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New Evidence on the Economics of Climate and Conflict
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ABSTRACT

We survey the quantitative research literature linking climate and conflict, a body of research that spans multiple academic disciplines and has roughly doubled in size in the last decade. It makes three main contributions. First, we carry out a meta-analysis – updating Hsiang et al (2013) and Burke et al (2015) with a far larger sample – and confirm that extreme climate is associated with elevated risk of inter-group conflict, intra-personal violence, and self-harm. The estimated average effects are smaller than the earlier estimates, although they remain meaningful in magnitude and highly statistically significant. Second, we present a methodological discussion and empirical illustration of how the use of data at different spatial and temporal scales can affect these results. Third, we discuss specific studies that present evidence on the mechanisms underlying this relationship including: (1) economic conditions, income, and agricultural productivity; (2) socio-demographic factors; (3) migration and transportation costs; (4) policy, politics and institutions; and (5) psychological and physiological factors. The chapter concludes with a discussion of policy implications and some open questions.

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1 Introduction

“The world must come together to confront climate change. There is little scientific dispute that if we do nothing, we will face more drought, more famine, more mass displacement – all of which will fuel more conflict for decades.”

– US President Barack Obama, 2009 Nobel Prize acceptance speech

Climate change and global warming are increasingly recognized by policymakers as major risk factors for armed conflict (IPCC 2022). The incidence of armed conflict worldwide rose over the last decade as many observers believe the effects of global warming are beginning to be felt in earnest. To illustrate this point with a rough measure, while 34 countries were experiencing armed conflict on average in a given year during the decade from 2002-2011, this number increased to 50 during 2012-2021 (see brown and blue shading in Figure 1), and total battle-related deaths also rose sharply (solid black line) and these have recently increased further due to Russia’s invasion of Ukraine.

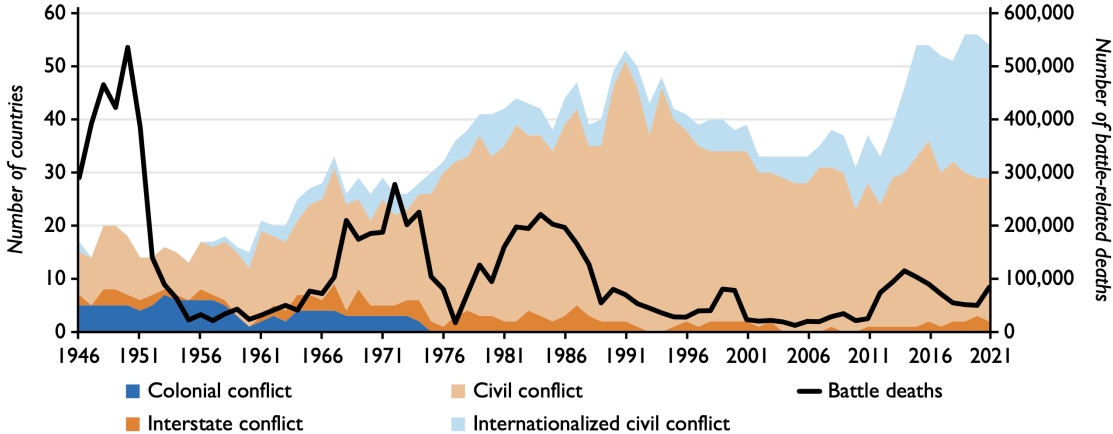


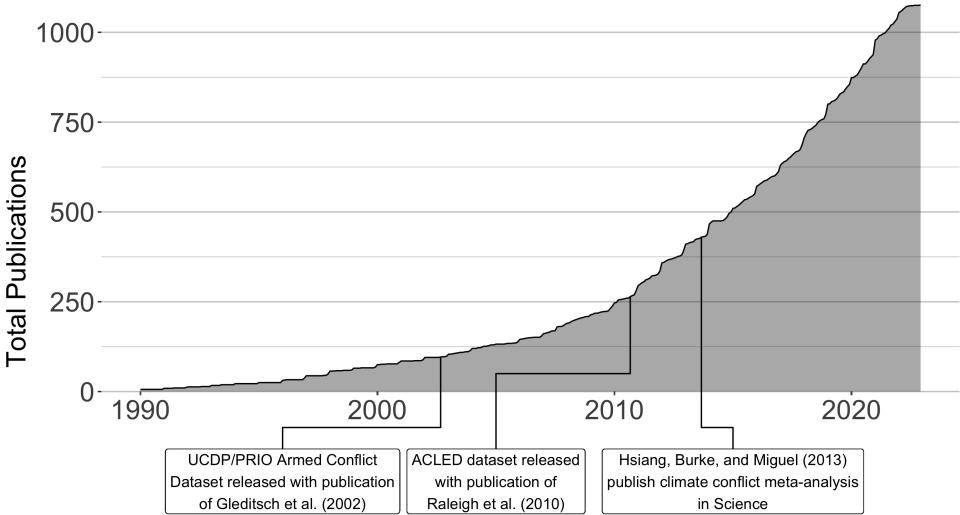
Figure 1: Conflict events worldwide, 1946-2021, figure reproduced from Palik, Anna Marie Obermeier, and Siri Aas Rustad (2022).

Of course, global patterns like these could be driven by many factors, and there remains some uncertainty about the nature of the relationship between climate variation and human violence. For instance, the 2014 United Nations IPCC5 report stated that: “...[I]t remains disputed whether, and if so, how, the changing climate directly increases the risk of violent conflict in Africa” (Niang et al. 2014). The more recent IPCC6 report asserts that there is some lingering doubt about the strength of this relationship, providing “medium confidence” in the relationship: “Climate variability and extremes are associated with increased prevalence of conflict, with more consistent evidence for low-intensity organised violence than for major armed conflict (medium confidence).” (O’Neill et al. 2022).

Here we survey and synthesize the large – and growing – quantitative research literature that attempts to establish causal relationships between climate and human violence by utilizing panel or longitudinal data sets and quasi-random variation in local climate variation. The analysis includes recent studies found via an intensive literature search (undertaken through June 2022). This scientific literature spans multiple disciplines, including economics, political science, psychology, history, public health,

and criminology, among others, and is expanding rapidly: based on a broad literature search using common keywords, over the last decade the cumulative number of studies in this broad area (across fields and methodologies) has more than doubled (Figure 2). Given this recent explosion of studies and remaining uncertainty around the importance of the climate-conflict relationship, we hope to provide a more comprehensive assessment of the key patterns in this literature than earlier work.

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 S. M. 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.

This chapter makes three main contributions, laid out in each of the three subsequent sections.

First, in section 2 we carry out a meta-analysis – updating the work in S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a) with a far larger sample – and confirm that extreme climate is associated with elevated risk of both inter-group conflict and inter-personal violence. We find that a 1 sd increase in local temperature is associated with a 2.5% increase in inter-group conflict and a 1.9% increase interpersonal conflict. These estimates are highly statistically significant. Importantly, the resulting average inter-group conflict and interpersonal violence estimates are roughly three quarters smaller and one fifth smaller, respectively, than the earlier estimates, although they remain empirically meaningful. At the same time, the median estimated effect among studies included in the inter-group conflict meta-analysis remains similar at approximately 5%. We also find evidence of significant

increases in the risk of suicide and self-harm at higher temperatures, with effect magnitudes similar to inter-group violence and interpersonal violence. The bottom line is that a large and rapidly growing interdisciplinary body of research now affirms that higher than normal temperatures are associated with far greater risk of many forms of violence and conflict. In our view, this should now be seen as a robust social science empirical fact.

Second, in section 3 we present a methodological discussion of how the use of data at different spatial and temporal scales can affect analytical results. This is highly relevant given the explosion of data at finer spatial and temporal scales over the last decade (e.g., the ACLED dataset) versus earlier data with observations only at the country-year level. We find that, holding the dataset constant, analyses that use more disaggregated data do largely reproduce the qualitative findings at more aggregated scales but the standardized magnitude of the estimated effect depends critically on the details of the specification. In particular, including fewer lagged climate shocks and failing to account for local seasonality with fixed effects can lead researchers to estimate systematically smaller effects of climate shocks on conflict. We also extend the analysis to examine effects at longer time frames, over decades or even multiple decades, and find that effect magnitudes tend to be larger in magnitude than those documented at shorter time scales. This is another piece of evidence (among others in recent work) that the process of adaptation to a warmer climate may not occur automatically even over an extended time frame, and suggests that the impacts of global warming in the coming decades could be severe for many human societies.

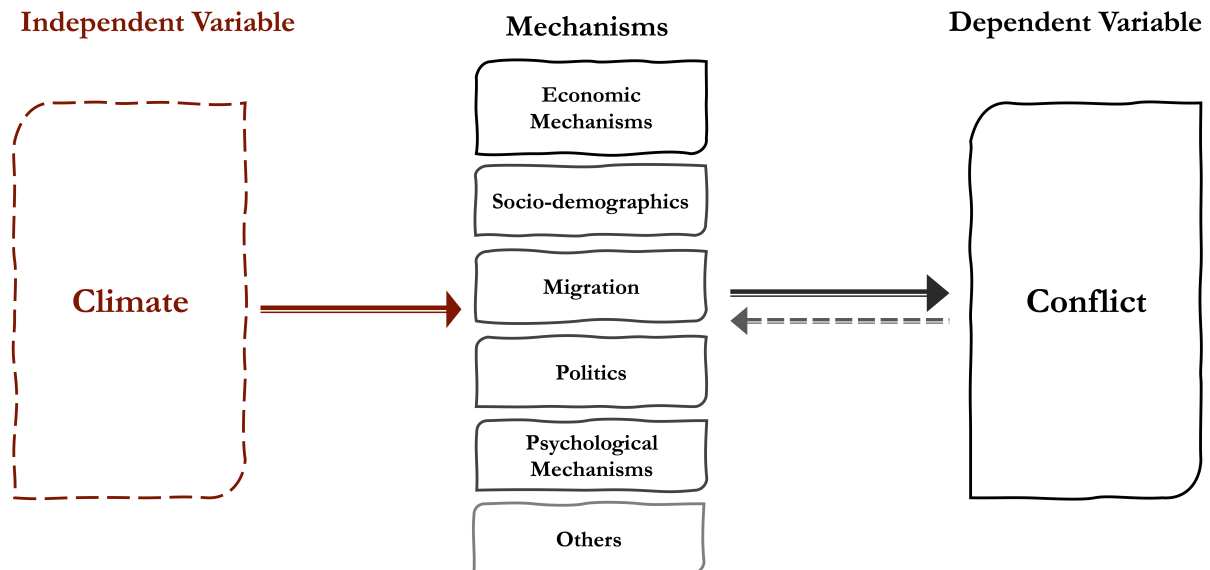
Third, in section 4 we describe noteworthy and important recent additions to the literature since the time of the earlier reviews (S. M. Hsiang, M. Burke, and Miguel 2013; S. M. Hsiang and M. Burke 2014; M. Burke, S. M. Hsiang, and Miguel 2015a). We focus on laying out where there has also been sufficient research to speak more confidently about the mechanisms underlying the strong statistical relationships between climate and violence. In particular, as laid out in Figure 3 there are now clusters of studies that imply that a range of factors can play a role, including: (1) economic conditions, income, and agricultural productivity; (2) socio-demographic factors; (3) migration and transportation costs; (4) policy, politics and institutions; and (5) psychological and physiological factors. We discuss the evidence for each of these mechanisms, and combinations of the channels, in particular studies and settings.

There is a particularly robust body of evidence connecting adverse economic conditions to increased conflict risk across settings. In a concurrent related paper, we present new empirical evidence indicating that conflict in wealthier African countries, but not necessarily in wealthier areas within those countries, is less sensitive to climate shocks (M. Burke, Ferguson, et al. 2024). In particular, in that study we utilize a novel and highly disaggregated measure of local asset wealth across Sub-Saharan Africa, and demonstrate that the interaction between climate shocks and this wealth measure is small. In contrast, the interaction between climate shocks and national GDP per capita is large and negative, meaning that there is a substantial dampening of the effect of climate shocks in wealthier countries. Between this evidence and the other studies discussed in section 4 of this chapter, we argue that there is now substantial evidence that economic conditions are a key mediator of the relationship between extreme climate and human violence. There is also ample evidence that the interaction of adverse economic conditions caused by climate shocks with pre-existing social and political

divisions can exacerbate conflict.

The chapter concludes (section 5) with a discussion of the policy implications of these findings, and some open research questions.

Figure 3: Mechanisms in the Climate-Conflict Relationship



Notes: This figure summarizes some of the main mechanisms through which climate affects conflict that we survey in this chapter. The most common types of climate shocks often considered in the existing literature include extreme temperatures, extreme precipitation, and drought. Common types of conflict outcomes include inter-group conflict (often between armed groups), inter-personal violence and crime, and suicide and other forms of self-harm. The figure also illustrates why the use of climate and weather variation as an instrumental variable for any one of these channels is potentially problematic due to the possibility of exclusion restriction violations.

2 New Meta-analysis Results

The work here builds on earlier meta-analysis studies, particularly those in S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a). Those studies have been widely cited both in the scholarly and policy literatures, including in the recent IPCC6 report (IPCC 2022). S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a) assembled all of the causal empirical evidence available at that time, reviewed it, and also carried out a meta-analysis combining data across studies. That allowed us to estimate the average impacts of climate variability on various forms of conflict in human societies, including both larger scale

intergroup conflicts, like civil wars, as well as more decentralized forms like violent crime.

By design, the current chapter uses similar inclusion criteria as the S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a) articles, namely, focusing on all quantitative studies utilizing panel or longitudinal data, which allows for the inclusion of both location and time fixed effects or other time controls. These are critical for allowing the analysis to account for non-random exposure to climate, enabling us to interpret the resulting estimates as the causal impacts on conflict outcomes, exploiting the “natural experiment” induced by weather shocks.

Although there is a general distinction between the weather shocks that are examined by the studies included in this chapter and climate, it is possible to relate the estimated effects to climate change impacts. “Climate” is the joint distribution over weather that may occur in a given period, whereas “weather” refers to realizations from this distribution. The empirical approach taken here and in the literature assumes that a given response curve relates the outcome of interest (in this case various forms of conflict) to particular weather variables (e.g., annual mean temperature), potentially with additional unobserved determinants. A research design which credibly estimates the response function can then be used to simulate outcomes under climate change by drawing realizations of the relevant weather variable from the future climate distribution (Carleton and S. M. Hsiang 2016). An important caveat is that such simulations typically assume a static response function, meaning that they describe climate change impacts in the absence of adaptation or other mechanisms through which a change in the weather distribution may alter the response function (S. Hsiang 2016). To date, a handful of studies have tried to directly test this assumption and found that a static response function is generally a reasonable first-order approximation for conflict and other personal violence outcomes (M. Burke, S. M. Hsiang, and Miguel 2015a; M. Burke, González, et al. 2018; M. Burke, Zahid, et al. 2024)

To ensure estimates are comparable across studies, we or the authors re-analyzed every study included in the meta-analysis for this chapter using a common econometric approach. We assembled and re-analyzed 50 new datasets for this chapter. With a goal of increasing relevance for contemporary societies, in this chapter’s new meta-analysis we exclude studies using historical data from periods before approximately 1960; nine of these studies had been included in the earlier M. Burke, S. M. Hsiang, and Miguel (2015a) paper.

The statistical analysis implements regression specifications of the following general form (and then combines the results in a meta-analysis estimate):

$$Conflict_{it} = \alpha + \sum_{j=0}^1 \beta_j Climate_{i,t-j} + \mu_i + \theta_t + \epsilon_{it}. \quad (1)$$

Here $Conflict_{it}$ is the conflict or violence outcome measure, for instance, an indicator for civil conflict or the violent crime rate in a given location i and time period t . The term $Climate_{i,t-j}$ is a vector of climate explanatory variables, typically including both the current and first lagged values (e.g., of temperature and/or precipitation in many applications), and the parameters of interest are the vector of β_j terms at each temporal

lag, where the overall effect for a given variable is the linear combination of the contemporaneous and lagged terms for that variable. ϵ_{it} is the usual error term, discussed below. As different locations can exhibit differing average levels of conflict (for a wide range of geographic and historical reasons) which may be correlated with climate, the specification includes a vector of location fixed effects μ_i . Their inclusion implies that the resulting estimates are effectively comparing locations to themselves, across periods with different climate conditions. For studies that use sub-annual data, we use location \times month or location \times quarter fixed effects whenever possible to account for local seasonality. The vector of time-period specific constants θ_t accounts for overall time trends in conflict outcomes as well as time-trending variables (such as gradual demographic changes) that could be correlated with both climate and conflict patterns. In some cases, time period fixed effects are replaced with location-specific time trends or related approaches.

Disaggregated weather products are necessarily interpolated across space, leading to spatial autocorrelation in weather variables after residualizing against fixed effects. Broadly speaking, this autocorrelation should be dealt with by clustering at a sufficiently aggregated level, estimating heteroskedasticity autocorrelation robust standard errors with a sufficiently large spatial kernel, non-parametrically accounting for cross-sectional correlation via Driscoll and Kraay (1998) standard errors in long panel settings, or using randomization inference when there is a good model of the distribution of the weather variable(s) being studied available. Here, statistical inference is generally conducted by clustering at the unit of analysis when units are geographically large, such as states or countries, and by two-way clustering at the unit of analysis and time period when units are geographically small and there are sufficient number of time periods, as is the case in some of the more disaggregated studies.

The S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a) studies focus on two forms of violence, namely, inter-group conflict (with N=21 estimates included in S. M. Hsiang, M. Burke, and Miguel (2013)) and interpersonal violence and crime (with N=11 estimates included in S. M. Hsiang, M. Burke, and Miguel (2013)), so a total of 32 quantitative estimates included in that meta-analysis in all (from somewhat fewer than 32 studies since some articles contributed multiple estimates, i.e., if they had multiple relevant outcomes). The central finding of both earlier studies is that a 1 normalized standard deviation (SD) increase (relative to the local distribution) in a climate variable (such as warmer temperature) leads to a +11% increase in inter-group conflict, and similarly to a +2.3% increase in interpersonal violence. Both of these effects are statistically significant at high levels of confidence.

The results in S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a) also received extensive attention because they implied very large effects when projecting the effects out to future climate. Over the next few decades (to 2050), depending on which part of the world one considers, there will be something like a 2 to 4 SD increase in average temperatures, so you can multiply these estimated effects above by roughly 2 to 4 times to get at the projected impacts on violence around the world due to climate change, assuming that human societies cannot come up with good adaptation mechanisms (either in terms of new technologies or public policies) before then. In other words, there could be something on the order of a 20 to 40% increase in intergroup conflict risk and 6 to 12% increase in interpersonal violence risk.

What we present in this chapter is a substantial update of that previous work, which will hopefully also be of interest for future UN IPCC assessments and policymakers. Since the 2013 and 2015 articles came out, there has been an explosion of new research (see Figure 2), with a more than doubling of articles in this general research area. Of course, not all of these studies use data amenable to our unified approach to analysis. After an exhaustive literature review, we determined that the number of studies that can be included in the meta-analysis has risen from 30 to 80, more than doubling over this time period. In addition to examining a comprehensive set of studies on intergroup conflict (with N=44 studies, see Table 1, Panel A) and interpersonal violence (with N=21 studies, Panel B) here (as in S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a)), we now also present a meta-analysis for the emerging literature on climate effects on self-harm and suicide (with N=8 studies or estimates, Panel C).

We searched for studies to be included in the meta-analyses as follows. We began by screening the set of papers that cite either S. M. Hsiang, M. Burke, and Miguel 2013 or M. Burke, S. M. Hsiang, and Miguel 2015a by reading the abstract to determine whether suitable data were used for an empirical analysis. Those that passed screening were read fully to finally determine whether or not they were eligible for inclusion. The references of papers that were fully read were also checked to identify additional studies that potentially fulfilled the inclusion criteria. Once a study was determined to be eligible for inclusion, we downloaded the replication data if available. If not, we contacted the author(s), asking if they could share the relevant data or were willing to run additional analyses that we would include in the meta-analysis. In the case of the latter, we would send the authors the relevant specification and check the returned code (when possible) to ensure the specification had been implemented correctly. This was a time-consuming endeavor, carried out by the authors of this chapter as well as multiple research assistants (gratefully mentioned in the acknowledgements). All 50 studies added since the M. Burke, S. M. Hsiang, and Miguel 2015a paper were re-analyzed, either by us or the authors of the studies, in order to generate comparable estimates that can be included in the meta-analysis.

In addition to the studies included in these meta-analyses, we also identified other articles that contain credible evidence on the importance of particular mechanisms linking climate variation to human conflict, many of which are discussed in the next section (and are listed in Table A.1).

Table 1: Summary of Studies included in the Meta-analyses

Panel A: Intergroup Conflict Studies

Study (Authors and year)	Sample period	Sample region	Time unit	Spatial unit	Climate variable	Outcome variable	Sample size	Effect Estimate
Almer, Laurent-Lucchetti, and Oechslin 2017	1990-2011	Sub-Saharan Africa	Month	Pixel (0.5°)	Temperature	Riot	1654724	13.93
Baysan et al. 2019	1990-2006	Mexico	Month	Municipality	Temperature	Gang killing	115244	2.33
Bergholt and Lujala 2012	1980-2007	Global	Year	Country	Storm	Civil Conflict	4109	-6.34
Bohlken and E. J. Sergenti 2010	1982-1995	India	Year	State	Rainfall	Ethnic Riot	191	-98.38
Böhmelt et al. 2014	1997-2009	Mediterranean countries	Year	Country	Temperature	Water conflict	411	22.61
A. Bollfrass and Shaver 2015	1989-2008	Global	Year	Province	Temperature	Civil war	27544	-1.30
Bounadi 2019	2005-2016	Afghanistan	Month	District	Temperature	Battle casualty	54526	0.51
Breckner and Sunde 2019	1997-2015	Africa	Month	Pixel (0.75°)	Temperature	Civil war	1100328	3.35
Brückner and Ciccone 2011	1980-2004	Sub-Saharan Africa	Year	Country	Rainfall	Institutional Change	914	0.33
Buhaug 2010	1981-2002	Sub-Saharan Africa	Year	Country	Temperature	Civil Conflict	848	-4.89
Paul J. Burke 2012	1962-2006	Global	Year	Country	Temperature	Leadership Exit	5328	0.62
Paul J Burke and Leigh 2010	1963-2007	Global	Year	Country	Temperature	Institutional Change	3985	5.02
M. B. Burke et al. 2009	1981-2002	Sub-Saharan Africa	Year	Country	Temperature	Civil Conflict	848	5.16
Caruso, Khadka, et al. 2017	2009-2011	South Sudan	Year	County	Rainfall	Killings	234	-9.34
Caruso, Petrarca, and Ricciuti 2016	1993-2003	Indonesia	Year	Province	Temperature	Group violence	98	60.17
Couttenier and Soubeyran 2014	1945-2005	Sub-Saharan Africa	Year	Country	PDSI	Civil Conflict	1426	11.83
C. M. Craig, Overbeek, and Niedbala 2021	1970-2015	Global	Month	Country	Temperature	Terrorism	8910	17.81
Dell, Jones, and Olken 2012	1950-2003	Global	Year	Country	Temperature	Civil War	5587	-1.13
Dell, Jones, and Olken 2012	1950-2003	Global	Year	Country	Temperature	Regime Change	6550	27.13
Fetzer 2020	2000-2014	India	Year	District	Rainfall	Conflict	8145	-9.05
Fjelde and Uexkull 2012	1990-2008	Sub-Saharan Africa	Year	Country	Drought	Communal Conflict	10320	1.61
Gatti, K. Baylis, and Crost 2021	2008-2014	Indonesia	Year	District	Rainfall	Civil conflict	3216	-10.01
Gerling 2017	1990-2007	Sub-Saharan Africa	Year	Country	Drought	Coup	643	-5.36
Gerling 2017	1990-2007	Sub-Saharan Africa	Year	Country	Drought	Protest duration	643	9.36
Guardado and Pennings 2020	2002-2014	West Asia	Month	District	Temperature	Conflict	7488	-1.03
Harari and Ferrara 2018	1960-2010	Sub-Saharan Africa	Year	Pixel (1°)	SPEI	Civil conflict	35042	7.59
Helman, Zaitchik, and Funk 2020	1992-2012	Africa & Middle East	Year	Pixel (0.5°)	Temperature	Non-state conflict	258774	-3.60
Salehyan and Hendrix 2014	1970-2006	Global	Year	Country	Rainfall Deviation	Social Conflict	544	11.06
Hidalgo et al. 2010	1988-2004	Brazil	Year	Municipality	Rainfall Deviation	Land Invasion	44340	9.72
Hodler and Raschky 2014	1992-2010	Africa	Year	District	Rainfall	Civil conflict	84969	-5.47
S. M. Hsiang, Meng, and Cane 2011	1950-2004	Global	Year	ENSO Region	ENSO	Civil conflict	52	9.51
Kim 2016	1960-2005	Global	Year	Country	Temperature	Coup	4959	12.43
König et al. 2017	1998-2010	D.R. Congo	Year	Group	Rainfall	Civil conflict	960	-44.01
Steven T Landis 2014	1979-2010	Global	Month	Country	Temperature	Civil war	67367	-6.85
Steven T Landis 2014	1979-2010	Global	Month	Country	Temperature	Non-state Conflict	51935	3.23
Steven T. Landis et al. 2017	1997-2012	Niger River Basin	Month	Pixel (0.5°)	Temperature	Political violence	631104	5.08
Levy et al. 2005	1980-2002	Global	Year	Pixel (0.25°)	Rainfall	Civil War	3709322	-19.83
A. M. Linke and Ruether 2021	2011-2018	Syria	Month	Sub-district	Temperature	Civil conflict	24206	3.24
Maystadt, Calderone, and You 2015	1997-2009	N. & S. Sudan	Year	Pixel (1°)	Temperature	Civil conflict	45543	27.05
Miguel, Satyanath, and E. Sergenti 2004	1981-1999	Sub-Saharan Africa	Year	Country	Rainfall	Civil War	702	1.78
O'Loughlin et al. 2012	1990-2009	East Africa	Year	Pixel (1°)	Temperature	Civil War	86832	47.15
Shaver and A. K. Bollfrass 2022	2003-2011	Iraq & Afghanistan	Day	City/Province	Temperature	IED Attack	1604634	0.99
Smith 2014	1990-2012	Africa	Month	Country	Rainfall	Urban riot	10403	6.07

Theisen, Holtermann, and Buhaug 2012	1960-2004	Africa	Year	Pixel (0.5°)	Drought	Civil War	364717	-0.81
Uexkull et al. 2016	1989-2014	Asia & Africa	Year	Ethnic group	SPEI	Ethnic civil war	7506	0.85
Wischnath and Buhaug 2014	1950-2008	Asia	Year	Pixel (0.5°)	Temperature	Civil war	542768	-35.16
Yeeles 2015	1960-2006	Asia & Africa	Month	City	Temperature	Urban social unrest	28150	11.83

Panel B: Interpersonal Violence Studies

Study (Authors and year)	Sample period	Sample region	Time unit	Spatial unit	Climate variable	Outcome variable	Sample size	Effect Estimate
Baysan et al. 2019	2007-2010	Mexico	Month	Municipality	Temperature	Homicide	491512	4.43
Behrer and Bolotnyy 2021	2010-2017	Texas	Day	County	Temperature	Violent Crime	738378	43.76
Blakeslee et al. 2021	2011-2016	Karnataka	Day	Precinct	Temperature	Crime	912311	2.04
Blanes i Vidal, Bolte, and Kirchmaier 2016	2008-2017	Manchester	Hour	City	Temperature	Domestic abuse	78104	6.16
Card and Dahl 2011	1995-2006	US	Day	Police Agency	Temperature	Domestic Violence	79355	2.96
C. Craig et al. 2016	2000-2011	NFL	Game	Stadium	Temperature	Aggression in sports	2788	-2.42
garg_can_2020	1998-2012	Mexico	Day	Locality	Temperature	Homicide	113 million	3.82
Horrocks and Menclova 2011	2000-2008	New Zealand	Day	District	Temperature	Violent crime	136813	0.85
Jacob, Lefgren, and Moretti 2007	1995-2001	US	Week	Police Agency	Temperature	Violent Crime	25658	5.24
Jacob, Lefgren, and Moretti 2007	1995-2001	US	Week	Police Agency	Temperature	Property Crime	25658	6.52
Larrick et al. 2011	1952-2009	MLB	Game	Stadium	Temperature	Violent retaliation	595500	0.80
Mares and Moffett 2016	1995-2012	Global	Year	Country	Temperature	Homicide	844	5.97
Miguel 2005	1992-2002	Tanzania	Year	Village	Rainfall	Murder	669	26.33
Prudkov and Rodina 2019	2010-2015	Russia	Month	Region	Temperature	Murder & assault	4544	1.03
Ranson 2014	1980-2009	US	Month	County	Temperature	Assault	1344187	1.67
Ranson 2014	1980-2009	US	Month	County	Temperature	Murder	1454447	0.89
Ranson 2014	1980-2009	US	Month	County	Temperature	Rape	1454447	1.06
Schinasi and Hamra 2017	2006-2015	Philadelphia	Day	City	Temperature	Violent crime	3646	4.15
Sekhri and Storeygard 2014	2002-2007	India	Year	District	Drought	Dowry murder	2915	-0.20
Sekhri and Storeygard 2014	2002-2007	India	Year	District	Drought	Domestic violence	2915	1.47
Sommer, Lee, and Bind 2018	2010-2017	LA & Boston	Day	City	Temperature	Violent crime	4687	1.48
Takahashi 2017	2009-2015	Japan	Year	Prefecture	Temperature	Assault	3760	1.38
Takahashi 2017	2009-2015	Japan	Year	Prefecture	Temperature	Murder	3760	5.46
Takahashi 2017	2009-2015	Japan	Year	Prefecture	Temperature	Rape	3760	4.08
Tompson and Bowers 2015	2002-2011	Glasgow	6-Hours	City	Temperature	Robbery	14603	4.38
Trujillo and Howley 2021	2010-2016	Barranquilla	Day	City	Temperature	Homicide	2556	-2.55
Vital and Almeida 2020	2013-2017	Rio de Janeiro	Day	City	Temperature	Theft	391	0.20

Panel C: Self-harm Studies

Study (Authors and year)	Sample period	Sample region	Time unit	Spatial unit	Climate variable	Outcome variable	Sample size	Effect Estimate
P. Baylis 2020a	2014-2016	US	Day	CBSA	Temperature	Sentiment	643733	3.25
Baysan et al. 2019	1990-2006	Mexico	Month	Municipality	Temperature	Suicide	608970	2.75
M. Burke, González, et al. 2018	1968-2010	US	Month	County	Temperature	Suicide	847790	1.21
Carleton 2017	1967-2013	India	Year	State	Temperature	Suicide	1409	-0.08
Dixon et al. 2014	1986-2009	Toronto	Day	City	Temperature	Suicide	8513	14.00
Fountoulakis et al. 2016	2000-2012	Europe	Year	Country	Temperature	Female suicide	305	1.05
Fountoulakis et al. 2016	2000-2012	Europe	Year	Country	Temperature	Male suicide	305	1.22
Mullins and White 2019	2005-2016	US	Month	County	Temperature	Mental health issues	8294	7.23
Obradovich et al. 2018	2002-2012	US	Day	Individual	Temperature	Mental health issues	1961743	0.87

Notes: This table lists all studies included in the meta-analysis. Each row corresponds to a particular outcome measured in the study. Studies included in S. M. Hsiang, M. Burke, and Miguel 2013 and M. Burke, S. M. Hsiang, and Miguel 2015a were included in the current meta-analysis if replication data were available and there was no other study with the same combination of climate data set and outcome data set with a larger sample. Additional studies were included conditional on using panel data for intergroup violence or longitudinal data for interpersonal violence and self-harm, using a climate data set-outcome data set combination not already represented in the meta-analysis, and data being available or the authors of the study agreeing to perform additional analyses.

An attractive feature of the collection of studies included in the meta-analyses is that the 80 studies we include come from many different regions of the world spanning a wide range of income levels, as well as many global scale studies. Figure 4 shows the regional composition of the intergroup study sample. The pool of studies analyzed in the current meta-analysis has broader geographic coverage than those of the S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a) articles, and thus could provide more general conclusions.

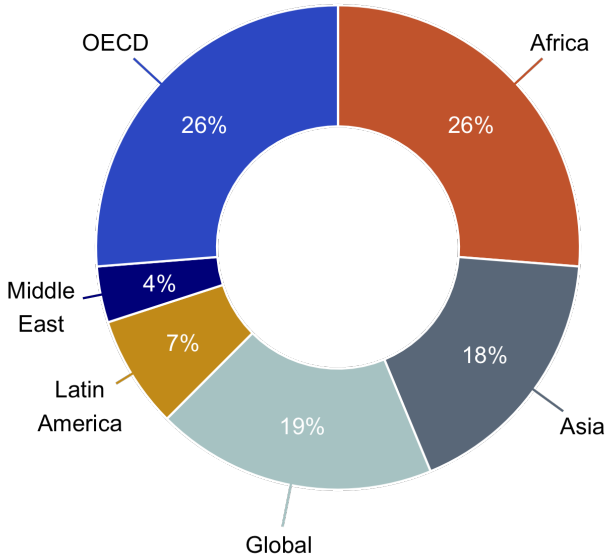


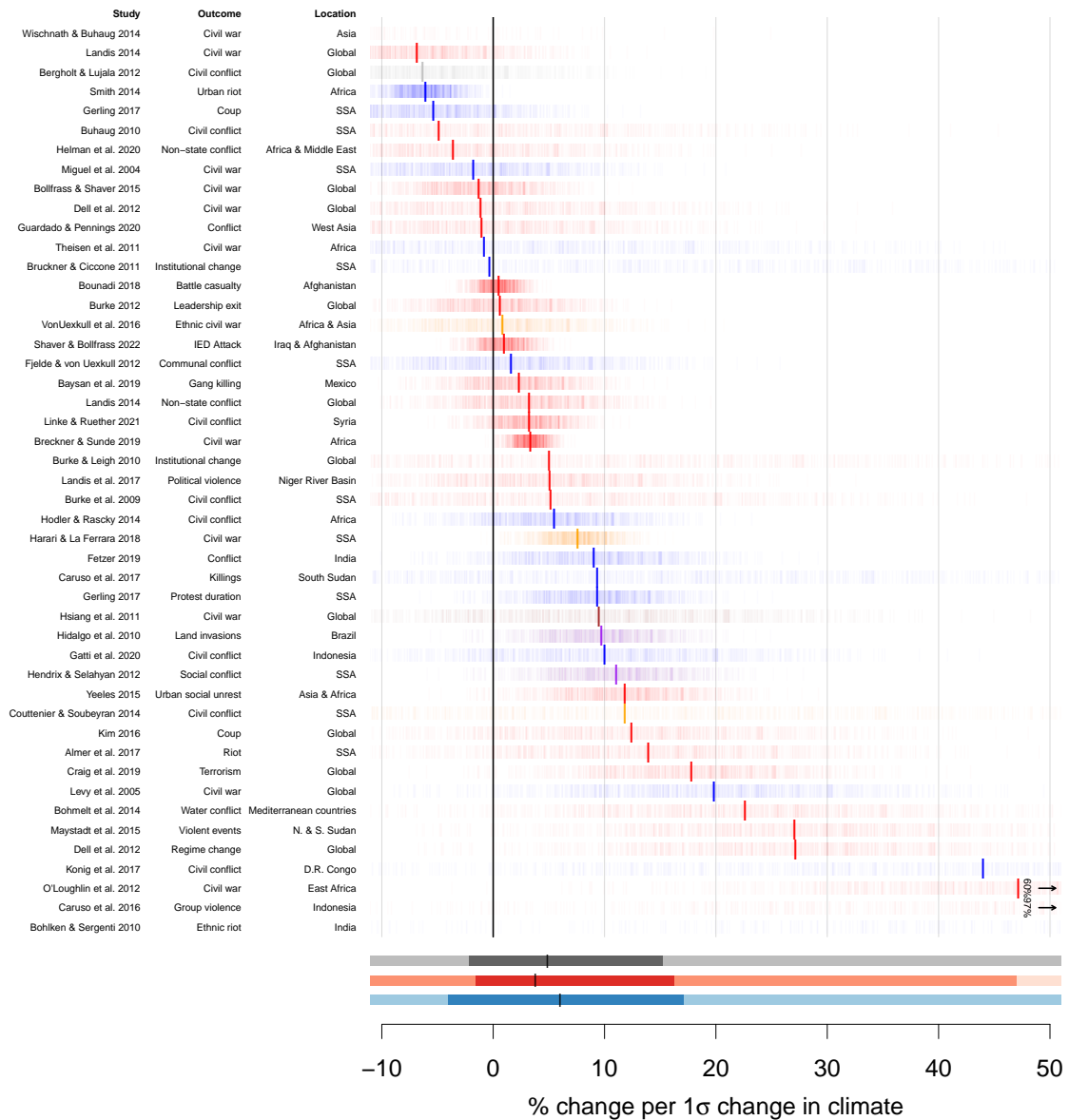
Figure 4: Geographic Distribution of Studies in the Meta-analyses

Notes: The figure presents the primary geographic location for the inter-group studies included in Table 1. The “Global” category includes studies covering multiple major world regions.

So what does the expanded body of evidence on the climate-conflict relationship show now? And how does it differ from the conclusions of the earlier articles?

We begin with the results on inter-group conflict (based on N=44 studies and 47 distinct estimates). The meta-analysis results are presented graphically in Figure 5 (and Figures 6 and 7 for inter-personal violence and self-harm, respectively, have the same figure structure). In the left column of the the figure, you can see the names of the authors of the studies and their geographic location (reproducing information Table 1 above). They come from all over the world, as noted, including many studies on civil conflict in low-income regions but also riots, coups, communal violence, and other forms of organized violence in other regions and globally. The main estimated effect of climate variation on inter-group conflict from each individual study is shown in the figure, where red colors indicate studies that focus on temperature impacts, blue denote precipitation studies, and yellow denotes drought. The vertical black line denotes a zero effect.

Figure 5: Meta-analysis of Intergroup Conflict Studies



Notes: This figure shows estimated effects of climate shocks on intergroup conflict and confidence distributions. All estimates are standardized to be the percent change in the outcome due to a one standard deviation change in the climate variable. Each row has a dark mark representing the estimate for an individual study-outcome and 1000 light marks drawn from the corresponding asymptotic distribution: a normal distribution with mean given by the estimate and variance given by the square of its standard error. The color of each row corresponds to the climate variable studied: temperature (red), rainfall (blue), rainfall deviation (purple), ENSO (brown), storms (grey), or drought (orange). The three horizontal bars along the x-axis display quantiles of the estimated effect distribution. For a given bar, the black vertical line represents the median, the darkest bar the 25th-75th percentile interval, the second darkest bar the 5th-95th percentile, and the lightest bar the 2.5th-97.5th percentile. Each quantile is calculated from the combined set of 1000 draws from the asymptotic distribution for all studies where the climate variable is temperature (red), rainfall (blue), or anything (grey).

It is visually apparent that most studies have estimated effects to the right of the zero line, meaning there is increased violence in response to climate shocks. Some have estimated effects of 10%, 20% or even larger impacts for each anomalous 1 SD increase in local climate. There is another cluster of studies with estimates closer to and typically

not statistically distinguishable from zero. The shading around each estimate captures the uncertainty around each estimate with 1000 draws from its asymptotic distribution.

In the bottom panel we combine these individual study estimates' asymptotic distributions into overall distributions of estimated effects in the literature. The darker shading on the horizontal lines at the bottom denotes the inter-quartile range of study estimates, and the full horizontal distance, which is generally not visible, captures the 2.5th-97.5th quantile range. The upper dark grey line combines all studies, and shows that the inter-quartile range of the combined effect distribution of all studies runs from close to zero up to around 15% per 1 SD increase in a climate shock.

We also present a number of meta-analysis estimates in Panel A of Table 2. Specifically, we calculate inverse variance-weighted average estimated effects. The overall inter-group estimate suggests that a 1 SD adverse change in climate is associated with a 2.53% (SE 0.59) increase in conflict, and the median estimate is 5.08%. Appendix figure A.1 shows that the meta-analysis estimate remains very stable when dropping one study at a time, suggesting that the effect is not driven by any particular estimate. The average overall effect of 2.53% is far smaller than the 11% average effect estimate on inter-group conflict in S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a), but the effects remain highly statistically significant ($p < 0.01$) and meaningful in magnitude using the expanded sample of studies we consider. The median estimate of 5.08% in the new meta-analysis is smaller than the median estimate of 13.8% in M. Burke, S. M. Hsiang, and Miguel (2015a). Recall that most regions of the world are projected to warm by between 2 to 4 SD's in the coming three decades, so multiplying the updated mean (median) effect 2 to 4 fold implies projected increases in inter-group violence on the order of 5-10% (10-20%) unless human societies can come up with new ways to adapt to climate change.

The change in effect magnitudes appears to be driven by both a different composition of studies in the new analysis as well as our updated statistical approach, which carries out a more uniform re-analysis across all studies. For instance, the meta-analysis inter-group violence estimate is smaller using the updated re-analysis method even when using the sub-sample of studies included M. Burke, S. M. Hsiang, and Miguel (2015a) due to our more unified approach to specification choice and statistical inference. Using only those earlier studies, we estimate a meta-analysis effect of 6.34%, as opposed to an effect of 1.70% among only the new intergroup violence studies added for this chapter.

Such a large reduction in the estimated effect warrants exploration. Figure 8 shows that the composition of studies has changed substantially over time in terms of the geographic and temporal size of the units of analysis, which may have contributed to the large reduction in estimated effects. Studies of inter-group conflict in the previous meta-analyses were much more likely to use countries as the geographic unit of analysis and year as the temporal unit of analysis. With the proliferation of spatially and temporally disaggregated conflict data (most importantly, the ACLED dataset), recent studies have shifted towards sub-country and sub-year units of analysis, which also tend to produce smaller meta-analysis estimates. Inter-group studies with country or larger units of analysis have a meta-analysis estimate of 3.83% as opposed to 2.34% for sub-country studies and year-level studies have a meta-analysis estimate of 5.1% compared to 1.7% for sub-year studies (Table 2). We show in section 3 that the use of shorter

Table 2: Subsample Meta-Analysis Estimates

Sample	Inverse Variance-Weighted Estimate	Standard Error	Median Estimate	N
<i>Panel A: Intergroup</i>				
All	2.53	(0.59)	5.08	47
Earlier Studies	6.34	(1.39)	6.37	22
Recent Studies	1.70	(0.65)	3.35	25
Country+	3.83	(1.65)	3.23	19
Sub-Country	2.34	(0.63)	5.31	28
Year	5.10	(1.19)	5.47	33
Sub-Year	1.70	(0.68)	3.23	14
Temperature	2.45	(0.68)	3.30	26
Temperature+	2.49	(0.68)	4.19	28
Rain	-0.35	(1.55)	7.26	14
Africa	2.97	(0.86)	5.31	20
Africa Temperature	3.93	(1.14)	5.16	7
Non-Africa	2.15	(0.81)	3.24	27
<i>Panel B: Interpersonal</i>				
All	1.90	(0.12)	2.04	27
<i>Panel C: Self-Harm</i>				
All	2.15	(0.16)	1.22	9

Notes: This table presents inverse variance-weighted meta-analysis estimates for different samples. "All" includes all studies for the type of conflict described in the panel title. "Earlier Studies" includes studies that were included in S. M. Hsiang, M. Burke, and Miguel 2013 or M. Burke, S. M. Hsiang, and Miguel 2015a. "Recent Studies" is the complement of "Earlier Studies". "Country+" includes all studies where the spatial unit of analysis is countries or larger geographic units. "Sub-Country" is the complement of "Country+". "Year" includes studies for which the temporal unit of analysis is years. "Sub-Year" is the complement of "Year," and all studies in this group have temporal unit of analysis shorter than a year. "Temperature" includes studies where temperature is the climate variable of interest. "Temperature+" includes temperature, drought, and ENSO studies. "Rain" includes studies where a continuous measure of rainfall is the climate variable of interest. "Africa" includes studies where the entire geographic coverage of the study is within Africa. "Africa Temperature" is the intersection of "Africa" and "Temperature". "Non-Africa" is the complement of "Africa". "Sub-Country" includes studies where the spatial unit of analysis is smaller than countries. Standard errors are calculated under the assumption that errors across studies are uncorrelated.

time periods in particular may have contributed to the reduction in the meta-analysis estimate.

A number of climate variables have been explored in relation to inter-group conflict but temperature and rainfall are especially prevalent. The inverse variance weighed average effect for temperature is very close to the overall estimate, with a 1 SD increase in temperature corresponding to a 2.45% increase in intergroup conflict. Rainfall does not have a statistically significant relationship with inter-group conflict according to our inverse variance-weighted meta-analysis estimate, although the median of the meta-analysis distribution is large at 7.26% (Table 2).

The most common setting for inter-group conflict studies in the meta-analysis is Africa, with over 40% of the sample. The inverse variance-weighted estimate for studies in Africa is a 2.97% increase in inter-group conflict per 1 SD increase in climate ($p < 0.01$). This is slightly larger than the 2.15% estimated for studies outside of Africa ($p < 0.01$). The inverse variance-weighted estimate for temperature in the African sample of studies is notably larger than in the full collection of temperature studies at 3.93% ($p < 0.01$).

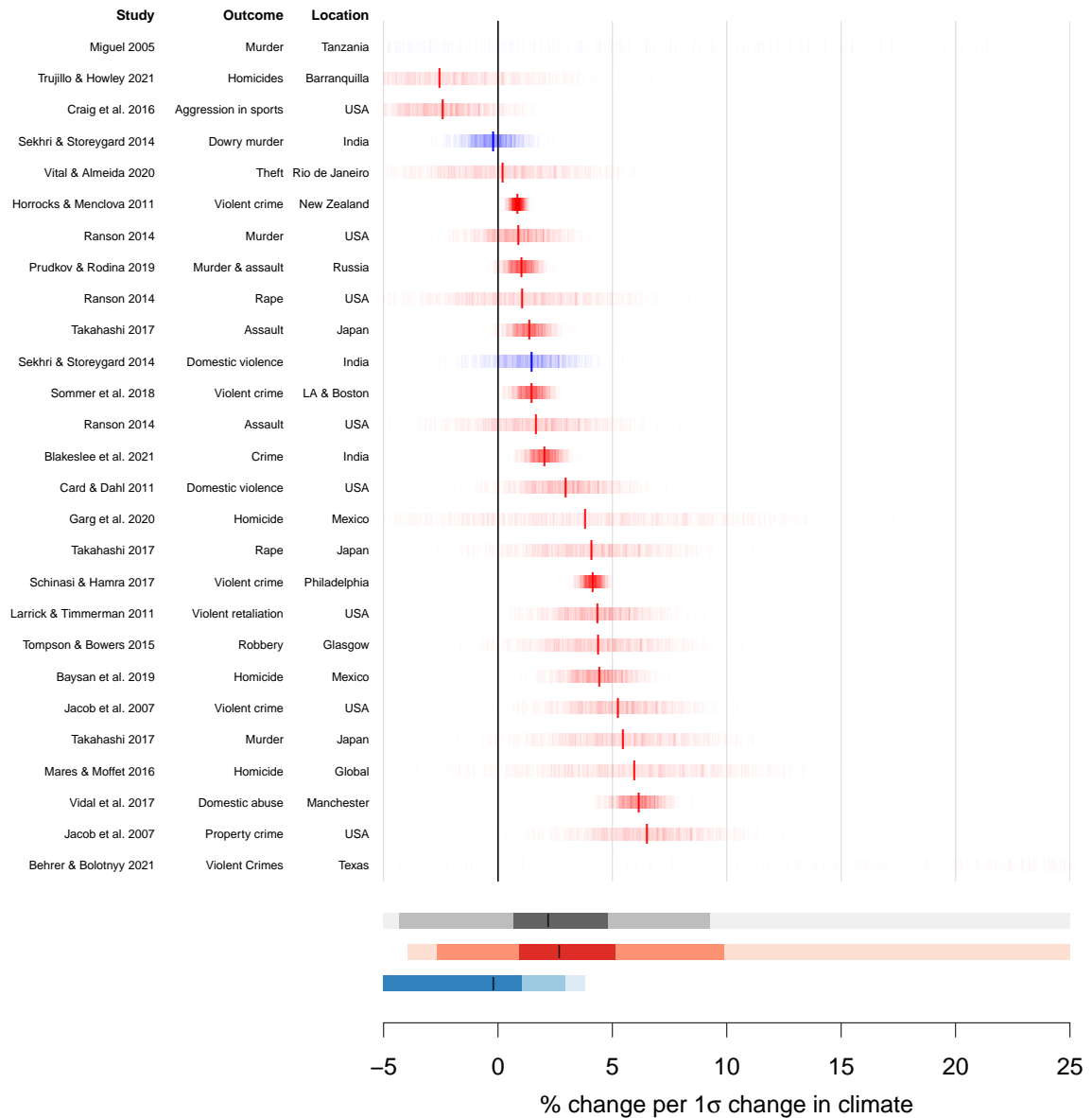
While we do not conduct analysis of non-linear temperature effects, there is some evidence in the literature that extreme cold also increases the likelihood of conflict Iyigun, Nunn, and Qian 2017. Similar non-linearity and non-monotonicity has been found in the case of economic growth M. Burke, S. M. Hsiang, and Miguel 2015b. If growth partially mediates the relationship between climate and conflict, it is feasible that low temperature shocks would also increase conflict incidence.

The results suggest that at the very least, temperature and related phenomena such as drought significantly increase the likelihood of inter-group conflict in a variety of global settings. Even if the magnitude of the implied average and median effects are somewhat smaller than earlier estimates in S. M. Hsiang, M. Burke, and Miguel 2013 and M. Burke, S. M. Hsiang, and Miguel 2015a, they remain large and of substantive importance.

Figure 6 presents analogous results for interpersonal violence studies (N=21 studies and 27 separate estimates), including outcomes such as homicide, armed robbery, and assault, among others. Again, the present meta-analysis includes roughly twice as many studies as found in S. M. Hsiang, M. Burke, and Miguel (2013) or M. Burke, S. M. Hsiang, and Miguel 2015a. Notably, newly included studies use data from many from low- and middle-income settings (including Brazil, Colombia, India and Mexico) whereas the 2013 meta-analysis predominantly featured studies of interpersonal conflict in wealthy countries such as the US. There is much less variety in the climate variable of interest in the interpersonal sample compared to inter-group: all but three studies focus on local temperature variation.

There is once again a range of estimated effects, with most indicating positive effects and a fairly tight cluster around 2%. The inverse variance-weighted meta-analysis indicates that local climate variation (including higher temperatures) tend to increase homicides, armed robbery, and assaults. The mean estimated effect in the meta-analysis

Figure 6: Meta-analysis of Interpersonal Violence Studies

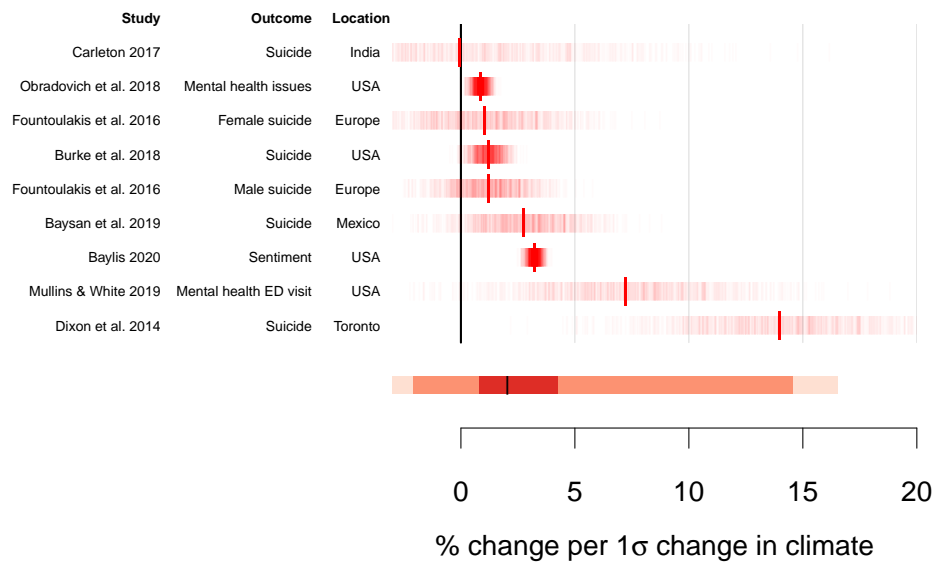


Notes: See notes to Figure 5.

is 1.90% (SE 0.12) per 1 SD increase in local climate, and the median effect is similarly 2.04% (Table 2, Panel B). This is roughly 20% smaller than the comparable estimates in S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel 2015a but is statistically significant (p-value<0.01) and still meaningful in magnitude. Projecting forward a few decades, by 2050 global warming could lead to increases on the order of 4 to 8% in interpersonal violence in the absence of successful adaptation or other changes.

Finally, there is a smaller but growing literature on how higher temperatures affect various forms of self-harm, including suicide or mental health distress, with studies

Figure 7: Meta-analysis of Self-Harm Studies



Notes: See notes to Figure 5.

from India, the US, Mexico, Canada, and Europe (N=8 studies based on 9 estimates, see Figure 7). There are multiple potential channels linking elevated temperatures to self-harm (as we discuss in the next section) including a psychological or physiological response, or effects operating through deteriorating economic conditions.

Overall, the mean increase in self-harm in response to 1 SD anomalously higher local temperature is 2.15% (SE 0.16), which is significant at $p < 0.01$ and broadly similar in magnitude to the mean inter-group and inter-personal violence effect estimates (Table 2, Panel C).

Taken together, there is strong evidence that climate shocks like elevated temperatures lead to more intergroup conflict, inter-personal violence, and self-harm, with effects that are statistically significant and meaningful in magnitude across all three dimensions. One takeaway from the updated analysis is that estimated magnitudes are smaller than they were in earlier meta-analyses, albeit still substantial, due to a combination of different studies included in the meta-analyses (due to the recent explosion of research in this field) as well as our different statistical approach in this chapter which attempted to apply a common econometric model across studies (rather than taking the authors' preferred estimate, as we generally did in the earlier 2013 and 2015 articles). The next section examines how variable the estimated effects are with the use of data aggregated at different spatial and temporal scales, and across econometric specifications that differ in the inclusion of time lags of the key climatic explanatory variables.

3 Lessons for Analysis across Spatial and Temporal Scales

Compared to the earlier meta-analysis work in the S. M. Hsiang, M. Burke, and Miguel (2013) and M. Burke, S. M. Hsiang, and Miguel (2015a) articles, there are far more intergroup conflict studies that utilize finer geographic and time scales, below the level of the country-year which was the modal level of analysis in the earlier meta-analyses. The rise in disaggregated analyses has been enabled in part by the increasing use of data, like the well-known ACLED dataset, that has information at the subnational level and time scales of less than a year.

Figure 8 illustrates the rise in spatially disaggregated studies in Panel a along with its implications on the share of observations (Panel b) and inverse-variance weight (Panel c) in the intergroup meta-analysis estimate at the sub-country level. The share of studies using a unit of analysis smaller than country rose from about 38.1% to 57.7% while the share of inverse variance weight for those studies increased by about 25 percentage points to a total of over 85%. A similar pattern is apparent for growing importance of studies that have time scales of less than a year: for studies included in the meta-analyses of 2013 and 2015 nearly all observations (Panel e) and weight in the analysis (Panel f) is derived from year level studies, while studies with more fine-grained time scales dominate the current meta-analysis presented in this chapter.

A related point (not shown directly in the figure) is that the share of weight in the average meta-analysis effect estimate accounted for by the most statistically precise estimates has slightly increased. Of the studies included in the earlier meta-analysis, the three with the most weight in the analysis — namely, Harari and Ferrara (2018), Baysan et al. (2019), and Hidalgo et al. (2010) — accounted for slightly more than half (53.2%) of the weight. In the current meta-analysis, the three most weighted studies — Breckner and Sunde (2019), Bounadi (2019), and Shaver and A. K. Bollfrass (2022) — received 55.5% of the weight. These patterns raise the question of how analysis at different levels of spatial and temporal aggregation affects results and conclusions regarding the climate-conflict relationship.

In principle, there are a wide range of temporal and spatial scales that could be of interest, and this could vary for different outcome variables. It might be advantageous to focus on highly localized effects (in time and space) if local effects might become diluted at higher levels of aggregation. At the same time, focusing on short-run effects in a small geographic area could lead the analysis to understate true effects that emerge more gradually over months or years with lags, or that spread out to nearby areas due to the natural dynamics of armed conflict. The appropriate scale certainly lies somewhere between studying the climate-conflict link at the kilometer-minute scale and the global-century scale – but where exactly should scholars focus? And how much do results change when using data at different scales?

We examine this issue by combining the Uppsala Conflict Data Program’s Global Event Data (GED) together with the Climate Hazards Center Infrared Temperature with Stations (CHIRTS) data set to form a panel data set covering Africa from 1989-2016, which allows us to estimate comparable regressions at different temporal and spatial scales, importantly with the exact same data and in the same settings; focusing on African societies is natural given that the region has been a major focus of recent research on

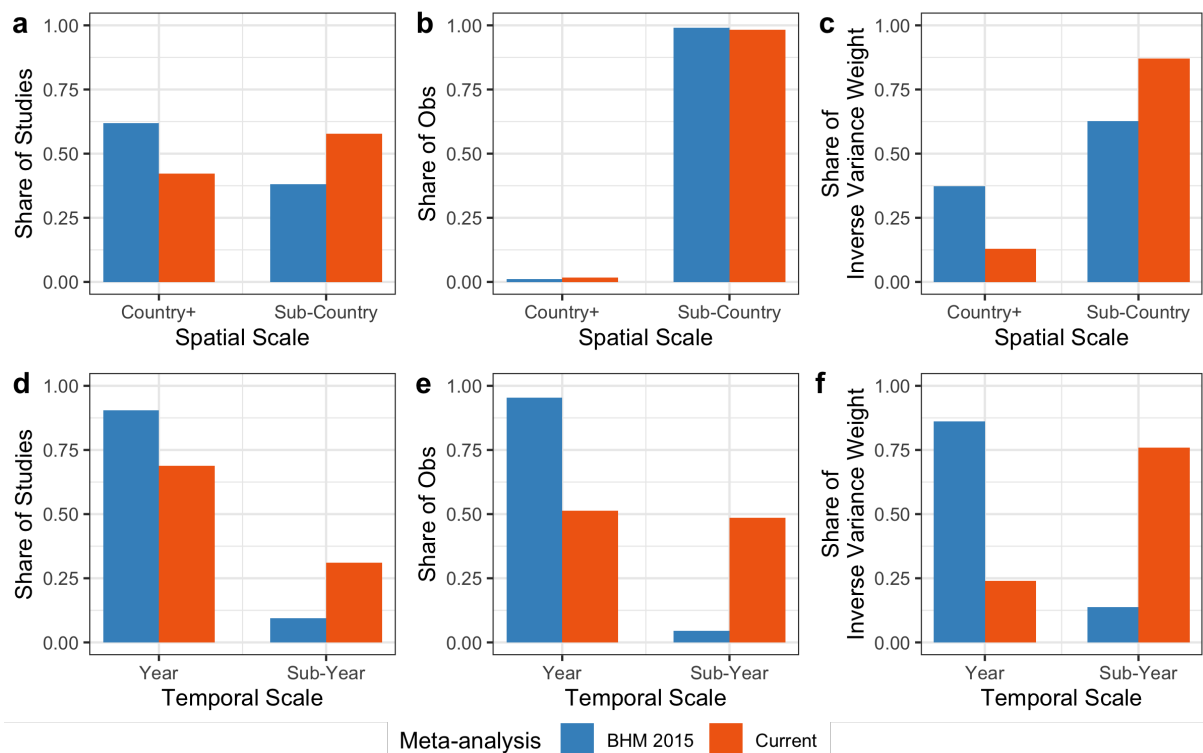


Figure 8: *Notes:* This figure compares the sample of inter-group conflict studies included in the current meta-analysis to the sub-sample included in M. Burke, S. M. Hsiang, and Miguel (2015a). Panels a, b, and c separate studies by spatial unit of analysis, with “Country+” referring to studies where the spatial unit of analysis is country or larger and “Sub-Country” refers to studies where the spatial unit of analysis is smaller than countries. Panels d, e, and f separate studies by temporal unit of analysis. In these panels, “Year” refers to studies where the temporal unit of analysis is years and “Sub-year” refers to studies where the temporal unit of analysis is shorter than years. Panels a and d report the share of studies in each category by meta-analysis. Panels b and e show the number of observations comprising the studies in each category by meta-analysis. Finally, Panels c and f show the share of total inverse variance weights given in each category conditional by meta-analysis using the estimated coefficients and standard errors of the current meta-analysis.

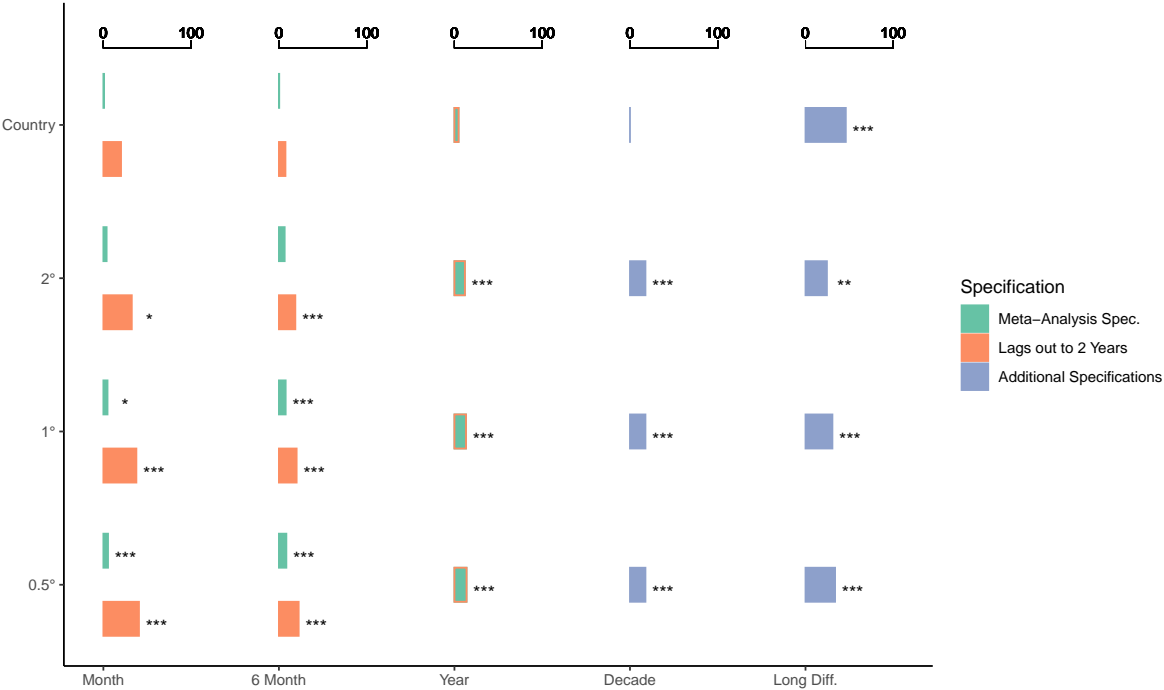
this topic. In other words, this approach enables us to assess the effect of aggregation alone along these two dimensions on estimates (while holding other factors constant). We also examine how effect estimates differ across distinct econometric specifications that account for different numbers of time lags, which turns out to be an important determinant of estimated effect magnitudes.

The results in Figure 9 present estimated temperature effects on intergroup conflict incidence at a range of spatial scales from 0.5 to 2 degrees and up to the country level, and from a time scale of one month, a year, a decade, and to long differences between the 1989-1998 and 2007-2016 averages, so nearly three decades¹. This captures the range of scales commonly found in most intergroup conflict studies in the existing literature (see section 4 on Mechanisms for more details on the data used in specific studies); some interpersonal violence studies have even finer geographic or temporal time frames (e.g., crime rates in a given week at the municipality level). The figure

¹ In separate work not shown here, we also carried out related analysis using spatial first difference regressions. These do not generally yield results similar to the more standard specifications presented here, likely because a small number of mountainous locations exhibit the majority of the variation in spatial differences in temperature.

presents both the relative effect magnitude (the length of the bars) and the level of statistical significance (the stars), and shows how they vary across specifications that do and do not account for seasonality and temporal lags.

Figure 9: Estimated Temperature Impacts on Intergroup Conflict at Different Spatial and Temporal Scales and across Regression Specifications



Notes: This figure shows the results of a set of specifications estimating the effect of temperature on conflict incidence using a single data set (in Africa, as described in the main text). The data set is constructed on a $0.5^\circ \times \text{month}$ scale. Aggregation in time and space is done by averaging for temperature and taking the maximum for conflict incidence. The “Meta-Analysis Spec.” specification includes contemporaneous temperature along with its first lag. For the month and 6 month level, location \times timescale and year fixed effects are included, e.g. location \times month and year, and at the year level includes location and year fixed effects. The “Lags out to 2 Years” specifications have the same fixed effects as the “Meta-Analysis Spec.” specifications, but include lags out to two years prior. For example, at the month level there would be contemporaneous temperature and 23 lags. The orange border around the green “Meta-Analysis Spec.” estimates at Year scale indicate that this specification includes lags out to 2 years. The Decade specifications do not include any lags. The long difference specification uses the difference between mean conflict incidence in 2007-2016 and 1989-1998 as the outcome and the difference between average temperature in the same time periods as the explanatory variable. The plotted estimates are the sum of the estimated effects on all lags of temperature and p-values are calculated from an F-test of the null hypothesis that the sum of the coefficients is 0 using the location-clustered variance-covariance matrix.

This exercise yields several robust patterns. First, the climate-conflict relationship has the same sign (higher temperature leads to more conflict) across all temporal and spatial scales examined here, as indicated by the direction of the bars (none are negative). Second, across all of the scales at the subnational level, the relationship remains highly

statistically significant, usually at $p < 0.01$ (indicated by the three stars), while at the country level the effect is only significant when using the long difference time frame. The documented causal relationship between elevated temperatures and more human violence is not just found at particular spatial or temporal scale, but rather appears quite general across scales.

Third, estimated effect sizes are significantly larger when considering effects over the long difference. Subnational effects also generally increase in magnitude as the time scale lengthens, with decade scale effects larger than year effects, and long difference effects larger than decade effects. (Note that for consistency the year scale estimates account for both temperature in the current year and the previous year, so across two years in all.) In other words, extended higher temperature shocks have much larger effect sizes than shocks that last for a shorter duration. This is an important result in its own right and provides little reason to believe that there has been widespread successful adaptation to higher temperatures in existing data (since adaptation would lead to lower sensitivity and dampened effects following extended adverse climatic shocks).

Fourth, estimated effects are sensitive to the econometric specification, as shown by the results at the 1 month and 6 month scales. In these cases, the top row (the green block) is the effect estimate using a sparse specification that only includes 2 time lags at that scale (in other words, for the monthly results, it includes temperature in the current month and past month as explanatory variables). Most estimated effects in this case are relatively small in magnitude, albeit highly statistically significant in some cases. The second row (the orange block) includes two years of time lags as explanatory variables. When two years of time lags are accounted for, estimated effects are far larger in magnitude (across all spatial scales shown here) than the other specification and are statistically significant for the 0.5, 1 and 2 degree scales. They are also similar in magnitude to (if not somewhat larger than) the estimates generated using data at the scale of 1 year. The divergence in estimates derived from specifications with and without time lags suggests that the common regression specification used in the current meta-analysis may lead to conservative estimates of the effect of temperature on intergroup conflict.

A key implication is that it is critical to account for sufficient numbers of time lags when estimating the climate-conflict relationship, and focusing only on immediate responses in the same month or two (or even a six month period) would lead one to drastically underestimate the actual total effect of temperature shocks on conflict outcomes. There are many reasons for this pattern, including the delayed effect of rainfall on later crop yields (due to growing season timing), as well as the time needed to organize insurgencies and fighting units, and other potential conflict dynamics. Moreover, the effect of extended warming is larger in magnitude than temporary shocks at all spatial scales, an indication that adaptation to changing climatic conditions has generally been limited to date.

To better understand what underlies these patterns, the next section discusses new research evidence on the channels linking climate to violence.

4 Recent Contributions with a Focus on Mechanisms Linking Climate and Conflict

4.1 Overview of literature on mechanisms

There has been a clear increase in the research that investigates not just the overall impact of climate shocks on conflict outcomes (which was surveyed in section 2) but also in the mechanisms that account for this relationship. Understanding the nature of these mechanisms, and how they might help in the design of effective public policy responses, has long been highlighted as a major gap in the literature (since at least S. M. Hsiang, M. Burke, and Miguel 2013). A main point of our discussion in this section is that there has been considerable progress in understanding mechanisms over the last decade, and we survey some of the lessons that have emerged from these studies in this section. Table A.1 contains a list of studies we have identified that contribute to understanding the underlying mechanisms.

In particular, we identify five leading mechanisms behind the climate-conflict relationship: (1) economic mechanisms, such as income, dependence on agriculture; (2) socio-demographic factors such as religion, ethnicity, marriage customs, etc; (3) migration and transportation costs; (4) policy, politics and institutions; and (5) psychological and physiological mechanisms, such as anger, stress, etc. One punchline of the review is that different mechanisms tend to be more important or active in particular settings. So there is not necessarily a one-size-fits-all public policy response to climate shocks, but the growing body of research provides greater insight into which types of factors could matter more in certain settings. This appears to be a useful first step in crafting effective policy responses to counter climate change.

Given the scores of studies in this area (see Table A.1), it is impossible for us to describe the methodology, data and results of each of these articles in any detail. Instead we opt to focus on a smaller number of studies that are particularly distinctive or influential in their approach, spread across these categories, that shed light on more general patterns in the literature. It is also the case that many studies provide evidence on the importance of more than one channel, for instance, some findings noted below indicate that income shocks matter but differentially so, depending on local socio-demographic characteristics or political institutions. In such cases (of which there are several), we note these interactions and overlaps. Readers interested in a more complete listing of studies with summaries of key findings can find it in Table A.1. In this section, we mainly focus on key patterns in the literature (rather than repeating the content in the table), synthesizing findings across multiple studies.

4.2 Empirical Approaches to Understanding Mechanisms

Before discussing key lessons, it is worth taking a short econometric detour. The studies on mechanisms that we focus on in this section typically employ one of two statistical approaches.

First, many of the studies utilize a research design similar to the one we have focused on so far, namely, estimating the effect of climate shocks on outcomes using panel (longitudinal) data, as in Eq. 1. The difference here is many of these studies examine impacts of climate variation on variables that they interpret as mechanisms (or *mediators*) for the effect of climate on conflict, rather than on the ultimate conflict outcome per se. For instance, they might ask how higher temperatures affect local economic conditions (where deteriorating living standards could be a mechanism connecting climate shocks to conflict). Taken together, the effects of climate shocks on multiple mechanisms combine to yield the overall reduced form effect of climate on conflict and violence that is the focus of the meta-analysis estimates (refer back to Figure 3 for an illustration).

Second, and in an alternative approach, some studies instead examine how particular factors affect the strength of the estimated relationship between climate and conflict (in other words, serving as *moderators*) in regression specifications similar to Eq. 1 but including interactions. To illustrate, the analysis might estimate how much less sensitive local crime rates are to higher temperatures in wealthier versus poorer municipalities, where lower sensitivity in richer areas would shed light on the role of economic conditions in enabling or dampening climate impacts. In the table, we distinguish between whether the analysis in an individual study focuses on mediators (the first approach) or moderators (the second), or both. In our view, both approaches provide useful evidence on the nature and strength of the channels linking climate to conflict.

4.3 Key Lessons on Channels

We organize the discussion in this section around four broad patterns in the emerging literature on mechanisms, recognizing that there are many other important findings that we simply do not have space to discuss in detail here (and that may not fit neatly into these general patterns); for those, we again refer the reader to appendix table A.1 with summaries of findings.

Lesson 1: Reliance on agriculture, and shocks to agricultural production and prices, are associated with more violent conflict.

This is one of the largest sub-literatures we identified, cutting across many historical periods and geographies. Using data across countries in the recent period, Goyette and Smaoui (2019) and Salehyan and Hendrix (2014) find that the climate-conflict relationship is significantly stronger in more agriculturally dependent countries. In contemporary African societies, Harari and Ferrara (2018) show that climate shocks (specifically, temperature and precipitation) significantly affect conflict risk. Importantly, this only holds for climate shocks that occur during agricultural growing seasons, direct evidence for the importance of an agricultural income channel.

Historically, Jia (2014) documents that the adoption of drought-resilient crops (here, sweet potatoes) in China during the period 1470-1900 significantly lowers the effect of droughts on conflict outbreaks (specifically, peasant revolts), suggesting the importance of income smoothing mechanisms in limiting the risk of violence. There is a related finding from contemporary Indonesia: Gatti, K. Baylis, and Crost (2021) show that poor rainfall triggers local conflict (across multiple dimensions of violence) in In-

Indonesia but the relationship is dampened where there is good local irrigation infrastructure for the staple crop (rice). This is presumably because local crop yields and economic conditions are no longer as closely tied to the weather when there is improved irrigation.

There is also increasing evidence that shocks to agricultural prices and real wages are important drivers of conflict. E. McGuirk and M. Burke (2020) show that a 1 SD increase in an agricultural production price index in an African sample reduces local conflict by about 17%, while a 1 SD increase in consumer price index increases conflict by 9% (although this latter effect is not significant). This pattern suggests that distributional considerations are important, and that it is important to think through how particular price shocks affect local living standards, for instance, since an increase in staple prices could end up leading to improved local economic conditions for rural producers (even while it reduces real wages for city dwellers). In a study of major urban areas in Africa, Smith (2014) finds that 1 SD increase in food prices as a result of rainfall shocks increases the probability of unrest by 14.3% to 17.8%. Guardado and Pennings (2020) exploit sub-national variation in the onset and intensity of the harvest (i.e., harvest shocks) in three countries (Afghanistan, Iraq, and Pakistan), and show that harvest shocks significantly reduce the probability of insurgent attacks. Since harvest shocks are associated with a positive labor demand shock in their setting, the finding is consistent with the importance of the opportunity cost channel in mediating the climate-conflict relationship.

Agricultural shocks are not just associated with greater risk of intergroup violence, but also affect the likelihood of self-harm. Using decades of suicide data for India, Carleton (2017) shows that elevated temperatures during the agricultural growing season (which can be damaging to crops) are associated with significantly higher suicide rates. Higher temperatures in other times of the year do not have the same effect in her sample (although as already noted in the meta-analysis, higher temperatures are associated with higher suicide rates in a range of societies and time periods).

Lesson 2: The effects of agricultural and other income shocks are shaped by local social divisions, migration options, and political institutions.

Communities and households facing climate shocks may adopt many different coping strategies, one of which could be moving to a different area in some cases. When they do so, a body of research indicates that the nature of social and political institutions is important for determining whether this could lead to violent conflict.

Historically, Pei and Zhang (2014) show that climate induced migration by herder communities into regions inhabited by agricultural communities in ancient China significantly increases the probability of conflict. There are parallel findings in contemporary societies. Eberle, Rohner, and Thoenig (2020) find that a 1°C increase in temperature leads to a 54% increase in the likelihood of conflict in areas populated by both farmers and herders in Africa, compared to a 17% increase in areas populated only by farmers or only by herders. This suggests that competition for resources between these two distinct social groups acts as a mediator of the climate-conflict relationship. This is a major issue in multiple African countries, including in Nigeria, the most populous African country. In related work, Guariso and Rogall (2021) find that a 1 SD increase in rainfall *inequality* across neighboring areas increases the likelihood of ethnic conflict by

50%, and these results only hold for groups that are politically excluded, again highlighting the role of political divisions and institutions in mediating conflict. (See also Uexkull et al. 2016 for a related finding on the importance of ethnic political exclusion in mediating the climate-conflict relationship.)

An important recent contribution in this area is E. F. McGuirk and Nunn (2021), who find that lower rainfall (including drought events) induce transhumant groups, which engage in seasonal migration tied to pastoralism, to migrate to areas inhabited by agriculturalists, leading to elevated rates of conflict. One way to understand this result is that migrating herders need to constantly look for food and water for their livestock, and when climatic conditions are not favorable for them, it leads them to encroach on cultivated land, leading to conflict. Since herders and farmers typically belong to different ethnic and religious groups, this could generate social conflict, although it is important to note that this conflict would at its base have an economic cause (namely, resource scarcity). It may also have a political solution: the authors also find that herder-cultivator clashes in West Africa are dampened when herders have more political power, presumably because in those cases it is easier to reach political deals to resolve or avoid conflicts. This points to the key role of political institutions, and democratic representation in particular, in possibly helping to address climate related stress in the coming decades.

These studies indicate that in some cases, in-migration of herder communities can spark conflict with other groups. However, this pattern does not appear to generalize across all contemporary societies. In a global sample, Bosetti, Cattaneo, and Peri (2021) show that migrant inflows are not associated with increased conflict in receiving locations, and Petrova (2021) documents a similar pattern for migrants in Bangladesh. Importantly, Bosetti, Cattaneo, and Peri (2021) also find that countries with traditions of emigration (higher past flows) are significantly less sensitive to higher temperatures, in terms of generating conflict, than countries with smaller previous diasporas, suggesting that improved mobility can serve as an important safety valve in situations of potential social instability driven by climate shocks.

Yet improved geographic mobility can also increase conflict risk. Rogall (2021) studies the role of rainfall in mobilizing the population for genocide in Rwanda in 1994, and finds that heavier than usual rainfall, interacted with the length of dirt roads (which become impassable with heavy rainfall), reduced militant groups' ability to mobilize civilians to take part in that conflict. This finding suggests that weather may affect logistical decision-making in conflict, at least in the short run. However, the limited causal evidence on this channel makes it difficult to conclude much more. Exploring this mobilization mechanism further may be a fruitful area of future research.

Lesson 3: Public policies that reduce income and employment volatility can dampen the risk of violence.

The findings in Jia (2014) and Gatti, K. Baylis, and Crost (2021) described above already indicated that the ability to smooth agricultural incomes (through the adoption of sweet potatoes in China and improved irrigation in Indonesia) played a role in reducing conflict risk. Several recent studies have detailed how expansion of government income assistance and social protection programs targeted to poor households and communities can play a similar role in dampening conflict along all three dimen-

sions that we consider, intergroup conflict, interpersonal conflict, and self-harm, and we present evidence for all three in turn here.

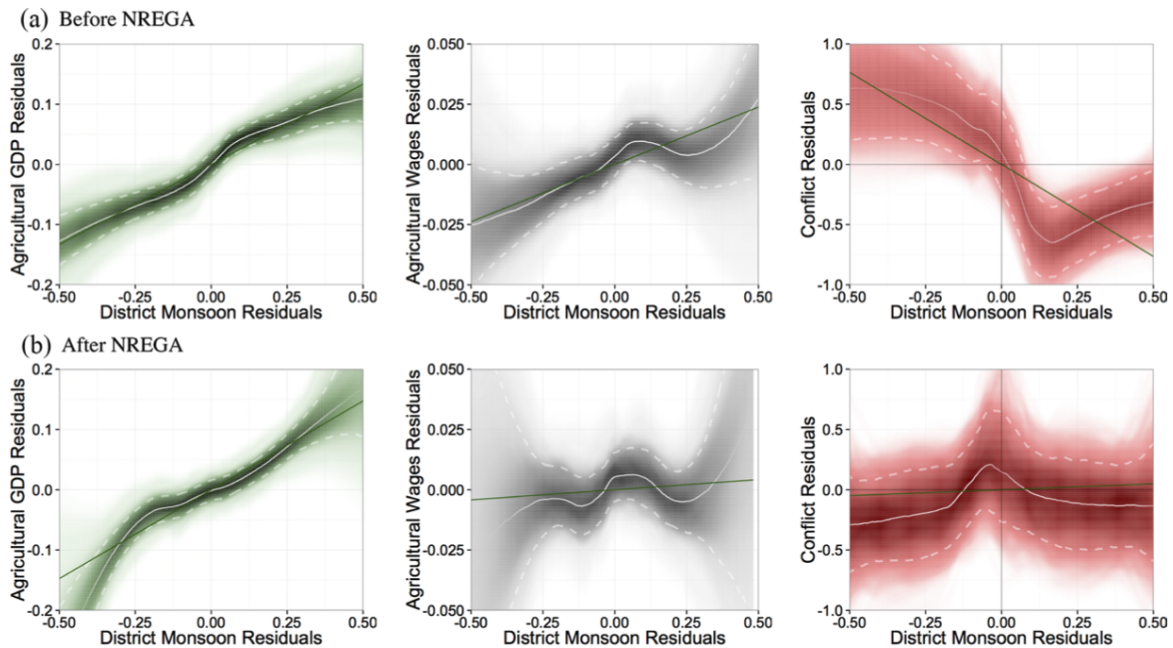


Figure 10: Reproduced from Fetzer 2020, Figure 5: Non-parametric local linear regressions of residualized outcomes on residualized monsoon shocks (i.e., after removing both district fixed effects as well as region by NREGA phase by time effects).

In the context of rural India, Fetzer (2020) first shows that extreme monsoon rainfall shocks are associated with higher levels of intergroup conflict, in terms of local Naxalite rebel violence. He then examines the impact of the gradual roll-out of the National Rural Employment Guarantee program (NREGA), the world’s largest public jobs program in terms of beneficiaries, which number in the tens of millions each month, and which provides paid manual labor jobs (often on public works projects) for low-income adults. He finds that the expansion of NREGA almost completely offsets the effects of these adverse climate (monsoon rainfall) shocks on conflict in India: note the before versus after contrast in the right hand panels in Figure 10, where the largely flat relationship in the bottom right panel indicates little sensitivity to climate shocks.

Garg, McCord, and Montfort (2024) first document that higher temperatures are associated with significantly more homicides (interpersonal violence) in Mexico, consistent with patterns shown earlier in related work by Baysan et al. (2019). Garg, McCord, and Montfort (2024) then examine how the expansion of the pioneering Mexican Progresa conditional cash transfer program affects this relationship; the program targeted poor households for large cash grants provided that they enrolled their children school and made regular health clinic visits. They show that the effect of temperature on homicide crime rates falls to be statistically indistinguishable from 0 in areas receiving the assistance program before rising to previous levels after initially receiving the program.

The decline is presented graphically in Figure 11 reproduced from their paper. Here the horizontal axis captures a time dimension, where the roll out of the Progresa program in a particular area occurs at Year = 0. This is when the cash transfers start in a given

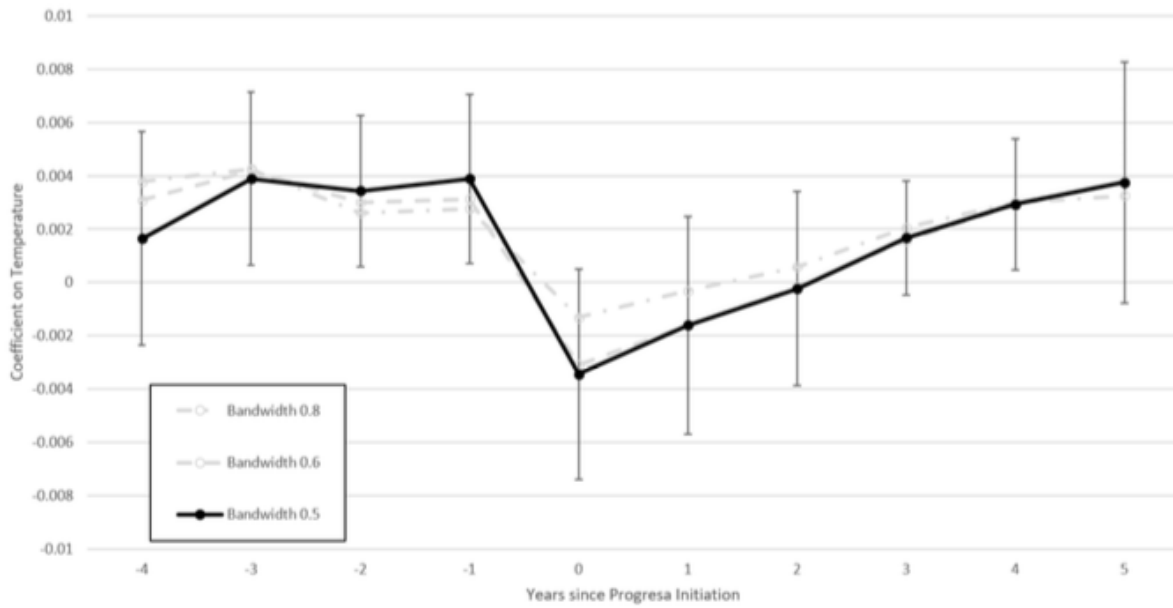
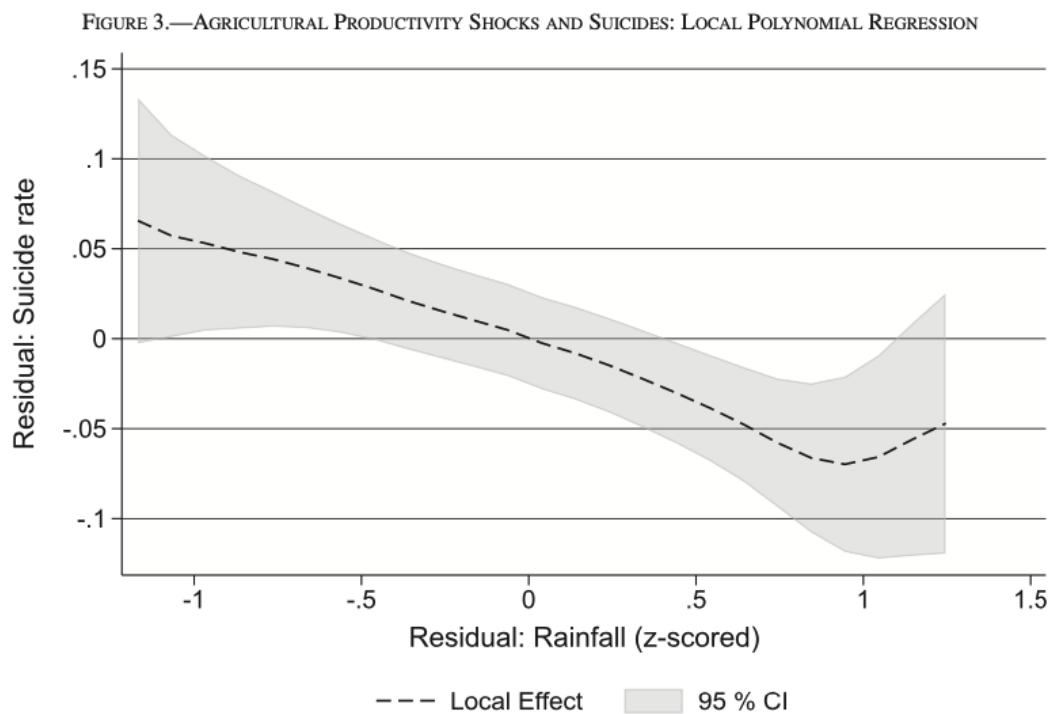


Figure 11: Reproduced from Garg et al. 2024, Figure 3: Event Study of Progresa Program on Effect of Temperature on homicides in Mexico.

area, and this roll out was staggered over time across Mexico. Before the expansion of this social protection program, there was high sensitivity of local homicide rates to current temperature shocks, with effects of around 0.4%, but immediately after the program starts, these effects fall to slightly below zero where before rising to previous levels over the next five years. As in the case of intergroup violence in India, with homicides in Mexico once economic conditions for the poor improve (in terms of levels and lower volatility), there is a much weaker link between climate shocks and local violence, at least in the first few years of the program.

Self-harm outcomes are also sensitive to climate shocks in agricultural communities (as already discussed above in Carleton (2017) in India), and may be affected by government programs. An illustration of the importance of government programs is found in Christian, Hensel, and Roth (2019), which examines suicide rates in Indonesia. Several pieces of evidence highlight the central role of income levels and volatility. First, areas experiencing worse (lower) rainfall levels have significantly more suicides, as indicated by the downward sloping relationship in Figure 12. Second, the authors show that receipt of a large-scale government conditional cash transfer program (Program Keluarga Harapan, PKH) is associated with a sizeable drop in suicide rates, by approximately 18%. This finding holds both in a randomized control trial (RCT) sample as well as when exploiting program roll-out in a difference-in-differences framework. In a main finding, the authors then go on to show that the relationship between poor rainfall and local suicide rates is significantly weaker (less steeply negative) in areas receiving the cash assistance program, falling by approximately two thirds. This provides further evidence that government income support for poor households can play an important role in reducing the risk that climate shocks translate into violence, in this case, into self-harm.

Figure 12: Christian, Hensel, and Roth (2019) Ag productivity shocks and suicides



Notes: Reproduced from Christian et al (2019), Figure 3.

Lesson 4: Independent of income-related mechanisms, there are psychological and physiological channels that link extreme temperature to conflict.

The key role of economic conditions comes through in all of the literature “lessons” noted above, even in the studies of self-harm in low- and middle-income countries (LMICs) that were just discussed (e.g., Carleton (2017), Christian, Hensel, and Roth (2019)). However, there are patterns in the literature that economic conditions cannot explain, most notably the rapid response of both interpersonal violence and self-harm to higher temperatures in richer societies (like the US and other OECD countries) where short-run variation in household incomes are not closely tied to climate drivers. These studies are presented in the meta-analysis discussion above (in Section 2).

There is now also evidence on how people’s behavior and psychology change at higher temperatures from both social media use and from controlled lab environments. P. Baylis (2020a) utilized data from billions of tweets, and analyzed them using natural language processing algorithms, to show that the use of profanity and aggressive language is significantly higher at extremely low and especially at extremely high temperatures. This sheds light on how elevated temperatures in particular may affect social cooperation, cohesion, and trust, all of which would presumably be adversely affected by more aggressive communication styles.

There is a literature (mainly in psychology) that tries to explore how intrinsic psychological or physiological mechanisms are affected by higher temperatures but most rely on correlations or small numbers of subjects rather than research designs similar to those that we focus on in this piece. A notable exception is Almås et al. (2019), which

carries out economics lab experiments in both Berkeley, California and Nairobi, Kenya in which participants were randomly allocated to either normal temperature rooms (at roughly 20°C / 68°F) or high temperature rooms (at 30°C / 86°F) and their economic choices and behaviors were measured over one hour. Many core economic behaviors and preferences (e.g., time and risk preferences) did not change significantly in the hot room relative to the cool room in either site. But the authors do document that participants in the hot room in the Nairobi sample often reacted more aggressively in the Joy of Destruction game (in which they can costlessly and anonymously destroy the endowment of another player), and this finding survives a multiple testing adjustment. This is experimental evidence for a direct psychological or physiological mechanism that emerges at higher temperatures and may contribute to violent conduct, although of course in the lab, there is no actual physical aggression. Echoing the results of several other studies discussed above (including E. F. McGuirk and Nunn (2021)), the temperature effects are more pronounced among individuals who come from politically marginalized ethnic groups in Kenya, suggesting that — whether the underlying channel is mainly economic deprivation or a psychological response — social divisions and political inclusion appear to be important moderators.

5 Discussion

This chapter surveys the burgeoning research literature examining the empirical links between climate and conflict, and updates previous meta-analysis estimates, assesses important methodological issues around the scale of statistical analysis, and discusses recent evidence on underlying mechanisms.

The meta-analysis results reinforce the previous conclusion that rising temperatures and extreme rainfall will contribute to conflict risk across many settings and types of violence. In particular, we survey and carry out a meta-analysis of the exploding literature on links between climate and conflict, a body of scientific evidence that has more than doubled in the last decade since the S. M. Hsiang, M. Burke, and Miguel (2013) *Science* study.

The bottom line conclusion remains qualitatively the same: for inter-group and interpersonal violence, as well as for a new body of work on self-harm, higher than normal temperatures and adverse rainfall shocks are statistically associated with elevated local violence outcomes. This relationship holds across many different geographic settings and types of conflict, and the statistical significance of these relationships (in terms of being able to reject a null effect) has grown since the earlier meta-analyses given the larger sample sizes and broader coverage of recent work. At the same time, the magnitudes of the estimated effect on intergroup conflict is substantially smaller, though they remain substantial and of practical importance given that the world is projected to warm by at least 2 degrees Celsius in the coming decades (IPCC 2022).

A key scientific advance of the recent research in this area is the expansion of evidence on the multiple mechanisms, and associated public policies, that appear to reduce climate risks. One robust pattern is that higher living standards reduce the sensitivity to climate, a finding that we demonstrate across Sub-Saharan Africa in a concurrent

paper (M. Burke, Ferguson, et al. 2024). Related to this, several economic policies that provide greater employment opportunities or boost incomes for households – such as cash transfers – have been shown to greatly reduce the effect of adverse climate shocks in low- and middle-income country settings (especially of note are the results in Fetzer 2020, Garg, McCord, and Montfort 2024, and Christian, Hensel, and Roth 2019). This encouraging evidence points toward concrete public policy approaches and ways forward in this space.

Beyond economic conditions, the new body of research contains more evidence on other specific mechanisms and policies that matter, including socio-demographic factors, migration and transportation, politics and institutions, and psychological and physiological factors, where the precise channels that drive violence appear to strongly depend on the specific context. That said, the study of mechanisms linking extreme climate to conflict outcomes, as well as research on concrete policies that can be shown to reduce conflict risk, remains a frontier research topic with potentially large social value. The design of specific social protection programs — and potentially policies in other sectors — that can reduce the sensitivity of local violence to warming temperatures is a major global priority.

Other directions of interest in this area include: more research on how the effects of climate shocks are moderated by local income levels as well as political institutions (including democratic representation); how climate affects the logistics and organization of conflict; and more detailed projections for what the associated results mean for conflict risk in the coming decades, taking into account more realistic assumptions about the pace and nature of adaptation and other socio-economic and technological changes.

At the same time that there has been some intellectual progress in understanding the issues surveyed in this chapter, the world's failure to slow global warming remains a major concern and threatens to increase conflict risk globally. Moreover, economic growth has stagnated (or become negative) in many low- and middle-income countries since the COVID-19 pandemic started in early 2020, and more recently with the disruptions to global agricultural trade and rising food prices due to the brutal Russian invasion of Ukraine. This deterioration of global environmental and economic conditions raise major concerns regarding political stability and the risk of conflict, violence and crime around the world, given what we now know. We fear that the coming decade could be a perilous moment for global peace, and that it could shine a spotlight on how critical continued economic development will be in allowing poor countries to deal with climate change. More evidence on how best to prevent climate and economic shocks from increasing violence in our societies cannot come soon enough.

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Appendix

Table A.1: Summary of Studies Identifying Mechanisms driving the Climate-Conflict Relationship

Study	Study Region	Dep. Var	Indep. Var	Mechanism	Mech: Type	Mediator / Moderator	Sign	Summary
Salehyan and Hendrix (2014)	165 countries	civil conflict and terrorism	PDSI, precipitation, and temperature	income	agricultural dependence	moderator	-	Less agriculturally dependent societies have weaker link between rainfall and political violence: 1 SD increase in rainfall (measured as average absolute precipitation) leads to 0.39 more battle deaths across all countries. This effect is 10x higher for African countries (vs. Africa), 1.7x higher for countries dependent on Agriculture, and 9.5x higher for countries below < Median GDPpc.
Uexkull et al. (2016)	Africa & Asia	civil conflict	PDSI	income	agricultural dependence	moderator	-	Drought seems particularly harmful in places with high agricultural dependence and for politically excluded ethnic groups. Successive years of drought have large cumulative effects.
Crost et al. (2018)	Philippines	number of casualties, number of violent incidents	rainfall	income	agricultural production	mediator	-	An increase in dry-season rainfall leads to an increase in agricultural production and dampens conflict intensity: a 10 cm increase in dry season rainfall is associated with 0.59 fewer casualties in the following year. By contrast, an increase in wet-season rainfall is harmful to crops and increases the likelihood of conflict (by 0.28 more incidents).
Axbard (2016)	Indonesia	piracy	fishing conditions	income	income	moderator	-	Improvements in fishing conditions - a function of temperature in combination with other oceanographic conditions - induce an income effect that make fishermen select away from piracy. Above median fishing conditions reduce the incidence of piracy attacks by 21%. These effects are driven by areas with slow economic growth in non-fishing occupations, suggesting that the income effect operates through changes in income opportunities.

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Table A.1: Mechanism Papers – continued from previous page

Study	Study Region	Dep. Var	Indep. Var	Mech: Type	Mechanism	Mediator / Moderator	Sign	Summary
Rothler, Blakeslee, and Fishman (2020)	India	Suicide	drought, temperature	income	irrigation, access to credit	moderator	-	The incidence of droughts increases the suicide rate in India by 19.1% - this effect is only driven by (male) farmers, is concentrated during agricultural seasons, decreases with irrigation cover, and increases with farmer indebtedness.
Buhaug et al. (2015)	Sub-Saharan Africa	conflict	rainfall	income	Food production	mediator	null	Rainfall linked to food production as measured by FAO, but not conflict - 1 unit increase in food production per capita lowers #civil conflict events by 0.695; but effect not significant
Jia (2014)	China	peasant revolt	drought, flood	income	resilient crop	moderator	-	The adoption of sweet potato, a weather-resilient crop, halved the impact of extreme droughts on peasant revolts in 15th-20th century China, relative to provinces that did not adopt the weather-resilient crop.
Almer, Laurent-Lucchetti, and Oechslin (2017)	Africa	violent events	SPEI	income	water scarcity	mediator	-	The effects of drought on violent outbreaks is more pronounced in grid cells with water scarcity, measured as less blue water per capita (relative to a long term average). Overall, a 1 SD decrease in SPEI increases conflict by 8.3%, but the effect increases by 1.69x in areas with water scarcity.
Shaver, Carter, and Shawa (2019)	Africa	civil conflict	precipitation	income	non-irrigated land	mediator	-	Replicates Miguel et al 2004: economic growth reduces conflict by 2.25 percentage points; 2.66 percentage points when instrumenting with rainfall x non-irrigated cropland. The study also finds that ruggedness increases the likelihood of conflict by 0.39 percentage points (through smaller shares of irrigated cropland).

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Table A.1: Mechanism Papers – continued from previous page

Study	Study Region	Dep. Var	Indep. Var	Mech: Type	Mechanism	Mediator / Moderator	Sign	Summary
Gatti, K. Baylis, and Crost (2021)	Indonesia	civil conflict	rainfall	income	irrigation infrastructure	moderator	-	Lower rainfall leads to an increase in the number of conflict incidents and the effect is mitigated by irrigation infrastructure: a 1 SD decrease in rainfall increases conflict by 0.29 incidents per district year, and a one standard deviation increase in irrigation capacity reduces this effect by approximately 36%.
Goyette and Smaoui (2019)	global	civil conflict	temperature	income	agricultural potential (land suitability)	moderator	-	A better [worse] endowment in agricultural potential mitigates [exacerbates] the effect of temperature on conflict incidence: in countries with low [high] agriculture suitability (low [high] endowment), a 1°C increase in temperatures increases [decreases] conflict incidence by 3pp [5pp].
Koren, Bagozzi, and Benson (2021)	Kenya	protest	climate shocks	income	Food and water security	moderator	-	Food insecurity and water insecurity together are associated with more conflict.
Eberle, Rohner, and Thoenig (2020)	Africa	Farmer-Herder Conflicts in Africa	temperature	income	resource competition	mediator	-	A 1°C increase in temperature leads to a 54% increase in the likelihood of conflict in areas populated by both farmers and herders, compared to 17% increase in farmer/herder only populated areas, suggesting competition for resources between the two social groups as a mediator of the climate-conflict relationship.
garg_can_2020	Mexico	homicide	temperature	income	cash transfers	moderator	-	Cash transfers (through Progresa) reduce the effect of temperature on crime in Mexico by 75%; without the cash transfers, a 1°C increase in temperature has a 2.1% effect on crime (homicide rates).

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Table A.1: Mechanism Papers – continued from previous page

Study	Study Region	Dep. Var	Indep. Var	Mech: Type	Mechanism	Mediator / Moderator	Sign	Summary
Christiana and Elbourneb (2018)	Europe (ancient roman empire)	mutinities, emperor assassinations	rainfall	income	food scarcity	mediator	–	Lower rainfall adversely affects food availability, increasing likelihood of mutiny among roman troops and hence assassinations of roman emperors: 1 SD lower rainfall increase the occurrence of mutinies by 13.3%.
Guardado and Pennings (2020)	Afghanistan, Iraq, Pakistan	insurgent / militant attacks in month m relative to total attacks in a year	harvest shock (interaction of intensity and onset of harvest)	income	agriculture, employment opportunities	mediator	–	In all three countries, the intensity of conflict is lower at harvest than at other times of the year, with greater falls in areas with larger areas under cultivation: onset of harvest reduces the average number of monthly attacks by around 6%-22% in Iraq, 20% in Pakistan, and 8%-18% in Afghanistan
Raleigh, Choi, and Kniveton (2015)	24 African countries	ACLED conflict	precipitation	income	food prices	mediator	–	Use simultaneous equations to estimate effects of rainfall deviations on food prices and conflict. Negative rainfall shocks increase food prices and increase prevalence of violence; and doubling a food prices is associated with a 13% increase in conflict.
Cohen and Gonzalez (2019)	Mexico	criminal charges	temperature	income	alcohol prices	moderator	–	Higher alcohol prices attenuate the effects of temperature on criminal charges. 18% of all weather-related crimes are triggered by excessive use of alcohol, and 1% higher alcohol prices are associated with 0.5% fewer offences from drunk people.
Harari and Ferrara (2018)	Africa	conflict	SPEI	income; SES	agriculture	mediator	–	1 SD lower SPEI during last year's growing season increases conflict by 8%, but SPEI has no effect on conflict outside of growing season. Ethnic cleavages and low state capacity exacerbate effect of conflict.
Petrova (2021)	Bangladesh	protest	drought	migration	internal migration	mediator	null	A drought shock resulting in lost harvest increases migration likelihood, but migrant receiving areas are not statistically more likely to experience protests.

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Table A.1: Mechanism Papers – continued from previous page

Study	Study Region	Dep. Var	Indep. Var	Mech: Type	Mechanism	Mediator / Moderator	Sign	Summary
Koubi et al. (2021)	Kenya	protest	environmental events	migration (in)	migrants' protest propensity	mediator	+	Individuals who had experienced both gradual or sudden environmental shocks at their initial location are more likely to join and participate in social movements about migrant rights.
Cattaneo and Foreman (2022)	World	Militarized International Disputes	Rainfall	migration	In-migration	mediator	+	1% increase in climate-induced migration increases the probability of (inter-state) conflict in receiving destination by 0.001 pp over a mean incidence 0.13 pp per year.
E. F. McGuirk and Nunn (2021)	Africa	violent conflict	precipitation	migration (in), SES	suitability to both agriculture and pastoralism	mediator	+	Areas bordering transhumant areas are 39% more likely to experience conflict with a 1 SD decrease in precipitation. Greater political power for transhumant groups alleviates the effects on conflict, although aid, agriculture, forestry and land conservation projects do not (if anything, the latter actually slightly worsen the effect on conflict).
Bosetti, Cattaneo, and Peri (2021)	world	civil conflict	temperature and precipitation	migration	migration (out and in)	moderator	out: -; in : null	Out migration serves as a "pressure release valve" and attenuates the effects of climate on conflict. A 1 SD increase in temperatures increases the probability of conflict in low-diaspora countries by 30%. The effect is also higher for low income countries.
Rogall (2021)	Rwanda	Genocide prosecutions	rainfall	migration	transportation costs	mediator	+	Rainfall along dirt roads before start of Rwandan genocide led to less military, and subsequently less civilian, participation by making remote villages inaccessible, thus reducing conflict. Conversely, lower rainfall induced 13 additional deaths from 1 additional external militiaman.

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Table A.1: Mechanism Papers – continued from previous page

Study	Study Region	Dep. Var	Indep. Var	Mech: Type	Mechanism	Mediator / Moderator	Sign	Summary
Chambru (2019)	pre-modern France	social conflicts, subsistence related conflicts	temperature	policy	the local experience of political leaders	moderator	–	One standard deviation increase in temperature increased the probability of social conflicts by about 5.3%; leaders with higher level of local experience were better able to cope with adverse weather conditions (and completely offset the effect on conflict)
Fetzer (2020)	India	conflict	rainfall	policy, income	NREGA	moderator	–	NREGA reduces impact of negative rainfall shocks on income and subsequently conflict by -1.4% (before NREGA 1% reduction in rainfall increases conflict by 1.4%)
Cervellati, Sunde, and Valmori (2017)	world	civil conflict	drought, temperature	psych	disease	mediator	+	Drought and heat waves promote the prevalence of disease vectors, which increase the likelihood of civil conflict by reducing opportunity cost through reduced potential lifetime earnings. 60% increase in conflict with a 1 SD increase in disease environment; effect is 3.6-5 pp higher in the event of a weather shock
Mehra, Stopnitzky, and Alloush (2019)	Uganda		recent exposure to drought	psych	psychological traits relevant to conflict	mediator	+	Droughts lead to 0.23 SD lower Agreeableness, 0.26 SD lower Conscientiousness and 0.11 SD lower Emotional Stability (obverse of neuroticism) - traits that dictate impulse restraint, conscience and aggression. This suggests one possible mechanism through which climatic shocks increase conflict.
Tiihonen et al. (2017)	Finland	violent crime	temperature	psych	peripheral serotonin transmitter density	mediator	+	Low serotonin levels and high ambient temperatures are associated with higher rates of violent crimes in Finland.

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Table A.1: Mechanism Papers – continued from previous page

Study	Study Region	Dep. Var	Indep. Var	Mech: Type	Mechanism	Mediator / Moderator	Sign	Summary
Blakeslee et al. (2021)	India	violent vs property crimes	daily and seasonal variations in temperature and precipitation	psych	psychological responses to daily variations and income responses to seasonal variations	mediator	+	1°C rise in daily maximum temperature is associated with 0.5% increase in the expected crime count on a given day. Violent crimes respond to both daily and seasonal variation in temperatures and rainfall, whereas property crimes only respond to seasonal variation. This is consistent with the existence of both (same-day) psychologically driven and (seasonal) agricultural-income driven impacts of weather on crime.
Younan et al. (2018)	California	aggressive behaviors	long-term daily ambient temperature	psych	socioeconomic status and gender	moderator	+	A 1°C increase in 2-3 year average temperature increases aggressive behavior by 36 percentage points. These associations were slightly stronger among girls and families of lower socioeconomic status but greatly diminished in neighborhoods with more green space
Baryshnikova, Davidson, and Wesselbaum (2021)	LA, NYC, Chicago, Indianapolis	crime	temperature	psych	sleep (deprivation)	mediator	+	suggests that sleep deprivation might be a mechanism based on results on the lags of hourly weather data
P. Baylis (2020b)	US, Australia, India, South Africa, Philippines, Kenya, Uganda	average sentiment	temperature	psych	sentiment (twitter)	mediator	+	below 12°C and above 30°C, a 1°C increase in temperature is associated with decline of 0.09 and 0.23 standard deviations in sentiment
Almås et al. (2019)	Berkeley and Nairobi	destructive behavior	temperature	psych	thermal stress	mediator	+	Participants in the treatment group exhibit a 50% increase in likelihood of destruction relative to control group. These effects are more pronounced among ethnically marginalized participants.

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Table A.1: Mechanism Papers – continued from previous page

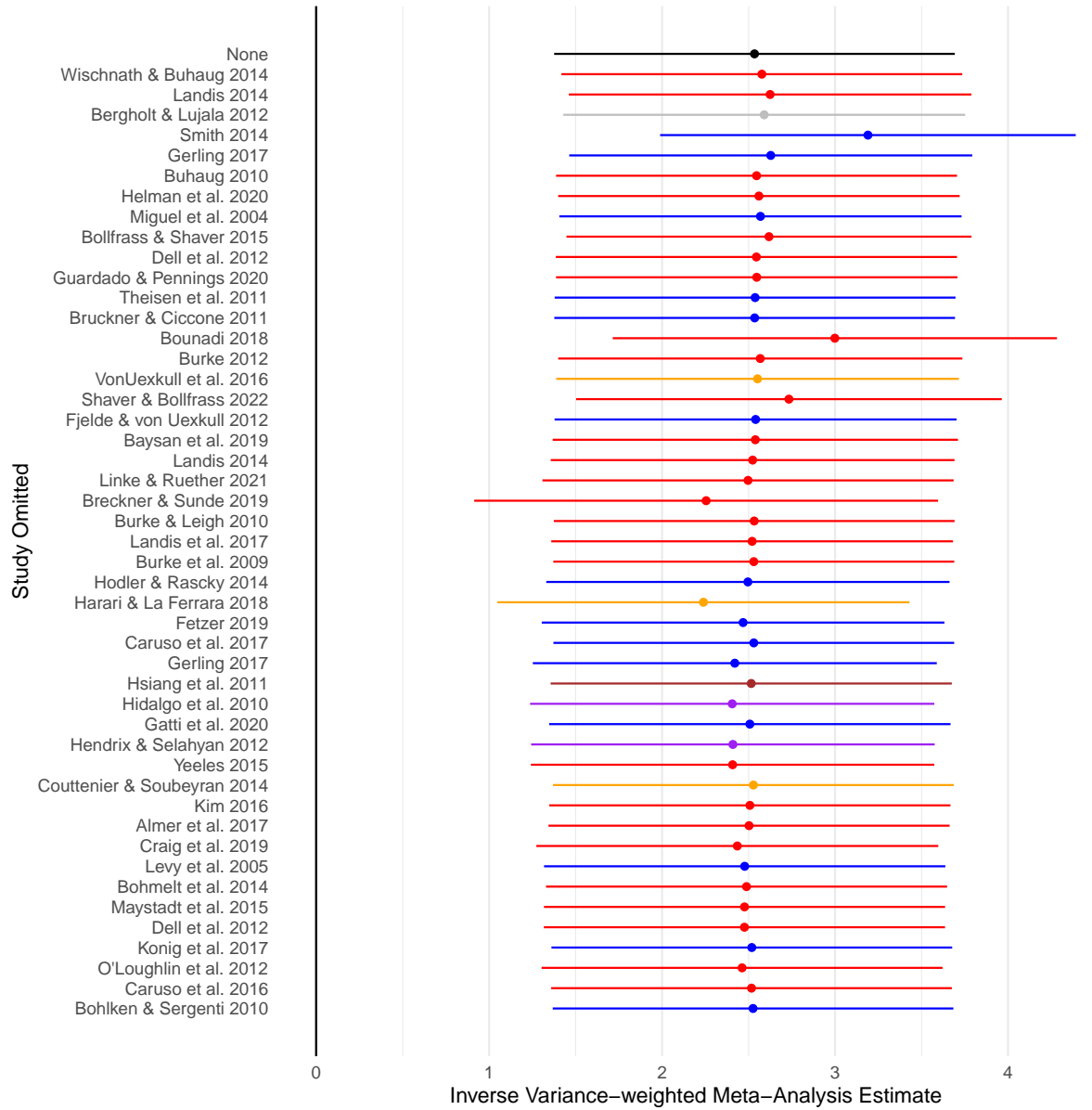
Study	Study Region	Dep. Var	Indep. Var	Mech: Type	Mechanism	Mediator / Moderator	Sign	Summary
De Juan and Wegenast (2020)	East Africa	violent conflict	droughts	psych	1) individual level intra-ethnic and inter-ethnic trust, 2) heterogeneous drought impacts across ethnic groups	mediator	–	Droughts are associated with an increase in both intra and inter group trust (1 SD increase in drought index increases trust by 0.1 SD). However, this effect only holds for low levels of horizontal inequality.
Wilkowski et al. (2009)			temperature	psych	anger	mediator	+	Show two-way causal relationship between anger related words and hot temperatures in a set of lab experiments.
Christian, Hensel, and Roth (2019)	Indonesia	suicide	rainfall	psych, income	mediator: depression induced by agricultural income loss; moderator: case transfers	mediator and moderator	–, –	1 SD increase in subdistrict rainfall (from long-run average) lowers the suicide rate by 0.08 (6% of national baseline) and depression by 0.12 of a standard deviation. cash transfers lower suicides by 0.3 suicides per 100K inhabitants in a year with subdistrict rainfall 1 SD below its long-run mean, but only lower suicides by 0.1 suicides per 100K inhabitants in a year with subdistrict rainfall 1 SD above its long-run mean.
Moreno-Medina (2021)	US	crime	precipitation	SES	religiosity	mediator	null	Religiosity might not affect violent crime: rainfall on sunday morning has no effect on violent crime.
Guariso and Rogall (2021)	Africa	ethnic conflict	precipitation	SES	rainfall inequality	mediator	+	1 SD increase in rainfall inequality causes 4 pp increase in ethnic conflict likelihood, about 50
Rexer (2022)	Nigeria	insurgency (extremist violence)	rainfall	SES	1) female pre-marriage income and expected bride-price 2) male marriage prospects	mediator	+	In the 2SLS models, a one-point increase in the Gini coefficient of brides increases Boko Haram fatalities by an 0.7-1.5 annual deaths (9-20%). This effect is entirely driven by polygamous communities; there is no effect for monogamous communities.

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Table A.1: Mechanism Papers – continued from previous page

Study	Study Re- gion	Dep. Var	Indep. Var	Mech: Type	Mechanism	Mediator / Moderator	Sign	Summary
<p><i>Notes:</i> This table provides a list of papers exploring mechanisms in the climate-conflict relationship found during the course of the search for studies to include in the meta-analysis. Mechanisms explored in this table fall into two broad categories: moderators and mediators. Moderators studies explore a mechanism that alters the climate-conflict relationship. Mediator studies explore a mechanism that acts as a channel through which climate affects conflict. Mechanisms are then categorized into five types (Mech: Type): income, migration, policy, psychology, and social. The conflict dependent variable (Dep. Var) and climate independent variable of interest (Indep. Var) are listed along with the study's citation, the geographic region covered in the study, the sign of the estimated coefficient on the moderator, and a short summary of the paper. Some studies listed only explore potential mechanisms, without exploring conflict related outcomes. For those studies the dependent variable is left unlisted.</p>								

Figure A.1: Leave-one-out Group Conflict Meta-analysis Estimates



Notes: This figure shows inverse variance-weighted meta-analysis estimates and 95% confidence intervals for the entire sample of group conflict studies as well as each subset constructed by leaving out a single study. The x-axis gives the meta-analysis estimates in terms of percent increase in conflict outcome per standard deviation in the climate variable. Studies which estimate the effect of temperature are shown in red, rainfall in blue, rainfall deviations in purple, storms in grey, ENSO in brown, and PDSI or SPEI in orange.