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Climate Change, or Climate Shocks: What Really Triggers Civil Conflicts?

Sherin Khalifa
Svetlana Petri
Christian Henning

Department of Agricultural Economics
University of Kiel

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Sherin Khalifa
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About the authors:
Sherin Khalifa is a research assistant at the Institute of Agricultural Economics, University of Kiel, Germany. The disputation of her phd in political economy took place in November 2020, Kiel. The focus of her phd thesis is on the linkages between climate change, economic development, and civil conflcit
Svetlana Petri is a doctor in political economy.
Christian Henning is professor and chair of agricultural economics, University of Kiel, Germany.
Corresponding author: skhalifa@agric-econ.uni-kiel.de

Abstract

This paper provides an analysis of the impact of extraordinary climate shocks on the incidence of civil conflict using cross-country panel data from Africa and the Middle East (1981 to 2015). We find that: (i) The estimated impact of climate shocks (mainly temperature effect) on economic growth rate and domestic food production ranges from 3 to 5% compared to the estimated impact of temperature growth 47%. (ii) We identified a direct impact of climate shocks on the incidence of civil conflict, where this impact is similar in magnitude to the negative impact of rainfall growth on conflict (3-4%). (iii) We confirmed the negative link between conflict and both economic indicators, conflict begets next conflict, the positive impact of good governance and polity IV estimates, and the freshwater availability on reducing the risk of conflict. Concluding that the main effect of climate comes from the temperature growth effects and it is not extreme shocks that drive economic declines, which indicates that the climate rather operates in a non-linear process.

Keywords: Climate shocks, civil conflict, economic development

1 Introduction

Scientists have provided evidence that climate change negatively affects economies and people, and significantly contributes to their involvement in disasters and armed conflict. In a previous part of this research, we have proved existing findings in the literature (e.g., Miguel et al. (2004)), that climate variation[1] has a significant impact on economic performance and the incidence of civil conflict. We have confirmed empirically (like Dell et al. (2012)) that higher temperatures contribute to climate variability more than decreased precipitation. Our data shows that a one percentage point change in the year-to-year temperature averages lead to a 0.31 pp reduction in economic growth rate and 0.23 pp in food production over the period 1981-2015. According to the estimated impact of temperature on economic indicators, some countries that currently have annual income growth of 1 to 1.4%, in the next 32 years, will not be able to achieve any income growth due to temperature changes. The sustained increase in temperatures shows devastating effects on cross-country economic performance over time. Dell et al. (2012) observed for each 1 Celsius degree increase in temperature a decline in per capita income of about 8 percent. We have identified a direct impact of climate through rainfall growth on the risk of civil conflict. Additionally, we confirmed the most robust finding in the literature that economic growth rate (Miguel et al., 2004) and domestic food production are negatively related to the incidence of civil conflict. However, estimating the impact of climate change using annual percentage change of rainfall and temperature following the method of some highly recognized studies in the literature (the previously mentioned study of Miguel et al. (2004)) has been criticized, for instance, by Ciccone (2011).

Using the annual percentage change of precipitation does not provide sufficient information about whether a wet year is a year with heavy rainfall, or just a wetter year than the previous one (mean reversion). To address this valid criticism, in this paper, we perform a more fine-grained analysis and focus instead on the effects of a true climate shock, which we identify at different levels of deviations from the long-term mean of climate variables. Moreover, to better capture the effect of occurred shocks, we define in which direction constructed shocks deviate from their respective historical long-term mean. The importance of taking into account precipitation deviations that may affect in both directions when estimating the impact of climate shocks is also emphasized by Papaioannou and deHaas (2015).

We suppose that positive or negative extreme climate shocks, lead to higher levels of conflict incidence, either directly or through economic reductions. Therefore, in this paper, our main aim is to estimate the effect of medium and extreme climate shocks compared to annual relative changes in weather variables from the previous year in selected model specifications.

[1]The relative change from previous year in rainfall and temperature variables

In the following section, we introduce data and methods. In section 3, we present empirical results. Section 4 discusses results and conclusions.

2 Data and methods

2.1 Data and measurement strategies

For estimates, we use our new cross-country panel data including 59 countries from Africa and the Middle East for 1981 to 2015, which contains data on conflict, climate, economic, political, and environmental variables.

1. **Climate variables**
   Data on annual average temperature (Celsius degree) and rainfall levels (millimeter) come from World Bank Climate Change Knowledge Portal (2018). We use different measurements for climate change as follows:
   To observe relative change from previous year in rainfall and temperature variables, we follow Miguel et al. (2004):
   $\mathbf{gr\_var(it)} = \frac{var(it) - var\_lag1}{var\_lag1}$.
   To construct shock variables, we derive annual climate deviation variables from their long-term mean in each country over the period 1981-2015 divided by standard deviation from their respective mean over 35 years, using the following formula:
   $dev.Xit = (Xi, t - \bar{X}i)/\sigma i$
   Where X it is the annual rainfall or temperature in country i time t, and $\bar{X}i$ denotes to the historical long-term mean of each country, and σi is the standard deviation of each country long-term respective mean. The temperature deviation data ranges from -3.03 to 3.18, deviation has a mean of 0.03, and a standard deviation of 0.98. While normalized annual rainfall data ranges from -2.69 to 3.76 and has a mean of almost zero and a standard deviation of 0.99.

   1. To consider that there is a shock in the constructed deviation variables, we define the direction of deviation (positive or negative) and classify two shock thresholds (1 indicates medium shock and 2 extreme shocks). Accordingly, the value of climate shock variables in-country (i) and time (t): ranging from -2 to +2, take four values: those greater than 1 and less than -1, greater than 2 and less than -2 excluding the effect of observations outside these thresholds. The separation of the effects of positive and negative shocks is thought to further explain existing relationships.

   2. Furthermore, we include the impact of observed shocks over lagged two to five previous years to better understand the dynamics of shocks on economic conditions and conflict risk (see the summary table of variables).

Data on other climate variables: water indicators come from FAO (2017), which are available for five-year periods from the 1980s for most countries of our sample. Including water stress indicator which is known as water withdrawal intensity. water_1km2 is the average annual level of freshwater withdrawal (calculated averagely over each decade) divided by country area as:
water_1km2= 10^6 x *wasser_total/area.km2*, in 10^3 m^3/km2.
For more information see the summary of variables in Appendix A5.

2. **Economic development indicators**

(i) Gross Domestic Product per capita estimates in constant price-US dollars(UNSD, 2020) [2]. We estimate the growth effect of GDP per capita observing changes from previous year (gr_gdp_c_con(it) $=\frac{gdp\_c\_con_{it}-gdp\_c\_con\_lag_{it}}{gdp\_c\_con\_lag_{it}}$).

(ii) Food production index represents the aggregate volume of agricultural production for each year compared to the base period 2004-2006, covers food crops that are considered edible, and contains nutrients. Coffee and tea are excluded because, although edible, they have no nutritive value, from the Food and Agriculture Organization of the United Nations (2016).
(iii)Time series of oil exporter status (% of merchandise exports) (World Bank, 2016).
(iv) Total merchandise trade of a country exports to the world in US dollar at current prices from the The World Trade Organization (2016).

3. **Conflict data**

For the conflict incidence indicator, which subsumes outbreak of a conflict and continuation of a conflict that results in at least 25 battle-related deaths each year, we use the UCDP/PRIO Armed Conflict Dataset, a conflict version 18.1. (Themnér et al., 2018)[3]

4. **Political Indicators**

We include the impact of political regime type (Polity IV) on the incidence of civil war. (i) Polity IV scores for each country on a range from -10 (full autocracy) to +10 (full democracy). Regimes that fall into the middle of this spectrum are called

[2]UNSD (2020) make available a complete and consistent set of GDP per capita time series, from 1970 onwards of the main National Accounts aggregates of all UN Members States and other territories in the world for which National Accounts information is available, GDP per capita estimates expressed either in current or constant price-US dollars. http://data.un.org/

[3]The UCDP/PRIO armed conflict, developed by the Uppsala Conflict Data Program (UCDP) at the Department of Peace and Conflict Research, Uppsala University in Sweden and the International Peace Research Institute in Oslo, (PRIO) for download: http://ucdp.uu.se/downloads/.

anocracies. The source is the project of Roser (2019), based on Polity IV Project (2013) and Wimmer and Min (2006). We transformed these scores to be instead on a range from 1 to 20 for easier interpretation of coefficients. (ii) Second, we include the impact of transition or stability in the political system "strength_gr_polityiv" by observing changes in absolute terms from the previous year in Polity IV scores when there is a shift in the regime either toward democracy or backward to the autocracy (strength_gr_polityiv= *polityiv_sh_tr - polityiv_sh_tr_lag_1*).

(iii) Voice and accountability indicator: percentile rank among all countries (ranges from 0=lowest to 100 = highest), reflects perceptions of the extent to which a country's citizens can participate in selecting their government, as well as freedom of expression, freedom of association, and a free media. The source is World Bank (2014).

5. **Other country characteristics**
   Such as agricultural land (% of land area) refer to the share of land area that is arable as defined by the FAO, under permanent crops and pastures. Land abandoned as a result of shifting cultivation is excluded. Arable land (hectares per person) (World Bank, 2016). Population (World Bank, 2018).

2.2 Methods

We examine the relationship between climate change (annual climate variations and shocks, water stress, and water availability) and the risk of civil conflict, either indirect through economic development applying instrumental variable approach like by Miguel et al. (2004); Ciccone (2011) or directly. The impact of climate change in country i and time t on economic growth rate (Miguel et al., 2004) and on the food index (Buhaug et al., 2015) is first estimated applying Ordinary Least Squares (OLS) equations number (1) and (2) using rainfall and temperature variables (growth and shock effects) as instruments with other controls related to economy and conflict. We include in all regressions country-fixed effects to capture time-invariant country characteristics that may be related to conflict and we include country-specific time trends to capture additional variation.
The first-stage equations (1) and (2) estimate the relationship between economic development (economic growth rate and Food Index), and weather conditions with other controls, with a vector X'_{it} of instruments as follow:

$$gr\_gdp_{it} = a_i + bX'_{it} + d_i year_t + e_{it}, \tag{1}$$

$$food\_index_{it} = a_i + bX'_{it} + d_i year_t + e_{it}, \tag{2}$$

country fixed effects a_{ji} and country-specific time trends $year_t$, to capture time-invariant country characteristics and additional variation over time, respectively. The error term e is allowed to be correlated across years for the same country in all regressions.

In the second step model, we use Dynamic Panel Data estimators (DPD) based on GMM estimator to estimate the effect of economic outputs from the first stage on the incidence of civil conflict together with other climate and political variables. We consider the impact of lagged conflict as an explanatory variable on the incidence of civil conflict since the impact of any shock on conflict may differ depending on whether the country is already experiencing conflict. In equation (3) we estimate our model with DPD based on GMM as introduced by Hansen (1982) and implemented by Roodman (2009) in the STATA-package xtabond2. This estimator allows the inclusion of lagged dependent variables (Roodman; 2009; Arellano and Bover; 1995; Blundell and Bond; 1995). To ensure that the estimator is robust to heteroskedasticity, we use the option robust on the command xtabond2.

$$conflict_{it} = \alpha_i + \beta \cdot gr\_gdp_{it} + \gamma \cdot food\_index_{it} + \delta \cdot X'_{it} + \sigma_i \cdot year_t + \epsilon_{it}. \qquad (3)$$

3 Empirical Results

In the model specification (presented in Table 1) which includes the impact of positive and negative shock thresholds of climate deviation variables over time, the first stage OLS (regression 1 and 2) show climate change impacts on economic growth rate and domestic food production. The effect of rainfall on economic growth rate is significant only through negative medium shocks (estimated coefficient: 3.9%). Whereas the effect of temperature, both positive and negative temperature shocks, is significantly correlated with the GDP growth rate (coefficients 3-5%). However, a greater impact is observed through growth temperature in year t (coefficient estimate of 47%). Additionally, our model yields other statistically significant coefficients for economic growth rate, positive on total trade exports, the share of agricultural land, and negative on political transition indicator. These correlations are consistent in the significance level among different econometric specifications. Domestic food production is affected significantly positively only by the impact of negative medium shock in temperature (coefficient estimate of 3.5%) and negatively by water stress with a coefficient of 0.07%.

In the second stage model, we assess the impact of linearly estimated economic outcomes from the first stage regressions adding various control variables on conflict (Column 3 of Table 1) applying GMM. The findings are straightforward and confirm (i) Negative relationships between both economic indicators, economic growth rate and domestic food production index, and conflict. (ii) The previous conflict begets the next conflicts. (iii) A direct impact of climate on conflict. Besides, the model yields expected negative and significant signs of control variables; freshwater withdrawal, Polity IV, and accountability on conflict. These control variables show consistent and significant signs with the incidence of conflict in all tested econometric specifications. Out of all included climate variables, growth in rainfall shows a consistent and significantly negative impact on the incidence of civil conflict in all tested model specifications for this research. Regarding climate shock effects presented in column 3 of Table 1, medium positive rainfall shocks show significant positive effects on the incidence of civil conflict, whereas medium positive temperature shocks show negative effects on the incidence of civil conflict.

In a similar model specification (results are reported in table 4 in the appendix), we control for the impact of lagged year-to-year temperature and rainfall variables to test whether a change in weather this year has an impact on the food production and economic growth rate next year (as by many, e.g., Miguel et al. (2004); Ciccone (2011)), and whether the inclusion of lagged growth effects changes type of already existing relationships. The model yields a significant impact also for lagged growth temperature on the GDP growth rate, but the size of the coefficient of growth temperature in time (t) remains greater, and all other relationships remain consistent in statistical significance.

Table 1: Annual climate shocks impact. Dependent variables: Economic growth rate, Food Index in the OLS, and Civil Conflict $\geq$ 25 Deaths/ year in the GMM

	(1)		(2)		(3)	
	GR_gdp_c_con		food_index		any_prio	
GR_oil_exp_wdi	0.00000119	(0.623)	-0.00000210	(0.289)		
GR_trade_exports	0.111***	(0.000)	-0.0148**	(0.027)		
agri_land	0.00387 *	(0.058)	0.0142***	(0.000)		
arable_land	-0.264 *	(0.070)	0.465***	(0.000)		
water_stress	-0.0000112	(0.914)	-0.000735***	(0.000)		
strength_gr_polityiv	-0.00673***	(0.001)	-0.00245	(0.147)		
GR_temp	-0.470**	(0.004)	-0.0618	(0.645)	0.185	(0.489)
GR_rainfall	-0.0167	(0.121)	-0.00621	(0.483)	-0.0332**	(0.020)
water_1km2	0.0000927	(0.931)	-0.000334	(0.704)	-0.00613**	(0.003)
Polity.IV_SH_tr	-0.000206	(0.879)	-0.00838***	(0.000)	-0.00553**	(0.048)
Accountab	0.000670	(0.422)	0.000584	(0.393)	-0.00363**	(0.026)
urban_pop	-0.00175	(0.460)	0.00483**	(0.013)	0.00815	(0.142)
rain_dev_Threshold=1	0.0396***	(0.000)	0.000803	(0.926)	0.0420**	(0.032)
rain_dev_Threshold=2	0.0000782	(0.997)	0.0244	(0.178)	-0.000206	(0.996)
rain_dev_Threshold=3	-0.0110	(0.285)	-0.0168**	(0.046)	0.0202	(0.297)
rain_dev_Threshold=4	-0.0230	(0.360)	0.000765	(0.970)	-0.0317	(0.550)
temp_dev_Threshold=1	-0.0138	(0.198)	-0.00439	(0.618)	-0.0349**	(0.049)
temp_dev_Threshold=2	0.0481 *	(0.064)	-0.00317	(0.881)	-0.0587	(0.205)
temp_dev_Threshold=3	-0.0256**	(0.018)	0.0315***	(0.000)	-0.0177	(0.458)
temp_dev_Threshold=4	-0.0287	(0.192)	0.0360**	(0.046)	-0.0498	(0.398)
L.any_prio					0.364***	(0.000)
L2.any_prio					0.0927 *	(0.051)
GR_gdp_c_con					-0.144**	(0.023)
food_index					-0.158**	(0.005)
FE and time effects	yes		yes		yes	
Constant	-0.173	(0.213)	-0.392***	(0.001)	1.084	(0.139)
Observations	1994		1994		1871	
Adj R-squared	0.11		0.86			
F	2.845		91.13			
AIC	-2005.221		-2798.827		-5028.188	

p-values in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$

We now turn to study whether the impact of climate shocks is more severe on economic development and the incidence of civil conflict when in a country the number of positive or negative climate shocks observed over the past two to five years in a row (number of shocks in the past) is higher. For this purpose, the results of the econometric specification that include the effects of the number of shocks in the previous period on the central variables and the civil conflict in time t are presented in Table 2. The clear evidence is that climate affects economic development through temperature; the OLS regressions show that each 1 Celsius degree change in growth temperature reduces 28,8% of economic growth rate and 36% of domestic food production. Even for shock variables, the dominant effect comes from temperature shocks, where the number of negative temperature shocks observed over the previous two years shows a significant impact on the economic growth rate and the food

index, 2.9% and 4.9%, respectively. However, the effect of temperature shocks is again less in magnitude than the growth effect. For the GMM model 3, we find that results are broadly consistent in statistical significance with displayed results in Table 5, except for the effect of rainfall. The direct impact of rainfall on the incidence of civil conflict instead depends on the number of negative rainfall shocks that occurred in the previous two years in country i time t. We also have tested this model specification including the occurred positive or negative climate shocks over the previous 5 years period (Table 5 in Appendix A5). All established linkages survived. The consistent conclusion for the impact of the number of climate shocks is that negative and positive rainfall shocks in those countries which experienced four, and five years of shocks, respectively, show negative significant coefficients on the incidence of civil conflict. However, it remains difficult to explain the sign and the significance of all these effects, because the total effect is distributed.

Overall, although the estimates of the first paper and the present one are based on different model specifications, mainly different measures of climate change, the results are largely compatible with each other. Our empirical analysis links an increase in temperature and growth in rainfall, with a lower economic growth rate and incidence of civil conflict, respectively, consistent almost to the inclusion of all model specifications and in the significance level.

Table 2: Impact of Observed climate shocks over previous two years on economic development in the OLS, and civil conflict $\geq$ 25 deaths/ year in the GMM

	(1)		(2)		(3)	
	GR_gdp_c_con		food_index		any_prio	
GR_oil_exp_wdi	0.00000102	(0.663)	-0.00000183	(0.349)		
GR_trade_exports	0.111***	(0.000)	-0.0107	(0.110)		
agri_land	0.00447**	(0.030)	0.0152***	(0.000)		
arable_land	-0.240	(0.108)	0.345**	(0.006)		
water_stress	-0.0000150	(0.884)	-0.000753***	(0.000)		
strength_gr_polityiv	-0.00638**	(0.002)	-0.000473	(0.780)		
GR_temp	-0.288 *	(0.061)	-0.362**	(0.005)	0.0638	(0.806)
GR_rainfall	-0.00216	(0.838)	0.00191	(0.828)	-0.0155	(0.265)
water_1km2	-0.000221	(0.835)	-0.000912	(0.300)	-0.00577**	(0.005)
Polity.IV_SH_tr	-0.00107	(0.441)	-0.00985***	(0.000)	-0.00519 *	(0.059)
Accountab	0.000528	(0.519)	0.000836	(0.220)	-0.00374**	(0.021)
urban_pop	-0.00308	(0.241)	0.00621**	(0.004)	0.00877	(0.102)
count_T_neg_shock	-0.0294**	(0.035)	0.0495***	(0.000)	-0.00208	(0.943)
count_T_pos_shock	0.0132	(0.358)	0.00112	(0.926)	0.00240	(0.908)
count_R_neg_shock	-0.000555	(0.969)	0.0190	(0.110)	-0.0492 *	(0.059)
count_R_pos_shock	0.00667	(0.642)	0.0126	(0.292)	-0.00890	(0.740)
L.any_prio					0.367***	(0.000)
L2.any_prio					0.0889 *	(0.060)
GR_gdp_c_con					-0.127**	(0.047)
food_index					-0.160**	(0.005)
FE and time effects	yes		yes		yes	
Constant	0.265	(0.457)	0.427	(0.150)	0.106	(0.199)
Observations	1871		1871		1871	
Adj R-squared	0.11		0.86			
F	2.840		87.42			
AIC	-1986.234		-2674.556		-5036.188	

R reefer to rainfall and T to temperature. p-values in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$

4 Discussion and conclusion

This study has examined the linkage between climate shocks and the incidence of conflict using a new cross-country panel data for 59 countries of Africa and the Middle East from 1981 to 2015. For the estimates, we applied two alternative econometric specifications, which include the effect of: (i) Extreme and medium climate shocks in both directions: positive and negative deviations. (ii) The number of observed shocks over lagged two years. The findings are: (1) the highly pronounced positive correlation between growth in rainfall and economic growth rate in the literature (e.g. by Miguel et al. (2004); Barrios et al. (2010)) is confirmed with our model through positive rainfall shock "medium shock: one deviation point". However, when the shock in rainfall becomes extreme (over two deviation points), that may lead to severe flooding, it shows an expectedly negative sign with economic growth rate although insignificant. Quantitatively, the estimated effect of rainfall shock on the economic growth rate is greater compared to what we observe through interaction effects in our first paper, 3.9% and 0.02%, respectively. None of the rainfall variables, neither the growth nor the shock variables, show a significant impact on food production. (2) Temperature shocks, both positive and negative, are also related to the GDP growth rate significantly. However, a greater effect is observed for the temperature growth (estimated coefficients between 0.47 pp and 0.69 pp in the model with lags, compared to 0.31 pp in our first paper). The negative deviation in temperature shows a significant positive effect on the food index. Furthermore, we see that the negative impact of temperature shock on economic growth rate is explained by the significant impact of the observed negative temperature shocks in the previous two years, where this indicator variable shows a similar positive impact on the food index. Overall, the main effect of climate comes from the temperature growth and it is not extreme shocks that drive economic declines, which indicates that the climate rather operates in a non-linear process. The pattern we find in our first paper remains the same, that temperature growth contributes to the climate impacts more than rainfall impacts.

3) Regarding the direct effects of climate shocks on the incidence of civil conflict, we find that: the medium positive rainfall shock increases the incidence of civil conflict significantly, whereas extreme deviations (two deviation points) have no effect. Our finding is consistent in part with the result of Papaioannou and deHaas (2015); Burke et al. (2015) who found that rainfall deviation increases conflict significantly, and with Papaioannou and deHaas (2015) who indicated that both drought and excessive rainfall have increased scarcity and created conditions that generated social tension and distress. However, it counters the finding of Fjelde and von Uexkull (2012) that large negative deviations in rainfall from the long-term mean are related to a higher risk of conflict. One explanation could be that 55.6% of our sample is considered as low-rainfall countries, therefore, higher rainfall leads to floods, thus destroying natural resources or losing livelihoods associated

with agriculture, thus increasing the likelihood of conflict. On the other hand, the impact of positive temperature shock (medium shock) on the risk of civil conflict is significantly negative. Annual rainfall growth is related negatively to the incidence of civil conflict similar to the consistent result of another part of this research and like in the literature (Hendrix and Glaser, 2007; Bohlken and Sergenti, 2010). The occurrence of two negative rain shocks in succession reduces conflict risk significantly, but in this context, the significant impact of rainfall growth on civil conflict disappears and appears instead on rainfall shocks. However, it is difficult to find an explanation for each individual effect that we observed for the indicator variables (shocks) because in any case, they do not show the overall effect of precipitation and temperature. In the literature it has been suggested by Tietenberg (2000); Baechler (2013) that an unexpected decrease in freshwater availability increases competition for access to water and land and that harvest failure that lead to food shortages increase the likelihood of civil conflict.

However, the direct effect of continuous and shock climate variables on the incidence of civil conflict in this paper is quantitatively similar and corresponds to the effect of rainfall growth on the decrease of the probability of civil conflict in the best fit model (3) table 2.3 in a previous paper[4] . The marginal impact of climate shocks on economic indicators and civil conflicts does not exceed 5%.

(4) Furthermore, the established links between economic development, domestic food production, and the incidence of civil conflict in Chapter 2 remain, almost the same quantitatively. Where a 10% reduction in economic growth or domestic food production leads to up to 1.44% and 1.6 increase in the probability of civil conflict, respectively. (5) In addition, the model observed negative and significant signs of control variables; Freshwater withdrawal, Polity IV, and accountability, all contribute to reducing the potential for conflict. While the exogenous variables such as the transition in a political system, the share of agricultural lands, and the increase in trade exports are critical factors for the economic growth rate and water stress is a critical factor for domestic food production. Overall, precipitation, and temperature shocks are statistically significant but quantitatively show smaller effects relative to growth effect, i.e. temperature growth has larger impact on economic growth rate, but positive rainfall shock also plays a role. Thus, the effect of climate on conflict seems to be non-linear. Performing such a fine-grained analysis benefits the literature in this field, especially as our data extends over a longer time (1981-2015) and covers two regions that are vulnerable to climate change in the world. By providing new indicators describing climate change and achieving a better understanding of the links between climate deviations and conflict, we bring a different perspective to the effects of climate on economic growth rate, food production, and conflict in Africa and the Middle East.

[4]If Climate Change Can Trigger Civil Conflicts, Can Good Economic Policy Trigger Peace. By S. Khalifa, S. Petri, Ch. Henning, 2020.

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Appendix A5

Summary of Variables

Dependent Variables	Independent variables	Variable Description	Source of data
Economic growth rate	***First stage variables***		
Food index	***Climate variables***		
	Rainfall/ mm	The annual rainfall (millimeter) is computed by adding up all the monthly observations in a given year.	World Bank Climate Change Knowledge Portal (2018).
	Temperature (Celsius degree)	The annual temperatures (Celsius degree) are computed by adding up all the monthly observations in a given year divided by the number of months in that year.	World Bank Climate Change Knowledge Portal (2018).
	Growth of climate variables	**gr_var(it)** $=\frac{var(it)-var\_lag1}{var\_lag1}$	
	Climate deviation variables	Annual climate deviation variables from their long-term mean in each country over the period 1981-2015 divided by standard deviation from their respective mean over 35 years.	
	Climate deviation thresholds (1, -1)	Medium shocks in climate deviation variables.	
	Climate deviation thresholds (2, -2)	Extreme shocks in climate deviation variables.	

	Lagged positive shocks in climate variables (rainfall, R and temperature, T).	Observed positive shocks (subsumes thresholds 1 and 2) over last 2 or 5 years period. "count_R/T_pos_shock"	
	Lagged negative shocks in climate variables(rainfall, R and temperature, T).	Observed negative shocks (subsumes thresholds -1 and -2) over last 2 or 5 years period "count_R/T_neg_shock"	
	Water/ 1Km2	Average annual level of freshwater withdrawal (calculated averagely over each decade) divided by country area as:$water\_1km2 = 10^6$ x $wasser\_total/area.km2$, in 10^3 m^3/km2.	FAO (2017)
	Water stress%	Freshwater withdrawal as a proportion of available freshwater resources. This indicator is also known as water withdrawal intensity and will measure progress towards SDG Target 6.4.	FAO (2017)
	Political variables		
	1. PolityIV score	Type of political regime for each country on a range from -10 (full autocracy) to +10 (full democracy).	The project of Roser (2019), based on Polity IV Project (2013) and Wimmer and Min (2006).
	2. Change in political system	Indicates changes from the previous year in absolute terms of Polity IV scores either toward democracy or backward to autocracy.	

	3.Accountability	Ranges from 0 (lowest) to 100 (highest) rank.	World Bank (2014).
	Environmental variables		
	1. Agricultural land	The share of land area that is arable as defined by the FAO, under permanent crops, and under permanent pastures. Land abandoned as a result of shifting cultivation is excluded.	World Bank (2016)
	2. Arable land	Arable land (hectares per person).	
	Demographic		
	The share of urban population	Percentage of the total population	(World Bank, 2018).
	Economic indicators		
	Oil exports (growth)	The proportion of merchandise exports.	World Bank (2016).
	Trade exports (growth)	Total merchandise trade of a country exports to the world in US dollar at current prices.	The World Trade Organization (2016).
3. Civil conflict	***Second stage***		
	1. Economic growth rate	GDP per capita estimates in constant price-US dollars.	The UNSD (2020) .
	2. Food index	The aggregate volume of agricultural production for each year compared to the base period 2004-2006, covers food crops that are considered edible and that contain nutrients. Coffee and tea are excluded because, although edible.	Food and Agriculture Organization of the United Nations (2016).

	Lag civil conflict	conflict incidence resulted at least 25 battel related death per year equals 1, otherwise 0[5].	The UCDP/ PRIO Armed Conflict Dataset, Version 18.1

[5]All country-year observations are coded as ones based on the type (3 and 4) and the intensity level 1 or 2 of the PRIO Uppsala conflict data (at least 25 battle-related deaths per year), otherwise zeros.

Table 4: Annal climate shocks impact. Dependent Variables: Economic growth rate, food index in the OLS, and civil conflict $\geq$ 25 Deaths/ year in the GMM

	(1)		(2)		(3)	
	GR_gdp_c_con		food_index		any_prio	
GR_oil_exp_wdi	0.00000114	(0.639)	-0.00000213	(0.283)		
GR_trade_exports	0.114***	(0.000)	-0.0142**	(0.033)		
agri_land	0.00395 *	(0.053)	0.0142***	(0.000)		
arable_land	-0.272 *	(0.063)	0.469***	(0.000)		
water_stress	-0.0000140	(0.892)	-0.000734***	(0.000)		
strength_gr_polityiv	-0.00677***	(0.001)	-0.00254	(0.132)		
GR_temp_lag_1	-0.0139	(0.922)	0.0203	(0.860)	0.0777	(0.705)
GR_rainfall_lag_1	0.000624	(0.773)	-0.00375**	(0.034)	0.00996	(0.340)
water_1km2	-0.0000189	(0.986)	-0.000324	(0.712)	-0.00608**	(0.003)
Polity.IV_SH_tr	-0.000355	(0.794)	-0.00838***	(0.000)	-0.00547 *	(0.051)
Accountab	0.000683	(0.414)	0.000584	(0.392)	-0.00367**	(0.024)
urban_pop	-0.00190	(0.422)	0.00487**	(0.012)	0.00795	(0.153)
rain_dev_Threshold=1	0.0368***	(0.000)	-0.00117	(0.889)	0.0329 *	(0.089)
rain_dev_Threshold=2	-0.00369	(0.862)	0.0209	(0.227)	-0.0189	(0.661)
rain_dev_Threshold=3	-0.00668	(0.498)	-0.0157 *	(0.051)	0.0296	(0.101)
rain_dev_Threshold=4	-0.0186	(0.454)	0.00229	(0.910)	-0.0191	(0.709)
temp_dev_Threshold=1	-0.0227**	(0.027)	-0.00528	(0.529)	-0.0306 *	(0.078)
temp_dev_Threshold=2	0.0305	(0.224)	-0.00396	(0.847)	-0.0505	(0.245)
temp_dev_Threshold=3	-0.0173 *	(0.100)	0.0334***	(0.000)	-0.0199	(0.388)
temp_dev_Threshold=4	-0.0108	(0.610)	0.0397**	(0.022)	-0.0547	(0.346)
L.any_prio					0.364***	(0.000)
L2.any_prio					0.0914 *	(0.055)
GR_gdp_c_con					-0.143**	(0.021)
food_index					-0.156**	(0.006)
FE and time effects	yes		yes		yes	
Constant	-0.176	(0.205)	-0.394***	(0.001)	1.081	(0.145)
Observations	1994		1994		1871	
Adj R-squared	0.11		0.85			
F	2.759		91.35			
AIC	-1994.861		-2803.037		-5028.899	

p-values in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$

Table 5: Climate shocks over a previous 5-year period and economic development in the OLS, and civil conflict $\geq$ 25 deaths/ year in the GMM

	(1)		(2)		(3)	
	GR_gdp_c_con		food_index		any_prio	
GR_oil_exp_wdi	0.000000637	(0.785)	-0.00000128	(0.507)		
GR_trade_exports	0.117***	(0.000)	-0.0115 *	(0.098)		
agri_land	0.00441**	(0.050)	0.0156***	(0.000)		
arable_land	-0.105	(0.515)	0.275**	(0.040)		
water_stress	0.0000167	(0.878)	-0.000767***	(0.000)		
strength_gr_polityiv	-0.00709***	(0.001)	0.000904	(0.608)		
GR_temp	-0.283 *	(0.063)	-0.253**	(0.044)	0.0392	(0.884)
GR_rainfall	-0.00791	(0.459)	0.00393	(0.656)	-0.0248**	(0.029)
water_1km2	-0.000953	(0.380)	-0.00165 *	(0.066)	-0.00536***	(0.002)
Polity.IV_SH_tr	-0.00189	(0.202)	-0.00920***	(0.000)	-0.00608**	(0.035)
Accountab	0.000230	(0.790)	0.000520	(0.466)	-0.00368**	(0.045)
urban_pop	-0.00900**	(0.008)	0.00973***	(0.000)	0.0118 *	(0.079)
count_R_pos_shock=1	-0.00894	(0.317)	-0.000504	(0.946)	-0.0268	(0.111)
count_R_pos_shock=2	0.0245**	(0.047)	0.00474	(0.641)	-0.0734**	(0.003)
count_R_pos_shock=3	-0.00757	(0.757)	0.0331	(0.102)	0.0107	(0.840)
count_R_pos_shock=4	-0.0492	(0.547)	-0.0587	(0.385)	-0.143**	(0.013)
count_R_neg_shock=1	0.00527	(0.546)	0.00185	(0.797)	0.0140	(0.391)
count_R_neg_shock=2	0.0149	(0.238)	0.0152	(0.146)	-0.0118	(0.652)
count_R_neg_shock=3	0.00940	(0.676)	0.0342 *	(0.066)	-0.0376	(0.360)
count_R_neg_shock=4	0.0354	(0.479)	0.102**	(0.013)	0.0436	(0.287)
count_R_neg_shock=5	-0.0964	(0.505)	0.216 *	(0.071)	-0.430***	(0.000)
count_T_pos_shock=1	-0.00108	(0.918)	0.0119	(0.170)	0.0130	(0.427)
count_T_pos_shock=2	0.00996	(0.479)	0.0167	(0.151)	-0.0229	(0.287)
count_T_pos_shock=3	0.0107	(0.611)	0.0334 *	(0.055)	-0.0252	(0.634)
count_T_pos_shock=4	0.0403	(0.443)	0.0112	(0.796)	-0.0281	(0.699)
count_T_pos_shock=5	0.0294	(0.786)	0.0763	(0.394)	-0.0743 *	(0.083)
count_T_neg_shock=1	-0.0319**	(0.006)	0.0174 *	(0.068)	0.0152	(0.544)
count_T_neg_shock=2	-0.0663***	(0.000)	0.0418***	(0.000)	0.0640 *	(0.062)
count_T_neg_shock=3	-0.0610***	(0.000)	0.0463***	(0.001)	-0.0354	(0.379)
count_T_neg_shock=4	-0.0338	(0.172)	0.0835***	(0.000)	0.00940	(0.873)
count_T_neg_shock=5	-0.155 *	(0.081)	0.0824	(0.260)	0.0223	(0.643)
L.any_prio					0.336***	(0.000)
L2.any_prio					0.0913 *	(0.057)
GR_gdp_c_con					-0.0756	(0.238)
food_index					-0.132**	(0.018)
FE and time effects	yes		yes		yes	
Constant	0.0691	(0.676)	-0.456***	(0.001)	0.467***	(0.000)
Observations	1685		1685		1685	
Adj R-squared	0.14		0.85			
F	2.936		68.42			
AIC	-1799.925		-2440.702		-4641.53	

p-values in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$

Table 6: Combining absolute moving climate shock variables over a previous 5-year period and economic development in the OLS, and civil conflict $\geq$ 25 deaths/ year in the GMM

	(1)		(2)		(3)	
	GR_gdp_c_con		food_index		any_prio	
GR_oil_exp_wdi	0.000000743	(0.751)	-0.00000135	(0.484)		
GR_trade_exports	0.118***	(0.000)	-0.0119 *	(0.085)		
agri_land	0.00476**	(0.032)	0.0159***	(0.000)		
arable_land	-0.174	(0.279)	0.276**	(0.038)		
water_stress	0.0000190	(0.862)	-0.000762***	(0.000)		
strength_gr_polityiv	-0.00727***	(0.001)	0.000810	(0.644)		
GR_temp	-0.410**	(0.006)	-0.212 *	(0.084)	0.105	(0.685)
GR_rainfall	-0.00720	(0.489)	0.00616	(0.472)	-0.0178 *	(0.085)
water_1km2	-0.000910	(0.401)	-0.00160 *	(0.073)	-0.00498**	(0.007)
Polity.IV_SH_tr	-0.00216	(0.144)	-0.00924***	(0.000)	-0.00578 *	(0.054)
Accountab	0.000553	(0.519)	0.000440	(0.534)	-0.00380**	(0.046)
urban_pop	-0.00950**	(0.005)	0.0101***	(0.000)	0.0124 *	(0.051)
R_count_combShok=1	-0.0209 *	(0.054)	0.00754	(0.401)	0.00763	(0.705)
R_count_combShok=2	0.00605	(0.603)	0.00649	(0.499)	-0.0313	(0.177)
R_count_combShok=3	0.0107	(0.446)	0.0179	(0.122)	-0.0382	(0.129)
R_count_combShok=4	-0.00567	(0.821)	0.0425**	(0.039)	-0.0130	(0.747)
R_count_combShok=5	-0.00273	(0.964)	0.0712	(0.156)	-0.0603	(0.438)
T_count_combShok=1	-0.0196 *	(0.068)	0.0218**	(0.014)	0.0121	(0.593)
T_count_combShok=2	-0.0262**	(0.021)	0.0308***	(0.001)	0.0121	(0.583)
T_count_combShok=3	-0.0290**	(0.032)	0.0427***	(0.000)	-0.0216	(0.528)
T_count_combShok=4	-0.0234	(0.276)	0.0727***	(0.000)	-0.00685	(0.885)
T_count_combShok=5	-0.0430	(0.353)	0.0975**	(0.011)	0.0104	(0.733)
L.any_prio					0.340***	(0.000)
L2.any_prio					0.0887 *	(0.058)
GR_gdp_c_con					-0.0811	(0.199)
food_index					-0.134*	(0.013)
FE and time effects	yes		yes		yes	
Constant	0.0133	(0.935)	-0.467***	(0.001)	0.502***	(0.000)
Observations	1685		1685		1685	
Adj R-squared	0.13		0.85			
F	2.951		72.76			
AIC	-1794.843		-2447.083		-4632.839	

p-values in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.001$