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The Intensifying Effects of Prolonged Climate Change on Conflict, 1400–1900 CE†

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This study investigates the long-run effects of climate change on political instability. We examine the cumulative effects of consecutive periods of temperature change on armed conflict in the long run, which are ambiguous ex ante. The optimistic view is that, over time, people can adapt by relocating to better climates and adopting new technologies (e.g., Nunn and Qian 2011), production processes, or even institutional structures and cultural norms that better suit the new environment (e.g., Buggle and Durante 2021). The pessimistic view is that the adverse effects of climate change intensify and compound over time. This can happen if, for example, food stocks erode, which then cascades into economic and political instability (e.g., Bai and Kung 2011). In practice, adaptation and intensification are not mutually exclusive, and both can occur. Whether the positive or negative forces dominate on net is ultimately an empirical question.

Studying the long-run effects of climate change requires an examination of historical contexts. The period we examine coincides with the "Little Ice Age." This was a period of extreme cooling, when glaciers expanded and seas froze as far south as present-day Turkey. As with climate change today, temperature changes were accompanied by increased variability in precipitation. Historians document that the changes in climate led to large disruptions of agricultural productivity and were accompanied by famines and conflicts (e.g., Ladurie and Bray 1972). Our study investigates this argument with rigorous empirical analysis.

We add to the rapidly growing body of evidence on climate change and conflict reviewed by Burke, Hsiang, and Miguel (2015), which has not examined the interaction of multiple periods of change in the long run. Our results complement recent evidence about the Little Ice Age, such as the relationship between cooling and urbanization (Waldinger 2022). We also add to studies on the short-run relationship between climate and conflict (e.g., Miguel, Satyanath, and Sergenti 2004) and those on the long-run relationship between agricultural productivity and conflict (e.g., Iyigun et al. 2020).

I. Background

Like modern global warming, the Little Ice Age manifested periods of climate change characterized by high variability in precipitation, particularly in the summer, which reduced agricultural output. Cycles of excessive cold and unusual rainfall often lasted for a decade or longer. The drastic reduction in agricultural productivity typically caused surges in food prices and increased the competition for land, which led to conflict. Belligerent neighbors also sometimes viewed the weakening of state capacity caused by climate change as good opportunities for conquest and invasion (e.g., Ladurie and Bray 1972).

The effects of climate change on conflict intensified if the disruptions were prolonged. Historical accounts suggest that continued climate change weakened state capacity, which reduced internal political stability and made states vulnerable to external invasion as well as internal strife. At the same time, there are examples to suggest that afflicted populations were able to adapt with time (Fagan 2000).

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II. Data

For our analysis, we construct a new dataset of all wars and each of their battles that were fought between 1400 and 1900 CE in Europe, the Near East, and Northern Africa and merge these data with historical climate data that were constructed by geologists and climatologists (Mann et al. 2009). The conflict data are taken from Iyigun et al. (2020).[1] These data contain information on the locations and dates of all battles fought during known wars.

Our baseline sample is at the decade and 400 kilometer-by-400 kilometer (km) grid-cell level. All cells contain some land. The grid cells are fairly large. For example, modern day France is approximately four grid cells. The large cell size is necessary to capture meaningful variation in the climate data, which are constructed by extrapolating information from a limited number of weather proxies (e.g., tree rings and fossilized pollen) across space and over time. The large cells also capture spillover effects. For example, disruptions to local agricultural productivity can lead to migration, which can lead to conflict not just in the original location but also the neighboring destinations of the migrants.

Cooling often persisted over long periods of time in our sample. Over a course of 500 years (i.e., 50 decades), the average grid cell experienced 25 decades of cooling. The cell that experienced the least cooling experienced it for 17 decades, whereas the grid cell that experienced the most cooling experienced it 33 decades.

Our main outcome variable is the onset of conflict, an indicator variable that equals 1 if at least one conflict started in a grid cell at any time during the decade. Our sample examines all conflicts fought on land. A conflict is the onset of a battle in a location and a decade. In total, there are 2,792 battles or conflicts in our sample.

III. Empirical Estimates

We examine the difference in temperature between the current decade and four decades ago (i.e., the 50-year change), $\Delta_{t-4}^{t} temp_i = temp_{i,t} - temp_{i,t-4}$. To focus on the effect of large changes in cooling, the main explanatory variable is a dummy variable for a cold shock, $\Delta_{t-4}^{t} C_i$, that takes the value of 1 if the temperature change in the previous five decades is equal to or below the twenty-fifth percentile of the grid-cell distribution of 50-year temperature changes. Analogously, we create a dummy variable for a warm shock, $\Delta_{t-4}^{t} W_i$, that takes the value of 1 if the temperature change within the previous 50 years is equal to or above the seventy-fifth percentile of the grid-cell distribution of 50-year temperature changes. The twenty-fifth percentile of the temperature change distribution is always a temperature decline, while the seventy-fifth percentile is always a temperature increase. We estimate the baseline equation

$$
\begin{aligned}
(1) \qquad y_{it} = {} & \beta_1 \Delta_{t-4}^{t} C_i + \beta_2 \Delta_{t-9}^{t-5} C_i \\
& + \beta_3 \left(\Delta_{t-4}^{t} C_i \times \Delta_{t-9}^{t-5} C_i\right) \\
& + \gamma_1 \Delta_{t-4}^{t} W_i + \gamma_2 \Delta_{t-9}^{t-5} W_i \\
& + \gamma_3 \left(\Delta_{t-4}^{t} W_i \times \Delta_{t-9}^{t-5} W_i\right) \\
& + \Gamma \mathbf{X}_{it} + \alpha_i + \delta_t + \epsilon_{it}.
\end{aligned}
$$

Conflict in cell i decade t, y_{it}, is a function of whether there was cooling between four decades ago and the current decade (i.e., during the past 50 years, 49 years ago to the current year), $\Delta_{t-4}^{t} C_i$, and between nine decades ago and five decades ago (i.e., the previous 50 years, 99 to 50 years ago), $\Delta_{t-9}^{t-5} C_i$, and the interaction of the two variables, the analogous variables for warming, a vector of controls $\mathbf{X}_{it}$ (that include temperature levels in the current decade t and conflict levels 100 years ago), and grid-cell and time-period fixed effects. Because climate change is spatially correlated and our differences contain overlapping decades, we estimate Conley standard errors that allow for spatial and temporal autocorrelation.

Table 1 column 1 presents the baseline estimates. The uninteracted variable for temperature is negatively associated with conflict, which implies that conflict is more frequent in colder temperatures. The uninteracted dummy variables for cold shocks in the current and previous 50 years are small and statistically insignificant. Thus, cooling over an isolated 50-year interval is unassociated with conflict. The interaction

[1] The historical temperature data are reported as deviations from the 1961–1990 mean temperature in degrees Celsius. Iyigun et al. (2020) hand codes conflict data from Brecke (1999) and Clodfelter (2008).

Table 1—The Intensifying Effects of Prolonged Climate Change on Conflict

	Dependent variable: Conflict onset							
			Suitability for old-world staples		War type		Border in cell, 1401–1450	
	Baseline	Grid cells with climate proxies	≤ Median	> Median	Intrastate	Interstate	None	Border
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Cold	0.0010	−0.0294	−0.0011	0.0019	−0.0036	−0.0002	0.0009	0.0070
	(0.0090)	(0.0232)	(0.0050)	(0.0174)	(0.0072)	(0.0084)	(0.0056)	(0.0162)
Cold × *Lag cold*	0.0386	0.1545	−0.0131	0.0766	0.0277	0.0140	−0.0019	0.0681
	(0.0204)	(0.0510)	(0.0117)	(0.0348)	(0.0162)	(0.0159)	(0.0100)	(0.0336)
Lag cold	−0.0106	−0.0355	−0.0012	−0.0195	0.0026	−0.0112	−0.0017	−0.0185
	(0.0089)	(0.0265)	(0.0072)	(0.0167)	(0.0059)	(0.0077)	(0.0045)	(0.0159)
Warm	0.0041	−0.0160	−0.0054	0.0145	−0.0025	0.0045	0.0062	0.0008
	(0.0099)	(0.0282)	(0.0080)	(0.0171)	(0.0060)	(0.0089)	(0.0056)	(0.0163)
Warm × *Lag warm*	−0.0263	−0.0684	-0.0117	−0.0469	−0.0145	−0.0133	−0.0054	−0.0542
	(0.0163)	(0.0554)	(0.0119)	(0.0314)	(0.0095)	(0.0137)	(0.0097)	(0.0281)
Lag warm	−0.0034	0.0141	−0.0054	0.0027	0.0079	−0.0087	0.0038	−0.0077
	(0.0096)	(0.0316)	(0.0055)	(0.0190)	(0.0066)	(0.0085)	(0.0052)	(0.0168)
Temperature	−0.0549	−0.0735	−0.0111	−0.1081	−0.0239	−0.0310	−0.0203	−0.0999
	(0.0217)	(0.0644)	(0.0125)	(0.0512)	(0.0144)	(0.0188)	(0.0110)	(0.0476)
Observations	11,200	2,160	5,400	5,360	11,200	11,200	5,200	6,000
R^2	0.288	0.323	0.090	0.264	0.182	0.228	0.124	0.262

Notes: The unit of observation is a decade and a 400 km × 400 km grid cell. All regressions control for grid-cell and time-period fixed effects and conflict 100 years ago. A cold (warm) shock is measured by *Cold* (*Warm*), a dummy variable that equals 1 if the temperature change in the past 50 years is ≤ 25th (≥75th) percentile of the within-cell distribution of 50-year temperature changes. *Lag Cold* (*Lag Warm*) equals 1 if the temperature change 99 to 50 years ago is ≤ 25th (≥75th) percentile of the within-cell distribution of 50-year temperature changes. In the sample, cold (warm) shocks are always decreases (increases) in temperature. The standard errors allow for spatial and temporal autocorrelation.

coefficient for cooling shows that a place that experiences two consecutive periods of cooling experiences 3.86 percentage points higher incidence of conflict. This implies that the adverse effects of cooling *intensify* over time. The estimates for the uninteracted and interacted warming variables are mostly negative in sign and statistically imprecise. Column 2 shows that the results are similar if we restrict the analysis to grid cells with climate proxies and that the results are not an artifact of extrapolations used to construct the historical climate data. The estimates in columns 3–8 imply that intensification is driven by places that rely on agriculture (the principal component of a grid cell's suitability for the cultivation of wheat, dry rice, wet rice, rye, and barley; column 4), intrastate or "civil" wars (column 5), and cells with a border in 1401–1450 CE (column 8). These results suggest that the negative effects of prolonged cooling were partly due to disruptions in agricultural production and that these disruptions had a larger effect on smaller conflicts in politically unstable locations like border regions. Note that the interaction of the warming variables, which captures the effects of prolonged warming, is negative and statistically significant at the 10 percent level for cells with a border in 1401–1450 CE (column 8). The sensitivity of border regions is consistent with the interaction estimate on cooling. Unfortunately, the historical data are underpowered to provide precise estimates of prolonged warming across samples.

IV. Conclusion

This study shows that large changes in temperature are uncorrelated with conflict but consecutive and prolonged drops in temperature are positively associated with conflict. This is consistent with conventional wisdom that societies and economies are able to adapt to a certain amount of environmental change. But if climate change is prolonged, then the disruptions that they cause can accumulate and lead to political instability.

Our estimates are specific to our context. We study times and places that were mostly cold relative to the optimal temperature for economic production where cooling was detrimental. Nevertheless, the main insight of our study, that intensification dominates adaptation if climate change is prolonged, is generalizable. Our results suggest several promising avenues for future research. The first is to obtain higher quality historical data to more precisely estimate the long-term effects of climate change. The second is to study the mechanisms and pathways of how prolonged change leads to increased political instability.

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