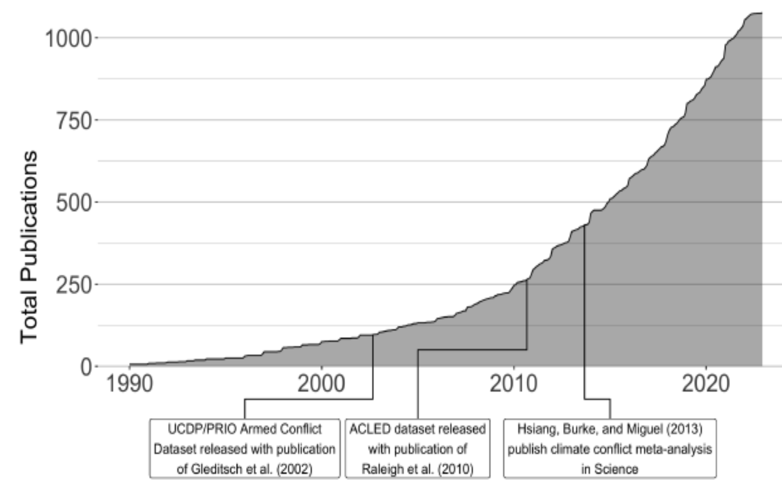
>> But cross-sectional analyses found large differences in GDP per capita between tropical (hotter) vs. non-tropical geographic regions (Hall and Jones 1999), with particularly large implications for Africa (Bloom and Sachs 1998).

Expansion of scientific literature since 2000.

- Both questions have been the subject of serious inquiry over the last two decades, with hundreds of empirical studies each + growing global scholarly consensus.
- Main scientific breakthrough: the use of statistical methods drawn from micro-econometrics to credibly estimate causal effects, **using weather and climate variation as a natural experiment**.

>> Key survey articles: Hsiang, Burke and Miguel (2013), Dell, Jones and Olken (2014), Burke, Ferguson, Hsiang and Miguel (2024, right).

Figure 2: Growth in Publications on the Climate-Conflict Relationship



Notes: The figure marks some milestones in this scientific literature, including the release of the UCDP/PRIO country-year level data in 2002 (Gleditsch et al. (2002)), the subnational level ACLED data in 2010 (Raleigh, A. Linke, et al. (2010)), and the publication of the Hsiang, M. Burke, and Miguel (2013) *Science* article in 2013. This count was carried out as follows. We accessed the Elsevier Search API, accessing SCOPUS, across all journals, on June 4 2022, and used the following keywords: (Conflict OR War OR Crime OR Suicide OR Self-harm) AND (Climate OR Weather OR Temperature OR Heat OR Precipitation OR Rainfall). Not all of these studies are relevant for the quantitative meta-analysis that follows but they provide an indication of the growth in research on this topic overall across various academic fields and methodologies.

Seminal contributions.

- The first study (to my knowledge) to address **both questions** was Miguel, Satyanath and Sergenti (2004, *Journal of Political Economy*).
- Uses exogenous weather/climate variation as a natural experiment, large-sample cross-country data, and remote sensing (satellite) weather data, focusing on 41 Sub-Saharan African countries during 1981-1999.
- Uses a specification with country fixed effects, time effects/trends that has become standard in the subsequent literature:

(#1) Effect of rainfall variation (current, lagged) on country economic growth,

(#2) Effect of rainfall variation (current, lagged) on armed civil conflict.

>> This study used an instrumental variables design, with rainfall shocks as the IV for GDP growth. Subsequent work (below) has found that climate variables can have impacts through channels other than growth (exclusion violation).

Miguel, Satyanath and Sergenti (2004).

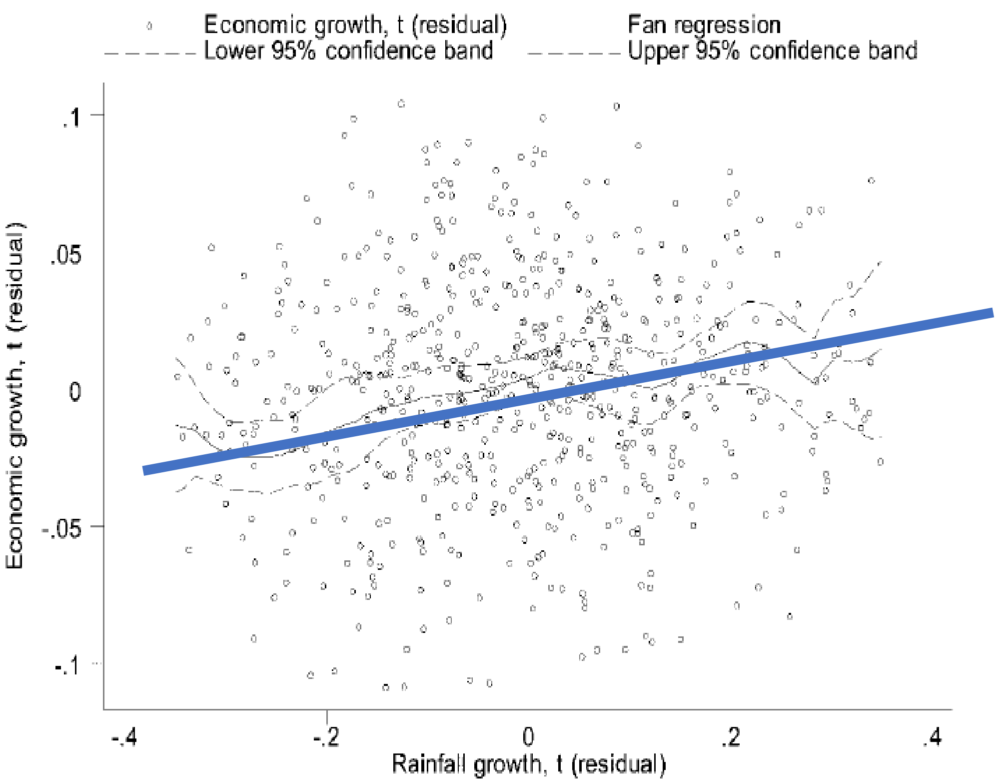


FIG. 1.—Current economic growth rate on current rainfall growth. Nonparametric Fan regression, conditional on country fixed effects and country-specific time trends.

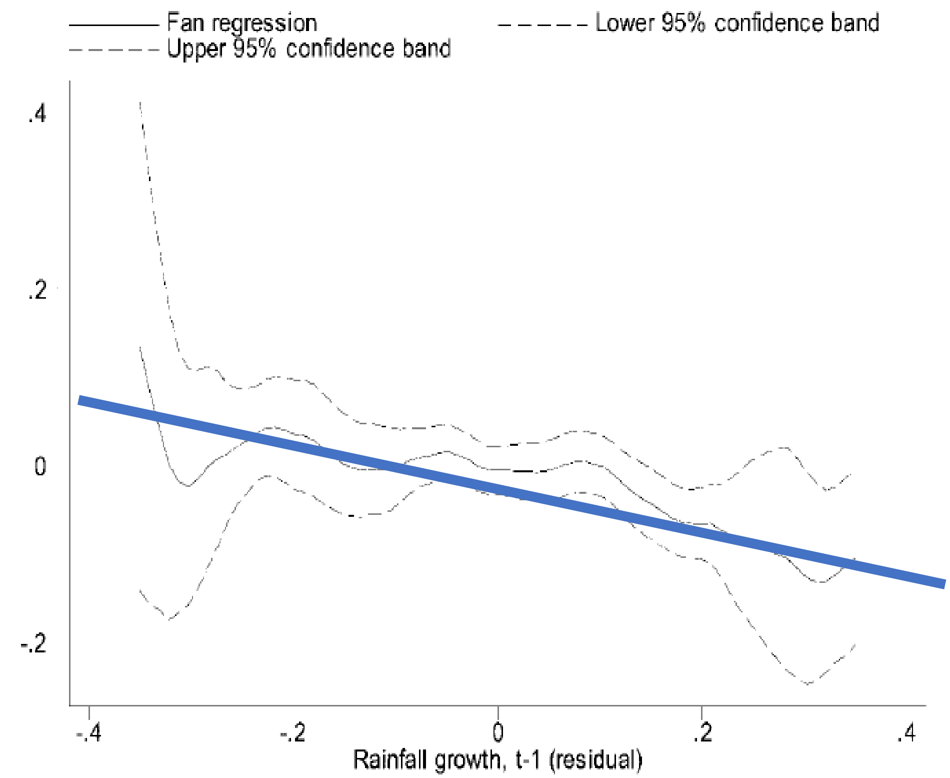


FIG. 2.—Current likelihood of civil conflict (≥25 battle deaths) on lagged rainfall growth. Nonparametric Fan regression, conditional on current rainfall growth, country fixed effects, and country-specific time trends.

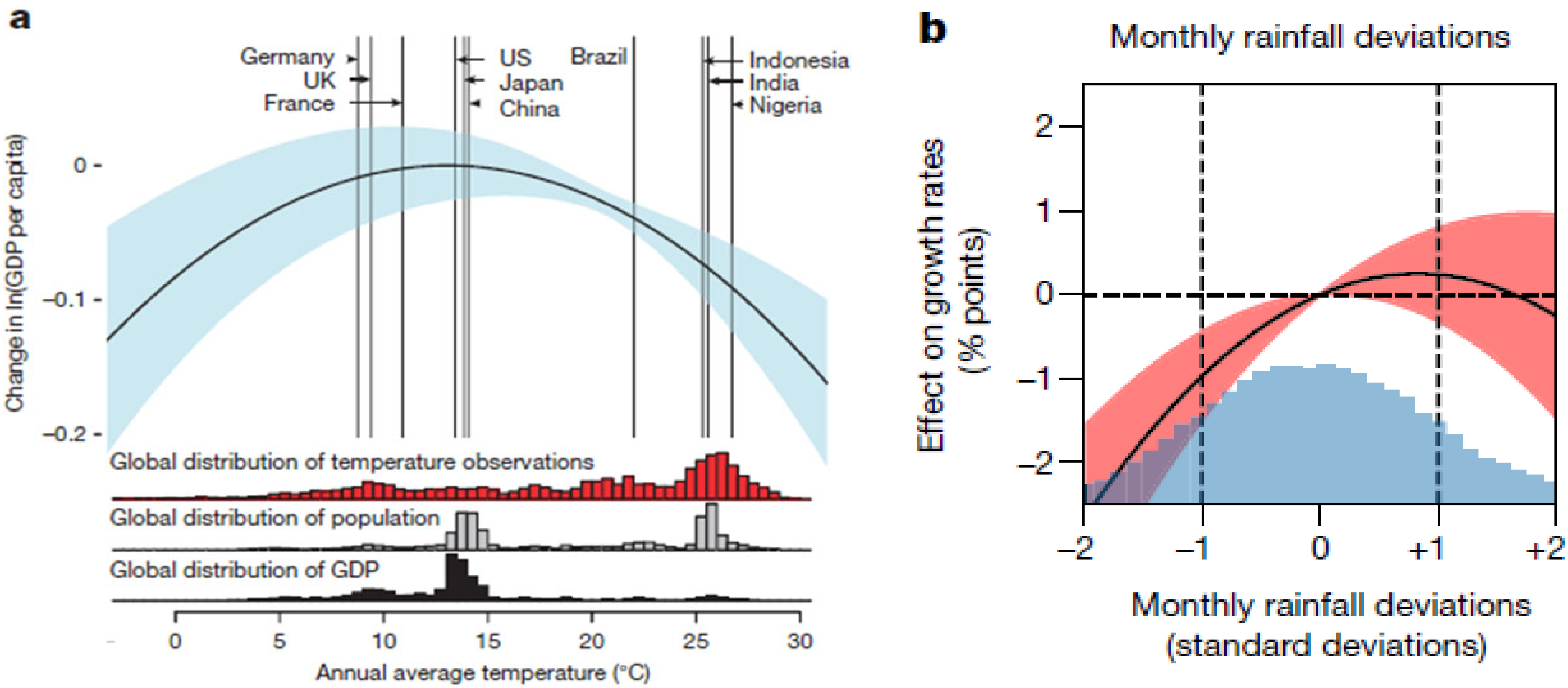
Key contributions: climate and growth.

- Dell, Jones and Olken (2012): incorporate temperature variation and find large magnitudes + multi-year persistence of climate shocks on growth rates.
- Burke, Hsiang and Miguel (2015): find evidence of global non-linearity in relationship between temperature and growth, plus project forward large impacts out to 2100: predicted decline in global GDP of -23%.

>> Sharp contrast with earlier Nordhaus findings: an order of magnitude larger impacts on global economic activity.

- **Growing scientific consensus** climate change impacts will be large: Nath, Ramey, Klenow (2023) assume eventual convergence of technology across countries and still project global GDP loss of -12%, 4x model-based estimates.

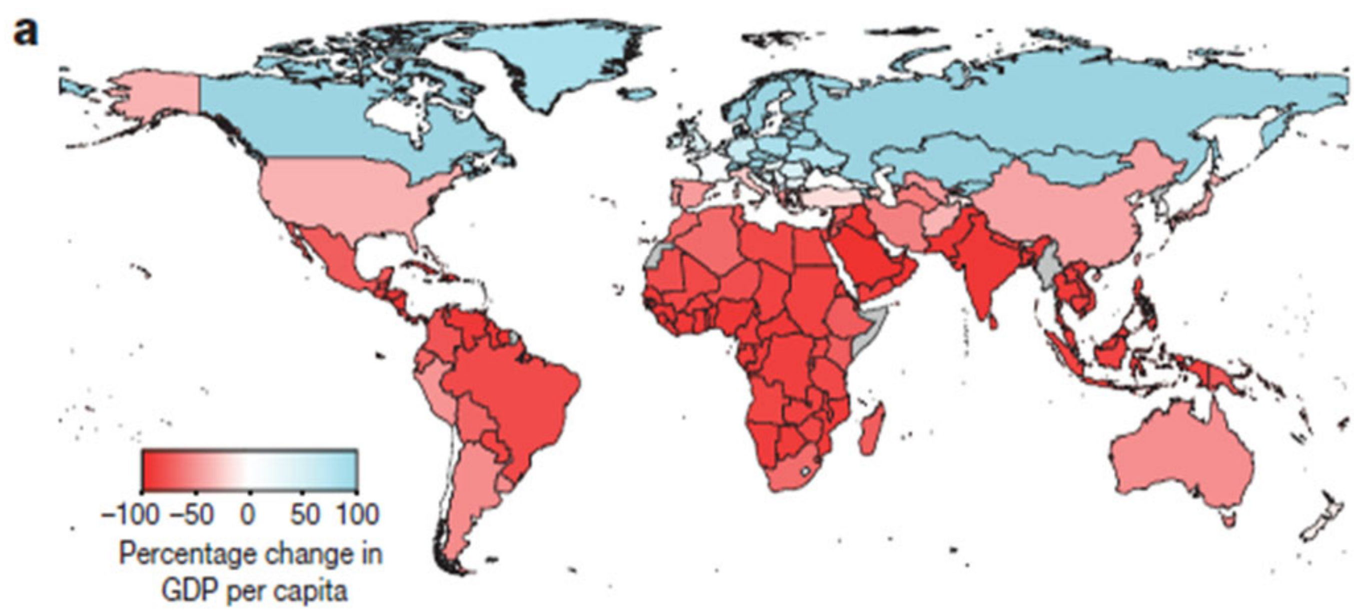
Nonlinear relationship between climate and growth.



- Burke, Hsiang and Miguel (2015, left), Kotz, Levermann and Wenz (2022, right).

Projected global economic growth effects of climate change.

- Adverse climate impacts on economic growth projected to be **concentrated in low- and middle-income countries,** including many of the poorest in the world in Sub-Saharan Africa, South Asia (Burke, Hsiang and Miguel 2015).



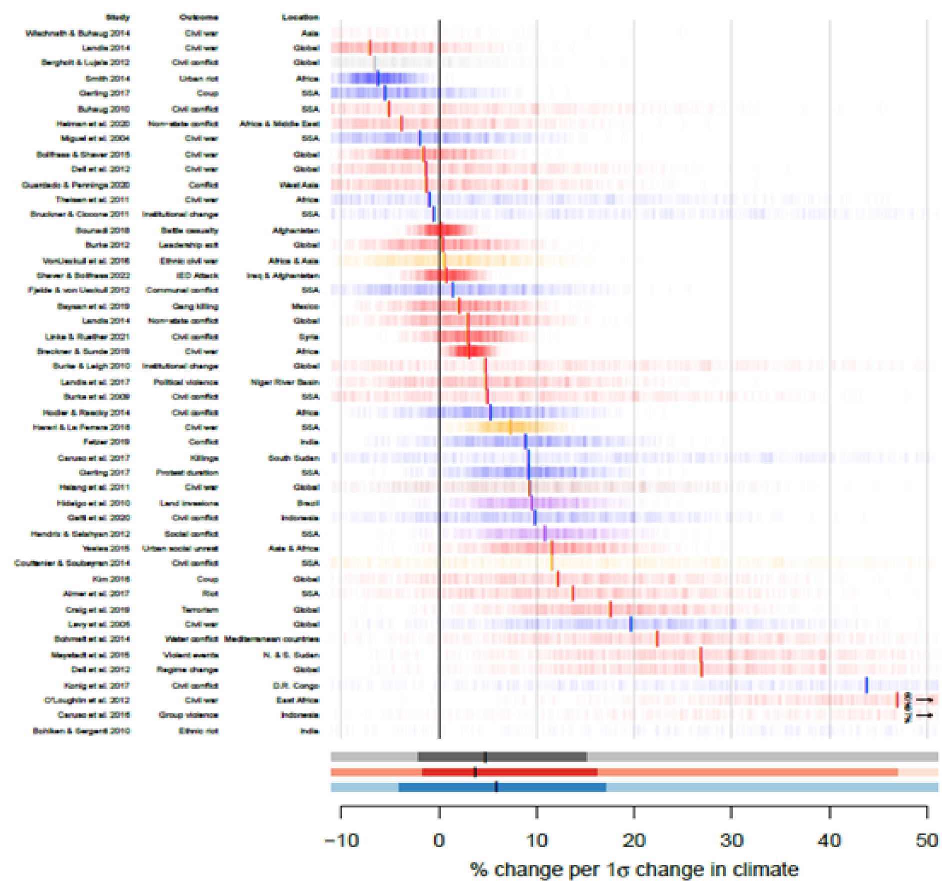
>> Recent estimates indicate effects are closer to zero in cooler countries.

Key contributions: climate and conflict.

- Several **meta-analyses** show that higher temperatures and extreme rainfall are associated with more violence at multiple levels: from civil conflict down to interpersonal crime (and even self-harm/suicide), most recent Burke, Ferguson, Hsiang and Miguel (2024, right)

>> **Large magnitude** effects: a 1 SD adverse change in climate leads to a 2.5% to 5% increase in conflict risk – and most world regions are projected to warm by 2 to 4 SD's in the next 30 years.

Figure 5: Meta-analysis of Intergroup Conflict Studies



Climate and conflict: mechanisms.

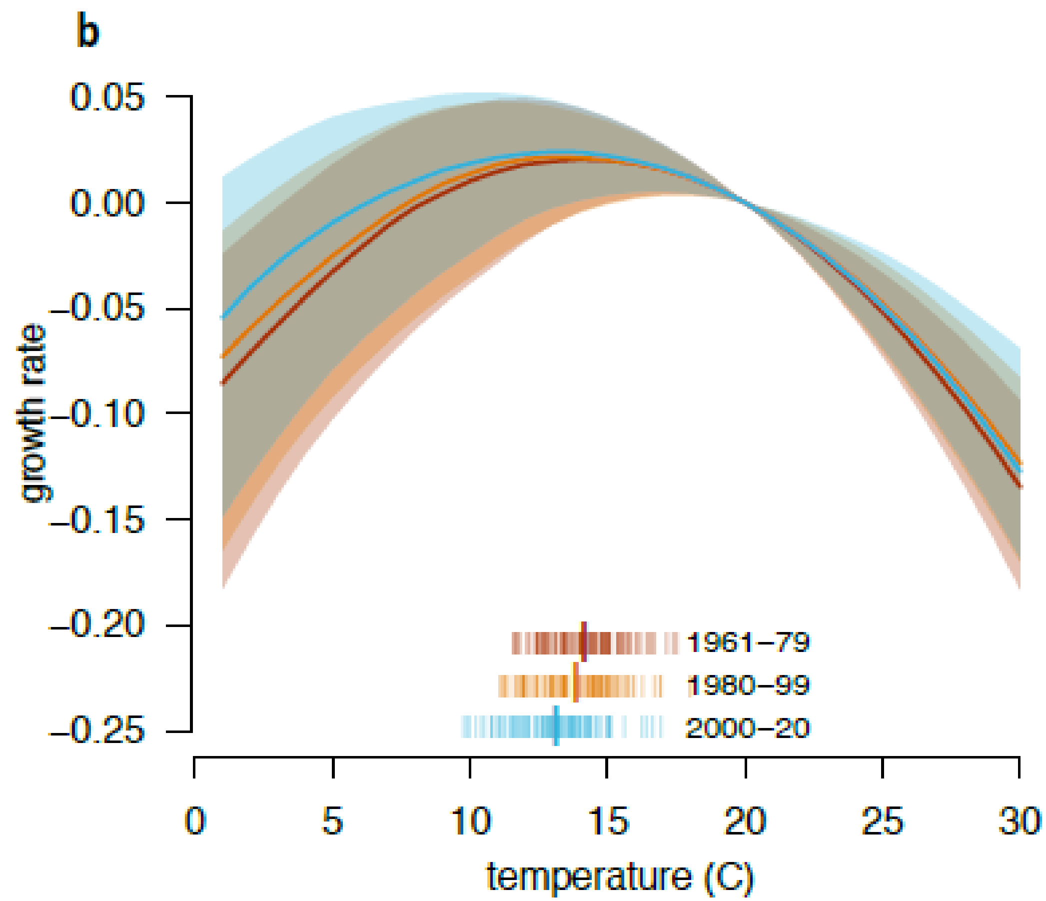
- Understanding mechanisms is a key research + policy priority:
- Many recent contributions highlight the key role of **economic factors** in driving conflict, i.e., Harari and LaFerrara (2018) on African agriculture, and McGuirk and Nunn (2023) further emphasize the interaction between climate, economic shocks and democratic political institutions.
- Public policy matters: expansion of social protection programs also weakens the extreme climate-violence link in India, Mexico, Indonesia (Fetzer 2020, Garg, McCord, Montfort 2020, Christian, Hensel, Roth 2019).

>> But other mechanisms matter, including possibly **psychological factors**: crime increases in rich countries in hot weeks, and aggressive behavior ("Joy of Destruction" game) increases in the lab when participants are placed in hot rooms 30^{o}C (Almås et al 2024).

Climate adaptation: evidence.

- **Little evidence** to expect rapid adaptation to climate change, either to limit damages in terms of economic growth or armed conflict. Longer-term panel studies (e.g., Burke, et al. 2023, right) indicate **minimal adaptation** to warm years since 1960 in terms of economic growth.

>> But how informative is this about the path of future innovation – technological + institutional – to address global warming?



A new consensus on the economics of climate change.

- **Bottom line:** the growing body of research in economics + related fields has rapidly shifted the scientific and policy consensus regarding the likely economic impacts of climate / climate change

>> Global warming has continued – are some of the early research predictions (unfortunately) already coming true? Semi-arid regions in Sub-Saharan Africa appear to be at particular risk.

Source: New York Times (10 Nov 2023)

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Extra slides.

MSS (2004): Base econometric specification.

- Innovation: use of modern panel econometric methods, including country fixed effects, to estimate impact of weather/climate "natural experiments".

Country fixed effects (a_i) are included in some specifications to capture time-invariant country characteristics that may be related to civil conflict, and we also include country-specific time trends in most specifications to capture additional variation:

$$\text{growth}_{it} = a_{1i} + X'_{it}b_1 + c_{1,0}\Delta R_{it} + c_{1,1}\Delta R_{i,t-1} + d_{1i}\text{year}_t + e_{1it}. \quad (1)$$

(The "1" subscript denotes the equation number here.) The term e is a disturbance term, and these disturbances are allowed to be correlated across years for the same country in all regressions.

BHM (2015, *AnnRevEc*): Econometric specification.

- Innovation: inclusion of further lags of multiple climate variables.

2.2.1. Lag structure, displacement, and persistence. In cases in which authors present a distributed-lag model or when we reanalyze a data set, the general form of the estimation equation is

$$\text{conflict\_variable}_{it} = \beta_0 \times \text{climate\_variable}_{it} + \beta_1 \times \text{climate\_variable}_{i,t-1} + \phi_i + \psi_t + \epsilon_{it}, \quad (4)$$

where β_1 is the effect of the prior period's climate $(t-1)$ on conflict in the present period (t), and β_0 is the contemporaneous effect. β_1 might be nonzero for three reasons. First, climatic events might induce conflicts to be displaced in time, for instance, delaying a conflict that will eventually occur anyway or accelerating the emergence of a conflict that would have otherwise occurred in the future. In either case, β_0 and β_1 would have opposite signs but be equal in magnitude, and the net effect of the climatic event—the sum of β_0 and β_1—would be zero. If there is an increase in the number of contemporaneous conflicts in addition to a displacement of conflicts forward in time (i.e., partial displacement), then the lagged effect will be negative, but the cumulative effect will remain positive (Hsiang et al. 2014). In the presence of either full or partial displacement, estimating Equation 3 instead of Equation 4 will overstate the effect of climate on conflict.

BHM (2015, *AnnRevEc*): Meta-analysis across studies.

- Similar effects across multiple levels of analysis.

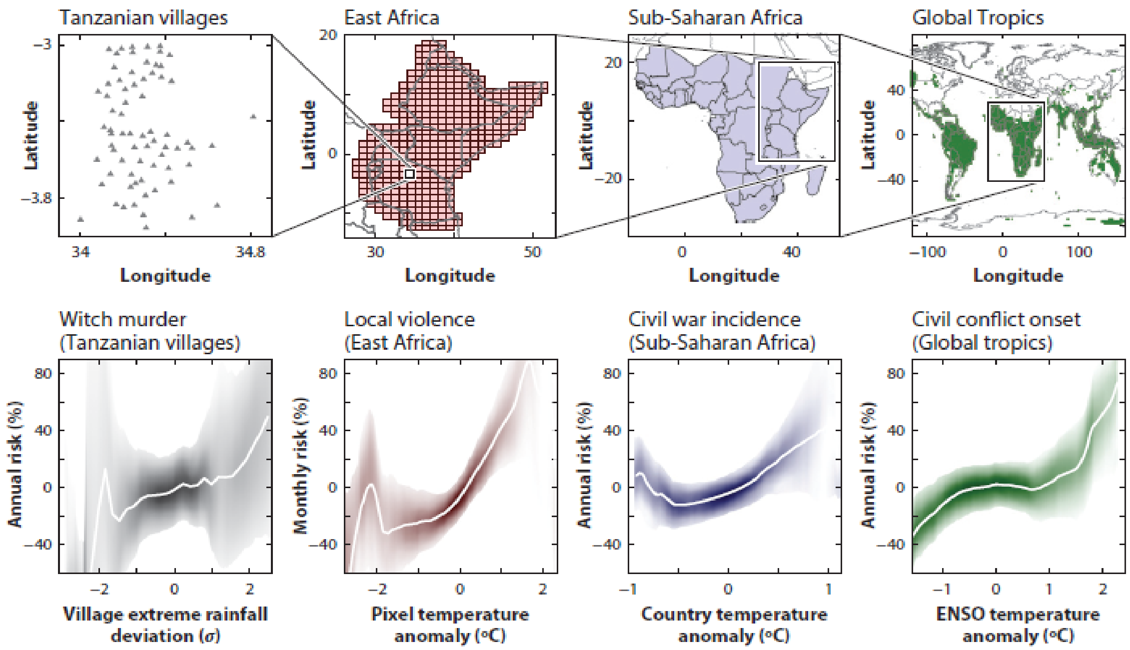


Figure 1

Climate and conflict across spatial scales, showing evidence that climate influences the risk of modern human conflict. Murder in Tanzanian villages increases with more extreme rainfall (data from Miguel 2005), local violence in 1° grid cells increases with temperature (data from O'Loughlin et al. 2012), civil war in African countries increases with temperature (data from Burke et al. 2009), and civil conflict risk in the tropics increases with sea-surface temperature (data from Hsiang et al. 2011). The top row illustrates nested spatial scales of analysis, and the bottom row displays estimated effects. Both dependent and independent variables have had location effects and trends removed, so all samples have a mean of zero. We reanalyze relationships between climate and conflict outcomes and display them as nonparametric watercolor regressions, in which the color intensity of 95% confidence intervals depicts the likelihood that the true conditional expectation function passes through a given value; darker is more likely (Hsiang 2012). The white line in each panel denotes the conditional mean. Abbreviation: ENSO, El Niño Southern Oscillation.

BHM (2015, *Nature*): Projects rising global inequality.

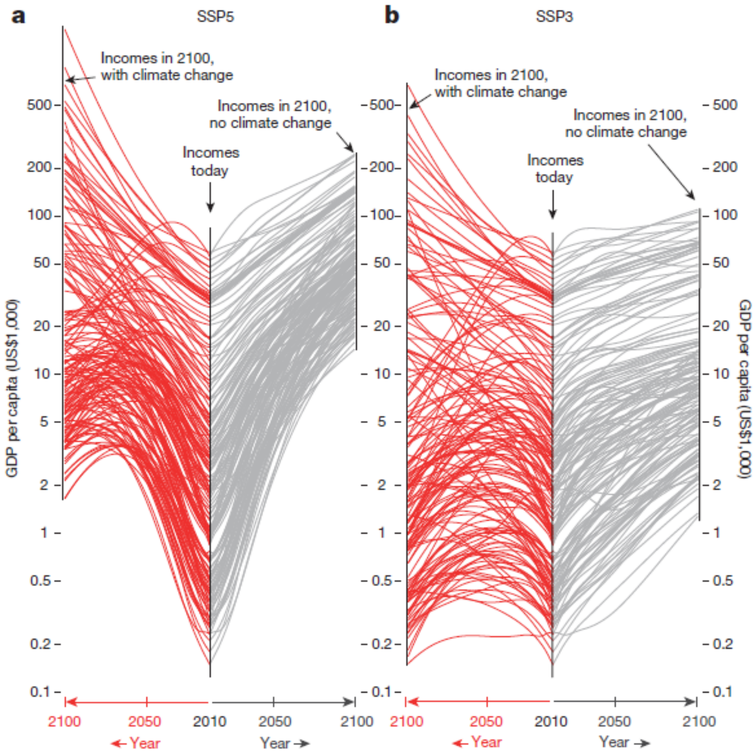


Figure 3 | Country-level income projections with and without temperature effects of climate change. a, b, Projections to 2100 for two socioeconomic scenarios[22] consistent with RCP8.5 'business as usual' climate change: a, SSP5 assumes high baseline growth and fast income convergence; b, SSP3 assumes low baseline growth and slow convergence. Centre in each panel is 2010, each line is a projection of national income. Right (grey) are incomes under baseline SSP assumptions, left (red) are incomes accounting for non-linear effects of projected warming.

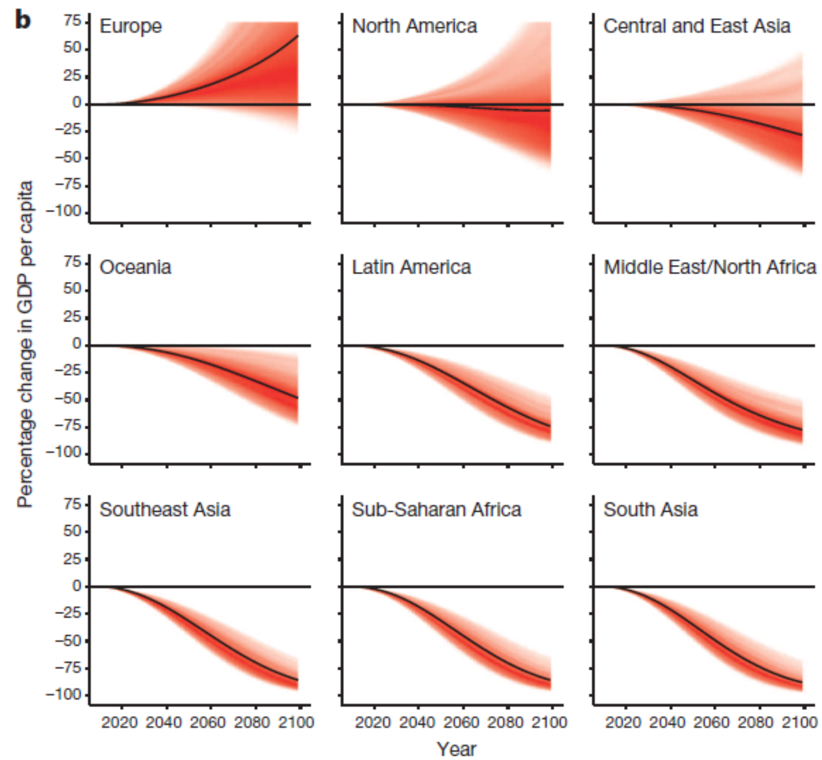
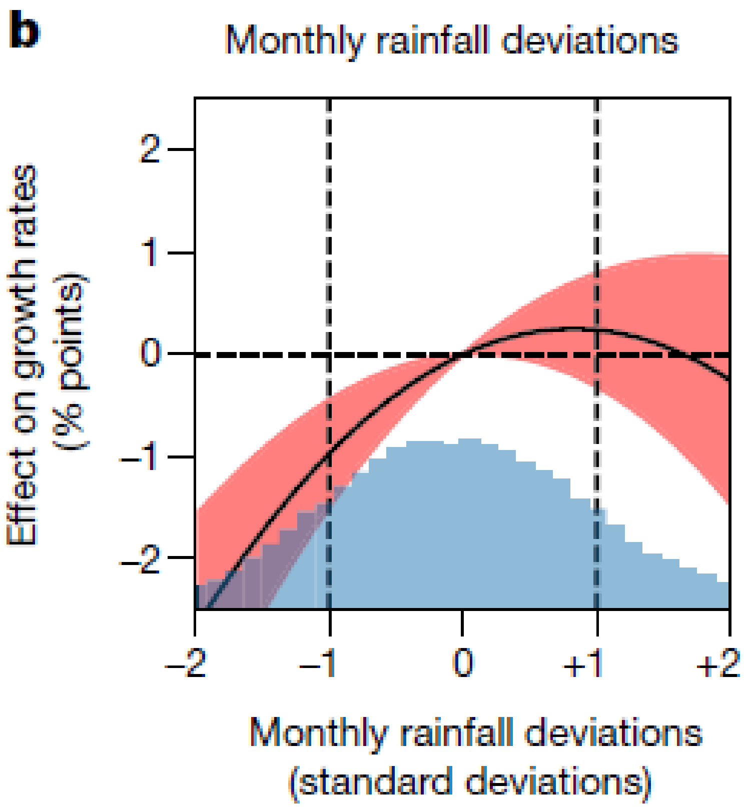
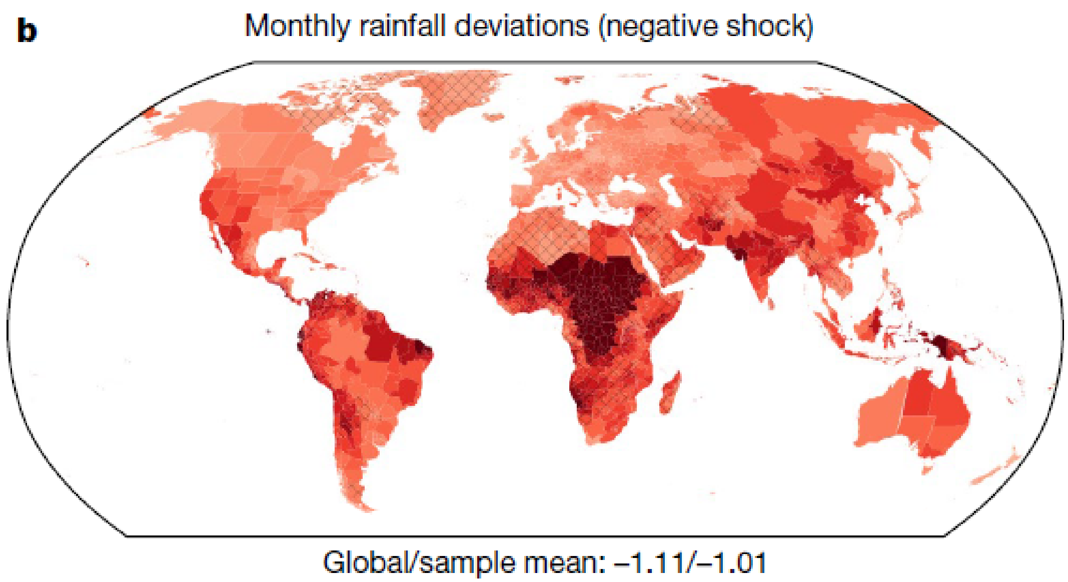


Figure 4 | Projected effect of temperature changes on regional economies. a, b, Change in GDP per capita (RCP8.5, SSP5) relative to projection using constant 1980–2010 average temperatures. a, Country-level estimates in 2100. b, Effects over time for nine regions. Black lines are projections using point estimates. Red shaded area is 95% confidence interval, colour saturation indicates estimated likelihood an income trajectory passes through a value[27]. Base maps by ESRI.

Kotz, Levermann and Wenz (2022) on rainfall shocks.





Callahan and Mankin (2023): persistent ENSO effects.

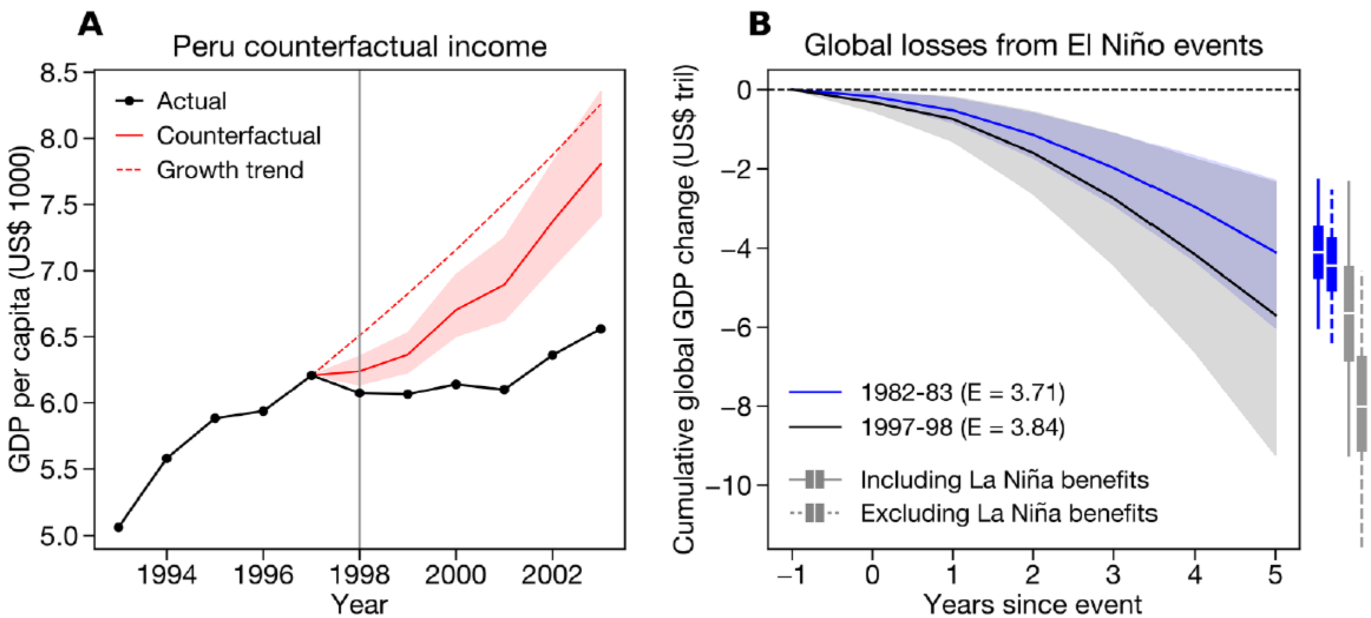
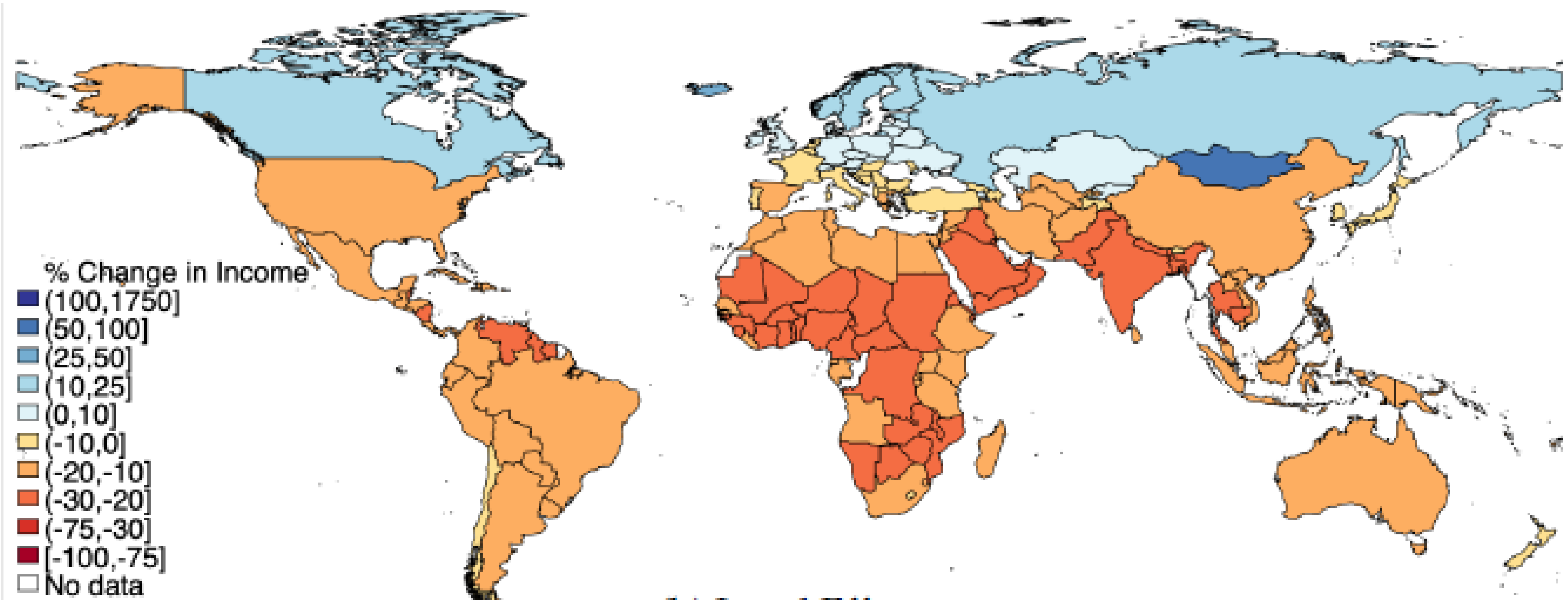


Fig. 2. Damages from extreme El Niño events. (**A**) GDP per capita (GDPpc) in Peru before and after the 1997–98 El Niño event. Black line shows actual GDPpc, red line shows the average counterfactual GDPpc across regression bootstrap samples (methods), and red shading shows 95% confidence interval. Dashed line shows GDPpc if Peru had maintained its average growth rate from the 5 years preceding the event. (**B**) Cumulative global GDP change for the 5 years after the 1982–83 (blue) and 1997–98 (black) El Niño events. Center line shows the mean and shading shows the 95% confidence intervals across regression bootstrap samples. Global GDP change is only calculated for countries with statistically significant marginal effects (Fig. 1C). Text in legends denotes the DJF-average E-index in the corresponding years. Boxplots at right show cumulative global GDP change when including the benefits of the following La Niña events (solid lines) and excluding those benefits (dashed lines). All dollar values are in constant 2017 prices.

Nath, Ramey, Klenow (2023, *working paper*).

Figure 7: Projected Impacts of Unabated Global Warming on Country-Level GDP

(a) Persistent Growth Effects



Burke, Ferguson, Hsiang, Miguel (2024, *Handbook chapter*).

Figure 5: Meta-analysis of Intergroup Conflict Studies

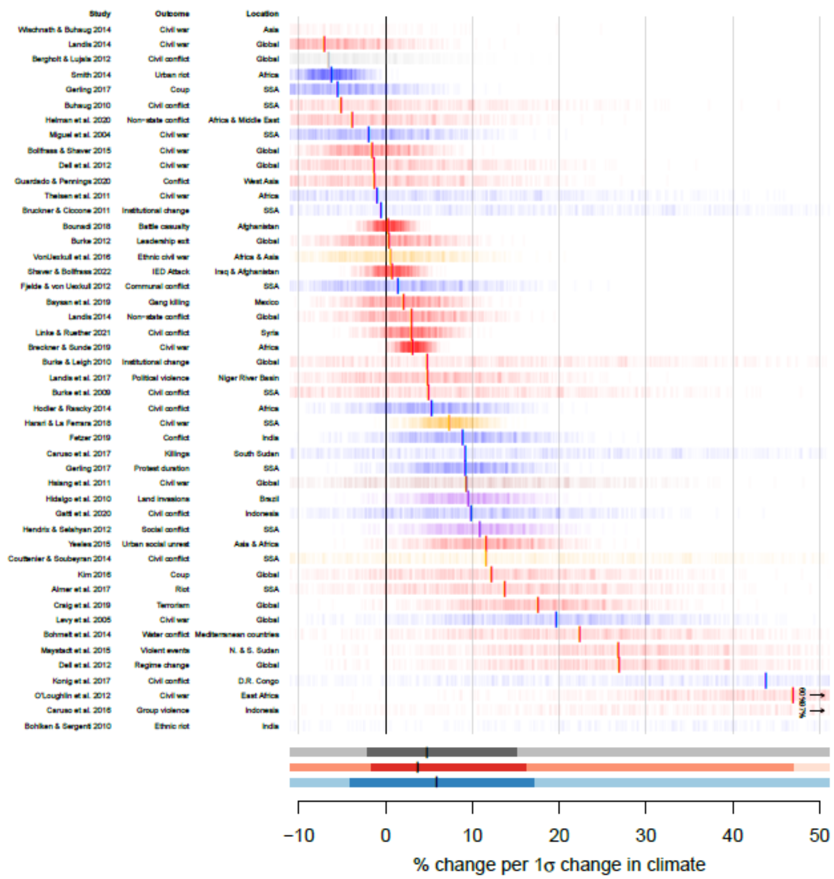
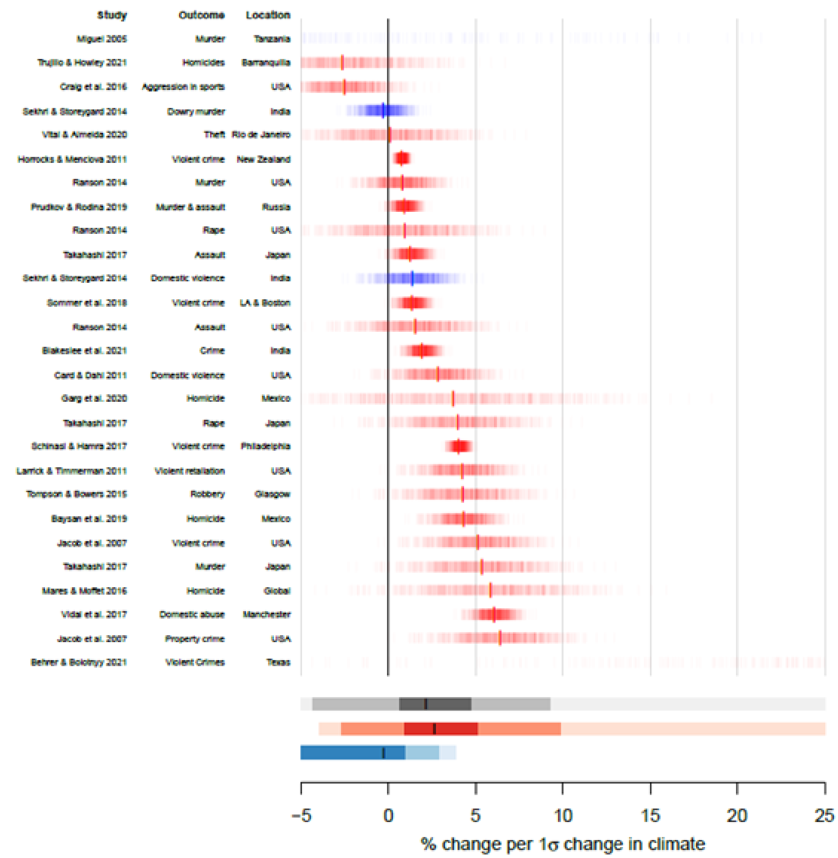
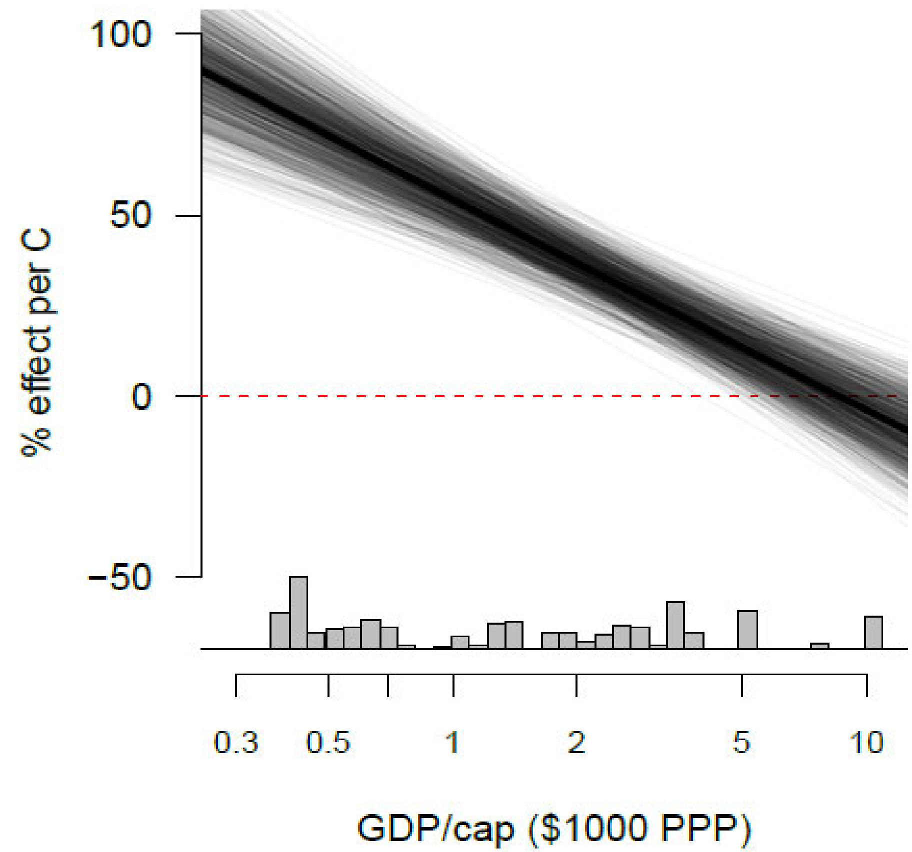


Figure 6: Meta-analysis of Interpersonal Violence Studies



Burke, Hsiang, Ferguson, Miguel (2024, *AEA P&P*).

- Recent empirical finding: as African countries become richer (in per capita GDP terms), the likelihood of conflict becomes less sensitive to temperature shocks.



Garg, McCord, Montfort (2020, *working paper*).

- The effect of local temperature shocks on homicide rates is substantial – but falls to near zero once a municipality is incorporated into the Mexico conditional cash transfer (CCT) social protection program (Progresa)

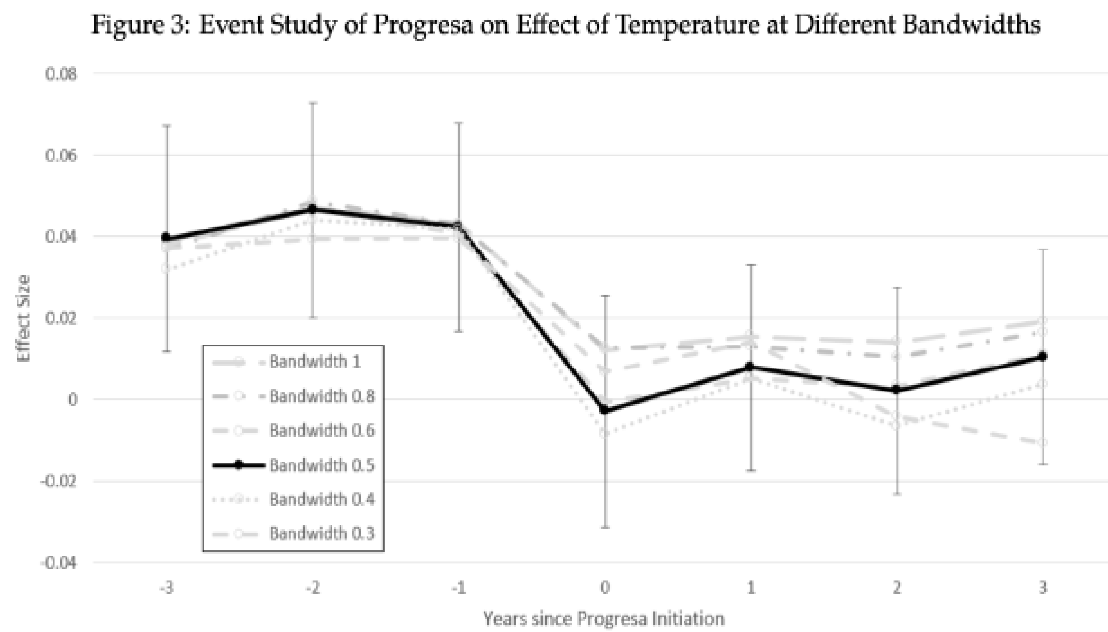


Figure 11: Reproduced from Garg et al. 2020, Figure 3: Event Study of Progresa Program on Effect of Temperature on homicides in Mexico.

Climate adaptation: evidence.

- There remains **less evidence** on the extent to which we should expect there to be adaptation to climate change, either to limit damages in terms of economic growth <u>or</u> armed conflict.

>> Longer-term panel studies (e.g., Burke, Hsiang, Miguel 2015, right) indicate that **adaptation has been limited to date** but may only be moderately informative about the path of future innovation – technological + institutional – to address global warming.

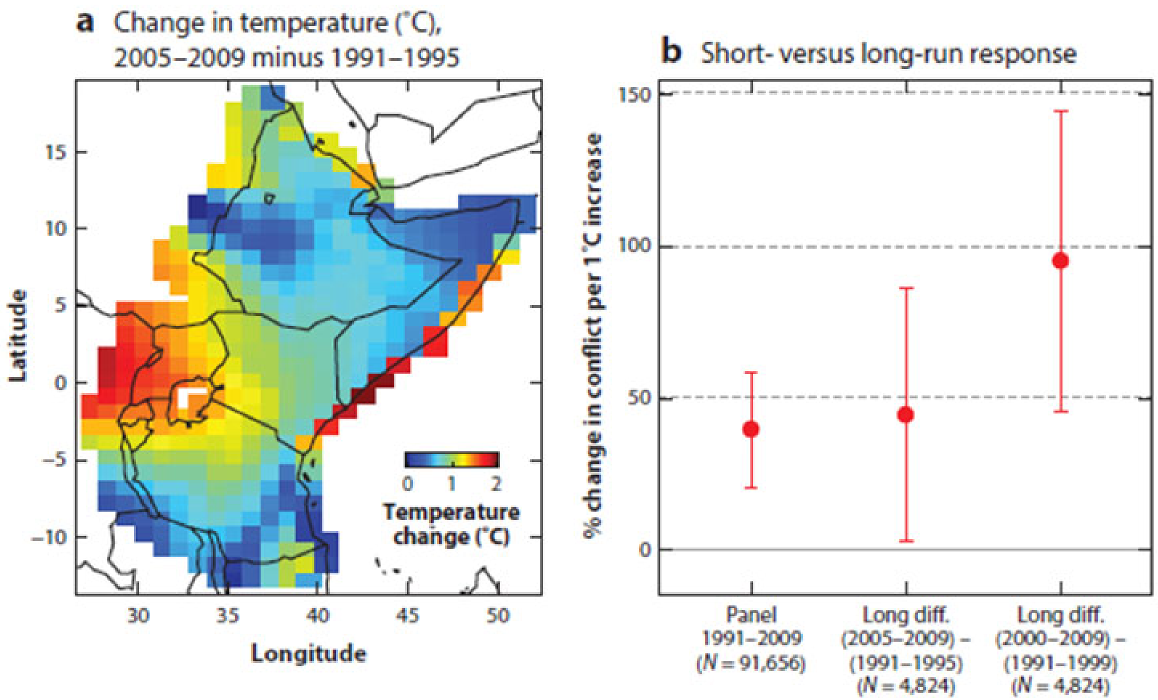


Figure 6

New calculations using data from O'Loughlin et al. (2012) demonstrating how adaptation to longer-run changes in temperature can be studied. (*a*) Multidecadal change in average temperature (in Celsius) across East Africa. (*b*) Comparison of panel estimates of how conflict responds to temperature using an annual panel data approach (as in Equation 3) and using a long-differences estimate that compares trends in conflict at each location with trends in temperature (from panel *a*).