

The Institute for Agricultural Economics  
of the Christian-Albrechts-Universität Kiel

**Analysing Linkages between Climate Change,  
Economic Development, and Civil War.  
An Econometric Analysis**

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# Abstract

This thesis analysed linkages between climate change, economic development and the incidence of civil conflict from 1981 to 2015. This dissertation consists of four empirical papers contributing to a better understanding of the complex interrelation between climate change, economic development and civil conflict. To analyse quantitatively these linkages, we use new cross-country panel data from 1981 to 2015. We include control variables for good governance and democracy as well as a food production index to identify potential mechanisms of climate change impacts on conflict. We test new measurements of changes in rainfall and temperature and compare the effects of shocks to the growth effects. We estimate the impact of lagged conflicts on the incidence of civil conflict with the inclusion of a lag-dependent variable in the econometric estimation. We take into account potential heterogeneity by testing for different impact mechanisms of climate change on conflict in both studied regions (sub-Saharan Africa compared to the Middle East and North Africa). Finally, we test different measurements of climate change (continuous growth rate versus extraordinary shocks in climate variables, in addition to annual levels of rainfall). In addition, we consider the role of economic policies in avoiding new conflicts and triggering peace if climate shocks cannot be avoided.

Several main conclusions are drawn based on the results of this thesis: (1) Weather variables are good instruments not only for economic growth rate but also for domestic food production. The main pattern found in this research on the climate change effects is that temperature contributes to climate impacts more than rainfall impacts on economic development. 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. (2) Beyond the economic growth rate, climate change also impacts civil war via domestic food production. A 10% reduction in economic growth or domestic food production leads to 1.2% and 1.59% increase in the probability of civil conflict, respectively. There appears to be evidence of different impact mechanisms of both indicators on the incidence of civil conflict, in different regions. (3) A direct impact of climate is identified on the incidence of civil conflict. Rainfall growth has a direct significant impact on reducing the likelihood of civil conflict, this finding is robust to the inclusion of several model specifications. (4) The inclusion of the impact of reverse conflict is essential in order not to overestimate the impact of climatic and economic factors on conflict. (5) The level of democracy of a political system and good governance are important control variables. (6) Proper economic policies that can accelerate economic growth and food policies that enhance food security seem to play a significant role towards peace.

However, applying an econometric “state-of-the-art” approach to control for potential endogeneity, unobserved heterogeneity and dynamic specification problems, still results in some limitations, i.e. sensitivity of estimation results with regard to used measurement concepts of central climate variables. Furthermore, applied econometric approaches are limited to identify causal relationships. Therefore, future research

is needed to address these problems. In this regard, we consider the combination of econometric and modelling approaches in a Bayesian estimation framework as a promising approach.



# Zusammenfassung

Diese Arbeit untersucht den Zusammenhang zwischen Klimawandel, wirtschaftlichen Entwicklung und dem Auftreten von ziviler Konflikte. Die Dissertation umfasst vier empirische Arbeiten, die zu einem besseren Verständnis der komplexen Zusammenhänge zwischen Klimawandel, wirtschaftlicher Entwicklung und zivilen Konflikten beitragen. Um diese Zusammenhänge quantitativ zu analysieren, schätzen wir innovative ökonometrische Methoden auf der Grundlage einer selbst zusammengestellten erweiterten cross-country Paneldatenbasis, die 41 SSA-Staaten und 18 arabische Staaten des Mittleren Ostens für den Zeitraum von 1981 bis 2015 umfasst. Im Vergleich zu der bisherigen Literatur wurden zusätzliche erklärende Variablen berücksichtigt, um relevante Wirkungsmechanismen der Auswirkungen des Klimawandels auf zivile Konflikte besser identifizieren zu können. Konkret wurden Indikatorvariablen für „Good Governance“ und der Polity-IV Demokratisierungsindex als zusätzliche politische Kontrollvariable sowie der „Domestic Food Production Index“ als zusätzliche Indikatorvariable für ökonomische Entwicklung berücksichtigt. Darüber hinaus wurden in der Promotionsarbeit einige methodisch-theoretische Erweiterungen eingeführt. Erstens werden alternative Messkonstrukte für die zentralen erklärenden Klimavariablen, Niederschlag und Temperatur, verwendet. Dies umfasst die explizite Berücksichtigung von Interaktionseffekten sowie die Unterscheidung zwischen positiven und negativen Veränderungen. Zentral wurde in der Arbeit auch erstmals analysiert, inwieweit kontinuierliche Klimaveränderungen, gemessen als jährliche Wachstumsraten, oder aber extreme Klimaschocks, gemessen als extreme jährliche Abweichungen im Vergleich zum langfristigen Durchschnitt, Auswirkungen auf ökonomische Entwicklung und zivile Konflikte ausüben. Zweitens berücksichtigen wir die Dynamik ziviler Konflikte, d.h. wir testen den kausalen Zusammenhang, dass aktuelle zivile Konflikte weitere zivile Konflikte in der Zukunft bedingen, in dem wir lagged-dependent Variablen in die Schätzungen mitaufnehmen. Drittens wird explizit die Heterogenität zwischen Ländern bzw. Ländergruppen analysiert. Konkret testen wir inwieweit verschiedene Wirkungsmechanismen des Klimawandels auf zivile Konflikte in afrikanischen und arabischen Staaten identifiziert werden können. Weiterhin simulieren wir auf der Grundlage der erzielten Schätzergebnisse, inwieweit bzw. ob adäquate Wirtschaftspolitik, den durch Klimawandel induzierten Ausbruch ziviler Konflikte verhindern könnte bzw. inwieweit Wirtschaftspolitik ein probates Mittel zur Beendigung von zivilen Konflikten darstellt.

Zentrale Schlussfolgerungen der Arbeit sind: (1) Das Hauptmuster der Auswirkungen des Klimawandels auf zivile Konflikte erfolgt indirekt über die wirtschaftliche Entwicklung. Dabei scheint eher ein kontinuierlicher Klimawandel als Klimaschocks Ursache von zivilen Konflikten zu sein. (2) Über die wirtschaftliche Wachstumsrate hinaus wirkt sich der Klimawandel auch über die heimische Nahrungsmittelproduktion auf die Wahrscheinlichkeit von zivilen Konflikten aus. Ein Rückgang des Wirtschaftswachstums bzw. der inländischen Nahrungsmittelproduktion um 10% führt zu einer Erhöhung der Wahrscheinlichkeit eines Bürgerkrieges um 1,2% bzw. 1,59%. (3) Die Einbeziehung der Auswirkungen bestehender Konflikte auf zukünftige Konflikte ist hoch signifikant und relevant. Ein bestehender Kon-

flikt impliziert eine Wahrscheinlichkeit von 45%, dass dieser Konflikt im nächsten Jahr fortgeführt wird. (4) Die institutionelle Ausgestaltung des politischen Systems (Demokratisierung und Good Governance) sind hoch signifikante und wichtige Kontrollvariablen. (5) Eine angemessene Wirtschaftspolitik, die das Wirtschaftswachstum beschleunigen kann bzw. die Ernährungssicherheit erhöht, sind effektive Mittel zur Vermeidung bzw. zur Beendigung von zivilen Konflikten als Folge des Klimawandels. Allerdings zeigen die Analysen auch ganz klar auf, dass Klimaveränderungen und daraus resultierende ökonomische Schocks nicht die zentralen Erklärungsfaktoren für den Ausbruch ziviler Konflikte darstellen, so dass gute Wirtschaftspolitik nur ein bedingtes Mittel zur Herstellung bzw. Wahrung von Frieden ist. (6) Es scheint Hinweise auf unterschiedliche Wirkungsmechanismen dieser Zusammenhänge in afrikanischen und arabischen Ländern zu geben.

Die Anwendung von klassischer State-of-the-Art ökonomischen Ansätzen, die auf inferenzstatistischen Verfahren beruhen, beinhaltet grundsätzlich einige fundamentale Einschränkungen, die eine robuste Identifikation kausaler Wirkungsmechanismen auf der Grundlage von „observational data“ relevant einschränken. Entsprechend sind zukünftige Forschungsaktivitäten notwendig, um diese Limitationen aufzulösen. In diesem Zusammenhang erscheint die Kombination von ökonomischen Schätzungen und polit-ökonomischen Modellierungsansätzen im Rahmen von Bayesianischen Schätzverfahren sehr vielversprechend.

# Chapter 1

## Introduction

A much-debated effect of climate change corresponds to the causal relationship between climate change and political conflicts. There are significant overlaps between countries that are particularly susceptible to climate-induced disasters and those with recurring armed conflicts, such as the extended region around the Horn of Africa and the Sahel zone of West Africa. The fact is that the poor suffer the most from the impact of climate change (Skoufias, 2012). There is a growing concern that climate change might slow down or possibly even reverse achieved progress in global poverty reduction. The concern is rooted in the fact that (i) most poor are concentrated in developing countries, highly dependent on the agriculture sector and other climate-sensitive natural resources (such as freshwater) for income and wellbeing, which are strongly affected by climate change. Especially when water is scarce as in Sub-Saharan Africa (SSA) and in the Arab world, climate change leads to large losses in national production, and thus, negatively affects rural income and food security (Zhu et al., 2009; Breisinger et al., 2010). Assunção and Feres (2009) have estimated that agricultural output per hectare in Brazil may decrease by 18 percent by 2040 because of climate change. (ii) Developing countries often lack sufficient financial and technical capacities to mitigate increasing climate risks (Hallegatte et al., 2011). The situation is intensified by the fact that the affected people often have neither expert knowledge nor capital to adapt to climate changes. To achieve the objective of eradicating poverty, efforts have frequently been geared towards agriculture intensification. However, unsustainable intensification of farming practices can lead to environmental damages such as soil degradation and deforestation (Garnett et al., 2013). These impacts may in turn lead to a decrease in agricultural productivity in the long run, in both plant and animal production, thus threatening food security.

Brinkman and Hendrix (2011) indicate that political violence is more prevalent in societies with higher levels of chronic food insecurity. Countries experiencing armed conflicts are often the worst-scoring countries in the Global Hunger Index (Von Greb-

mer et al., 2015). However, the reality is more complex, and the scarcity of food is usually only one of many reasons responsible for the outbreak of conflicts. Weak government institutions, stagnating economic growth, and unequal access to income, land and natural resources can create an environment for the marginalization of populations and a climate of hopelessness, making people more receptive to strategies of violence.

Overall, there is a complex interrelation between climate change, poor economic development, and political conflict, which might create a *circulus vitiosus*, where climate change induces higher poverty and reduces local food production implying a higher risk of political conflict and civil war which in turn reduces economic developments and food security. In this context, it is of particular interest to contribute first, to a better understanding of this complex interrelation in order to avoid further conflicts and inefficient economic development in the future. Second, the question that has not yet been fully addressed in the literature is, what is the role of economic policies in avoiding the outbreak of a new war in light of climate change, or in triggering peace? We quantitatively assess policy options in Chapter 2.

To analyse quantitatively the complex linkages between climate change, economic development and civil conflict, (1) we use a new cross-country panel data that can describe climate shocks, economic conditions, and conflict, collected from various recognized sources providing consistently updated time series. (2) We introduce new control variables for good governance and democracy as well as a food production index to control more potential mechanisms of climate change impacts on conflict. Food production index is relevant, because climate also impacts domestic food production beyond income growth, and local food production may be a better measurement to observe shocks in the income of the rural poor. (3) We test new measurements of climate change (rainfall and temperature), shocks compared to the growth effects. (4) The inclusion of a lag-dependent variable in the econometric estimation to estimate the impact of reversed conflict as lagged exogenous variable on the incidence of civil conflict. Furthermore, we take into account potential heterogeneity by testing for different impact mechanisms of climate change on conflict in specific regions (sub-Saharan Africa compared to the Middle East and North Africa).

In chapter 2, we revisit the work of Miguel et al. (2004) in which the climate-conflict link has been examined using panel data for SSA from 1981 to 1999. We develop a framework for estimates. First, we extend the cross-country panel data including Sub-Saharan Africa and the Middle East and North Africa, from 1981 to 2015 constructing a new cross-country time series from different data sources. Second, we

include additional control variables, i.e. variables on good governance and democracy as well as domestic food production. Third, we extend the econometric estimation including a lag-dependent variable applying GMM to estimate the impact of previous conflict on the current conflict. We capture the indirect impact of weather variation (rainfall and temperature) and other external shocks on the incidence of civil war in country (i) year (t) through the economy applying the IV-approach. Additionally, in the two-stage regressions, we also examine the independent impact of climate change on civil conflict, rather than covering its impact only through the economy. In the literature, econometric studies investigating the relationship between climate change, economic growth rate and civil conflict have shown mixed results due to slight changes in model specifications and measurements of climate shocks, or data sources.

The research questions addressed in this chapter are: To what extent and does climate change impact economic development (economic growth rate and local food production), and civil conflict? Can adequate economic policies reduce the probability of civil war, or at least trigger peace after an outbreak of war?

Moreover, we illustrate the case of Syria to explain results from cross-country panel data, given the country's location in a region that is consistently expected to be among the most affected by climate change (Breisinger et al., 2011). Thus, climate change may threaten the future development of Syria and place a significant burden on economic development. Since 2011, Syria faces the intractable conflict that continues in 2020 to complete nine years of intense violence. Therefore, Syria is an important example to explain the proposed relationships in depth.

In Chapter 3, we aim to reproduce the finding of Miguel et al. (2004), who find a negative significant relationship between economic shocks and the likelihood of civil conflict in sub-Saharan Africa (SSA) for the period 1981-1999, as a further robustness check on our new setup of data. Their results have been already reproduced and/or considered as a reference point for many efforts in civil war economies, e.g.(Ciccone, 2011). We test to what extent this theory is stable using different data, new rainfall measurement (rainfall levels: the preferred empirical approach of Ciccone (2011)), and different econometric specifications and methods.

In Chapter 4, we test mechanisms of climate change impacts on the incidence of civil conflict separately in sub-Saharan Africa (SSA) compared to the Middle East and North Africa (MENA) for the period 1981 to 2015. SSA and MENA are both vulnerable to climate change and have experienced civil wars historically, but the regions are diverse in agriculture systems, economic structure, political-institutional

and social characteristics, and the resilience of human systems, and thereby in their adaptive capacity. Thus, climate change impacts and the channels over which they operate might be different. Therefore, (i) we aim to analyse these relationships separately in both regions, using our constructed data set and a variety of instruments. (ii) In addition, we test the impact of rainfall variables from different sources of data. Climate, economic development and conflict relationships have been already demonstrated intensively in Africa. However, to the best of our knowledge, we are the first to prove these relationships quantitatively in the Middle East and North Africa.

In Chapter 5, we revisit the measurement of climate change. Estimating climate change impacts through annual percentage change (like by Miguel et al. (2004)) in climate variables has been criticized, for instance by Ciccone (2011) because rainfall growth does not provide information about whether a wet year is a year with heavy rainfall, or just a wetter year than the previous one (mean reversion). We suggest that extra ordinary climate shocks (extreme positive temperature and negative rainfall shocks) have an impact on civil conflict. Therefore, in this final chapter, we focus instead on estimation of the effects of climate shocks. For this, first, we identify shocks at different levels of deviations (1 and 2 standard deviation) from the long-term mean of climate variables. Second, we define whether the constructed shock variables deviate in a positive or negative direction from their respective historical long-term mean. We suppose that positive or negative extreme climate shocks, lead to higher levels of conflict. Third, we count the number of climate shocks observed over the past. We offer a different perspective on the effects of climate on the economic growth rate, food production and conflict.

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## Chapter 2

# If Climate Change Can Trigger Civil Conflict, Can Good Policy Trigger Peace? Empirical Evidence from Cross-Country Panel Data

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### Abstract

Based on the analysis of a new cross-country panel data from Africa and the Middle East for the time period between 1981 and 2015, we show that reductions in per capita income growth and domestic food production induced by climate variation significantly increase the probability of civil conflict. A 10% reduction in economic growth or domestic food production leads to a 1.25% and 1.59% increase in the likelihood of civil conflict, respectively. Furthermore, we identify a direct link of climate on the incidence of civil conflict. Additionally, the level of democracy and good governance are good control variables. Applying our model to the case of civil war in Syria, it is evident that the change in temperature growth in 2010 explains around 30% of the decrease in income growth and 85% of the decline in food production index, thus contributes to the outbreak of civil war. While during wartime, we explain with our model about 43-56% of civil conflict incidence. Lagged conflicts and low economic development contributed to explaining the incidence of civil conflict the most. Concluding that adequate economic policies that are able to accelerate economic development, have the potential to reduce the risk of conflict and play a role towards peace.

**Keywords:** Climate variation, economic growth rate, food production index, civil war

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## 2.1 Introduction

Climate variability and change affect a country's economy and households through multiple channels. For example, an increase in temperature and changing rainfall patterns affect the agricultural output of irrigated crops. Rising sea level will result in the loss of land, landscape, and infrastructure. The frequent flooding and extreme drought will change hydropower generation, and frequent floods will also increase the demand for public investment in physical infrastructure (Breisinger et al., 2011; Zenghelis, 2006; Dasgupta et al., 2007; Garnaut, 2008; Yu et al., 2010). Researchers warn of disastrous consequences for countries where fresh water is scarce and whose economies depend on local agriculture, such as many in sub-Saharan Africa (SSA). Those countries are more vulnerable to a changing climate, leading to large losses projected in their national output (Thurlow et al., 2009). Likewise, many countries of the Arab world have additional declines in agricultural yields, resulting in negative effects in rural incomes and food security (Breisinger et al., 2010).

In this way, in addition to social and political tensions, climate change impacts the likelihood of conflict in direct and indirect ways. Directly, researchers argue that deviations from moderate temperatures and precipitation patterns systematically increase the risk of conflict (Burke et al., 2015; Hendrix and Salehyan, 2012), while other studies have found that low or declining rainfall increases the risk of communal conflicts, such as Hindu–Muslim riots in India (Bohlken and Sergenti, 2010; Sarsons, 2011), and leads to leadership change (Burke et al., 2012; Dell et al., 2012).

Furthermore, there is a lot of research devoted to the indirect impact of climate change when new natural conditions lead to negative consequences on food production and economic development, thus increase conflict risks.<sup>4</sup> For example, some studies provide evidence on the effects of temperature and rainfall variations on economic growth and its relations to conflict. Evidence from the Philippines shows that rainfall has an effect on agriculture and is related to civil conflict, whereby an increase in agriculture production dampens conflict intensity (Croston et al., 2018). Blattman and Miguel (2010) identify, among the most robust findings in the litera-

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<sup>4</sup>Surely, the relationship between economic development (or food insecurity) and conflict is more complicated. While many studies suppose that food insecurity can be a cause of conflict, there are also studies suggesting that food insecurity can be strongly established as a consequence of conflict. It is more appropriate to regard both aspects in the way that economic conditions and conflict risks are referred to each other in a harmful cycle, a “circulus vitiosus”: in the absence of appropriate political responses and equal opportunities for all population groups, climate change can induce economic shocks and increase local environmental problems. That finally implies political conflicts and civil war. In turn, civil wars amplify environmental and economic development problems, leading to poverty and hunger.

ture, that economic shocks induced by climate change are strongly correlated with civil conflict, where negative rainfall shocks reduce economic growth and thereby increase conflict risk. Collier et al. (2003) pointed to a correlation between food insecurity and political conflict, claiming that both are symptoms of low development. Food security has been also identified by Maystadt et al. (2014) to be key for a peaceful transition in the Arab world. Most types of political violence addressed in a paper by Brinkman and Hendrix (2011) are more prevalent in societies with higher levels of chronic food insecurity.

The most widely cited study of Miguel et al. (2004) is the cornerstone of existing literature on civil war economies e.g., by (Collier and Hoeffler, 2005; Hegre and Sambanis, 2006; Collier et al., 2009; Miguel and Satyanath, 2011). The results of Miguel et al. (2004) prove that a positive growth rate of rainfall increases GDP growth and reduces conflict risks in the countries of sub-Saharan Africa. Afterwards, based on this paper, Ciccone (2011) re-examined the correlation between civil conflict and weather variations using an extended database from Miguel et al. (2004). He found no robust link between civil conflict and year-to-year rainfall growth or yearly rainfall levels. However, applying Ciccone's approach, Miguel and Satyanath (2011) re-examined the results and found that the findings hold even using rainfall levels as instruments. The second important point of Miguel and Satyanath (2011) is that the relationship between rainfall and GDP growth is weaker after 2000, suggesting that alternative instruments are needed when investigating recent conflicts.

In this context, it is of particular interest to contribute first, to a better understanding of the complex interrelation between economic development (and food insecurity) and conflict risks. Second, the question that has not yet been fully addressed in the literature is, what is the role of economic policies in avoiding the outbreak of a new war in light of climate change, or in triggering peace?

In this chapter, we investigate the impacts of climate variations on conflict risks both in direct and indirect ways (through economic growth) Miguel et al. (2004), Ciccone (2011), and Miguel and Satyanath (2011). We estimate models with country and time fixed effects by means of a two-stage approach. However, compared to the above-mentioned authors who use mainly panel data for sub-Saharan Africa, we developed an empirical framework with (i) a new cross-country panel data collected by ourselves. In this dataset, we combine the conflict data of Themnér et al. (2018) with other climate, economic, social, political, environmental, and demographic variables for 59 countries of Africa and the Middle East from 1981 to 2015, collected from different sources (such as World Bank, FAO of the United Nations, WTO,

UNESCO, etc.), described in more detail in our Data set and variable description (Appendix A). (ii) Our Data set includes additional control variables, i.e. variables on good governance and democracy as well as domestic food production. Food production index appears to be a strong instrument for explaining conflict risks. (iii) We extend the econometric estimation including a lag-dependent variable applying GMM to estimate the impact of previous conflict on the current conflict. Additionally, in the two-stage regressions, we also examine the independent impact of climate change on civil conflict, rather than covering its impact only through the economy. (iv) Compared to previous literature, our research does not focus on the relationship between explanatory variables and civil conflicts in African countries only, since the linkage between climate and conflict is not a phenomenon unique to Africa but rather can be explained as a phenomenon of low levels of economic development and high levels of agricultural dependence (Salehyan and Hendrix, 2011). (v) Moreover, based on the results from the two-stage approach, our paper explicitly takes Syria into account as the most important conflict in the last decade, as it has caused the displacement of more than six million Syrian people.

We highlight the case of Syria, since this is the best instance of a conflict apparently arising from the interrelations between climate change, economic development, and political conflict. Syria is a country with relatively high income inequality.<sup>5</sup> Regarding food security, Syria is highly dependent on agriculture. Moreover, agriculture is a source of livelihood and economic growth in rural areas (Solh and Saxena, 2011). Between 2006 and 2011, Syria experienced a multiyear period of extreme drought that contributed to agricultural failures (Gleick, 2014), causing worrying tensions in local food prices. While some studies try to explain a civil conflict in Syria only by reference to political instability (Karimi and Shafae, 2018) or increasing international food prices (Johnstone and Mazo, 2011), we assume that only a combination of environmental, social-cultural, and economic factors can possibly give us a complete illustration of the incidence of civil war in Syria. Particularly, by means of computing marginal and total effects, we provide empirical evidence for the extent to which each group of factors contributed to probability of civil war in Syria.

In this Chapter, we first give a short overview about the economic, social, and political conditions in the country in the time before the crisis exploded. Second, we explain the data and the methodological framework. Last, we present our empirical results and discuss them.

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<sup>5</sup>For example, the Gini index of inequality for Syria increased from 33.7 in 1997 to 37.4 in 2004. Inequalities in economic development, education, and the use of resources are strongly aggravated between urban and rural populations (Bibi and Nabli, 2010).

## 2.2 The crisis in Syria

From the 1980s onwards, there was a course of liberalization of the Syrian economy, and the process was accelerated with the ascent of Bashar al-Assad in 2000. Given the importance of the agricultural sector in general and the livestock sector especially, the government focused on the development of the animal sector so that the contribution of the agricultural sector to the Gross Domestic Product (GDP) in fixed price ranged between 24% and 27% in the early 2000s and decreased to 16% during the 2005–2010 (Bibi and Nabli, 2010). The situation in this important branch of the economy had become very serious when the 2006–2010 drought converged with a shift in government agricultural policy regarding subsidies for irrigation and fertilizers. The combining of the withdrawal of the subsidies with the low rainfall apparently reduced production significantly (Middleton et al., 2018). While Syria’s food security index had been steadily increasing from the index of 2.2 in 1961 to 8.0 in 2007 when the government was promoting irrigated agriculture (Aw-Hassan et al., 2014), in 2006 the government sold off its grain reserves to take advantage of high global prices. Thus, no reserves were available when the drought hit in 2007–2008 so that food security in the country was violated (Akhmedkhodjaeva, 2015). Furthermore, during the worst three-year drought, there was a large-scale migration mostly from rural farming areas to urban centers, where young people needed to enter a depressed job market (Selby et al., 2017; Solh, 2010; Kelley et al., 2015). According to FAO (2017b), around 7 million food-insecure people were in urgent need of assistance during war years in Syria.

With roughly 23.5 million citizens in 2010, Syria is a country with many diverse religious and ethnic backgrounds including Sunnis, Alawites, Christians, Kurds, Armenians, Assyrians, Druze, and Turkmans (Van Dam, 2011). The Sunni majority (75%) had regrets about privileges that were granted to Alawite elites (Hinnebusch and Zintl, 2015). Moreover, the problem generated mistrust between diverse population groups because this tension could not be faced or dealt with openly (Hinnebusch and Zintl, 2015).

In addition to the above-mentioned agricultural, religious, and ethnic factors, the lack of government accountability<sup>6</sup> and the dependence on petroleum rent played important roles in the political and economic crisis in Syria (Hinnebusch, 2012; Hinnebusch and Zintl, 2015). The budget was highly dependent upon petroleum

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<sup>6</sup>Based on the Voice and Accountability index, Syria was ranked 187 out of 193 states during 1996 to 2014 (World Bank, 2017).

rent, making the country vulnerable to rent declines. In addition, the spread of electronic media contributed to political mobilization when there were attempts to demonstrate against regimes in neighbouring countries (Hinnebusch, 2012; Howard and Hussain, 2011). A combination of these factors, at least to a certain extent, led to increased poverty, influencing political conflicts and finally escalating into armed conflict by June 2011 (Hinnebusch and Zintl, 2015).

## 2.2.1 Data and description of variables

### Data on civil conflict

As in recent studies (Miguel et al., 2004; Miguel and Satyanath, 2011), for our conflict variables, we adopted the UCDP/PRIO Armed Conflict Dataset<sup>7</sup> for countries in our sample. However, we included many more countries and years than the study of Miguel et al. (2004). Our sample contains data for 59 countries of the African continent and the Middle East from 1981 to 2015. While the conflict data include four types of conflicts (type 1, 2, 3, and 4), we focus on conflicts of type 3 and type 4 covering civil conflicts with and without intervention from other states on one or both sides, respectively. In this way, the conflicts of type 3 and type 4 indicate internal and internationalized internal conflict.

According to the data coding of Themnér et al. (2018) and in a similar manner to Miguel et al. (2004), we generate three dependent conflict variables (*any\_prio*, *minor\_prio*, and *war\_prio*) by means of comparing the intensity level of conflicts. Minor conflict (*minor\_prio*) implies between 25 and 999 deaths in a given year, war (*war\_prio*) implies at least 1,000 battle-related deaths in a given year, and any conflict (*any\_prio*) caused at least 25 battle-related deaths in a given year, thus it covers the two conflict variables (minor conflicts and wars). In this way, based on the type and the intensity level of the conflict, all country-year observations (for country  $i$  and time  $t$ ) are coded as ones, otherwise as zero. More details on constructing these variables are described in Appendix A attached to this research (Data Set Description), while detailed definitions of the types of conflict are available in the UCDP/PRIO Armed Conflict Dataset Codebook as described for example in Themnér et al. (2018), Gleditsch et al. (2002), Harbom et al. (2009), or in the dataset of Miguel et al. (2004).

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<sup>7</sup>We used the Armed Conflict Dataset, version 18.1, available on the website: <http://ucdp.uu.se/downloads/>.

### Weather variables

To quantify the direct and indirect effects of climate change on the incidence of conflict, we considered various measures capturing exogenous variation in climate (rainfall and temperature). The climate variables used in this paper are:

- The annual rainfall level (mm) is computed by adding up all of the monthly observations in a given year and its respective lags:  $rainfall$ ,  $rainfall_{lag_1}$ ,  $rainfall_{lag_2}$ ;
- A relative change in precipitation in a given year related to the previous year, and this is the principal measure of many above-mentioned studies:  
 $gr\_rainfall = (rainfall - rainfall_{lag_1}) / rainfall_{lag_1}$ ;
- The annual temperature (degrees Celsius) is computed by adding up all of the monthly observations in a given year divided by the number of months in that year, and its lags:  $temp$ ,  $temp_{lag_1}$ ,  $temp_{lag_2}$ .

Furthermore, we are interested in understanding whether rainfall level and rainfall growth rate are still important measures for conflict risks when regarding the total water availability in a country. For instance, a high level of precipitation might be a real problem for countries which frequently suffer from floods destroying infrastructures, but it might be no problem for countries with dry climate conditions. On the other hand, the extremely low level of rain availability might be a real challenge for regions with frequent drought and may pose no problem for regions in which water has been stored in the reservoirs in the past. Therefore, we computed interaction effects. We have taken Germany (with 727 mm annual precipitation) as a reference country with a peaceful situation and a sufficient level of precipitation in the last decade. We have computed dummy and interaction effects as follows:

- A dummy  $low\_rainfall\_countr$  is equal to 1 if the annual rainfall level in a country was lower than in Germany, otherwise 0;
- The interaction effect between the dummy  $low\_rainfall\_countr$  and the growth rate of rainfall is  $inter\_L\_gr\_rainfall = low\_rainfall\_countr \times gr\_rainfall$ ;
- The interaction effect between the dummy  $low\_rainfall\_countr$  and rainfall level is  $inter\_L\_rainfall = low\_rainfall\_countr \times rainfall$ ;

In the same way, countries with a high mean level of available water have been taken into account (variables are described in the Appendix A).

### Socio-economic variables

There are several sources which provide GDP per capita, but most of the time series data (such as the World Development Indicators source) are not complete for our sample of 59 countries from 1980 to 2015. However, we found that the database of UNSD (2020) was able to cover gaps over almost all countries and years. This database provides a complete and consistent set of GDP per capita time series from 1970 onwards of the main National Accounts data aggregated for all UN Member States and other territories in the world for which National Accounts information is available.

Overall, constructing our own database, we faced the problem that different sources use various methodologies for measuring the same indicators. Therefore, in our database we adopted more as one indicator (for example, GDP per capita) measured in different ways, e.g., in current and constant prices (see Appendix A).

However, in this paper we present the results based on the following indicators:

- Measure of GDP per capita in constant price (US dollars), and its two lags from the source UNSD (2020):  $gdp\_c\_con$ ,  $gdp\_c\_con\_lag\_1$ ,  $gdp\_c\_con\_lag\_2$ ;
- Relative changes in GDP per capita from the previous year and its lag:  
 $gr\_gdp\_c\_con = (gdp\_c\_con - gdp\_c\_con\_lag\_1) / gdp\_c\_con\_lag\_1$  and  
 $gr\_gdp\_c\_con\_1 = (gdp\_c\_con\_1 - gdp\_c\_con\_lag\_2) / gdp\_c\_con\_lag\_2$  ;
- Food production index is the aggregate volume of agricultural production for each year compared to the base period 2004–2006, covering food crops that are considered edible and that contain nutrients (Food and Agriculture Organization of the United Nations, 2016):  $food\_index$ ;
- Oil exporter status (% of merchandise exports) from World Bank (2016), and its lags:  $oil\_exp\_wdi$ ,  $oil\_exp\_wdi\_lag\_1$ ,  $oil\_exp\_wdi\_lag\_2$ ;
- Relative changes in oil exporter status from the previous year:  $gr\_oil\_exp\_wdi = (oil\_exp\_wdi - oil\_exp\_wdi\_lag\_1) / (oil\_exp\_wdi\_lag\_1)$ ;
- Total merchandise trade of a country exports to the world in US dollars at current prices from The World Trade Organization (2016), and its lags:  $trade\_exports$ ,  $trade\_exports\_lag\_1$ ,  $trade\_exports\_lag\_2$ ;

- Changes in total merchandise trade of a country exported to the world in US dollars at current price from previous year:  
 $gr\_trade\_exports = (trade\_exports - trade\_exports\_lag\_1) / (trade\_exports\_lag\_1)$ .
- Share of the urban population as a percent: *urban\_pop*.

### Fractionalization data

For measuring ethnic and religious fractionalization, we use the fractionalization index provided by Alesina et al. (2003), computed by the formula  $FRAC_m = 1 - \sum_{i=k}^N S_{km}^2$ , where  $S_{km}$  is the share of group  $k$  in country  $m$ . The variables for ethnic and religious fractionalization were disaggregated and combined from several sources (see more details in the Data set), but the primary source was Encyclopaedia Britannica (2001):

- Ethnic fractionalization: *ethnic*;
- Religious fractionalization: *religion*.

### Political controls

- Polity IV scores: Type of political regime for each country on a range from -10 (full autocracy) to +10 (full democracy) (Roser, 2019; Polity IV Project, 2013; Wimmer and Min, 2006): *polityiv*;
- Transformed Polity IV scores (*polityiv*) on a positive range from 1 to 20, and its two lags: *polityiv\_tr*, *polityiv\_tr\_lag\_1*, *polityiv\_tr\_lag\_2*;
- The variable constructed to measure the absolute strength of a political shock in a country and a year compared to the previous year:  
 $strength\_gr\_polityiv = |polityiv\_tr - polityiv\_tr\_lag\_1|$ . It does not matter whether the shock was toward democracy or backward to autocracy, because we are interested in the absolute strength of a political shock;
- Voice and accountability indicator as percentile rank among all countries (ranges from 0=lowest to 100=highest rank), which reflects perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, association, and a free media (World Bank, 2014): *accountab*.



## Natural conditions

- *agri\_land*: Agricultural land (% of land area) refers to 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).
- *arable\_land*: Arable land in hectares per person.
- *area.km2*: Is the total area of a country in km<sup>2</sup>.

Furthermore, based on the data of FAO (2017a), which are available for five-year periods from the 1980s for most countries in our sample, we generated the following variable for water use:

- *freshwater* is freshwater withdrawal as % of total renewable water resources.
- *agri\_renew* is agricultural water withdrawal as % of total renewable water resources (%).
- *water\_stress* is an aggregated indicator of freshwater withdrawal as a proportion of available freshwater resources. This indicator is also known as water withdrawal intensity.
- *wasser\_total* is the annual level of freshwater withdrawal, calculated as an average over each decade (1980–1989, 1990–1999, 2000–2017), in 10<sup>9</sup> m<sup>3</sup>/year.
- *water\_1km2* is average annual level of freshwater withdrawal (calculated as an average over each decade) divided by country area as  $water\_1km2 = 10^6 \times wasser\_total / area.km2$ , in 10<sup>3</sup> m<sup>3</sup>/km<sup>2</sup>.

## 2.3 Empirical framework

In the two-stage approach, we capture direct and indirect effects of weather variation (rainfall and temperature) as well as other external shocks on the incidence of civil war. In the first-stage regressions, economic growth rate and food index are instrumented by weather and other control variables with fixed effects. Then the effect of first-stage (economic growth rate and food index) with the effect of lag-dependent variable (since the experience of war in the past increases the likelihood of entering into new conflicts), weather variables directly, and control variables will be measured on the incidence of civil conflict. To the best of our knowledge the only study considered the effect of food production in such a relationship between climate and conflict in Africa is the one of Buhaug et al. (2015) who revealed a robust link between weather patterns and food production across sub-Saharan Africa and indicated that covering indirect and conditional effects of climate variability on collective political violence via food production shocks is very important.

With the econometric software STATA, we have tested a wide range of methods: Generalized Method of Moments (GMM), a two-stage least squares method by instrumental variable estimator (IV-2SLS), as well as probit models. First, to take lagged conflict explicitly into account, we estimated our model with Dynamic Panel Data estimators (DPD) based on GMM, because this kind of model allows us to include one or more lagged dependent variables (Roodman, 2009; Arellano and Bover, 1995; Blundell and Bond, 1995). We applied an estimator of GMM introduced by Hansen (1982) and implemented by Roodman (2009) in the STATA package *xtabond2*. To ensure that the estimator is robust to heteroskedasticity, we used the option *robust* on the command *xtabond2*.

Second, we applied the IV-2SLS-method with package *ivreg2*. In this method, we excluded lagged dependent variables from regressions because this method doesn't control unobserved heteroskedasticity. We applied this method first of all for identifying strong instruments for endogenous variables of economic development in the first stage.

Additionally to these two approaches, we also applied Probit models. However, Probit models are not able to take into account lagged explanatory variables. Moreover, using Probit models with endogenous variables may lead to inconsistency and even bias in the case of fixed effects (Greene, 2002; Arellano González, 2005). Therefore, in this Chapter we focus on results for the GMM and 2SLS methods.

Additionally, we computed some statistical tests to ensure that the chosen instruments are strong enough for endogenous variables  $gr\_gdp$  and  $food\_index$ . First, we applied the IV-2SLS method and used the Sanderson-Windmeijer (SW) Chi-squared and  $F$ -statistics that test underidentification and weak identification of endogenous variables. The null hypotheses were rejected. The SW Chi-squared statistic<sup>8</sup> equals 172.66 ( $p$ -value=0.000) for GDP growth and 293.09 ( $p$ -value=0.000) for the food index. SW  $F$  statistics account for 31.72 and 53.85 for both regressors, respectively—greater than recommend level of 10. Next, we test for overidentification by Hansen J-statistic after command *ivreg2*.<sup>9</sup> The joint null hypothesis of the Hansen J-test that the instruments are valid instruments (i.e., they are uncorrelated with the error term) could not be rejected with the  $p$ -value 0.529. Furthermore, we controlled our sample with respect to heteroskedasticity with the Breusch-Pagan/Cook-Weisberg test: the null hypothesis that the error variance is constant was rejected with  $Prob>Chi^2=0.000$ , pointing to heteroskedasticity in our sample. In this context, since in IV-2SLS the heteroskedasticity problem may make our estimated coefficient less precise, we focus on the results from GMM estimation eliminating this problem. However, we will take into account the results from both methods.

### 2.3.1 Results from the first stage

In the first stage, economic growth rate and food index for country  $i$  and year  $t$  are instrumented by a vector of explanatory variables for weather and environment conditions ( $X'_{it}$ ) including fixed effects. Similarly to Miguel et al. (2004), we included country fixed effects  $a_i$  to capture time-invariant country characteristics that may be related to civil conflict, as well as country-specific time trends  $year_t$  to capture additional variation over time:

$$gr\_gdp_{it} = a_i + bX'_{it} + d_i year_t + e_{it}, \quad (2.1)$$

$$food\_index_{it} = a_i + bX'_{it} + d_i year_t + e_{it}, \quad (2.2)$$

where the error term  $e$  is allowed to be correlated across years for the same country.

When searching for strong instruments, we applied many different variables available in our dataset. However, a constellation of explanatory variables presented in the

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<sup>8</sup>SW Chi-squared was computed for  $(L1 - K1 + 1)$  degrees of freedom where  $L1$  is the number of excluded instruments and  $K1$  is the number of endogenous regressors.

<sup>9</sup>Remark: the Hansen test was done after country fixed effects were removed from the equation because otherwise an estimated covariance matrix with dummy variables is not of full rank.

following discussion provided statistically better results fitted by values of  $R^2$  and the  $F$ -test. Moreover, we present only the results of those variables which show no multicollinearity problem. Furthermore, fixed effects and country specific time trend are included for all countries and estimations. However, focusing on the Syrian conflict in this paper, in Table 2.1 we decided to include estimated coefficients only for four selected countries (Syria, Turkey, Iraq, and Iran), although all countries were included in the estimation.

Although the food index is positively correlated with economic growth rate (0.12), but it seems to be affected by the same variables differently. In Table 2.1, in the OLS regression the given explanatory variables explained the food index better than economic growth (with  $R^2$  equaling 0.87 versus 0.16). Overall, there are only a few variables that have a significant impact on GDP growth. From the first group of variables related to economic and agricultural factors, agricultural land and a relative change in trade exports enhance economic growth significantly by 0.004 and 0.113, respectively. However, arable land decreases GDP growth rate (-0.284\*). This may be explained by the fact that a high share of crop items being less expensive than oil or even animal products may have a negative effect on their proportion in the total value of gross domestic product.

Table 2.1: First-stage results for economic growth rate and food index

	(1)		(2)	
	<i>gr_gdp_c_usd</i>		<i>food_index</i>	
<i>gr_trade_exports</i>	0.113***	(0.000)	-0.016**	(0.015)
<i>gr_oil_exp_wdi</i>	0.000001	(0.620)	-0.000002	(0.289)
<i>agri_land</i>	0.004**	(0.044)	0.014***	(0.000)
<i>arable_land</i>	-0.284*	(0.052)	0.481***	(0.000)
<i>urban_pop</i>	-0.002	(0.490)	0.005**	(0.016)
<i>gr_temp</i>	-0.310**	(0.032)	-0.227*	(0.056)
<i>gr_rainfall</i>	0.047	(0.251)	-0.012	(0.715)
<i>rainfall</i>	-0.000004	(0.933)	0.00003	(0.483)
<i>inter_L_gr_rainfall</i>	-0.068	(0.110)	0.003	(0.927)
<i>inter_L_rainfall</i>	0.0002**	(0.026)	0.0001*	(0.091)
<i>water_stress</i>	-0.00002	(0.869)	-0.001***	(0.000)
<i>water_1km2</i>	0.0002	(0.877)	-0.0004	(0.617)
<i>polityiv_tr</i>	-0.0004	(0.785)	-0.008***	(0.000)
<i>strength_gr_polityiv</i>	-0.007***	(0.001)	-0.003	(0.126)
<i>accountab</i>	0.001	(0.397)	0.001	(0.417)
<i>ethnic</i>	0.019	(0.922)	-0.303*	(0.058)
<i>religion</i>	-0.143	(0.557)	0.090	(0.652)
<i>year_trend_TUR</i>	-0.001	(0.822)	0.019***	(0.000)
<i>year_trend_SYR</i>	-0.002	(0.431)	0.020***	(0.000)
<i>year_trend_IRQ</i>	0.005*	(0.073)	0.012***	(0.000)
<i>year_trend_IRN</i>	0.004	(0.228)	0.028***	(0.000)
<i>dummy_country_TUR</i>	0.125	(0.244)	-0.088	(0.315)
<i>dummy_country_SYR</i>	0.101	(0.459)	-0.518***	(0.000)
<i>dummy_country_IRQ</i>	0.270	(0.175)	0.611***	(0.000)
<i>dummy_country_IRN</i>	0.151	(0.141)	0.010	(0.905)
Constant	-0.209*	(0.072)	-0.391***	(0.000)
Observations	1994		1994	
$R^2$	0.16		0.87	
$F$	2.791		93.99	

Country and time fixed effects are included for all countries.

p-values in parentheses: \*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

By contrast, the food index is negatively affected by a growth rate of trade exports (-0.016\*\*), pointing out that more industrialized countries exporting industrial goods and oil give less support for agricultural branches and rely heavily on food imports (Maystadt et al., 2014). For example, in the Gulf countries, oil production is dominant at the expense of arable land and agricultural production, and simultaneously the highest share of total exports in Oman and Yemen is fish and fish products needing no arable land. Furthermore, agricultural and arable land raise the food index by 0.014\*\*\* and 0.481\*\*\*, respectively. Furthermore, the share of urban population is positively related to the food index (0.005\*\*). It seems that a higher share of urban population forces a higher food supply. This is because in higher urbanised countries, agricultural branches that are more intensified are able to provide relatively more food (Satterthwaite et al., 2010).

Regarding the second group of variables referring to environmental conditions, a change of one percentage point (1 pp) in temperature growth significantly reduces economic growth by 0.310 pp and food index by 0.227 pp. Considering the temperature increase in the last two decades, this is a huge effect. For example, while in the 2000s global mean temperature difference was around 0.6°C above pre-industrial levels (1850–1900), in 2019 this temperature change was already around 1.1 ± 0.1°C (World Meteorological Organization, 2019). **That means a near doubling of temperature growth, or a 100% increase over 20 years**, calculated as:

$$\frac{\Delta t}{t} = \frac{\bar{t}_{2019-1900} - \bar{t}_{2000-1900}}{\bar{t}_{2000-1900}} = \frac{1.2 - 0.6}{0.6} = \frac{0.6}{0.6} = 1, \quad (2.3)$$

where  $\bar{t}_{y-1900}$  is an average temperature change between year  $y$  and 1900. We controlled for the average increase in temperature growth in our data. First, we observe a significant increase of the average temperature over all countries as well as in Syria. For example, according to our sample the average annual temperature in Syria was 17.42°C in the 1980s, 18.02°C in the 1990s, and 18.6°C in the 2000s. Second, we were interested to investigate a change in temperature growth in our data in order to appreciate the estimation. Similar to the formula above, we took the mean temperature of the 1980s as a reference level, and we computed a mean change in temperature growth for the 16 last available years between 2000 and 2015, comparing to the reference level of 1980s. Thus, we received

$$\frac{\Delta t}{t} = \frac{\bar{t}_{2015-80s} - \bar{t}_{2000-80s}}{\bar{t}_{2000-80s}} = \frac{0.784 - 0.275}{0.275} = \frac{0.509}{0.275} = 1.85, \quad (2.4)$$

or computed by means of relative temperature change  $\bar{T}$  (in %) as

$$\frac{\Delta T}{T} = \frac{\bar{T}_{2015-80s} - \bar{T}_{2000-80s}}{\bar{T}_{2000-80s}} = \frac{3.34 - 1.17}{1.17} = \frac{2.17}{1.17} = 1.85. \quad (2.5)$$

Surely, we have deviating results because we had a shorter time perspective compared to the period 1980-2000. Nevertheless, the positive change in temperature of  $0.51^{\circ}\text{C}$  over 16 years is absolutely comparable with an increase of  $0.6^{\circ}\text{C}$  over 20 years, illustrated above. Calculated on average over all countries, we obtained a mean change in temperature growth of 2.17 pp for 16 years (or 0.14 pp annually). Thus, according to our computation, a 2.17 pp increase in temperature growth would induce a reduction in economic growth and food index by 0.67 pp and 0.49 pp, respectively, over 16 years. In other words, only due to rising temperature, every 16 years income growth would fall by 0.67 pp and the food index would decline by 0.49 pp, all else being equal. For example, **if some countries currently have a limited income growth of 1–1.4% annually, in 32 years these countries will be not able to achieve any income growth only due to climate change, ceteris paribus. Additionally, rising food prices due to decreases in harvesting would mean a catastrophe for ordinary citizens in such countries.**

Furthermore, in our estimation neither rainfall level nor its relative change has a significant impact on GDP growth rate or the food index. However, in countries suffering from rain shortages, more precipitation increases economic growth by 0.0002\*\* and the food index by 0.0001\*. Furthermore, more water stress decreases the food supply (-0.001\*\*\*).

Considering the third group of political factors, the level of democracy (Polity IV estimates) is significantly negatively related to the food index (-0.008\*\*\*). In this context, more democratic countries are even less effective in ensuring food production, while stronger autocratic regimes cope better with food supply stresses. Furthermore, democracy level has no significant impact on GDP growth rate. However, the power of political shocks reduces economic growth significantly (-0.007\*\*\*), regardless of a change in direction of the political system in “transition time”.

Last, with respect to social structure, only increasing ethnic fractionalization reduces the food index (-0.303\*). Furthermore, we included some idiosyncratic effects for several chosen Middle Eastern countries. For these four selected countries, the food index appears to have an increasing trend over time compared to 1981. Moreover, the interesting result is that the food index was significantly smaller in Syria

than in other countries (-0.518\*\*\*): this points to the fact that Syrian government disregarded the importance of agricultural production and provision of food to the population. Next, we are interested to understand how food production decreased in the years before the Syrian conflict—and to what extent we are able to explain this reduction by reference to temperature growth as the most important explanatory variable for economic indicators.

### Predicted impact of temperature growth on economic indicators in Syria

First, it is interesting that the average annual temperatures in Syria fluctuates. The mean value of temperature growth rate is 0.316, whereby the interval of the mean  $\pm$  standard deviation is [-4.015, 4.647]. In the first column of Table 2.2, it can be seen that in the years before the war there was a temperature growth rate of 1.932 in 2007 and 8.078 in 2010, whereby the second value lies outside of the computed interval [-4.015, 4.647] and therefore was an extraordinary change of temperature.

Based on our estimation, we are interested to figure out the extent to which a change in temperature growth can explain the decreased income and food index. Therefore, in columns 2, 4, and 7 we calculated the difference in observed temperature growth, income change rate, and food index when comparing to 2007. The maximum difference in temperature growth rate is 6.147 in 2010, i.e., shortly before the war broke out. Based on our estimates, in columns 5 and 6 we computed partial predicted impact of temperature growth on economic indicators by multiplying the increments with respective coefficients.

Table 2.2: Predicted effects of temperature growth in Syria

	$gr\_temp, \%$	$\Delta gr\_temp_{y-2007}$	$gr\_gdp\_con$	$\Delta gr\_gdp_{y-2007}$	$\hat{\beta}_k \Delta gr\_temp_{y-2007}$	$FI, \%$	$\Delta FI_{y-2007}$	$\hat{\beta}_m \Delta gr\_temp_{y-2007}$
2007	1.932		17.200			93.600		
2008	0.235	-1.697	26.085	8.885	0.526	90.040	-3.560	0.385
2009	-0.065	-1.997	0.464	-16.736	0.619	96.230	2.630	0.453
2010	8.078	<b>6.147</b>	10.739	<b>-6.461</b>	<b>-1.906</b>	91.970	<b>-1.630</b>	<b>-1.395</b>
2011	-10.543	-12.475	12.096	-5.104	3.867	102.840	9.240	2.832
2012	5.070	3.139	-28.868	-46.068	-0.973	93.830	0.230	-0.713
2013	-2.607	-4.538	-40.541	-57.741	1.407	83.430	-10.170	1.030
2014	1.929	-0.003	-11.730	-28.930	0.001	67.790	-25.810	0.001
2015	0.428	-1.504	-15.365	-32.565	0.466	78.800	-14.800	0.341

Thus, shortly before the conflict exploded in 2010, we consider that the 6.15 pp increase in temperature growth contributed to lower income growth by 1.91 pp, whereas the total reduction of income growth was 6.46 pp. In other words, the increase in temperature growth seems to explain around 30% of reducing income growth. Simultaneously, we observe that the increase in temperature growth by 6.15 pp contributed by decreasing food index by 1.39 pp, where we observe a total



reduction of food index of 1.63 pp. This means that based on our estimation, the increase in temperature growth could have contributed to 85% of the decrease in food index. Surely, we cannot exclude that this result is not shaped by any error term. However, we believe that these findings are reliable. Moreover, based on this empirical evidence, we believe that in the Syrian case, climate change and rapidly rising temperatures essentially contributed to economic instability and food insecurity, which obviously led to rising social tensions and a war. Moreover, we suppose that 2010 was a crucial year generating a considerable deterioration of economic prospects and growing dissatisfaction among the population. To what extent the climate change and economic situation contributed to war, we will reveal in the following.

### 2.3.2 Results from the second stage

As explained above, we provide estimation results for the GMM method (Models 1–12 in Table 2.3) and the IV-2SLS approach (Models 13–24 in Table 2.4). Each of the two methods was applied for three dependent variables related to conflict. Moreover, to control the stability of the estimation, we included explanatory variables step-by-step in four phases. In this way, we present four models for each independent variable and each method. However, when interpreting results, our discussion will mostly focus only on regressions with the dependent variable “any conflict”, since the impact of explanatory variables on two other dependent variables of conflict is much weaker, and thereby the statistical fit  $R^2$  of those regressions is lower. However, the results for all dependent variables are very similar, as can be seen from the tables presented. The second-stage equation estimates the impact of economic growth rate and domestic food production ( $gr\_gdp$  and  $food\_index$ ) predicted in the first stage, as well as the impact of other controls  $X'_{it}$  added in the regression step-by-step, on the incidence of civil conflict:

$$conflict\_dummy_{it} = \alpha_i + \beta \cdot gr\_gdp_{it} + \gamma \cdot food\_index_{it} + \delta \cdot X'_{it} + \sigma_i \cdot year_t + \epsilon_{it}. \quad (2.6)$$

As mentioned, we improved our estimations by including climate-relevant, political, and social controls  $X'_{it}$  in four phases,<sup>10</sup> whereas explanatory variables for economic development are included in all steps. Country fixed effect and specific time trend

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<sup>10</sup>In this Chapter, we present only significant and stable results controlled by statistical tests for underidentification of instruments, although many other different variables of our database (such as oil exporter status, trade exports, etc.) were regressed on civil conflict. Unfortunately, impacts of other independent variables were insignificant or unstable.

effects are also included in all regressions. In the first phase, we included change in rainfall and temperature. In the second step, we added precipitation level and water availability. Then, we added some additional variables for political system and social structure. Last, we introduced some variables for interaction effects of rain. As can be seen in Table 2.3, for the GMM method, the results over four described phases are stable when including additional variables step-by-step in Models 1–4 for any conflict and in Models 5–8 for dependent variable *war*, as well as in Models 9–12 for minor conflict. In Table 2.4, for the IV-2SLS approach, the addition of further explanatory variables also provides relatively stable results in Models 13–16 for any conflict, in Models 17–20 for *war*, and in Models 21–24 for minor conflict. Since the results are relatively robust over all models, we will mainly focus only on certain specifications.

With respect to the results in model 4, it is very interesting that a 1 pp change in lagged dependent variables increases the probability of any civil conflict significantly by around 0.36 percentage points in the year  $(t - 1)$  and by 0.09 pp at time  $(t - 2)$ . This means that the observed incidence in the past (100% – probability) contributes up to 36% to a conflict likelihood in the future. In this context, there is a strong path-dependency of conflicts over time: a conflict in the past causes a higher probability of an incidence in future.

Furthermore, our estimation establishes a significant negative link between economic development and conflict incidence and this finding is robust in all model specifications. Thus, a 1 pp reduction in GDP growth may raise conflict probability by 0.125 pp, while a 1 pp reduction in food production index may increase conflict probability by 0.159 pp. This strong negative link between economic growth and the incidence of civil conflict corresponds with the findings of Miguel et al. (2004). Comparing these outputs with results from Model 16 for the IV-2SLS estimation, we consider an essential overestimation of regression coefficients. For example, a 1 pp reduction in economic variables may induce an increase of conflict risks by 0.391 pp (for GDP growth rate) or even by 0.963 pp (for food index).



Obviously, the IV-2SLS approach considerably overestimates the effects. The reasons for this overestimation of coefficients in the IV-2SLS approach might be that the approach ignores the impact of lagged dependent variables as well as disregarding heteroskedasticity, whereas both may be taken into consideration by the GMM method of Roodman (2009).

Furthermore, temperature growth has no significant impact on any conflict-indicator; however, a 1 pp positive change in temperature growth enhances the probability of war by 0.391 pp. Given the average increment in temperature growth of 2.17 pp for the last 16 years in our data, we can calculate that over 32 years, temperature growth then can contribute to war probability by 1.7 pp. We see that this effect is a considerable direct contribution of climate change to conflict risks.

Additionally, a 1 pp increase in rainfall growth reduces the likelihood of any conflict by around 0.202 pp, and thereby this effect appears to be much stronger for minor conflict than for war (-0.260\*\*\* versus 0.045). It corresponds to the findings of Miguel et al. (2004), Hendrix and Glaser (2007), and Bohlken and Sergenti (2010) indicating that a positive increase in rainfall growth decreases conflict risk. However, we additionally found that in countries with low levels of precipitation, an increase in rainfall growth enhances the risk of any conflict and minor conflict by 0.196 pp and 0.274 pp, respectively. In this way, the impact of rainfall growth on conflict risk differs between countries in our sample and among the countries suffering from rain shortage. It appears that in countries with a rain shortage, there might be additional tensions in years with a positive increase in precipitation, as if the countries would fight for rainfall as a water source—if, for example, traditional planting and harvest cycles become disrupted. Another hypothesis is that after extreme weather events, such as strong rainfall and flooding, destruction of natural resources and the usual livelihood conditions may increase the probability of conflict due to higher pressure on agriculture and economies.

Further, regarding annual precipitation level, we observe a positive significant impact of rainfall level on any conflict and minor conflict (0.0003\*\*\*). This means that the probability of an incidence increases by 0.03 pp when the annual rainfall level changes by 1 mm, or by 3 pp when the rainfall level changes by 100 mm. Our results partly confirm the findings of Ciccone (2011) that higher rainfall level at point  $(t - 2)$  is related to the rising risks of conflict at point  $t$ . Our results show that a higher rainfall level already at point  $t$  is positively related to conflict probability.<sup>11</sup>

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<sup>11</sup>We excluded the rainfall levels at time points  $(t - 1)$  and  $(t - 2)$  because of the test for weak instruments and the high correlation between the different time points.

However, our results additionally imply that in countries with rainfall shortages, the impact of rainfall level on conflict risk is the reverse. Thus, the likelihood of conflict incidence falls by 0.06 pp when increasing rainfall by 1 mm, or by 6 pp when annual precipitation increases by 100 mm. It appears that a heterogeneity between countries with respect to their annual level of precipitation may yield different effects on conflict risk. Obviously, in countries with a strong lack of rainfall, the effects of rainfall and rainfall growth do not fit into the entire picture. This phenomenon should be explained more precisely in the future by other variables or more disaggregated data.

Regarding other natural conditions, available water decreases the probability of any conflict (-0.006\*\*\*). Thus, the additional possibility of withdrawing 1000 m<sup>3</sup> of fresh water per km<sup>2</sup> reduces the risk of any conflict by 0.06 pp. This also points to the fact that people appear to fight for water sources. However, this stands in contrast to Hendrix and Glaser (2007), who pointed out that freshwater resources per capita are positively associated with the likelihood of conflict.

Regarding the political factors such as level of democracy and government accountability, our results confirm theoretical works indicating that countries with stronger democratic institutions are better able to negotiate compromises among different social groups to avert unrest (Benhabib and Rustichini, 1996; Easterly and Levine, 1997). Thus, the increase in Polity IV scores by one unit implies a significant reduction in the likelihood of any conflict by 0.5 pp. Similarly, the probability of any incidence falls by 0.4 pp when enhancing accountability by one point.

Concerning social structure, in contrast to the results of Miguel et al. (2004) and Fearon and Laitin (2003), who found no significant association of ethnic and religious diversity with civil conflicts, we noted a significantly positive impact of religious fractionalization on conflict risk with the GMM estimator (1.305\*\*\*). Moreover, the IV-2SLS approach yields a negative impact of ethnic diversity on any conflict and minor conflict (-0.644\*\*\* and -0.580\*\*\*). However, both fractionalizations appear not to be strong predictors for conflict risks because of unstable results dependent upon an estimator and model specification. By contrast, share of urban population seems to provide a stable positive impact on probability of any conflict and minor conflict. Thus, a 1 pp increase in share of urban population enhances the probability of any conflict and minor conflict by 0.7 pp and 1.3 pp, respectively. This indicates that the higher density of the urban population with limited access to job opportunities, food, and fresh water additionally increases the likelihood of being in conflict. That result correlates with findings of other researchers (Nedal et al.,

2020; De Soysa, 2002; Raleigh and Urdal, 2007) that highly concentrated states with a greater proportion of urban population are more likely to experience widespread political violence compared to those with a lower share of urban population.

### Total predicted effects of conflict probability in Syria

Next, we are interested in computing the extent to which independent variables that were changing in Syria in the years before the conflict are able to explain the likelihood of civil conflict in Syria. Therefore, we see the total effects of civil conflict probability. We are interested to check how well explanatory variables are able to predict the conflict since 2011 with reference to the previous non-conflict time in Syria. We have taken 2006 as a reference year, i.e., five years before the Syrian civil war broke out. Thus, we compute the total change in predicted probability,  $\Delta PROB_{it}$ , induced by the increment in the explanatory variable in year  $t$  of time period 2007–2015 as:

$$\Delta PROB_{it} = \beta \cdot (gr\_gdp_{it} - gr\_gdp_{i,2006}) + \gamma \cdot (food\_index_{it} - food\_index_{i,2006}) + \delta \cdot (X'_{it} - X'_{i,2006}) + \sigma_i \cdot (year_t - year_{2006}) + (\epsilon_{it} - \epsilon_{i,2006}). \quad (2.7)$$

In Table 2.5, we display the effects. Obviously, some variables (such as *water\_1km2*, *ethnic*, *religion*, *urban\_pop*) do not contribute to predicted war likelihood because they did not vary over time or they changed only slightly.

Thus, when comparing to 2006, declining economic growth in Syria contributes to a predicted conflict probability only by 0.08 pp in 2011, while the contribution of the decline in the economic growth rate was at its highest of 6.66 pp in 2013. Obviously, this positive effect arises from a negative difference in economic growth rates multiplied by a negative estimated coefficient. When comparing with 2006, falling economic growth is able to explain war likelihood by 3–7 pp. However, in 2009, income growth considerably contributed to conflict risks by 1.5 pp, as well.

Furthermore, the food production index explains the likelihood of conflict only by 0.61 pp in 2011. Overall, the food index is able to predict war probability by 2–6 pp in conflict years and by 1–2 pp in the years before the war. The impact of food index increased over time with increasing intensity of the conflict and reached 6.20 pp in 2014. Interestingly, in the two last years in the dataset, the food index contributes to the conflict likelihood even more strongly than the economic growth (6.2 and 4.44

Table 2.5: Total effects of explanatory variables on the probability of civil conflict, reference year is 2006

	<i>any_prio_lag_1</i>	<i>any_prio_lag_2</i>	<i>gr_gdp_c_con</i>	<i>food_index</i>	<i>gr_temp</i>	<i>gr_rainfall</i>	<i>rainfall</i>	<i>water_1km2</i>	<i>polityu_tr</i>	<i>accountab</i>	<i>ethnic</i>	<i>religion</i>	<i>urban_pop</i>	<i>inter_L_gr_rainfall</i>	<i>inter_L_rainfall</i>	<b>Sum over vars.</b>	<b>Constants</b>	<b>Residuals</b>
2007	0.00	0.00	-0.55	2.08	0.15	4.39	-1.10	0.00	0.00	0.18	0.00	0.00	0.72	-4.26	2.03	3.64	-19.35	15.72
2008	0.00	0.00	-1.66	2.65	0.04	7.13	-3.03	0.00	0.00	0.00	0.00	0.00	0.72	-6.92	5.62	4.54	-17.57	13.03
2009	0.00	0.00	1.54	1.66	0.02	-11.31	0.40	0.00	0.00	-0.32	0.00	0.00	0.72	10.98	-0.75	2.93	-15.78	12.85
2010	0.00	0.00	0.25	2.34	0.55	7.39	-2.04	0.00	0.00	0.03	0.00	0.00	1.43	-7.17	3.79	6.57	-14.00	7.43
2011	0.00	0.00	0.08	0.61	-0.67	-7.70	0.90	0.00	0.00	0.38	0.00	0.00	0.72	7.47	-1.66	0.13	-12.21	112.08
2012	36.12	0.00	5.20	2.05	0.36	-0.44	1.90	0.00	0.93	0.56	0.00	0.00	0.00	0.43	-3.51	43.58	-10.43	66.84
2013	36.12	9.05	6.66	3.71	-0.15	5.67	-0.10	0.00	0.93	0.56	0.00	0.00	-0.72	-5.50	0.18	56.42	-8.64	52.23
2014	36.12	9.05	3.06	6.20	0.15	3.48	-0.81	0.00	0.93	0.50	0.00	0.00	-1.43	-3.38	1.50	55.38	-6.86	51.48
2015	36.12	9.05	3.51	4.44	0.05	1.81	-0.83	0.00	0.93	0.68	0.00	0.00	-1.43	-1.75	1.54	54.13	-5.07	50.94

pp vs. 3.06 and 3.51 pp).

Regarding the total contribution of all rainfall variables (such as *gr\_rainfall*, *rainfall*, *inter\_L\_gr\_rainfall*, *inter\_L\_rainfall*) to the probability of civil conflict, we computed only minor effects of -1.0, -1.63, 0.25, 0.79, and 0.76 pp after the outbreak of the war. However, in the years before the conflict (2007–2010), low precipitation seems to have sharpened the situation in Syria, because the contribution of all rainfall indicators to the probability of conflict is mostly positive (such as 1.07, 2.80, -0.68, 1.97 pp). Nevertheless, regarding the years of conflict, both economic variables together are much more able to predict the ongoing conflict (by 7–10 pp) than variables for precipitation.

Furthermore, we recognize an essential effect of temperature growth in the years before the war. All years after 2006 have a positive effect of (respectively) 0.15, 0.04, 0.02, and 0.55 pp in increments of temperature growth when drawing a comparison with 2006. The largest increase in temperature growth was in 2010, shortly before the war began. We suppose that a direct impact of temperature growth on conflict risk (0.55 pp) is a considerable effect when drawing a comparison, for example, with the food index effect of 2.34 pp.

Regarding the official years of conflict, we must admit that it is difficult to explain the outbreak of war in Syria in 2011. Twenty-ten, the year before the conflict erupted, seems to be even more able to explain the conflict likelihood by the selected variables. By contrast, it appears to be possible to explain the ongoing conflict in 2012–2015 by 43–56 pp through involving explanatory variables. However, considering this total effect more closely, it is noticeable that the strongest impact of 36–45 pp arises from lagged dependent variables, whereas the effect of economic variables accounts for

7–10 pp. All other explanatory variables contribute to the conflict relatively weakly.

With the Figure 2.1, we illustrate the contribution of the model (GMM) components including control variables, lagged conflicts, fixed effects, and errors, to the probability of civil conflict in Syria over time. Numbers from 1 to 35 indicate the time series from 1981 to 2015. It is clear that the model produces high errors in the outbreak years of the early conflict in the '80s and the 2011 conflict. Second, it is obvious from the estimated impact of the controls included in our model, i.e., the impact of the economic, climate variables, political, socio-economic, and demographic, show a trend toward the war that began in 2011 and increased the probability of civil war (we showed previously that the year 2010 contributed the most to explaining the probability of conflict before the outbreak in 2011). Third, the impact of controls rises during wartime from 2011 to 2015, indicating the reverse impact of conflict on the income and food production in the country. Fourth, we see in our model simply that war brings war from the impact of lagged dependent variables (blue bars).

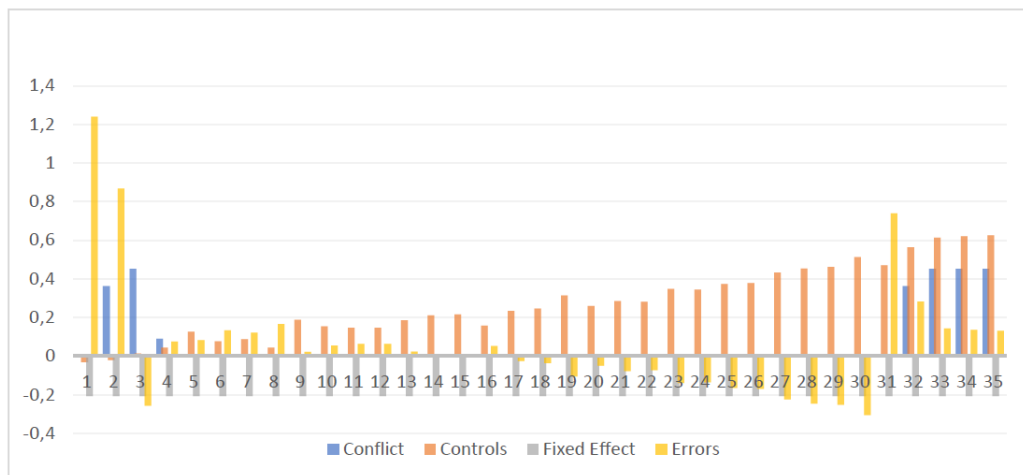


Figure 2.1: The total contribution of the model components to the probability of civil conflict in Syria from 1981 to 2015

The justification of our work and the criticism of others' studies may be that other researchers do not exactly compute a total contribution of explanatory variables to predicted probability as well as respective residuals. Although some studies investigate marginal effects (estimated coefficients) for the onset of conflict—for example, Fearon and Laitin (2003), Miguel et al. (2004)—they cover neither predicted probabilities nor emerging residuals. Therefore, drawing any conclusions as to the extent to which their significant variables contribute to the onset of conflict is only hardly possible. Apparently, explaining conflict onset is much more difficult than antici-



pated in our study as well as those of other researchers, and it requires including more country-specific factors. Even significant marginal effects do not guarantee high explanatory power in each specific case.

### **Political interventions to reduce the incidence of civil conflicts and trigger peace**

After presenting empirical evidence on the impacts of climate change on economic development and its contribution to increasing the likelihood of conflict, it is particularly important to assess economic policies that can reverse economic shocks and lead to a stable economic development, thus reducing conflict risks. Based on simulation analysis, we anticipate the amount of income growth versus increased food production that can be achieved to country's negative economic growth during war. For example, Syria had in 2012 an economic growth rate of -0.28 pp, assuming that through global aid it would have been possible to stabilize the economic growth rate of Syria by an amount of money equal to 10% of the Syrian GDP in 2011 (the outbreak-year, i.e., 2011 is a base year), so that, this is a certain amount of money or  $0,1 * GDP\_base$ . Using this amount of money as a transfer in the country in year  $t$  (which could be 2012, 2013, or 2015) implies the following growth rate:

$$W\_GDP = \text{Transfer} / \text{GDP\_year}_{t-1} = 0,1 * \text{GDP\_base} / (1 - w\_year) \text{GDP\_base} = 0,1 / (1 - w\_year).$$

$w\_year$  is the decrease in GDP due to the civil war in year  $t$ ; e.g., year\_2013, then  $w\_2013$  is the decline in GDP in 2013 compared to the base year (2011).

For the same amount of money (10% of  $\text{GDP\_base}$ ) invested in increasing food production, it is important to know how much production growth can be achieved with a 10% of the base-budget, and this leads to an output growth of approximately 5% (but permanently, i.e., investment One-time, then the increase occurs every year, like technical progress). The smaller the size of agricultural sector of GDP, the greater this effect. Assuming that the size of the agricultural sector makes up 20% of GDP; then  $0,5 * 0.2 / \text{share}$

$\text{share}$ : is the actual share of the agricultural sector in Syria. Interestingly, investing in increased food production also has an effect on the growth rate, i.e., the indirect growth effect. A 10% of  $\text{GDP\_base}$  investment corresponds to 3% total growth (measured on the  $\text{GDP\_base}$ ), therefore, the impact of indirect growth rate increases depending on the size of actual GDP, so this is multiplied by  $1 / (1 - w\_year)$  gives the actual effect.

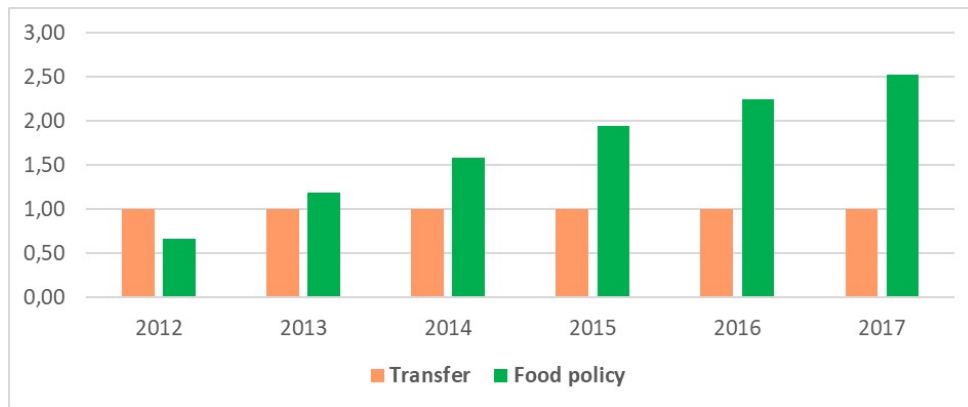


Figure 2.2: Relative effects of policy interventions triggering peace

Figure 2.2 shows the simulation results of the relative effects of political interventions (Transfer compared to food policy) in stabilizing economic development, thus reducing the incidence of civil conflict, and triggering peace. The orange bars indicating policy interventions that accelerate economic growth rate show a higher effect in the first year than the effect of food policy (green bars) and this effect remains the same in the following years, while policies that enhance food production (technical progress) indicate a higher effect in the later years due to the effect of the previous year (cumulative). Therefore, proper food policies that enhance food security seem to play a more affordable role towards peace. Accordingly, policy interventions that are able to increase food security as well as global aid to accelerate economic development, have the potential to reduce the risk of conflict and triggering peace.

However, it is particularly important to take appropriate measures at the right time, especially when war breaks out, otherwise, the costs of returning back to peace will increase over time because when a war breaks out it is no longer related to the negative effects of only climate change on economic growth rate. Therefore, in order to achieve the same amount of income growth during a war, a greater amount of money will be required compared to the pre-war situation.

The findings of this study are relevant to other countries in the region that face comparable environmental challenges and can inform policies for mitigating and alleviating future conflicts.

## 2.4 Conclusion

This paper evaluates the linkages between climate change, economic indicators, and conflict probability based on a new panel database. This data sample includes many socio-economic, political, and environmental variables for 59 countries of Africa and the Middle East from 1981 to 2015, collected from different prominent resources. We contributed to current research in the following ways:

First, we investigated an indirect impact of climate change on war probability through its effect on economic development. In addition to other environmental and socio-political characteristics, weather indicators seem to be suitable instrumental variables not only for economic growth but also for domestic food production index. For example, a 1 pp change in temperature growth can significantly decrease income growth (by 0.31 pp) and food index (by 0.23 pp), respectively. This is a huge effect. For example, while in the 2000s the global mean temperature difference was around  $0.6^{\circ}\text{C}$  above pre-industrial levels (1850–1900), in 2019 this temperature change was already around  $1.1 \mp 0.1^{\circ}\text{C}$  (World Meteorological Organization, 2019): that means a near doubling of temperature growth, or a 100% increase during only 20 years. Regarding countries in our dataset, we found a 185% increase of temperature growth during the last 16 years of the sample when comparing with the '80s. We calculated a mean change in temperature growth of 2.17 pp during the last 16 years. By means of estimated coefficients, it can be seen that a reduction in economic growth is 0.67 pp due to temperature increase during 16 years, whereas reduction in food index is 0.49 pp. This means that **if some countries currently have an income growth rate of 1–1.4% annually, within only 32 years these countries will be not able to achieve any income growth only due to climate change, ceteris paribus.**

Second, we found that climate change directly affects the likelihood of civil war. According to our estimation, a 1 pp change in temperature growth can cause an increase in war probability of 0.391 pp. Taking the average increment in temperature growth of 2.17 pp for the 16 years, we calculated that for 32 years, temperature growth alone can contribute to war probability by 1.7 pp. Regarding the impact of precipitation on conflict likelihood, our findings imply that a 1 pp increase in rainfall growth reduces the mean likelihood of any civil conflict by 0.2 pp. However, in countries with high rainfall shortage, the result is the opposite, i.e., an increase in rainfall growth enhances any conflict risk by around 0.2 pp. Overall, our results indicate that the effect of both rainfall variables on conflict likelihood may be significantly different according to countries' dependence on usual precipitation level.

Third, we confirmed the most robust finding of Miguel et al. (2004): that economic situations induced by climate variability can significantly raise the risk of conflict. Additionally to GDP growth, the food production index appears to be a further appropriate economic variable for explaining conflict probability. Considering all countries, a 10% reduction in economic growth or domestic food production leads to 1,2% and 1,59% increase in the probability of civil conflict, respectively. Economic development seems to play an essential role for preventing new conflicts.

Fourth, ignoring lagged dependent variables leads to overestimation of marginal effects. Our results, based on comparing two different approaches, point to the fact that other studies usually overestimate the impact of economic and weather variables on conflict probability because effects of lagged dependent variable were not taken into account. According to our results, being in conflict in the past increase the likelihood of further conflicts by 36–45 pp and automatically decreases the significant effects of other explanatory variables. The simple logic behind our motivation for involving lagged dependent variable is that human losses cause psychological obstacles and barriers to peace-building.

Next, our results show that increases in temperature growth have a great impact on a country's economic situation. For Syria, based on our estimation, we found out that the strong increase in temperature growth explains 30% of shrinking income growth as well as 85% of decreasing food index in 2010. Moreover, we suppose that 2010 was a crucial year generating a high probability for war. The high increase in temperature growth in 2010 strongly contributed to economic instability and food insecurity, both obviously led to rising social tensions.

We explained the Syrian conflict by our estimates. The effects of explanatory variables in 2010 point to the rising probability of conflict. While the onset of conflict in 2011 could not be explained well with the explanatory variables, the ongoing conflict in 2012–2015 could be empirically predicted by explanatory variables to the tune of 43–56%. Obviously, the strongest factor explaining the ongoing conflict is the occurrence of war in the last two years: it accounts for up to 45% of conflict likelihood. The second important factor contributing to conflict risks arises from both economic variables. We empirically showed that an unstable economic situation, decreasing income, and food insecurity essentially contributed to the Syrian conflict. Thus, GDP change and food index together seem to have contributed to conflict in Syria by 7–10%. Moreover, both economic variables are much more able to predict the ongoing conflict than variables for climate change.

Moreover, we would like to point to the fact that obtaining a significant impact of explanatory variables on dependent conflict variables is easier than receiving a highly predicted probability itself. The investigation of causes of conflict requires much more than only receiving significant coefficients. To understand each current incidence and empirical estimation, it is much more interesting and helpful to reveal total effects and predicted probabilities. Explaining each current incidence requires the inclusion of more country-specific factors. Notice that while growth indicators calculated as year-by-year change give researchers only a short perspective for analysis, serious consequences of climate change are much more noticeable by considering a long-term perspective. Therefore, for empirical investigation, it is recommended to calculate indicators of temperature growth and rainfall growth based on a period of time longer than one year. Last, the investigation of the onset of conflict requires more precise attention in the future. Proper economic policies that stabilize the negative GDP growth and enhance food production index seem to play a more affordable role toward peace. The findings of this Chapter are relevant to other countries in the region that face comparable environmental challenges and can inform policies for mitigating and alleviating future conflicts.

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## Chapter 3

# If there is a stable relationship between climate change and civil war in sub-Saharan Africa? –A replication study of Miguel et al. (The Journal of Political Economy, 2004)

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### *Replication materials and data availability*

For this chapter, we used two data sets; The data of the original study “MSS’ dataset”, which is available at the web page of Edward Miguel, Berkely, University of California <http://emiguel.econ.berkeley.edu/research/>, data replication files (STATA Dta-files and Do-file). A new data set (A description of variables used in the estimations of this Chapter is in the Appendix A3).

### **Abstract**

We replicated the findings of Miguel and his co-authors, who find a significant negative relationship between economic shocks and the likelihood of civil conflict in sub-Saharan Africa (SSA) for the period 1981- 1999, using rainfall growth as an instrumental variable for the economic growth rate. The replication of this study is successfully performed. Furthermore, we apply a robustness test to the results using new cross-country panel data, with different measurements, and econometric specifications. The results appear to be sensitive to changes in data sources that use different methods of making the data available, although we find partly the same patterns between weather and economic growth rate, and between the income growth and the likelihood of civil conflict, like Miguel et al. (2004) for SSA period 1981– 1999.

**Keywords:** Rainfall, economic growth rate, conflict, sub-Saharan Africa

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### 3.1 Introduction

We reproduce results of a study published by Miguel, Satyath, and Sergenti (MSS, 2004; the first letters of authors' names) in the JPE, the article is cited by around 2400 research papers on civil conflict in Africa at the time of writing this replication study (February 2020). They empirically proved that economic growth is negatively related to civil conflict in sub-Saharan Africa (SSA) during the period 1981- 1999 using rainfall variations (annual rainfall growth) as an instrumental variable for income growth, where countries' economies largely rely on rainfed agriculture. However, their results have been already reproduced and/or considered as a reference point for many efforts in civil war economies, e.g.(Ciccone, 2011). Moreover, to address the problem of endogeneity, MSS argued that the approach of Fearon and Laitin (2003) by lagging explanatory variables implicitly assumes that economic actors do not anticipate the incidence of civil war and adjust economic activity (e.g., investment) accordingly. Therefore, the instrumental variable approach addresses the attenuation bias that may result from mismeasured explanatory variables, which, if not addressed, would bias coefficient estimates on these terms toward zero.

In this replication study, after reproducing results of MSS (2004), first, as a further investigation on results and data, we examine their established link between rainfall and economic growth using a new cross-sectional time-series data (named SH-dataset), unlike most of the previous efforts that depend on the same dataset of MSS for SSA studying same or other aspects. In addition, we include the impact of temperature growth on economic growth. Moreover, we examine the impact of country rainfall level as a measurement for rainfall variations, this is the preferred empirical approach of Ciccone (2011), who reached different results than Miguel et al. (2004) in his comment on MSS' paper. Therefore, we attempt to show results of both rainfall measurements with our data. Second, we estimate the impact of induced economic shocks by climate change from the first-stage on the incidence of civil conflict. Third, the direct link between climate change and civil conflict incidence is estimated.

## 3.2 Data and measurement

The SH-dataset we use to establish the link between climate and economic growth rate, and the incidence of civil conflict, covers the same sample of Miguel et al. (2004): 41 countries in sub-Saharan Africa for the period 1981- 1999 <sup>3</sup>. This data set contains information on conflict, climate, and economic growth rate. We focus on the conflict incidence (subsumes conflict outbreak and conflict continuation) as an indicator variable of a conflict (any-prio over two other indicators) defined in a comparable way as by MSS (more description is in the Appendix A3), conflict data comes from the UCDP/ PRIO Armed Conflict Dataset, a conflict version 18.1. For the annual rainfall (millimetre) and average temperature (Celsius degree), we use the historical climate data provided by World Bank Climate Change Knowledge Portal (2018) <sup>4</sup>, whereas MSS focused on results of rainfall data from the Global Precipitation Climatology Project (GPCP) database over two other global weather sources<sup>5</sup>, it is indicated by Miguel et al. (2004) this is the only data set that at the same time includes both gauge and satellite data, corrects for systematic errors in gauge measures, and rejects gauge measures thought to be unreliable (Rudolf, 2000) (The results using other rainfall data as instrument for economic growth on civil conflict are different). For more details see available data replication files of MSS <sup>6</sup>. To measure economic shocks, we take annual economic growth rate as an indicator from the National Accounts Estimates of Main Aggregates-United Nations Statistics Division (UNSD, 2020), which provides a complete and consistent set of time series of GDP per capita expressed in constant price-US dollars, from 1970 onwards. A detailed description on variables and data is in Appendix A3. We follow MSS-2004 in deriving growth of relevant variables;  $(Var_{it} - Var_{i,t-1})/(Var_{i,t-1})$ , denoted  $Gr\_Var_{it}$ .

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<sup>3</sup>Note: MSS indicated that Eritrea and Equatorial Guinea were dropped from the analysis due to lack of data, and For Djibouti, Liberia, and Somalia, GDP data are missing since 1992. For Sudan and the Democratic Republic of Congo, GDP data are missing for 1999. Namibia became independent in 1990. Although the sources of our data provides a complete time series but we present and include same number of observations as by MSS in the estimations, to be comparable.

<sup>4</sup>Data assessed and retrieved from <http://climateknowledgeportal.worldbank.org>.

<sup>5</sup>The GPCP data set is: a combination of actual weather station rainfall gauge measures, as well as satellite information on the density of cold cloud cover (which is closely related to actual precipitation), to derive rainfall estimates, at 2.5 latitude and longitude degree intervals

<sup>6</sup><http://emiguel.econ.berkeley.edu/research/economic-shocks-and-civil-conflict-an-instrumental-variables-approach>

### 3.3 Climate conditions and economic growth rate, first-stage estimation

The rainfall and temperature instruments (annual rainfall in mm, year-to-year rainfall variation, and year-to-year temperature variation) are expected to identify exogenous variation in economic growth rate that related to agriculture (equation (3.1)). We included country fixed effects to capture time-invariant country characteristics that may also be driving civil conflict, and country-specific time trends to capture additional variation over time, in all presented models. The error term is allowed to be correlated across years for the same country in all regressions. The estimated equation of the first-stage with a vector  $X'_{it}$  is:

$$GrGDP_{it} = a1_i + X'_{it}b_1 + d1_iyear_t + e1_{it} \quad (3.1)$$

We introduce regression analyses for SSA from 1981-1999 in Table3.1, reproducing the results of MSS' data set (regression 4) compared to analyses of SH-dataset (regression 1 same model specification as by MSS) both climate indicators; rainfall and temperature (regression 2) and rainfall levels instead of rainfall growth in regression 3 (as reported by Ciccone (2011)). The main finding of MSS' data is that a significant positive relationship exists between economic growth rate and rainfall growth in both current and previous year. Whereas the use of the new dataset resulted in a positive but statistically insignificant coefficient estimates only on lagged rainfall growth. This positive relationship between rainfall and economic growth rate remains to the inclusion of temperature growth (regression 2), which has no significant impact on economic growth during this period of time in SSA. In the case of using rainfall levels as a measure of rainfall variation, they have no significant impact on economic growth rate as well (regression 3). However, by replacing our rainfall data (the World Bank Climate Change Knowledge Portal 2018) with their data (Table3.4), regression shows highly significant coefficient on lagged rainfall when it regressed on the GDP growth rate from our dataset (0.0826101, p-value 0.006), both rainfall data are correlated at 0.6413.

### 3.4 Economic growth rate and the incidence of civil conflict, second-stage results

Miguel et al. (2004) preferred the IV-2SLS method. The impact of induced economic shocks by weather variation in the first-stage on the incidence of civil conflict is estimated in the second-stage (equation (3.2)):

$$Conflict_{it} = a_2i + X'_{it}b_2 + g_{2,0}GrGDP_{it} + g_{2,1}GrGDP_{i,t-1} + d_2iyear_t + e_{2it} \quad (3.2)$$

We present results of IV 2SLS and OLS methods for both data sets in Table3.2, MSS's results have been successfully reproduced, where the IV-2SLS shows a big impact of lagged economic growth on conflict (each unit decline in lagged economic growth rates increases the probability of civil conflict by over two percentage points), while the OLS method (regression 3) yields much smaller coefficients on current GDP growth rate. Regarding the impact of lagged economic growth on conflict, it is even positive although insignificant. Applying same model' specifications as by MSS using SH-dataset, the OLS regression captures same coefficient signs as by MSS (regression 1 in Table3.2), but in contrast, the preferred model IV 2SLS by MSS captures positive coefficient' signs insignificant on both current and lagged economic growth rate (regression 2 in Table3.2). Despite the greater statistical fit of our model, economic growth rate cannot explain conflict, it is rather explained by country fixed effect and country specific time trend. Although a great number of empirical studies find that economic shocks affect the probability of conflict, e.g., (Miguel et al., 2004; Dube and Vargas, 2013), however, some have doubt on this view (Djankov and Reynal-Querol, 2010; Koubi et al., 2012).

### 3.5 Rainfall and conflict results

Now, we turn to the link between rainfall and civil conflict incidence in SSA during the period 1981- 1999 for both data sets (MSS, SH-dataset)<sup>7</sup>. This link has been already examined using MSS' data by Ciccone (2011), results are reported in Table 3.3 regression 3 and 4. Column (1 and 3) report least-squares, while column (2, 4) report system-GMM results of SH-dataset and MSS' data, respectively. Generalized Method of Moments (GMM) was introduced by Hansen (1982) and implemented by

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<sup>7</sup>Conflict variable (lagged conflict) in both data sets has 41 missing in observations because first observation for each country in the first year of our time series 1981 (comes from 1980) is missed.

Roodman (2009) in the STATA-package "xtabond2". GMM methods results show a negative significant link between civil conflict and current rainfall growth (SH-dataset), while according to MSS data this negative significant link between rainfall and conflict is found for the lagged rainfall growth. The impact of adverse conflict on the current conflict (LDV) is positive insignificant (SH-dataset) highly significant (MSS' data).

### 3.6 Conclusion

The main finding of MSS (2004) is that instrumented economic growth rate has a significantly negative effect on the incidence of conflict in SSA during 1981- 1999. They indicate that a 1 percentage point drop in lagged economic growth rate increases the incidence of civil conflict by 2.55 percentage point. The replication of this study is successfully implemented. To what extent this finding applies to the use of different sources of data? In the first stage with our new data, lagged rainfall growth is positively related to the economic growth rate (regression 1, 2) but insignificant, whereas temperature shows expected negative signs but no significant effect on the GDP in both model specifications (regression 2, 3). Examining rainfall levels as instruments for GDP instead of using rainfall growth in regression (3) show also positive insignificant coefficients on the current and lagged rainfall levels with the income growth. For the link between economic growth rate and the incidence of civil conflict, the OLS yields expected negative coefficient on the current economic growth rate although insignificant (this result is consistent with MSS). Moreover, there is a direct negative impact of rainfall on the incidence of civil conflict (consistent with results using MSS data set).

Overall, our empirical results lead us to the conclusion that theory on the relationship between economic growth rate and the likelihood of civil conflict is rather sensitive to the difference in econometric specifications, and to the changes in data sources that use different methods of making the data available.

Table 3.1: Rainfall and economic growth (First-stage). Dependent variable: Economic growth rate,  $t$  for SSA, period 1981- 1999

	(1)		(2)		(3)		(4)	
	SH		SH		SH		MSS	
GR_rainfall	-0.0159	(0.483)	-0.0164	(0.488)			0.0486**	(0.007)
GR_rainfall_lag_1	0.000301	(0.908)	0.000299	(0.908)			0.0280*	(0.055)
GR_temp			-0.0211	(0.944)	0.0192	(0.950)		
log_rainfall					0.0158	(0.664)		
log_rainfall_lag_1					0.0487	(0.172)		
Constant	0.0594	(0.589)	0.0595	(0.589)	-0.291	(0.199)	-0.0782***	(0.000)
Observations	743		743		743		743	
$R^2$	0.06		0.06		0.06		0.13	
F	0.490		0.483		0.503		.	

fixed effect and specific time trends are included in all regressions

$p$ -values in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 3.2: Economic growth and civil conflict. Dependent variable: Civil conflict  $\geq 25$  deaths. For SSA, period 1981- 1999

	(1)		(2)		(3)		(4)	
	SH		SH		MSS		MSS	
	OLS		2SLS		OLS		2SLS	
GR_gdp_c_con	-0.0248	(0.699)	5.815	(0.565)	-0.211	(0.197)	-1.132	(0.425)
GR_gdp_c_con_lag_1	0.0578	(0.373)	1.348	(0.694)	0.0668	(0.685)	-2.546**	(0.026)
Constant	-0.00311	(0.645)	-0.542	(0.588)	-1.770***	(0.000)	-1.921***	(0.000)
Observations	743		743		743		743	
$R^2$	0.74		.		0.71		.	

Instrumental Variables for economic growth rate in regression 2 and 4 are growth in rainfall year  $t$ , and  $t-1$ .

For the replication, we had to use a newer version (Ver. 3.0.06) of the ivreg2 command.

$p$ -values in parentheses \*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

Table 3.3: Rainfall and civil conflict. Dependent variable: Civil conflict  $\geq 25$  deaths, period 1981- 1999

	(1)		(2)		(3)		(4)	
	SH		SH		MSS		MSS	
	LS		GMM		LS		GMM	
GR_rainfall	-0.0579**	(0.027)	-0.0532**	(0.036)	-0.0238	(0.555)	-0.0172	(0.693)
GR_rainfall_lag_1	-0.000389	(0.487)	-0.000266	(0.588)	-0.122**	(0.011)	-0.123**	(0.013)
Lagged dependent var			0.0937	(0.323)			0.282***	(0.000)
Constant	0.576***	(0.000)	1.309***	(0.000)	0.510***	(0.000)	1.091***	(0.000)
Observations	743		702		743		743	
$R^2$	0.74				0.71			
F	27.04				0.0770			

$p$ -values in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$



Table 3.4: Rainfall and economic growth  $t$ : replacing data on variables in the regression (OLS) between both MSS and SH data sets for SSA, period 1981- 1999

	MSS-dataset		SH-dataset	
	Economic growth		Economic growth	
GR_rainfall(SH)	0.0111	(0.293)		
GR_rainfall_lag1(SH)	0.000328	(0.786)		
Gr-rainfall(MSS)			0.0243	(0.414)
Gr-rainfall lag1(MSS)			0.0826***	(0.006)
Constant	-0.0194	(0.704)	0.0492	(0.654)
Observations	743		743	
$R^2$	0.12		0.07	
F	1.058		0.585	

Fixed effect and specific time trends are included in all regressions

$p$ -values in parentheses

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

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## Appendix A3

### Variable Description

#### Civil conflict data and derivation of variables

We use for conflict variables the UCDP/PRIO Armed Conflict Dataset, a conflict version 18.1., 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)<sup>8</sup>.

**An armed conflict** is defined by the PRIO/Uppsala as a contested incompatibility that concerns government and/or territory over which the use of armed force between two parties, of which at least one is the government of a state, has resulted in at least 25 battle-related deaths in one calendar year.

We focus on civil wars, in the PRIO/Uppsala conflict data, four types of conflict are classified (type 1,2,3, and 4), type3 and type4 cover civil conflict without and with intervention from other states on one or both sides<sup>9</sup>, respectively.

The values that each of type3 and type4 of civil conflict can take, as follows:

#### *TYPE3:*

This type of conflict is the PRIO/Uppsala's indicator of Internal Conflict. It can take on four distinct values: 0: No Internal Conflict, 1: Internal Minor Armed Conflict, 2: Internal Intermediate Armed Conflict, 3: Internal War.

#### *TYPE4:*

Whereas this type of conflict is the PRIO/Uppsala's indicator of Internationalized Internal Conflict. It can take on four distinct values: 0: No Internationalized Internal Conflict, 1: Internationalized Internal Minor Armed Conflict, 2: Internationalized Internal Intermediate Armed Conflict, 3: Internationalized Internal War<sup>10</sup>.

While the intensity level of a conflict in a given year distinguishes minor armed conflicts from wars based on the battle-related deaths<sup>11</sup>, as following:

1. Minor conflicts (Intensity level 1): resulted in between 25 and 999 battle-related deaths in a given year.
2. War (Intensity level 2): resulted in at least 1,000 battle-related deaths in a given year.

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<sup>8</sup>The UCDP/PRIO armed conflict for download <http://ucdp.uu.se/downloads/>.

<sup>9</sup>Side A, is always the government side in intrastate conflicts, side B: is the country or opposition organization(s) (The PRIO/Uppsala conflict data, 18.1. 2017).

<sup>10</sup>This is very well documented in the mss\_manual as well, p.16 (MSS data set, 2004), the source is the PRIO/Uppsala conflict data.

<sup>11</sup>UCDP/PRIO Armed Conflict Dataset Codebook, version 4\_2009, updated by: Harbom et al. (2009). The dataset was first presented in Gleditsch et al. (2002), and is available for download from: [www.prio.no/CSCW/Datasets/ArmedConflict/UCDP-PRIO/](http://www.prio.no/CSCW/Datasets/ArmedConflict/UCDP-PRIO/)  
[www.pcr.uu.se/research/UCDP/our\\_data1.htm](http://www.pcr.uu.se/research/UCDP/our_data1.htm)

According to the data coding of Themnér et al. (2018) and in a similar manner to Miguel et al. (2004), we constructed three dependent conflict variables (any conflict, minor, and war), all country-year observations are coded as ones based on the type (3 and 4) of conflict and the intensity level of conflict as follows:

1. **war\_prio**: a war equals 1 when the type of conflict in year  $t$  is 3 or 4 and has an intensity level of 2 (at least 1,000 battle-related deaths per year).  
**war\_prio\_lag\_1**: lagged one year.  
**war\_prio\_lag\_2**: lagged two years.
2. **minor\_prio**: a minor conflict equals 1 when the type of conflict in year  $t$  is 3 or 4 and has an intensity level of 1 (at least 25 battle-related deaths per year and fewer than 1,000 battle-related deaths during the course of the conflict).  
**minor\_prio\_lag\_1**: minor conflict lagged one year.  
**minor\_prio\_lag\_2**: minor conflict lagged two years.
3. **any\_prio**: any conflict equals 1 when minor conflict or war equals 1. Otherwise, are coded as zeros.  
**any\_prio\_lag\_1**: any conflict lagged one year.  
**any\_prio\_lag\_2**: any conflict lagged two years.

### Weather variables

We use the historical climate data provided at World Bank Climate Change Knowledge Portal (2018)<sup>12</sup>. We observe growth in weather variables from the previous year following Miguel et al. (2004): **gr\_rainfall** =  $\frac{\text{rainfall} - \text{rainfall\_lag1}}{\text{rainfall\_lag1}}$

### Rainfall variables

- **rainfall**: The annual rainfall (millimetre) is computed by adding up all of the monthly observations in a given year.
- **rainfall\_lag\_1**: lagged one year.
- **rainfall\_lag\_2**: lagged two years.
- **gr\_rainfall**: rainfall growth =  $(\text{rainfall} - \text{rainfall\_lag1})/(\text{rainfall\_lag1})$ .
- **gr\_rainfall\_lag\_1**: growth rainfall lagged one year:  
 $(\text{rainfall\_lag\_1} - \text{rainfall\_lag\_2})/(\text{rainfall\_lag\_2})$ .
- **log\_rainfall**: log of rainfall levels in country  $i$  and year  $t$ .
- **log\_rainfall\_lag\_1**: lagged one year.

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<sup>12</sup><http://climateknowledgeportal.worldbank.org>.

- **log\_rainfall\_lag\_2:** lagged two years.

### Temperature variables

- **temp:** The annual temperature (Celsius degree) are computed by adding up all of the monthly observations in a given year divided by the number of months in that year.
- **temp\_lag\_1:** temperature lagged one year.
- **temp\_lag\_2:** temperature lagged two years.
- **gr\_temp:** temperature growth =  $(temp - temp\_lag_1)/(temp\_lag_1)$ .

### Economic variables

The **Gross Domestic Product (GDP) per capita**, i.e. the total amount of goods and services produced in the economy, divided by its population. Data on this variable comes from the main National Accounts aggregates of all UN Members States (UNSD, 2020), which provides 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/>.

The derived variables are as follows:

- **gdp\_c\_con:** GDP per capita estimates in constant price-US dollars.
- **gdp\_c\_con\_lag\_1:** GDP per capita estimates lagged one year.
- **gdp\_c\_con\_lag\_2:** GDP per capita estimates lagged two years.
- **gr\_gdp\_c\_con:**  
GDP growth rate =  $(gdp\_c\_con - gdp\_c\_con\_lag_1)/(gdp\_c\_con\_lag_1)$
- **gr\_gdp\_c\_con\_lag\_1:**  
GDP lagged growth rate:  $(gdp\_c\_con\_lag_1 - gdp\_c\_con\_lag_2)/(gdp\_c\_con\_lag_2)$

# Chapter 4

## Climate change and civil conflict in SSA and MENA: The same phenomena, but different mechanisms?

Sherin Khalifa <sup>1</sup> and Christian H.C.A. Henning <sup>2</sup>

### Abstract

In this Chapter, the mechanisms of climate change impacts on the incidence of civil conflict are tested separately in sub-Saharan Africa (SSA) compared to the Middle East and North Africa (MENA) for the period 1981 to 2015. We draw several conclusions: **(i)** Climate has a significant impact on economic development, through economic growth rate in the MENA, and food production in SSA. **(ii)** Economic growth rate and food production index are significant indicators for social stability reduce the risk of civil conflict, in SSA and MENA, respectively. **(iii)** A direct impact of climate change on civil conflict is identified. **(iv)** Conflict in the previous year increases the probability of civil conflict in SSA by 0.30 pp, and in the MENA by 0.50 pp. Moreover, as the type of political system and accountability are important control variables in SSA, water availability reduces the risks of conflict in the MENA region. There appears to be evidence of different mechanisms in different regions. However, the identification of stable mechanisms needs to be precisely addressed in future work.

**Keywords:** Climate impact mechanisms, conflict, economic development, MENA, SSA

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## 4.1 Introduction

Climate change is a global phenomenon, but its impacts are unequally distributed across regions of the world (Darwin, 1995) due to the diversity of agriculture systems, the resilience of human systems, and environmental sustainability. Climate change, in the absence of appropriate policy responses, can exacerbate already existed political crises and ultimately lead to civil wars in some territories. Most of the severe negative impacts appear in regions that are (i) highly vulnerable to climate change because they rely on rainfed agricultural systems that provide a livelihood for a large percentage of these regions' populations (Serdeczny et al., 2017). (ii) Where it suffers from water scarcity as in the Middle East and North Africa's region, where is likely to experience additional declines in agricultural yields, resulting in negative effects on rural incomes and food security (Zhu et al., 2009; Breisinger et al., 2010). Consequently, economic consequences may lead to conflicts that are unlikely to occur in developed countries. Africa has been already identified as one of the regions of the world most vulnerable to the impacts of climate change (Niang et al., 2017). At the same time, the major focus for civil wars in recent years has been in sub-Saharan Africa, where 29 of 43 countries suffered from civil conflict during the 1980s and 1990s (Miguel et al., 2004). Likewise, the Middle East and North Africa region is expected to become hotter and drier in the future due to climate change next to its growing dependence on international markets for key staple food products<sup>3</sup> (OECD-FAO, 2018). In the dataset, which we use for estimations in this Chapter, 12 of the 18 countries (66%) in the MENA region experienced between 1981 and 2015 civil conflicts.

In this Chapter, we demonstrate empirically climate change effects on the economies of countries from different regions of the developing world, and its relationship to civil conflict over the past four decades. We applied the same approach and similar model specifications as in the chapter two of this research, using cross-country panel data. Economic growth rate and domestic food production are instrumented by rainfall and temperature, in addition to other control variables, i.e. variables on good governance and democracy as well as on demographic and environmental indicators.

Climate, economic development, and conflict relationship has been already demonstrated intensively in Africa. For instance, positive relationship has been proved between rainfall and income growth, and its significant relation to the rise of civil conflict probability in Sub-Sharan Africa for the period 1981- 1999 (Miguel et al.,

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<sup>3</sup>OECD/FAO 2018: The Middle East and North Africa: Prospects and Challenges

2004). This robust association has been also found between rainfall and higher food production, but only a weak and inconsistent link between agricultural production and civil conflict in the second step of the causal model by Buhaug et al. (2015) in SSA. Couttenier and Soubeyran (2014) has also proved the impact of extreme drought on the risk of conflict during the period 1977- 2005 in SSA, that the risk of war increases by more than 42% but only 2.5% of this effect is channelled through economic growth. On the other hand, Barrios et al. (2010) proved that rainfall has been a significant determinant for economic growth in Africa, but not for other developing countries. However, there is another part of the literature that reached different conclusions, like Ciccone (2011) when he extended the data from Miguel and his co-authors in 2004, concluded that there is no robust link between transitory income shocks and civil wars, but reveals strong spill-over effects (Ahrens, 2015), among others who have reached different conclusions (e.g.,(Burke et al., 2009; Buhaug, 2010; Koubi et al., 2012)). Not surprisingly, that such mixed or inconsistent results have been observed, even for a single geographic region, due to differences in climate shock measurement, applied approaches, and model specifications. However, this sequence of relations in the MENA region has not been studied as intensively as in Africa. Where for example, Gleick (2014) has pointed out that there is a long history of conflict over water because of the natural water scarcity, the early development of irrigated agriculture, and complex religious and ethnic diversity.

### **The socio-economic development and environmental characteristics of the MENA and SSA**

#### **The MENA:**

The MENA region consists of a heterogeneous group of countries ranging from the high-income oil-exporting countries in the Gulf to middle income and lower-middle-income countries as well as least developed countries such as Yemen (OECD-FAO, 2018). The agricultural sector still has a significant share in the economies of most countries in the MENA region as a source of food and income especially for non-oil producing countries and is an important vehicle for economic growth (Siam, 2009). Therefore, the dominant policy in the region concerning development has been the modernization of the agricultural sector in terms of the production (modern irrigation systems and agricultural technology) of cereals and livestock initially and later in the development of fruits, vegetables, and cash crops from irrigated or partially irrigated land (Dixon et al., 2001). This could be a reason that smallholders could not benefit from public support and have left them small, technologically backward, and poor (OECD-FAO, 2018). According to Siam (2009) the demand for food imports has markedly increased because the region is characterized by a food shortage



in most food commodities, thereby seriously aggravated the shortage of foreign exchange in the majority of the MENA countries, particularly the non-oil producing countries. About the proportion of arable land from the total land area in the region, it is limited, estimated at 53 million hectares in the year 2005, with per capita arable land of only 0.17 hectares, compared to 0.22 hectares at the global level. In addition to that agriculture uses 89% of the scarce water in the MENA region compared to 70% at the world level, it has been pointed out by Huang et al. (2016) that it is the driest region in the world according to the annual precipitation of 166 mm, and since the 1970s has become even dryer (Cook et al., 2015). The drought peaked during the period 2006 and 2009 (Al-Ansari, 2013), during this period e.g., Syria and Iraq in the region received 10 percent less precipitation compared to the four years prior to 2006 (Chenoweth et al., 2011). This is also evident from our dataset, Syria and Iraq received less precipitation during this period, 18 and 23 percent, respectively. Regarding the effect of temperature, in the region, it was at about 4°C above average in the 1960s (Carrington, 2015). The well-being indicator; Gross Domestic Product (GDP) of the region reached 734 billion dollars in 2006, which constituted 1.5% of the world GDP. Its population in the same year was (311 million), i.e. 4.8% of the world's population, growing by 2.4% annually during the period 1990- 2006, compared to 1.4% of the world population (Siam, 2009).

### **The SSA:**

The continent of Africa is commonly divided into five regions, four of which are in sub-Saharan Africa. The ethnicity is one of the key drivers of diversity in SSA, therefore, it is important to take it into account in socio-economic studies (Appiah et al., 2018). According to Olamosu and Wynne (2015), the gross domestic product of Nigeria and South Africa accounts for about three-quarters of the SSA's GDP. The contribution of the agricultural sector to the GDP ranges from less than 3% in Botswana and South Africa to more than 50% in Chad, represents 15% of GDP on average. This high contribution underlines the limited diversification of most economies in the region (OECD-FAO, 2016). However, the significant growth in SSA' agricultural output is driven by area expansion and intensification of cropping systems, as opposed to large-scale improvement in productivity (Brink and Eva, 2009), but the failure to keep pace with the demand resulting from population growth and income has led to an increase in demand for the import of commodities such as wheat, rice, and poultry (OECD-FAO, 2016), compared to agricultural modernization in the MENA. For SSA according to Iliffe (2017) during 2000- 2007 significant GDP growth of 3.9 is registered. The population growth rate of SSA in

2006 was 2.7% (World Bank, 2016).

In the following sections, we present empirical results of economic and social responses to the impact of climate change over time in two vulnerable regions of the developing world that differ in their economic, social, political and environmental characteristics.

## 4.2 Data and methods

For the estimations of this part, we use our new collected cross-country panel data including sub-Saharan Africa (41 countries) and the Middle East and North Africa (18 countries), for SSA's countries, we have adopted same sample (countries and years) of Miguel et al. (2004)<sup>4</sup> and extend it for the period from 1981 to 2015. This new setup of data contains information on climate, economic indicators, and civil conflict, as well as political factors, and social fragmentation with other country characteristics information. We focus on the conflict incidence (subsumes outbreak of a conflict and continuation of a conflict) as an indicator of conflict that results in at least 25 battle-related deaths in a given year.

Conflict data comes from the UCDP/PRIO Armed Conflict Dataset-V18.1.<sup>5</sup> Economic shocks are measured by (1) annual economic growth rate; we use a complete and consistent time series expressed in constant price-US dollar provided by National Account Estimates of Main Aggregate-United Nations statistics division (UNSD, 2020). (2) Food index from Food and Agriculture Organization of the United Nations (2016).

For climate change, we have data on temperature from the World Bank Climate Change Knowledge Portal (2018), and precipitation data from Global Precipitation Climatology Project (GPCP) database version 2.3 (Adler et al., 2016).<sup>6</sup> The advantage of the GPCP rainfall data that it includes at the same time both gauge and satellite data, corrects for systematic errors in gauge measures (Miguel et al., 2004). While data on Polity IV scores, which indicates the level of democracy/ autocracy of

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<sup>4</sup>We kept the same sample of MMS (2004) when we revisited their work using different measurement strategies and sources of data in a previous chapter of this research. Therefore, for this part of the study, we extended their cross-country (SSA), including MENA countries from 1981 to 2015, data on similar variables has been updated with most recent versions of the corresponding databases.

<sup>5</sup>Conflict version 18.1, for download; <http://ucdp.uu.se/downloads/>.

<sup>6</sup>Adler et al., 2016. An Update (Version 2.3) of the GPCP Monthly Analysis. (in Preparation). Huffman, G.J., R.F. Adler, P. Arkin, A. Chang, R. Ferraro, A. Gruber, J. Janowiak, A. McNab, B. Rudolf, U. Schneider, 1997: The Global Precipitation Climatology Project (GPCP) Combined Precipitation Dataset. Bull. Amer. Meteor. Soc., 78(1), 5-20.

a political system in-country ( $i$ ) time ( $t$ ) comes from Roser (2019) based on Wimmer and Min (2006). Based on Polity IV scores, we constructed an indicator "changes in the political system" without distinguishing whether a political transition undergoing dictatorship or under democracy, this is thought to reflect the political stability of a country at a given time. Besides, we examine the effect of quality of governance (accountability) (World Bank, 2014).

Data on water indicators (FAO, 2017). The index of ethnic and religious diversity from Alesina et al. (2003). A detailed description of the variables that are used to perform the estimates in this chapter is provided in Appendix A4.

Estimates of the impacts of climate change as mentioned are undertaken separately for SSA and MENA from 1981- 2015, applying instrumental variable approach. The model is first estimated applying Ordinary Least Squares (OLS) (equations (4.1) and (4.2)) using weather (temperature and rainfall) as instruments for economic growth rate and food production. We included several additional controls for comparison purposes, particularly those related to conflicts such as political and social controls. Country fixed effects and country-specific time trends are included in all regressions to capture time-invariant country characteristics and additional variation, respectively. Standard errors are clustered at the country level to allow for a potential correlation between observations for any given country at different times. The relationship between variables included in the analysis and the significance level could be overstated without clustering standard errors.

$$Gr\_gdp_{it} = a_i + bX'_{it} + d_i year_t + e_{it}, \quad (4.1)$$

$$food\_index_{it} = a_i + bX'_{it} + d_i year_t + e_{it}, \quad (4.2)$$

The term  $e$  is a disturbance term, and these disturbances are allowed to be correlated across years for the same country in all regressions. Country fixed effects  $a_{ji}$  are included in all regressions to capture time-invariant country characteristics that may be related to civil conflict, and also country-specific time trends  $year_t$  to capture additional variation over time.

Then in the second stage, we estimate the impact of quantified economic outcomes from the first stage (climate indirect), and the direct impact of climate on civil conflict incidences<sup>7</sup> as in equation (4.3). We apply the Generalized Method of Moments (GMM) model introduced by Hansen (1982) with lagged dependent variable (LDV). We test our samples concerning heteroskedasticity by Breusch-Pagan/Cook-

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<sup>7</sup>The incidence of civil war: defined by Elbadawi and Sambanis (2002) as the probability of observing either a new war onset or the continuation of an ongoing war or both (p. 307).

Weisberg test; the null hypothesis that the error variance is constant was rejected with  $\text{Prob} > \chi^2 = 0.000$  for both samples.

$$\text{Conflict}_{it} = \alpha_i + \beta \cdot \text{gr\_gdp}_{it} + \gamma \cdot \text{food\_index}_{it} + \delta \cdot X'_{it} + \sigma_i \cdot \text{year}_t + \epsilon_{it}. \quad (4.3)$$

We have applied IV OLS estimation implemented in STATA to choose instruments for endogenous variables: GDP growth rate and Food Index. The Sanderson-Windmeijer (SW) chi-squared and F-statistics test under-identification and weak identification of both endogenous variables, respectively. The null hypotheses were rejected (Table 4.1); SW Chi-squared with  $(L1 - K1 + 1)$  degrees of freedom, where L1 is the number of excluded instruments and K1 is the number of endogenous regressors: for SSA's sample, SW chi-sq equals 134.16 with p-value 0.000 for GDP growth and 71.56 with p-value 0.000 for Food Index, and SW-F statistics account 24.34 and 12.98 for both regressors, respectively (greater than 10). For MENA, SW chi-sq equals 45.41 with p-value 0.000 and 183.73 with p-value 0.000, for GDP growth and Food Index, respectively. While SW-F statistics values are 7.90 and 31.98, for GDP growth and Food Index, respectively. Accordingly, the chosen instruments are considered strong.

Furthermore, Hansen J statistic test for over-identification restrictions after `ivreg2`.<sup>8</sup> The joint null hypothesis of the Hansen J test is that the instruments are valid for both samples (Table 4.2), i.e. they are uncorrelated with the error term, the null hypothesis is rejected with p-value 0.000.

## 4.3 Main results

### 4.3.1 Climate impacts on economic growth and food production: first-stage estimations

Based on the estimates for all sample countries in chapter 2 of this research, the effect of climate variability on the economic growth rate and food production is mainly the effect of temperature growth. A 1 pp change in annual temperature growth significantly reduces economic growth and food index by 0.31 pp and 0.23 pp, respectively. The increase in temperature during the 16 years after the year 2000 of our time series compared to the average temperature in the eighties is estimated

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<sup>8</sup>Hansen-test is done after country fixed effects are removed because an estimated covariance matrix with dummy variables is not of full rank.

at 2.17 pp. This implies a reduction in economic growth and food index by 0.67 pp and 0.49 pp, respectively, during the period after 2000 only due to the temperature change. Applying the estimates to separate regions in this chapter indicates the source of predictive power for the significance we observed for the variables of interest in our model of the first paper.

The OLS regression (Table 4.1) using the new source of rainfall data (the GPCP) that includes at the same time both gauge and satellite data, separately for SSA and MENA in this chapter shows: (i) A positive correlation between precipitation and both economic indicators (economic growth rate and food production) but only significant for economic growth rate at a confidence level of 0.10 in the MENA sample with a coefficient estimate of 3.7%. (ii) Annual growth temperature is negatively related to both economic indicators, it is highly significant only for food production in SSA (coef. 33.2%) and economic growth rate in the MENA region (49.2%).

Additionally, **in the first stage model for SSA**, we observe for economic growth rate some other statistically significant coefficients; positive on total trade exports, and negative on political transition indicator in-country ( $i$ ) time ( $t$ ). Using our data, it shows that the significant climate determinants for economic growth rate are water variables in the SSA region. Whereas for the food production index in SSA we also observe some common significant coefficients; positive on the share of agricultural land and the arable land, and accountability. **In the MENA region**, other than the positive impact of growth rainfall and the negative impact of growth temperature on GDP per capita, this indicator is affected positively significantly by growth trade exports and the share of agricultural land, but it is affected negatively highly significant by the share of arable land and transition in the political system. While the food index is negatively significantly affected by water stress and political indicators in particular, and positively by the share of urban population. Although theoretically, one would expect that good governance should affect economic indicators positively. It is indicated in a study by Emara and Jhonsa (2014) about governance and economic growth, that most MENA countries in the year 2009 have achieved a relatively high but fragile standard of living for their citizens, that is not based on firm governance.

Overall, it is obvious that: (i) There is a positive link as exists in the literature for SSA e.g, by Miguel et al. (2004) between economic growth rate and growth rainfall and negative with annual growth temperature, significant in the MENA region with our new data and model specification. (ii) There is a high negative impact for the share of cultivated area “arable land” and a positive impact for the share of

urban population on economic growth rate and food production, respectively, in the MENA region. (iii) Changes in a political system (instability) has a negative impact on economic growth rate in both regions.

Table 4.1: First-stage results, SSA and MENA from 1981-2015. Dependent variables are: Economic growth rate and food index

Expl. Variables	SSA		MENA	
	growth rate	food index	growth rate	food index
gr_oil_exp_wdi	0.000001 (0.680)	-0.000002 (0.276)	0.000006 (0.791)	-0.000009 (0.683)
gr_trade_exports	0.136*** (0.000)	-0.0192** (0.039)	0.0912*** (0.000)	-0.0142 (0.154)
agri_land	0.00286 (0.290)	0.0194*** (0.000)	0.00683** (0.043)	0.00659** (0.040)
arable_land	-0.214 (0.189)	0.408*** (0.001)	-1.034** (0.040)	-0.107 (0.822)
water_stress	0.00951** (0.014)	-0.00399 (0.158)	-0.00005 (0.599)	-0.00079*** (0.000)
strength_gr_polityiv	-0.00519** (0.029)	-0.00105 (0.547)	-0.00952** (0.037)	-0.00104 (0.811)
gr_gpcp_neu	0.00329 (0.919)	0.00815 (0.732)	0.0371 * (0.079)	0.00573 (0.775)
gr_temp	-0.206 (0.370)	-0.332** (0.049)	-0.492** (0.006)	-0.232 (0.169)
water_1km2	-0.0090** (0.016)	0.0006 (0.825)	0.000615 (0.595)	-0.000617 (0.575)
rainfall levels	0.00004 (0.544)	-0.00023*** (0.000)	-0.00001 (0.870)	0.00004 (0.483)
polityiv_sh_tr	-0.00032 (0.837)	-0.00872*** (0.000)	-0.00405 (0.256)	-0.00703** (0.039)
accountab	0.00016 (0.876)	0.00278*** (0.000)	0.00246 (0.104)	-0.00363** (0.012)
urban_pop	-0.00358 (0.264)	0.00299 (0.205)	0.00403 (0.338)	0.0113** (0.005)
Constant	0.0224 (0.939)	-0.705*** (0.001)	-0.256 (0.505)	-0.452 (0.216)
Observations	1324	1324	612	612
$R^2$	0.15	0.88	0.23	0.85
F	2.327	99.62	3.438	66.36

*p*-values in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

### 4.3.2 Economic shocks, direct climate impacts, and incidence of civil conflicts, second stage estimations

The results of this stage are introduced in Table 4.2 for SSA and MENA. First, not surprisingly, that civil conflict is more likely when there was a conflict in the previous year in both regions, increase of around 0.498 pp and 0.302 pp in the probability of current conflicts in the MENA and SSA, respectively. Second, regarding the impact of economic shocks on the civil conflict probability, it does not seem to function through the same economic indicators in both regions, although both indicators show negative coefficient signs on the incidence of civil conflict. i.e. in the MENA region climate change increases the probability of civil conflict significantly through reduction in food production index, and in SSA the effect appears through economic growth rate. Third, for the direct impact of climate variables on civil conflict incidence, our model yields negative coefficient signs on growth rainfall in both regions, significant in MENA (coef. -0.061\*). Other than that, for MENA countries fresh groundwater withdrawal reduces civil conflict incidence statistically significant. While in SSA, political indicators show statistically significant impact reducing conflict probability.

Overall, we find that (i) positive economic growth rate and domestic food production reduce the likelihood of civil conflict, in SSA and the MENA region, respectively. (ii) Annual growth rainfall directly reduces the probability of civil conflict significantly in the MENA region. (iii) Previous conflicts increase the possibility of civil conflicts in both regions, have a greater impact in the MENA region. (iv) As the type of political system and accountability are important to reduce the risks of conflict in SSA, water availability reduces the risks of conflict in the MENA.

Table 4.2: Second stage results (GMM) for SSA and MENA from 1981-2015. Dependent variable: Civil conflict  $\geq 25$  deaths/ year

Exp. Variables	SSA	MENA
L.any_prio	0.302*** (0.000)	0.498*** (0.000)
L2.any_prio	0.105* (0.073)	0.0156 (0.797)
gr_gdp_c_con	-0.150** (0.030)	-0.0295 (0.790)
food_index	-0.0928 (0.213)	-0.205** (0.005)
gr_gpcp_neu	-0.0203 (0.705)	-0.0609* (0.093)
gr_temp	0.174 (0.654)	0.125 (0.731)
water_1km2	0.00142 (0.774)	-0.00657*** (0.001)
rainfall_levels	0.00009 (0.390)	0.00027* (0.075)
polityiv_sh_tr	-0.00644* (0.065)	0.00051 (0.882)
accountab	-0.00524** (0.010)	-0.00375 (0.111)
urban_pop	0.0102 (0.169)	0.00479 (0.575)
Constant	0.129* (0.076)	0.852 (0.257)
Observations	1238	576

Fixed effects and specific time trends are included in all regressions

*p*-values in parentheses

\*  $p < 0.1$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$



## 4.4 Discussion and conclusion

Estimates using new cross-country panel data during 1981- 2015 for SSA and the MENA separately, show that climate change operates on economic indicators differently in both regions. **First**, rainfall has a positive impact on both economic growth rate and food production, with a statistically significant impact on the GDP per capita in the MENA region. However, this runs counter to the finding of Barrios et al. (2010) that precipitation is important for income growth in Africa but not for other developing countries. Quantitatively, a one unite rise of annual rainfall growth leads to a 3.7 percent rise in economic growth rate in MENA, compared to 4.9 percent as reported by Miguel et al. (2004) for SSA during 1981-99.

**Second**, with respect to the effect of temperature, we emphasize the long known negative relationship between the increase in temperatures and the economic growth rate. One change in annual growth temperature reduces the economic growth rate by 0.49 pp in the MENA and 0.33 pp of domestic food production in SSA' sample, compared to 3.22 pp and 1.3 pp as reported by Odusola and Abidoye (2015) and Dell et al. (2012), respectively, for Africa. Thus, periodic floods or droughts is quite damaging to the economy i.e. food production in SSA is negatively significantly affected through annual rainfall levels (coef. 0.023 percent). Also, annual temperature variation in SSA affects food production negatively significantly at 5% level (point estimate of 0.332 pp), this is consistent with the finding of a case study of Kenya that temperature harms crop production and has a greater impact than rainfall (Ochieng et al., 2016). In general, temperature and rainfall variations are critical to the GDP growth rate in the MENA region, and temperature growth is critical to the food production index in sub-Saharan Africa. Water stress indicator seems to be a significant factor for food production index in MENA. This region has the lowest freshwater resource endowment in the world, and the demand of water and food production has been achieved through abstraction of groundwater, water harvesting and storage, wastewater reuse, desalinization plants and food imports (Verner, 2012), led to groundwater resource depletion (Waha et al., 2017) due to the over-extraction of available water, which is an important input into agricultural production. The effect of other natural resources such as the share of oil exports of total merchandise is positively correlated with the economic growth rate but insignificantly (the same relationship has been found by Miguel et al. (2004)), this results indicates that both regions do not rely heavily on oil exports significantly or affected by World oil prices, but a robust significant positive impact of total merchandise trade of a country exports to the world on the economic growth rate in

both region has been found.

Regarding the impact of the level of democracy/ autocracy on economic indicators, it affects both economic indicators negative but only statistically significant on food index. Descriptive statistics table (Appendix A4) indicate that the average of Polity IV estimates of most of the political systems in our samples laying between autocracies and anocracies. In our estimation, this is evident from the significant negative impact of the transition in political systems on domestic food production in both regions. In the literature, a positive significant impact of the Polity IV indicator has been found on the economic growth rate (Masaki and Van de Walle, 2014) that a one-point increase in the POLITY score is expected to produce a 0.10 percent increase in economic growth rate. While Miguel et al. (2004) for SSA in their model specification for economic growth rate did not observe any significant coefficient on Polity IV lagged one year.

Now turning to the impact of economic shocks induced by climate variability and the direct impact of climate variation on the incidence of civil conflict in both regions, we confirm the main result of Miguel et al. (2004) that the reduction in per capita income growth induced by extreme weather events together with other country controls significantly increases the probability of civil conflict in SSA. In quantitative terms, a 10% reduction in economic growth rate leads to 1.5% increase in the probability of civil conflict in SSA. A 10% reduction in food production index leads to 2% increase in the probability of civil conflict in the MENA. The finding of the insignificant relationship between food production and civil conflict in SSA corresponds to the result of Buhaug et al. (2015), which we find rather statistically significant in the MENA region. Helman et al. (2020) has illustrated that the relationship between agricultural dependence and violence is stronger about four fold in the Middle East, although the share of agricultural area in Africa is greater than in the Middle East, 14% and %11, respectively, in their study. This is also evident from the descriptive statistics table (Appendix A4) attached to this Chapter. Furthermore, a negative direct impact of climate variability exist between growth rainfall and risk of conflict in the MENA, thus, it is important to assess both direct and indirect impacts of climate change on the civil conflict when studying climate change. Chen et al. (2016) has proved that the decrease in current rainfall compared to the previous year increases the possibility of civil conflict. Moreover, our results proved that conflict begets conflict in both regions, but lagged dependent variable has a greater impact in the MENA region.

The clear evidence of the impact of climate change is that higher temperature con-

tributed more to climate change than reduced precipitation, especially in the MENA region. Second, results indicate that food production and economic growth rate are stabilizing factors against conflict, food production in MENA, and economic growth rate in SSA.

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## Appendix A4

### Summary of Variables

Dependent Variables	Independent variables	Variable Description	Source of data
1.GDP growth rate 2.Food production index	<b><i>First stage variables</i></b>		
	<b>Climate variables</b>		
	1.Rainfall in millimeter	Annual rainfall (mm) is computed by adding up all the monthly observations in a given year.	The World Bank Climate Change Knowledge Portal (2018).
	2.Rainfall in millimeter "gpcp_neu"	Total yearly rainfall (mm) for country $i$ on a resolution of 2.5° latitude/longitude degree nodes in the given country (see Huffman (1997); Miguel et al. (2004)).	The Global Precipitation Climatology Project (GPCP) database version 2.3
	Rainfall growth	$Gr\ rain = (rainfall_t - rainfall_{t-1}) / (rainfall_{t-1})$	
	3.Temperature (Celsius degree)	Annual averages are computed by adding up all of monthly observations in a given year divided by the number of months in that year	The World Bank Climate Change Knowledge Portal (2018).
	Temperature growth	$Gr\ temp = (tempt - tempt_{t-1}) / (tempt_{t-1})$	
	<b>Political variables</b>		
	1.Polity IV score	Type of political regime 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 anocracies. We transformed Polity IV scores, to be instead on a range from 1 to 20, for easiest interpretation "polityiv_sh_tr".	The project of Roser (2019) based on Polity IV Project (2013) and Wimmer and Min (2006).

	2.Change in the political system	Indicates changes in Polity IV scores in year $t$ compared to year $t-1$ either toward democracy or backward to autocracy "strength_gr_polityiv".	
	3.Accountability	Ranges from 0 (lowest) to 100 (highest) rank, reflects perceptions of the extent to which a country's citizens can participate in selecting their government, as well freedom of expression, association, and a free media.	The World Bank (2014)
	<b>Environmental variables</b>		
	1.Water withdrawal  2.Water stress%	The annual level of freshwater withdrawal, calculated averagely over each decade divided by country area as: $water\_1km2 = 10^6 * wasser\_total / area.km2$ , in $10^3 m^3/km2$ .  Aggregated indicator (SDG 6.4.2.) freshwater withdrawal as a proportion of available freshwater resources.	AQUASTAT main database, Food and Agriculture Organization of the United Nations (FAO, 2017)
	3.Agricultural land  4.Arable land	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)	The World Bank (2016)
	<b>Demographic/ social diversity</b>		
	1.Ethnicity  2.Religion	fractionalizations index computed using the same formula applied to different underlying data (Ethnic and religion)  $FRAC_m = 1 - \sum_{i=k}^N S_{km}^2$ , where $S_{km}$ is the share of group $k$ in country $m$ .	The Encyclopaedia Britannica (2001); CIA (2000); Levinson (1998).  Religion data: The Encyclopaedia Britannica (2001)

	3.Urban population	Percentage of the total population	The World Bank (2018)
	<b>Economic indicators</b>		
	Oil exports	The proportion of merchandise exports)	The World Bank (2016)
	Trade exports	Total merchandise trade of a country exports to the world in US dollar at current prices	The World Trade Organization (2016)
<b>3. Civil conflict</b>	<i>Second stage</i>		
	1.Economic growth rate	GDP per capita estimates in constant price-US dollar.	The database of National Accounts Estimates of Main Aggregates-United Nations Statistics Division (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, they have no nutritive value	Food and Agriculture Organization of the United Nations (2016)
	3.Lag civil conflict	Any conflict resulted at least 25 battle related death per year equals 1, otherwise 0. <sup>9</sup>	The UCDP/PRIO Armed Conflict Dataset, Version 18.1.

<sup>9</sup> 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.



## Descriptive statistics

	<b>SSA</b>					<b>MENA</b>				
<i>Variables</i>	<i>Obs.</i>	<i>Mean</i>	<i>Std.Dev.</i>	<i>Min</i>	<i>Max</i>	<i>Obs.</i>	<i>Mean</i>	<i>Std.Dev.</i>	<i>Min</i>	<i>Max</i>
	<b>Economic indicators</b>									
Annual GDP	1399	1028.14	1402.77	82	10716	630	9970.43	13785.36	172	88565
GDP growth rate	1399	0.027	0.152	-0.645	1.78	630	0.037	0.146	-0.66	0.91
Food index	1399	0.877	0.304	0.281	2.07	630	0.84	0.32	0.071	2.033
	<b>Civil Conflict Measures</b>									
Civil conflict: $\geq 25$ deaths	1399	0.237	0.426	0	1	630	0.321	0.467	0	1
	<b>Weather Variables</b>									
Rainfall (CCKP 2018)	1399	903.57	562.13	49.27	2795.72	630	234.54	207.56	13.03	967.53
Rainfall (GPCP-V2.3)	1399	879.878	718.573	9.029	2715.39	630	539.74	372.10	60.97	1727.37
Temperature	1399	24.615	3.355	12.21	29.75	630	21.797	4.449	9.651	29.033
Growth Rainfall (CCKP)	1399	0.02	0.221	-0.659	1.69	630	0.085	0.52	-0.808	4.064
Growth rainfall (GPCP-V2.3)	1358	0.012	0.136	-0.611	1.369	612	0.039	0.318	-0.626	2.387
Growth Temperature	1399	0.001	0.018	-0.126	0.107	630	0.002	0.031	-0.164	0.133
	<b>Other Country Characteristics</b>									
water per 1km2	1399	5.182	8.506	0.031	60.01	630	54.64	72.96	1.53	352.06
water stress	1399	13.89	31.33	0	131.31	630	392.035	644.795	14.89	2347
arable land	1365	0.282	0.202	0.001	1.585	630	0.145	0.141	0.001	0.57
agri_land	1365	47.71	19.18	7.94	82.67	630	32.03	25.51	2.45	80.85
Polity IV	1399	9.09	5.75	0	19	630	5.42	5.47	0	19

	<b>Other Country Characteristics</b>									
<i>Variables</i>	<i>Obs</i>	<i>Mean</i>	<i>Std.Dev.</i>	<i>Min</i>	<i>Max</i>	<i>Obs</i>	<i>Mean</i>	<i>Std.Dev.</i>	<i>Min</i>	<i>Max</i>
Changes in PolityIV/ both directions	1398	0.525	1.81	0	15	630	0.275	1.261	0	12
Accountability	1399	29.61	17.45	0.99	74	630	24.63	15.13	0	71.92
Ethnic	1399	0.702	0.194	0.058	0.93	630	0.398	0.218	0	0.746
Religion	1399	0.552	0.231	0.003	0.86	630	0.26	0.25	0.00	0.79
Urban pop.	1399	33.42	16.15	5	88	630	69.45	19.149	21	100
Growth trade ex- ports	1399	0.09	0.327	-0.73	3.81	630	0.11	0.54	-0.96	8.39
Growth oil exports	1399	53.45	1583.54	-1	58572.3	630	12.51	246.19	-1	5950.57

# Chapter 5

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

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### 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 (1981–2015). 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

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## 5.1 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<sup>4</sup> 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).

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<sup>4</sup>The relative change from previous year in rainfall and temperature variables

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.

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

## 5.2 Data and methods

### 5.2.1 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):

$$\mathbf{gr\_var(it)} = \frac{\mathit{var(it)} - \mathit{var.lag1}}{\mathit{var.lag1}}.$$

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:

$$\mathit{dev.Xit} = (X_{i,t} - \bar{X}_i) / \sigma_i$$

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  $\sigma_i$  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, Appendix A5).

**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:

$$water\_1km2 = 10^6 \times wasser\_total / area.km2, \text{ in } 10^3 \text{ m}^3/\text{km}^2.$$

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 dollar (UNSD, 2020).<sup>5</sup> 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

<sup>5</sup>UNSD (2020) make a complete and consistent set of GDP per capita time series available, from 1970 onwards. GDP per capita estimates expressed either in current or constant price-US dollars. <http://data.un.org/>

year, we use the UCDP/PRIO Armed Conflict Dataset, a conflict version 18.1. (Themnér et al., 2018).<sup>6</sup>

#### 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 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 ( $\text{strength\_gr\_polityiv} = \text{polityiv\_sh\_tr} - \text{polityiv\_sh\_tr\_lag\_1}$ ). (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).

### 5.2.2 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 (5.1) and (5.2) using rainfall and temperature

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<sup>6</sup>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/>.

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 (5.1), (5.2) 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:

$$gr\_gdp_{it} = a_i + bX'_{it} + d_i year_t + e_{it}, \quad (5.1)$$

$$food\_index_{it} = a_i + bX'_{it} + d_i year_t + e_{it}, \quad (5.2)$$

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 (5.3) 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`.

$$conflict_{it} = \alpha_i + \beta \cdot gr\_gdp_{it} + \gamma \cdot food\_index_{it} + \delta \cdot X'_{it} + \sigma_i \cdot year_t + \epsilon_{it}. \quad (5.3)$$



### 5.3 Empirical Results

In the model specification (presented in Table 5.1) 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 5.1) 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 5.1, 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 5.4 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

Table 5.1: 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

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

(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.

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 5.2. 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 5.5, 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 5.5 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 5.2: 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* refer to rainfall and T to temperature. p-values in parentheses

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

## 5.4 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 our first paper (Chapter 2) 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 in the first paper (Chapter 2). 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.

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## Appendix A5

### Summary of Variables

Dependent variables	Independent variables	Variable description	Source of data
<b>Economic growth rate</b>	<b><i>First stage variables</i></b>		
<b>Food index</b>	<b><i>Climate variables</i></b>		
	<b>Rainfall in millimeter</b>	The annual rainfall (mm) is computed by adding up all the monthly observations in a given year.	World Bank Climate Change Knowledge Portal (2018).
	<b>Temperature (Celsius degree)</b>	The annual temperatures, 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: $water\_1km2 = 10^6 \times wasser\_total / area.km2$ , 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)
	<b><i>Political variables</i></b>		
	1. Polity IV 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 PolityIV scores either toward democracy or backward to autocracy.	
	3.Accountability	Ranges from 0 (lowest) to 100 (highest) rank.	World Bank (2014).
	<b><i>Environmental variables</i></b>		
	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).	
	<b><i>Demographic</i></b>		
	The share of urban population	Percentage of the total population	(World Bank, 2018).
	<b><i>Economic indicators</i></b>		

	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).
<b>3. Civil conflict</b>	<b><i>Second stage</i></b>		
	1. Economic growth rate	GDP per capita estimates in constant price-US dollar.	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 battle related death per year equals 1, otherwise 0 <sup>7</sup> .	The UCDP/ PRIO Armed Conflict Dataset, Version 18.1

<sup>7</sup>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 5.4: 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 5.5: 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	0.00000637	(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 5.6: 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

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

# Chapter 6

## Conclusion

This thesis analysed linkages between climate change, economic development and the incidence of civil conflict in sub-Saharan Africa and the Middle East and North Africa from 1981 to 2015. In fact, it is essential to provide empirical evidence to which extent extreme climate events placed a significant burden on the economic development that contributed to conflict. Thereby, it is possible to estimate the potential to reduce the probability of civil conflict by identifying proper policy options (e.g. climate-smart agricultural policies).

We draw conclusions based on the analysis of state-of-the-art econometric techniques to deal with endogeneity, unobserved heterogeneity and dynamics using new cross-country panel data for the period 1981-2015.

In Chapter 2, we estimate the direct and indirect impact of climate on the probability of civil conflict for sub-Saharan Africa and the Middle East and North Africa from 1981 to 2015. We conclude that: **First**, weather variables are good instruments not only for economic growth rate but also for domestic food production. Quantitatively, 1 pp change in temperature growth reduces 0.31 pp of economic growth rate and 0.227 pp of food production index. According to the estimated impact of temperature growth on economic growth rate, some countries that currently have annual income growth of 1 to 1.4%, within 32 years, will not be able to achieve any income growth due to temperature changes. Positive rainfall shows a significant positive impact on both economic indicators in this sample of countries and time. However, quantitatively the estimated effect of increased temperature is much higher than rainfall impact on economic performance. **Second**, the significant impact of positive economic growth rate and stable food index is confirmed in reducing the incidence of civil conflict. A 10% reduction in economic growth or domestic food production leads to 1.2% and 1.59% increase in the probability of civil conflict, respectively. **Third**, temperature and rainfall directly affect the likelihood of civil conflict, where a 1 pp change in temperature growth and rainfall growth variables induce a significant increase of 0.39 pp and a decrease of 0.20 pp in the likelihood of



civil conflict, respectively. Rainfall growth has a direct significant impact on reducing the likelihood of civil conflict, this finding is robust to the inclusion of several model specifications. However, the estimated impact of rainfall varies depending on whether a country normally receives low or high annual precipitation. **Fourth**, ignoring the inclusion of the lagged dependent variables leads to overestimating the marginal effects (when applying IV 2SLS). Moreover, having a conflict this year increases the risk of next year's conflict, and therefore, including the impact of the previous conflict, which is allowed by the GMM estimator, is essential for estimates of conflict relationships. We conclude that, the level of democracy of a political system (Polity IV) and good governance are important control variables.

Applying our model to the case of Syria, we conclude that: (i) The predicted contribution of the low economic growth rate in Syria during the war years to raising the probability of war ranges from 3-7 pp compared to 2006 (pre-war period). The reduction in economic growth rate explains only 0.08 pp of the probability of civil war in the outbreak-year (2011) and 0.25 pp in 2010. (ii) The food production index explains 0.61 pp of the probability of war in the outbreak-year and 2.34 pp in the previous year. The impact of food production on the probability of war has increased over time, it seems to be greater when war gets intensive compared to the impact of economic growth rate. (iii) The contribution of the direct effect of climate variables in explaining the probability of war is noticeable through the decrease in precipitation in the pre-war period. (iv) Lagged conflicts in Syria explain up to 45 pp of the probability of civil war. Overall, the total estimated probability of civil war in Syria by all explanatory variables together in the year 2010 is 6.57 pp higher than in 2011 (outbreak year, 0.13 pp). One can conclude that 2010 was crucial year which raised the probability of civil war in Syria. Quantitatively, climate has contributed significantly to explain around 30% of the reduced economic growth rate and 85% of the reduced food index in 2010. Accordingly, policies that are able to increase food security as well as global aid to accelerate economic development, have the potential to reduce the risk of conflict.

We quantitatively assess policies that can reduce the probability of war and avoid new conflicts, based on simulation analysis. For instance, during wartime in 2012 Syria had a negative income growth rate, assuming that through global aid it would have been possible to invest an amount of money equal to 10% of the GDP in the base year (2011, outbreak-year) as transfers, then this would lead to add a certain amount of money (10% of GDP in base year, 2011). For the same amount of money (10% of GDP in base year) invested in increased food production, it would add

around a 5% on food production of 2012, in addition to the increase that occurs in the following year's production like technical progress from the investment in food production, this effect depends on the share of the agricultural sector in GDP (the smaller the size of the agricultural sector, the greater the impact). Moreover, investment in enhancing food production has an indirect effect of a 3% increase on GDP. Therefore, proper food policies that enhance food security seem to play a more affordable role towards peace. The findings of this study are relevant to other countries in the region that face comparable environmental challenges and can inform policies for mitigating and alleviating future conflicts.

In Chapter 3, the main finding of Miguel et al. (2004) that income growth is strongly related to the incidence of civil conflict in sub-Saharan Africa during the period 1981 to 1999, is revisited using our new data set. We find that: first, there is a positive relationship between rainfall and economic growth rate although insignificant. This relationship is robust to the inclusion of temperature growth effect in the regression, which shows expectedly a negative sign on the economic growth rate. Second, the relationship between economic growth rate and the likelihood of civil conflict reveals same negative signs on the coefficients at least in one of the presented models. Third, for the link between rainfall and civil conflict incidence in SSA using our setup of data compared to the data of Miguel et al. (2004), we find consistent negative significant coefficients applying the LS and GMM. Fourth, the impact of adverse conflict on the current conflict is positive with both data sets but not consistent in the significance. We confirm the finding of Miguel et al. (2004) that there is a negative relationship between economic growth and conflict. However, this finding is not perfectly robust and appears to be sensitive to changes in data sources that use different methods of making the data available, although we find partly the same patterns between weather and economic growth rate, and between the income growth and the likelihood of civil conflict for SSA period 1981– 1999.

In Chapter 4, mechanisms of climate change impacts on the incidence of civil conflict are tested separately in sub-Saharan Africa (SSA) compared to the Middle East and North Africa (MENA) for the period 1981 to 2015. We conclude that: **First**, the long-known relationship between weather conditions and economic growth rate, which is significantly positive with precipitation and negative with temperature, has been confirmed in the MENA region. However, in sub-Saharan Africa, the effects of climate (the negative effect of temperature growth) are observed on the food production index, not on economic growth rate. **Second**, beyond economic growth rate climate variability also impacts civil war via domestic food production. Both

indicators, food production index in MENA and economic growth rate in SSA, are significant indicators for social stability reducing the risk of civil conflict. **Third,** There is a positive effect of political stability on the economic growth rate in both regions, and the quality of governance (accountability) and freshwater withdrawal reduce civil conflict in sub-Saharan Africa and the MENA region, respectively. Overall, in the given estimation, there appears to be evidence of different mechanisms in different regions. However, the identification of stable mechanisms needs to be precisely addressed in future work.

In Chapter 5, we estimate the impact of different thresholds of climate shocks on the probability of civil conflict for sub-Saharan Africa and the Middle East and North Africa from 1981 to 2015. We conclude that: (1) Rainfall and temperature shocks are statistically significant but quantitatively show smaller effects relative to growth effect of climate variables. The marginal impact of climate shocks on economic indicators and civil conflicts does not exceed 0.05 pp. Overall, 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. (2) The pattern we find as well in other parts of this research remains, that temperature growth contributes to climate impacts more than rainfall impacts on economic development. Moreover, we find a direct impact of rainfall growth on the reduction of the probability of civil conflict, in addition to the established links between economic development, domestic food production and the incidence of civil conflict. Freshwater withdrawal, the level of democracy, performance of government, all contribute to reducing the potential for conflict.

This thesis analyses the linkages between climate change, economic development, and civil conflicts for a sample of African countries and the Middle East and North Africa. Thereby, I contribute to current research by providing new cross-country panel data, applying an econometric “state-of-the-art” approach to deal with the endogeneity, the unobserved heterogeneity, and dynamics. However, this approach results in some limitations, like the measurement problem of climate change and econometric identification. Furthermore, it is limited to identify causal relationships. Therefore, future approaches need to address the reverse causation, for example by modeling in addition to econometrics, like Bayesian estimations.

## References

Miguel, E., Satyanath, S., and Sergenti, E. (2004). Economic shocks and civil conflict: An instrumental variables approach. *Journal of Political Economy*, 112(4):725–253.

# Appendix A

## Data set and variable description

### Preface

In order to estimate the impact of climate and induced economic shocks, social fragmentation, and political status on the incidence of civil conflict in country  $i$  year  $t$ , we use new cross-section panel data collected from various recognized sources providing consistently updated time series, for African and Middle East countries (total 59) from 1981 to 2015. We relied only on one source to cover all observations for one variable. However, some variables, especially those related to development indicators, suffer from missing for some cross-sections, but however, in the end, we choose the source that contains fewer missing and we use a technique that deals with missing values (replaced missing values by the mean value of each variable in each country).

We make this data set available in STATA format, which consists of the following data and variables:

### A.1 Identification variables

- `country_code`  
The three letter codes (ISO alpha-3) are internationally recognized codes that designate every country, from United Nation ISO 3166-1 alpha-3 <sup>1</sup>.
- `country_name`  
Country name: Almost all sub-Saharan Africa countries are the same as in the study of Miguel et al. (2004)<sup>2</sup>.
- `ccode`  
The numeric country codes; for countries that match the MSS-sample, we keep the same codes, for the rest countries of our sample, three numeric codes were also randomly assigned. This variable is used only to facilitate data binding, not more.

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<sup>1</sup>Total sample observations are 2029, Namibia starts from 1990 after independence.

<sup>2</sup>Note: MSS indicated that Eritrea and Equatorial Guinea were dropped from the analysis due to lack of data, and For Djibouti, Liberia, and Somalia, GDP data are missing since 1992. For Sudan and the Democratic Republic of Congo, GDP data are missing for 1999. Namibia became independent in 1990. Although the sources of our data provides a complete time series but we present and include same number of observations as by MSS in the estimations, to be comparable.

- year  
From 1981 to 2015. Only Namibia starts in 1990, after independence.

## A.2 Civil conflict data and derivation of variables

We use for conflict variables the UCDP/PRIO Armed Conflict Dataset, a conflict version 18.1. ((Themnér et al., 2018)), 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).<sup>3</sup>

**An armed conflict** is defined by the PRIO/Uppsala as a contested incompatibility that concerns government and/or territory over which the use of armed force between two parties, of which at least one is the government of a state, has resulted in at least 25 battle-related deaths in one calendar year.

We focus on civil wars, in the PRIO/Uppsala conflict data four types of conflict are classified (type 1, 2, 3, and 4), type3 and type4 cover civil conflicts without and with intervention from other states on one or both sides<sup>4</sup>, respectively.

The values that each of type3 and type4 of a civil conflict can take are as follows:

### *TYPE3:*

This type of conflict is the PRIO/Uppsala's indicator of Internal Conflict. It can take on four distinct values: 0: No Internal Conflict, 1: Internal Minor Armed Conflict, 2: Internal Intermediate Armed Conflict, 3: Internal War.

### *TYPE4:*

Whereas this type of conflict is the PRIO/Uppsala's indicator of Internationalized Internal Conflict. It can take on four distinct values: 0: No Internationalized Internal Conflict, 1:Internationalized Internal Minor Armed Conflict, 2:Internationalized Internal Intermediate Armed Conflict, 3:Internationalized Internal War.<sup>5</sup>

While the intensity level of a conflict in a given year distinguishes minor armed conflicts from wars based on the battle-related deaths.<sup>6</sup>

1. Minor: between 25 and 999 battle-related deaths in a given year.
2. War: at least 1,000 battle-related deaths in a given year.

<sup>3</sup>The UCDP/PRIO armed conflict for download <http://ucdp.uu.se/downloads/>.

<sup>4</sup>Side A, is always the government side in intrastate conflicts; side B, is the country or opposition organization(s) (The PRIO/Uppsala conflict data, 18.1. 2017).

<sup>5</sup>This is very well documented in the mss\_manual as well, p.16 (MSS data set, 2004), the source is the PRIO/Uppsala conflict data.

<sup>6</sup>UCDP/PRIO Armed Conflict Dataset Codebook, version 4\_2009, updated by: Harbom et al. (2009). The dataset was first presented in Gleditsch et al. (2002), and is available for download from: [www.prio.no/CSCW/Datasets/ArmedConflict/UCDP-PRIO/](http://www.prio.no/CSCW/Datasets/ArmedConflict/UCDP-PRIO/)  
[www.pcr.uu.se/research/UCDP/our\\_data1.htm](http://www.pcr.uu.se/research/UCDP/our_data1.htm)

### *Conflict variables and derived*

We construct three dependent conflict variables (any conflict, minor, and war), all country-year observations are coded as ones based on the type (3 and 4) and the intensity level of the PRIO/Uppsala conflict data as follows:

1. **war\_prio:** War equals 1 when the type of conflict in year  $t$  is 3 or 4 and has an intensity level of 2 (at least 1,000 battle-related deaths per year).  
**war\_prio\_lag\_1:** Lagged one year.  
**war\_prio\_lag\_2:** Lagged two years.
2. **minor\_prio:** Minor conflict equals 1 when the type of conflict in year  $t$  is 3 or 4 and has an intensity level of 1 (at least 25 battle-related deaths per year and fewer than 1,000 battle-related deaths during the course of the conflict).  
**minor\_prio\_lag\_1:** Minor conflict lagged one year.  
**minor\_prio\_lag\_2:** Minor conflict lagged two years.
3. **any\_prio:** Any conflict equals 1 when minor conflict or war equals 1. Otherwise, are coded as zeros.  
**any\_prio\_lag\_1:** Any conflict lagged one year.  
**any\_prio\_lag\_2:** Any conflict lagged two years.

## A.3 Weather variables

We employ two rainfall data sets:

1. **The historical climate data provided at World Bank Climate Change Knowledge Portal (2018).**

We observe changes in rainfall variable from the previous year following (Miguel et al., 2004):  $\mathbf{gr\_rainfall} = \frac{rainfall - rainfall\_lag1}{rainfall\_lag1}$

For the climate (precipitation) measurement strategy in this thesis, we have included and generated the following variables:

### A.3.1 Rainfall variables and derived

- **rainfall:** The annual rainfall (millimeter) is computed by adding up all of the monthly observations in a given year.
- **rainfall\_lag\_1:** Lagged one year.
- **rainfall\_lag\_2:** Lagged two years.
- **gr\_rainfall:** Growth in rainfall:  $(rainfall - rainfall\_lag1)/(rainfall\_lag1)$ .

- **gr\_rainfall\_lag\_1:** Growth rainfall lagged one year:  $(\text{rainfall\_lag\_1} - \text{rainfall\_lag\_2}) / (\text{rainfall\_lag\_2})$ .
- **log\_rainfall:** Log of rainfall levels.
- **log\_rainfall\_lag\_1:** Lagged one year.
- **log\_rainfall\_lag\_2:** Lagged two years.

In order to examine some interaction effects (rainfall) following variables have been generated:

- **dummy\_gr\_rain\_neg:** Equals 1 if a change in rainfall variable in country  $i$  year  $t$  from the previous year is less than zero (1 if  $\text{gr\_rainfall} < 0$ ), otherwise zeros.
- **dummy\_gr\_rain\_pos:** Equals 1 if a change in rainfall variable in country  $i$  year  $t$  from the previous year is greater than zero (1 if  $\text{gr\_rainfall} > 0$ ), otherwise zeros.
- **dummy\_rain\_pos:** Equals 1 if rainfall level in country  $i$  year  $t$  is greater than the mean of rainfall level variable of the sample (1 if  $\text{rainfall} > 57.98657$ ).
- **dummy\_rain\_neg:** Equals 1 if the value of rainfall level in country  $i$  year  $t$  is less than the mean of rainfall levels in the sample (1 if  $\text{rainfall} < 57.98657$ ).
- **inter\_pos\_pos:** Interaction effect between measures of positive growth rainfall and positive rainfall levels; ( $\text{dummy\_gr\_rain\_pos} * \text{dummy\_rain\_pos}$ ).
- **inter\_pos\_neg:** Interaction effect between measures of positive growth rainfall and negative rainfall levels; ( $\text{dummy\_gr\_rain\_pos} * \text{dummy\_rain\_neg}$ ).
- **inter\_neg\_pos:** Interaction effect between measures of negative growth rainfall and positive rainfall levels; ( $\text{dummy\_gr\_rain\_neg} * \text{dummy\_rain\_pos}$ ).
- **inter\_neg\_neg:** Interaction effect between measures of negative growth rainfall and negative rainfall levels; ( $\text{dummy\_gr\_rain\_neg} * \text{dummy\_rain\_neg}$ ).

Moreover, several variables are generated to consider the effect of precipitation depending on where it falls, and thus, we determined whether our sample countries had historically low or high precipitation rates compared to the average precipitation in Europe. (Germany took specifically: 727 mm) to build interaction effects as follows.

- **low\_rainfall\_countr:** Dichotomous variable equals 1 if the annual rainfall levels of a country is lower than 727 mm, otherwise zero.
- **high\_rainfall\_countr:** Dichotomous variable equals 1 if the annual rainfall levels of a country is higher than 727 mm, otherwise zero.



- **inter\_L\_gr\_rainfall:** Interaction effect between the dummy variable "low\_rainfall\_countr" and measures of rainfall growth "gr\_rainfall" in country (*i*) time (*t*).
- **inter\_h\_gr\_rainfall:** Interaction effect between the dummy variable "high\_rainfall\_countr" and measures of rainfall growth "gr\_rainfall" in country (*i*) time (*t*).
- **inter\_l\_rainfall:** Interaction effect between the dummy variable "low\_rainfall\_countr" and measures of rainfall levels "rainfall" in country (*i*) time (*t*).
- **inter\_h\_rainfall:** Interaction effect between the dummy variable "high\_rainfall\_countr" and measures of rainfall levels "rainfall" in country (*i*) time (*t*).

**2. The Global Precipitation Climatology Project (GPCP) database version 2.3** of monthly rainfall estimates, at 2.5 latitude and longitude degree intervals and cover the period 1979- 2015 (Adler et al., 2016). The GPCP data rely on a combination of actual weather station rainfall gauge measures and satellite information on the density of cold cloud cover, which is closely related to actual precipitation. The units of measurement are in millimeters of rainfall per day and are the average. The GPCP uses the Huffman (1997) method of data selection and merging, and how estimates of total yearly rainfall at the country-level have been produced see the Data set of MSS (2004), and for the calculation of total yearly rainfall/country measures from recently provided version 2.3 by GPCP, we determined grid nodes that fell within the national boundaries for our sample countries, otherwise, we assigned rainfall measures from the nearest nodes to their borders. For sub-Saharan Africa' countries, we used same nodes that were defined by MSS-2004 for rainfall data (A List of all nodes used in the calculation of rainfall data from the GPCP-V2.3, in Appendix B).

**Derived variables for this data source are as follows**

- **gpcp\_neu:** Total yearly rainfall for country (*i*) is the average of the yearly rainfall estimates in millimeters on a resolution of 2.5° latitude/longitude degree nodes in the given country.
- **lag\_gpcp\_neu:** Lagged one year, with 0 for start of country series.
- **gr\_gpcp\_neu:** Growth in gpcp\_neu:  $(\text{gpcp\_neu} - \text{lag\_gpcp\_neu})/(\text{lag\_gpcp\_neu})$ , with 0 for start of country series.

### A.3.2 Temperatures variables

- **temp:** The annual temperatures (Celsius degree) are computed by adding up all of the monthly observations in a given year divided by the number of months in that year.

- **temp\_lag\_1**: Temperature lagged one year.
- **temp\_lag\_2**: Temperature lagged two years.
- **gr\_temp**: Growth in temperature from the previous year:  
(temp - temp\_lag\_1)/(temp\_lag\_1).
- **gr\_temp\_lag\_1**: Growth temperature lagged one year:  
(temp\_lag\_1 - temp\_lag\_2)/ (temp\_lag\_2).

### A.3.3 Climate Shocks

First, rainfall and temperature deviation variables are constructed using the following formula:  $dev.Xit = (Xi,t - \bar{X}i)/\sigma i$  where  $Xi,t$  is the annual rainfall or temperature in country  $i$  time  $t$ , and  $\bar{X}i$  denotes to the long-term mean (35 years) for each country, and  $\sigma i$  is the standard deviation for each country long-term (35 years) mean. The normalized annual temperature data ranges between -3.03, 3.18 deviation, has a mean of 0.03 and standard deviation of 0.98. While normalized annual rainfall data ranges from -2.69, 3.76 has a mean of almost zero and standard deviation of 0.99.

The defined climate derivation variables in the data set are as follows:

- **dev\_rain** Annual rainfall deviation in a given country and year.  $dev\_rain = (rainfall - rain\_avg)/rain\_sd$
- **dev\_temp** Annual temperature deviation in a given country and year.  $dev\_temp = (temp - temp\_avg)/temp\_sd$

In order to define if deviation in climate variables are positive or negative, we have generated dummies determining different thresholds (1 and 2) as follows:

- Rainfall deviation thresholds: takes four values;  $rain\_dev\_Threshold = 1$  if  $dev\_rain$  is  $>$  than 1,  
2 if  $dev\_rain > 2$ ,  
3 if  $dev\_rain < -1$ ,  
4 if  $dev\_rain < -2$ , otherwise zero.
- Temperature deviation thresholds: takes four values;  $temp\_dev\_Threshold = 1$  if  $dev\_temp$  is  $>$  than 1,  
2 if  $dev\_temp > 2$ ,  
3 if  $dev\_temp < -1$ ,  
4 if  $dev\_temp < -2$ , otherwise zero.

Second, counting observed shocks (positive or negative) over previous 5-year period, to better understand the dynamics of shock thresholds

- $R\_pos\_thresholds$ : Rainfall positive thresholds = (rain\_dev\_Threshold= 1 | rain\_dev\_Threshold= 2)
- $R\_neg\_thresholds$ : Rainfall negative thresholds = (rain\_dev\_Threshold= 3 | rain\_dev\_Threshold= 4)
- $count\_R\_pos\_shock2Y$ : The number of observed positive rainfall shocks =  $(12.R\_pos\_thresholds + 1.R\_pos\_thresholds)/2$
- $count\_R\_neg\_shock2Y$ : The number of observed negative rainfall shocks =  $(12.R\_neg\_thresholds + 1.R\_neg\_thresholds)/2$
- $T\_pos\_thresholds$ : Temperature positive thresholds = (temp\_dev\_Threshold= 1 | temp\_dev\_Threshold= 2)
- $T\_neg\_thresholds$ : Temperature negative thresholds = (temp\_dev\_Threshold= 3 | temp\_dev\_Threshold= 4)
- $count\_T\_pos\_shock2Y$ : The number of observed positive Temperature shocks =  $(12.T\_pos\_thresholds + 1.T\_pos\_thresholds)/2$
- $count\_T\_neg\_shock2Y$ : The number of observed negative Temperature shocks =  $(12.T\_neg\_thresholds + 1.T\_neg\_thresholds)/2$

Third, to estimate the absolute impact of (combined) shocks over previous 5 years period on the interest variables in time  $t$ , without differentiating between positive and negative shocks, we have generated following variables:

- $R\_count\_combShok=1$ : Indicates the number of observed rainfall shocks (experienced 1 year shock) over previous five years period.
- $R\_count\_combShok=2$ : Indicates the number of observed rainfall shocks (2 shocks) over previous five years period.
- $R\_count\_combShok=3$ : Indicates the number of observed rainfall shocks (3 shocks) over previous five years period.
- $R\_count\_combShok=4$ : Indicates the number of observed rainfall shocks (4 shock shocks) over previous five years period.
- $R\_count\_combShok=5$ : Indicates the number of observed rainfall shocks (5 shocks). It was exposed to climatic shocks in 5 consecutive years period.
- $R\_count\_combShok=1$ : Indicates the number of observed rainfall shocks (experienced 1 year shock) over previous five years period.
- $T\_count\_combShok=2$ : Indicates the number of observed temperature shocks (2 shocks) over previous five years period.
- $T\_count\_combShok=3$ : Indicates the number of observed temperature shocks (3 shocks) over previous five years period.

- **T\_count\_combShok=4:** Indicates the number of observed temperature shocks (4 shocks) over previous five years period.
- **T\_count\_combShok=5:** Indicates the number of observed temperature shocks (5 shocks) over previous five years period.

Finally, moving average measurement that smoothes a data series by consolidating the yearly data points into a longer period of time, which is a mean of five years from  $t$  to  $t - 4$ . Odusola and Abidoye (2015) has examined the impact of moving averages of climate variables and economic growth rate in Africa:

- **MA\_rainfall:** smoothed average of rainfall variable in country  $i$  year  $t$  based on averages of the previous five years, including the given current year.
- **MA\_gr\_rainfall:** smoothed average of growth rainfall in country  $i$  year  $t$  based on averages of  $t$  to  $t - 4$  five years.
- **MA\_temp:** smoothed average of annual temperature in country  $i$  year  $t$  based on averages of the previous five years, including the given current year ( $t$  to  $t - 4$ ).
- **MA\_gr\_temp:** smoothed average of annual temperature averages in country  $i$  year  $t$  based on averages of the previous five years, including the given current year ( $t$  to  $t - 4$ ).

## A.4 Socio-Economic variables

### A.4.1 Gross Domestic Product per capita

For the major economic variable GDP per capita, i.e. the total amount of goods and services produced in the economy, divided by its population, there is no complete time series for our sample (59 countries) from 1980 to 2015 such as the World Development Indicators source. However, we have estimated with data on this variable from two different sources; (i) James et al. (2012) has developed a comprehensive time series of GDP per capita for 210 countries from 1950 to 2015, which covers the time period and countries exist in our study. In their time series GDP per capita estimates expressed in either constant US dollar terms or international dollar terms (corrected for purchasing power parity) from seven sources to derive in the end two new GDP per capita series (the base year 2005).

(i) From James et al. (2012) study, we include GDP per capita indicator (In international (ID) and constant (USD) dollar), its derived variables as follows:

- **gdp\_c\_id:** GDP per capita in international dollar terms (ID).
- **gdp\_c\_id\_lag\_1:** GDP per capita (ID) lagged one year.

- **gdp\_c\_id\_lag\_2:** GDP per capita (ID) lagged two years.
- **gr\_gdp\_c\_id:** To observe changes in GDP per capita (ID) from the previous year:  $(\text{gdp\_c\_id} - \text{gdp\_c\_id\_lag\_1}) / (\text{gdp\_c\_id\_lag\_1})$ .
- **gr\_gdp\_c\_id\_lag\_1:** GDP growth (ID) lagged one year:  $(\text{gdp\_c\_id\_lag\_1} - \text{gdp\_c\_id\_lag\_2}) / (\text{gdp\_c\_id\_lag\_2})$ .
- .....
- **gdp\_c\_usd:** GDP per capita in constant US dollar terms (USD).
- **gdp\_c\_usd\_lag\_1:** GDP per capita (USD) lagged one year.
- **gdp\_c\_usd\_lag\_2:** GDP per capita (USD) lagged two years.
- **gr\_gdp\_c\_usd:** To observe changes in GDP per capita (USD) from the previous year:  $(\text{gdp\_c\_usd} - \text{gdp\_c\_usd\_lag\_1}) / (\text{gdp\_c\_usd\_lag\_1})$ .
- **gr\_gdp\_c\_usd\_lag\_1:** GDP growth (USD) lagged one year:  $(\text{gdp\_c\_usd\_lag\_1} - \text{gdp\_c\_usd\_lag\_2}) / (\text{gdp\_c\_usd\_lag\_2})$ .
- **basis\_gdp\_id\_1981:** GDP per capita in international dollar terms at the beginning of period analysis, 1981 (1991 for Namibia).
- **basis\_gdp\_usd\_1981:** GDP per capita in constant US dollar terms at the beginning of period analysis, 1981 (1991 for Namibia).

(ii) The second source is the database of UNSD (2020), which provides a complete and consistent set of GDP per capita time series from 1970 onwards, from 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 dollar: <http://data.un.org/>

#### Derived variables are as follows

- **gdp\_c\_cur:** GDP per capita estimates expressed in current price-US dollars.
- **gdp\_c\_cur\_lag\_1:** GDP per capita estimates expressed in current price-US dollars lagged one year.
- **gdp\_c\_cur\_lag\_2:** GDP per capita estimates expressed in current price-US dollars lagged two years.
- **gr\_gdp\_c\_cur:** Changes in GDP per capita estimates expressed in current price-US dollars from previous year:  $(\text{gdp\_c\_cur} - \text{gdp\_c\_cur\_lag\_1}) / (\text{gdp\_c\_cur\_lag\_1})$ .
- **gr\_gdp\_c\_cur\_lag\_1:** GDP growth in current price-US dollars lagged one year:  $(\text{gdp\_c\_cur\_lag\_1} - \text{gdp\_c\_cur\_lag\_2}) / (\text{gdp\_c\_cur\_lag\_2})$ .

- **gdp\_c\_con:** GDP per capita estimates in constant price-US dollars.
- **gdp\_c\_con\_lag\_1:** GDP per capita estimates in constant price-US dollars lagged one year.
- **gdp\_c\_con\_lag\_2:** GDP per capita estimates in constant price-US dollars lagged two years.
- **gr\_gdp\_c\_con:** Changes in GDP per capita estimates expressed in constant price-US dollars from previous year:  
 $(\text{gdp\_c\_con} - \text{gdp\_c\_con\_lag\_1}) / (\text{gdp\_c\_con\_lag\_1})$ .
- **gr\_gdp\_c\_con\_lag\_1:** GDP growth estimates in constant price-US dollars lagged one year:  $(\text{gdp\_c\_con\_lag\_1} - \text{gdp\_c\_con\_lag\_2}) / (\text{gdp\_c\_con\_lag\_2})$ .

#### A.4.2 Food production index variable

**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, they have no nutritive value, from the **Food and Agriculture Organization of the United Nations (2016)**.

#### A.4.3 Oil exporter status variables

- **oil\_exp\_wdi:** Oil exporter status (% of merchandise exports) using time series cover our sample countries from **the World Bank (2016)**.
- **oil\_exp\_wdi\_lag\_1:** Oil exporter status lagged one year.
- **oil\_exp\_wdi\_lag\_2:** Oil exporter status lagged two years.
- **gr\_oil\_exp\_wdi:** Changes in oil exporter status from the previous year:  
 $(\text{oil\_exp\_wdi} - \text{oil\_exp\_wdi\_lag\_1}) / (\text{oil\_exp\_wdi\_lag\_1})$ .
- **gr\_oil\_exp\_wdi\_lag\_1:** Growth of oil exporter lagged one year:  
 $(\text{oil\_exp\_wdi\_lag\_1} - \text{oil\_exp\_wdi\_lag\_2}) / (\text{oil\_exp\_wdi\_lag\_2})$ .

#### A.4.4 Total merchandise trade variable

- **trade\_exports:** Total merchandise trade of a country exports to the world in US dollar at current prices using time series from the **The World Trade Organization (2016)**.
- **trade\_exports\_lag\_1:** Total merchandise trade of a country exports to the world in US dollar at current prices lagged one year.

- **trade\_exports\_lag\_2:** Total merchandise trade of a country exports to the world in US dollar at current prices lagged two years.
- **gr\_trade\_exports:** Changes in total merchandise trade of a country exports to the world in US dollar at current price from previous year:  $(\text{trade\_exports} - \text{trade\_exports\_lag\_1}) / (\text{trade\_exports\_lag\_1})$ .
- **gr\_trade\_exports\_lag\_1:** Growth in total merchandise trade lagged one year:  $(\text{trade\_exports\_lag\_1} - \text{trade\_exports\_lag\_2}) / (\text{trade\_exports\_lag\_2})$ .

### A.4.5 Demographic indicators

#### Population

- **population\_sh:** Total indicator in thousands counts all residents regardless of legal status or citizenship. The source of this data is **the World Bank (2018)**.
- **population\_sh\_lag\_1:** Total population lagged one year.
- **population\_sh\_lag\_2:** Total population lagged two years.
- **Urban\_pop:** Expressed as a percentage of the total population.

#### Education and unemployment

- **educ\_attainment:** The percentage of educational attainment at least completed primary (ISCED 1 or higher), population > 25 years for both sexes, from UNESCO Institute for Statistics (2008).<sup>7</sup>
- **unempl\_inter\_edu:** Unemployment with intermediate education (% of total labour force with basic education) from **World Bank (2016)**

### A.4.6 Fractionalization variables

For measuring ethnic and religious fractionalization, we use fractionalization's index, provided by Alesina et al. (2003), and computed using the formula  $FRAC_m = 1 - \sum_{i=k}^N S_{km}^2$ , where  $S_{km}$  is the share of group  $k$  in country  $m$ .

- **ethnic\_sh:** For the ethnic variable data on various ethnic groups that were disaggregated, combined from several sources, however, the primary source is Encyclopaedia Britannica (2001), in addition to the Central Intelligence Agency (CIA, 2000; Levinson, 1998), and the Minority Rights Groups International (Thornberry et al., 1997).

<sup>7</sup>The UNESCO Institute for Statistics. <http://data.uis.unesco.org/>

- **ethnic\_sh\_lag\_1**: Ethnic data lagged one year.
- **ethnic\_sh\_lag\_2**: Ethnic data lagged two years.
- **religion\_sh**: Religious data is based exclusively on data from **Encyclopaedia Britannica, 2001**.
- **religion\_sh\_lag\_1**: Religious data lagged one year.
- **religion\_sh\_lag\_2**: Religious data lagged two years.

#### A.4.7 Political variables

- **polityiv\_sh**: Type of political regime 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 anocracies. The source is the project of Roser (2019), based on Polity IV Project (2013) and Wimmer and Min (2006).
- **polityiv\_sh\_tr**: We transformed Polity IV scores (**polityiv\_sh**) to be instead on a range from 1 to 20, for easier interpretation of coefficients.
- **polityiv\_sh\_tr\_lag\_1**: Transformed Polity IV scores (**polityiv\_sh\_tr**) (range from 1 to 20) lagged one year.
- **polityiv\_sh\_tr\_lag\_2**: Transformed Polity IV scores (**polityiv\_sh\_tr**) (range from 1 to 20) lagged two years.
- **strength\_gr\_polityiv**: We constructed this variable to observe the absolute strength of the political crisis in a given country and year compared to the previous year. It indicates changes from the previous year in absolute terms of Polity IV scores either toward democracy or backward to autocracy.  
 $\text{strength\_gr\_polityiv} = |\text{polityiv\_sh\_tr} - \text{polityiv\_sh\_tr\_lag\_1}|$

#### A.4.8 Voice and Accountability indicator

- **accountab**: Percentile rank among all countries (ranges from 0=lowest to 100 =highest rank), reflects perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well freedom of expression, association, and a free media. The source is World Bank (2014) covering time from 1960 to present.

### A.5 Natural conditions:

- **agri\_land**: Agricultural land (% of land area) refers to 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. The source is World Bank (2016).

- **arable\_land:** Arable land (hectares per person).
- **mountains\_sh and log\_mountains\_sh:** the proportion of mountainous terrain and its logarithmic value. We kept most mountainous terrain data of Miguel et al. (2004), but we complete our new data base (i.e. the rest of countries and years) by data of Fearon and Laitin (2003), who formed their data with respect to the geographer Gerrard (2014).
- **area.km2:** The total area of a country in  $km^2$ .
- **Latitude:** GeoDist provides useful data incorporates country-specific geographical variables, including geographical coordinates of their capital cities (CEPII, 2020).

We have included information of the water use variable from FAO (2017), which is classified into sub-variables (i) pressure on water resources for following sub-sub-variables:

- **freshwater:** Freshwater withdrawal (MDG 7.5.) as % of total renewable water resources.
- **agri\_renew:** Agricultural water withdrawal as % of total renewable water resources (%).
- **water\_stress:** Aggregated indicator (SDG 6.4.2.) freshwater withdrawal as a proportion of available freshwater resources. This indicator is also known as water withdrawal intensity.
- **wasser\_total:** Annual level of freshwater withdrawal, calculated averagely over each decade (roundly 1980-1989, 1990-1999, 2000-2017), in  $10^9 m^3$ /year.
- **water\_1km2:** The average annual level of freshwater withdrawal (calculated averagely over each decade) divided by country area  
 $water\_1km2 = 10^6 \times wasser\_total / area.km2$ , in  $10^3 m^3/km^2$ .

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## Appendix B

### Longitude and latitude points for rainfall data-GPCP V2.3

Longitude and latitude points used in the calculation of the GPCP' data version 2.3 yearly rainfall estimates. For sub-Saharan Africa' sample we used same points presented by Miguel et al. (2004).<sup>1</sup>

Country	Node	Latitude	Point	Longitude	Point
1.Angola	1	-16.25	S	13.75	E
	2	-13.75	S	13.75	E
	3	-8.75	S	13.75	E
	4	-6.25	S	13.75	E
	5	-16.25	S	16.25	E
	6	-13.75	S	16.25	E
	7	-11.25	S	16.25	E
	8	-8.75	S	16.25	E
	9	-6.25	S	16.25	E
	10	-16.25	S	18.75	E
	11	-13.75	S	18.75	E
	12	-11.25	S	18.75	E
	13	-8.75	S	18.75	E
	14	-16.25	S	21.25	E
	15	-13.75	S	21.25	E
	16	-11.25	S	21.25	E
	17	-8.75	S	21.25	E
	18	-11.25	S	23.75	E
2.Benin	1	11.25	N	1.25	E
3.Botswana	1	-26.25	S	21.25	E
	2	-23.75	S	21.25	E
	3	-21.25	S	21.25	E
	4	-18.75	S	21.25	E
	5	-23.75	S	23.75	E
	6	-21.25	S	23.75	E

<sup>1</sup>For SSA' sample, it is mentioned by MSS (2004): No degree grid node fell within the national boundaries for five small African countries— Burundi, Djibouti, Gambia, Guinea-Bissau, and Rwanda—so in these cases they assigned rainfall measures from the node nearest to their borders. We do so for MENA' sample, countries where no degree grid node fell within their boundaries are: Lebanon, Bahrain, Kuwait, Israel, and Qatar

	7	-18.75	S	23.75	E
	8	-23.75	S	26.25	E
	9	-21.25	S	26.25	E
4.Burkina Faso	1	11.25	N	3.75	W
	2	11.25	N	1.25	W
	3	13.75	N	1.25	W
5.Burundi	1	-3.75	S	28.75	E
	2	-3.75	S	31.25	E
6. Cameroon	1	3.75	N	11.25	E
	2	6.25	N	11.25	E
	3	3.75	N	13.75	E
	4	6.25	N	13.75	E
	5	8.75	N	13.75	E
7. Central African Republic	1	3.75	N	16.25	E
	2	6.25	N	16.25	E
	3	6.25	N	18.75	E
	4	6.25	N	21.25	E
	5	8.75	N	21.25	E
	6	6.25	N	23.75	E
	7	6.25	N	26.25	E
8. Chad	1	13.75	N	13.75	E
	2	8.75	N	16.25	E
	3	11.25	N	16.25	E
	4	13.75	N	16.25	E
	5	16.25	N	16.25	E
	6	18.75	N	16.25	E
	7	21.25	N	16.25	E
	8	8.75	N	18.75	E
	9	11.25	N	18.75	E
	10	13.75	N	18.75	E
	11	16.25	N	18.75	E
	12	18.75	N	18.75	E
	13	21.25	N	18.75	E
	14	11.25	N	21.25	E
	15	13.75	N	21.25	E
	16	16.25	N	21.25	E
	17	18.75	N	21.25	E
	18	16.25	N	23.75	E
	19	18.75	N	23.75	E
9. Congo, Brazzaville	1	-3.75	S	11.25	E
	2	-3.75	S	13.75	E
	3	-1.25	S	16.25	E
	4	1.25	N	16.25	E
10. Congo, Kinshasa	1	-3.75	S	16.25	E
	2	-6.25	S	18.75	E
	3	-3.75	S	18.75	E

	4	-1.25	S	18.75	E
	5	1.25	N	18.75	E
	6	3.75	N	18.75	E
	7	-6.25	S	21.25	E
	8	-3.75	S	21.25	E
	9	-1.25	S	21.25	E
	10	1.25	N	21.25	E
	11	3.75	N	21.25	E
	12	-8.75	S	23.75	E
	13	-6.25	S	23.75	E
	14	-3.75	S	23.75	E
	15	-1.25	S	23.75	E
	16	1.25	N	23.75	E
	17	3.75	N	23.75	E
	18	-11.25	S	26.25	E
	19	-8.75	S	26.25	E
	20	-6.25	S	26.25	E
	21	-3.75	S	26.25	E
	22	-1.25	S	26.25	E
	23	1.25	N	26.25	E
	24	3.75	N	26.25	E
	25	-8.75	S	28.75	E
	26	-6.25	S	28.75	E
10.Congo, Kinshasa (cont	27	-3.75	S	28.75	E
	28	-1.25	S	28.75	E
	29	1.25	N	28.75	E
	30	3.75	N	28.75	E
11.Cote d'Ivoire	1	6.25	N	6.25	W
	2	8.75	N	6.25	W
	3	6.25	N	3.75	W
	4	8.75	N	3.75	W
12.Djibouti	1	11.25	N	41.25	E
	2	11.25	N	43.75	E
13.Equatorial Guinea	1	3.75	N	8.75	E
	2	1.25	N	11.25	E
14.Eritrea	1	16.25	N	38.75	E
	2	13.75	N	41.25	E
15.Ethiopia, post 1993	1	6.25	N	36.25	E
	2	8.75	N	36.25	E
	3	11.25	N	36.25	E
	4	3.75	N	38.75	E
	5	6.25	N	38.75	E
	6	8.75	N	38.75	E
	7	11.25	N	38.75	E
	8	13.75	N	38.75	E
	9	6.25	N	41.25	E

	10	8.75	N	41.25	E
	11	11.25	N	41.25	E
	12	6.25	N	43.75	E
	13	8.75	N	43.75	E
15. Ethiopia, pre 1993	1	16.25	N	38.75	E
	2	13.75	N	41.25	E
	3	6.25	N	36.25	E
	4	8.75	N	36.25	E
	5	11.25	N	36.25	E
	6	3.75	N	38.75	E
	7	6.25	N	38.75	E
	8	8.75	N	38.75	E
	9	11.25	N	38.75	E
	10	13.75	N	38.75	E
	11	6.25	N	41.25	E
	12	8.75	N	41.25	E
	13	11.25	N	41.25	E
	14	6.25	N	43.75	E
	15	8.75	N	43.75	E
16. Gabon	1	-1.25	S	11.25	E
	2	-1.25	S	13.75	E
	3	1.25	N	13.75	E
17. Gambia	1	13.75	N	16.25	W
	2	13.75	N	13.75	W
18. Ghana	1	6.25	N	1.25	W
	2	8.75	N	1.25	W
19. Guinea	1	11.25	N	13.75	W
	2	11.25	N	11.25	W
	3	8.75	N	8.75	W
	4	11.25	N	8.75	W
20. Guinea-Bissau	1	11.25	N	16.25	W
21. Kenya	1	-1.25	S	36.25	E
	2	1.25	N	36.25	E
	3	3.75	N	36.25	E
	4	-3.75	S	38.75	E
	5	-1.25	S	38.75	E
	6	1.25	N	38.75	E
	7	-1.25	S	41.25	E
	8	3.75	N	41.25	E
22. Lesotho	1	-28.75	S	28.75	E
23. Liberia	1	6.25	N	351.25	E
24. Madagascar	1	-23.75	S	43.75	E
	2	-23.75	S	46.25	E
	3	-21.25	S	46.25	E
	4	-18.75	S	46.25	E
	5	-16.25	S	46.25	E

	6	-18.75	S	48.75	E
	7	-16.25	S	48.75	E
	8	-13.75	S	48.75	E
25.Malawi	1	-13.75	S	33.75	E
	2	-11.25	S	33.75	E
26.Mali	1	16.25	N	1.25	E
	2	18.75	N	1.25	E
	3	16.25	N	3.75	E
	4	18.75	N	3.75	E
	5	13.75	N	11.25	W
	6	13.75	N	8.75	W
	7	11.25	N	6.25	W
	8	13.75	N	6.25	W
	9	23.75	N	6.25	W
	10	13.75	N	3.75	W
	11	16.25	N	3.75	W
	12	18.75	N	3.75	W
	13	21.25	N	3.75	W
	14	23.75	N	3.75	W
	15	16.25	N	1.25	W
	16	18.75	N	1.25	W
	17	21.25	N	1.25	W
27.Mauritania	1	21.25	N	16.25	W
	2	16.25	N	13.75	W
	3	18.75	N	13.75	W
	4	21.25	N	13.75	W
	5	16.25	N	11.25	W
	6	18.75	N	11.25	W
	7	21.25	N	11.25	W
27.Mauritania (cont	8	N	23.7	51.25	W
	9	16.25	N	8.75	W
	10	18.75	N	8.75	W
	11	21.25	N	8.75	W
	12	23.75	N	8.75	W
	13	16.25	N	6.25	W
	14	18.75	N	6.25	W
	15	21.25	N	6.25	W
28.Mozambique	1	-23.75	S	33.75	E
	2	-21.25	S	33.75	E
	3	-18.75	S	33.75	E
	4	-16.25	S	33.75	E
	5	-18.75	S	36.25	E
	6	-16.25	S	36.25	E
	7	-13.75	S	36.25	E
	8	-16.25	S	38.75	E
	9	-13.75	S	38.75	E



	10	-11.25	S	38.75	E
29.Namibia	1	-21.25	S	13.75	E
	2	-18.75	S	13.75	E
	3	-26.25	S	16.25	E
	4	-23.75	S	16.25	E
	5	-21.25	S	16.25	E
	6	-18.75	S	16.25	E
	7	-28.75	S	18.75	E
	8	-26.25	S	18.75	E
	9	-23.75	S	18.75	E
	10	-21.25	S	18.75	E
	11	-18.75	S	18.75	E
30.Niger	1	13.75	N	1.25	E
	2	13.75	N	3.75	E
	3	13.75	N	6.25	E
	4	16.25	N	6.25	E
	5	18.75	N	6.25	E
	6	13.75	N	8.75	E
	7	16.25	N	8.75	E
	8	18.75	N	8.75	E
	9	21.25	N	8.75	E
	10	13.75	N	11.25	E
	11	16.25	N	11.25	E
	12	18.75	N	11.25	E
	13	21.25	N	11.25	E
	14	16.25	N	13.75	E
	15	18.75	N	13.75	E
	16	21.25	N	13.75	E
31.Nigeria	1	8.75	N	3.75	E
	2	11.25	N	3.75	E
	3	6.25	N	6.25	E
	4	8.75	N	6.25	E
31.Nigeria (cont	5	11.25	N	6.25	E
	6	6.25	N	8.75	E
	7	8.75	N	8.75	E
	8	11.25	N	8.75	E
	9	8.75	N	11.25	E
	10	11.25	N	11.25	E
	11	11.25	N	13.75	E
32.Rwanda	1	-1.25	S	28.75	E
	2	-1.25	S	31.25	E
33.Senegal	1	13.75	N	16.25	W
	2	16.25	N	16.25	W
	3	13.75	N	13.75	W
34.Sierra Leone	1	8.75	N	11.25	W

35.Somalia	1	1.25	N	41.25	E
	2	1.25	N	43.75	E
	3	3.75	N	43.75	E
	4	3.75	N	46.25	E
	5	6.25	N	46.25	E
	6	8.75	N	46.25	E
	7	6.25	N	48.75	E
	8	8.75	N	48.75	E
	9	11.25	N	48.75	E
36. South Africa	1	-33.75	S	18.75	E
	2	-31.25	S	18.75	E
	3	-33.75	S	21.25	E
	4	-31.25	S	21.25	E
	5	-28.75	S	21.25	E
	6	-33.75	S	23.75	E
	7	-31.25	S	23.75	E
	8	-28.75	S	23.75	E
	9	-26.25	S	23.75	E
	10	-33.75	S	26.25	E
	11	-31.25	S	26.25	E
	12	-28.75	S	26.25	E
	13	-26.25	S	26.25	E
	14	-31.25	S	28.75	E
	15	-26.25	S	28.75	E
	16	-23.75	S	28.75	E
	17	-28.75	S	31.25	E
	18	-23.75	S	31.25	E
37.Sudan	1	8.75	N	23.75	E
	2	11.25	N	23.75	E
	3	13.75	N	23.75	E
	4	8.75	N	26.25	E
	5	11.25	N	26.25	E
	6	13.75	N	26.25	E
	7	16.25	N	26.25	E
	8	18.75	N	26.25	E
	9	21.25	N	26.25	E
37.Sudan (cont	10	6.25	N	28.75	E
	11	8.75	N	28.75	E
	12	11.25	N	28.75	E
	13	13.75	N	28.75	E
	14	16.25	N	28.75	E
	15	18.75	N	28.75	E
	16	21.25	N	28.75	E
	17	6.25	N	31.25	E
	18	8.75	N	31.25	E

	19	11.25	N	31.25	E
	20	13.75	N	31.25	E
	21	16.25	N	31.25	E
	22	18.75	N	31.25	E
	23	21.25	N	31.25	E
	24	6.25	N	33.75	E
	25	8.75	N	33.75	E
	26	11.25	N	33.75	E
	27	13.75	N	33.75	E
	28	16.25	N	33.75	E
	29	18.75	N	33.75	E
	30	21.25	N	33.75	E
	31	13.75	N	36.25	E
	32	16.25	N	36.25	E
	33	18.75	N	36.25	E
	34	21.25	N	36.25	E
38.Swaziland	1	-26.25	S	31.25	E
39.Tanzania	1	-6.25	S	31.25	E
	2	-3.75	S	31.25	E
	3	-1.25	S	31.25	E
	4	-8.75	S	33.75	E
	5	-6.25	S	33.75	E
	6	-3.75	S	33.75	E
	7	-1.25	S	33.75	E
	8	-11.25	S	36.25	E
	9	-8.75	S	36.25	E
	10	-6.25	S	36.25	E
	11	-3.75	S	36.25	E
	12	-8.75	S	38.75	E
	13	-6.25	S	38.75	E
40.Togo	1	6.25	N	1.25	E
	2	8.75	N	1.25	E
41.Uganda	1	1.25	N	31.25	E
	2	3.75	N	31.25	E
	3	1.25	N	33.75	E
	4	-1.25	S	31.25	E
	6	-1.25	S	29.75	E
	5	3.75	N	33.75	E
42.Zambia	1	-16.25	S	23.75	E
	2	-13.75	S	23.75	E
	3	-16.25	S	26.25	E
	4	-13.75	S	26.25	E
42.Zambia (cont	5	-16.25	S	28.75	E
	6	-13.75	S	28.75	E
	7	-11.25	S	28.75	E
	8	-13.75	S	31.25	E

	9	-11.25	S	31.25	E
	10	-8.75	S	31.25	E
43.Zimbabwe	1	-18.75	S	26.25	E
	2	-21.25	S	28.75	E
	3	-18.75	S	28.75	E
	4	-21.25	S	31.25	E
	5	-18.75	S	31.25	E
	6	-16.25	S	31.25	E
MENA' countries					
44.Tunisia	1	33.75	N	8.75	E
	2	36.25	N	8.75	E
45.Morocco	1	26.25	N	8.75	W
	2	26.25	N	11.25	W
	3	28.75	N	8.75	W
	4	31.25	N	6.25	W
	5	31.25	N	8.75	W
	6	33.75	N	3.75	W
	7	33.75	N	6.25	W
46.Algeria	1	21.25	N	1.25	E
	2	21.25	N	3.75	E
	3	21.25	N	6.25	E
	4	23.75	N	1.25	E
	5	23.75	N	3.75	E
	6	23.75	N	6.25	E
	7	23.75	N	8.75	E
	8	23.75	N	11.25	E
	9	23.75	N	1.25	W
	10	26.25	N	1.25	E
	11	26.25	N	3.75	E
	12	26.25	N	6.25	E
	13	26.25	N	8.75	E
	14	26.25	N	1.25	W
	15	26.25	N	3.75	W
	16	26.25	N	6.25	W
	17	28.75	N	1.25	W
	18	28.75	N	1.25	E
	19	28.75	N	3.75	E
	20	28.75	N	6.25	E
	21	28.75	N	6.25	W
	22	28.75	N	8.75	E
	23	28.75	N	3.75	W
	24	31.25	N	1.25	W
	25	31.25	N	1.25	E
	26	31.25	N	3.75	E
	27	31.25	N	3.75	W
	28	31.25	N	6.25	E

	29	31.25	N	8.75	E
	30	33.75	N	1.25	W
	31	33.75	N	1.25	E
	32	33.75	N	3.75	E
	33	33.75	N	6.25	E
	34	36.25	N	1.25	E
	35	36.25	N	3.75	E
	36	36.25	N	6.25	E
47.Yemen	1	13.75	N	43.75	E
	2	13.75	N	46.25	E
	3	16.25	N	43.75	E
	4	16.25	N	46.25	E
	5	16.25	N	48.75	E
	6	16.25	N	51.25	E
	7	18.75	N	51.25	E
48.Oman	1	18.75	N	53.75	E
	2	18.75	N	56.25	E
	3	21.25	N	58.75	E
	4	21.25	N	56.25	E
	5	23.75	N	56.25	E
	6	26.25	N	56.25	E
49.Bahrain	1	26.25	N	51.25	E
50.United Arab Emirates	1	23.75	N	53.75	E
51.Kuwait	1	28.75	N	48.75	E
52.Qatar	1	26.25	N	51.25	E
53.Saudi Arabia	1	21.25	N	51.25	E
	2	21.25	N	48.75	E
	3	21.25	N	46.25	E
	4	21.25	N	43.75	E
	5	21.25	N	41.25	E
	6	21.25	N	53.75	E
	7	23.75	N	38.75	E
	8	23.75	N	41.25	E
	9	23.75	N	43.75	E
	10	23.75	N	46.25	E
	11	23.75	N	48.75	E
	12	23.75	N	51.25	E
	13	26.25	N	43.75	E
	14	26.25	N	41.25	E
	15	26.25	N	38.75	E
	16	26.25	N	48.75	E
	17	26.25	N	46.25	E
	18	28.75	N	36.25	E
	19	28.75	N	38.75	E
	20	28.75	N	41.25	E
	21	28.75	N	46.25	E

	22	28.75	N	43.75	E
	23	31.25	N	38.75	E
	24	31.25	N	41.25	E
54.Israel	1	31.25	N	33.75	E
55.Jordan	1	31.25	N	36.25	E
56.Egypt	1	26.25	N	26.25	E
	2	26.25	N	33.75	E
	3	31.25	N	31.25	E
	4	28.75	N	31.25	E
	5	26.25	N	31.25	E
	6	23.75	N	31.25	E
	7	23.75	N	33.75	E
	8	28.75	N	33.75	E
	9	23.75	N	28.75	E
	10	23.75	N	26.25	E
	11	26.25	N	28.75	E
	12	28.75	N	28.75	E
	13	28.75	N	26.25	E
	14	31.25	N	26.25	E
	15	31.25	N	33.75	E
57.Lebanon	1	33.75	N	36.25	E
58.Turkey	1	36.25	N	33.75	E
	2	36.25	N	36.25	E
	3	38.75	N	43.75	E
	4	38.75	N	28.75	E
	5	38.75	N	31.25	E
	6	38.75	N	33.75	E
	7	38.75	N	36.25	E
	8	38.75	N	38.75	E
	9	38.75	N	41.25	E
	10	41.25	N	41.25	E
	11	41.25	N	36.25	E
	12	41.25	N	33.75	E
	13	41.25	N	28.75	E
59.Syria	1	33.75	N	36.25	E
	2	33.75	N	38.75	E
	3	36.25	N	38.75	E
	4	36.25	N	41.25	E
60.Iraq	1	31.25	N	43.75	E
	2	31.25	N	46.25	E
	3	33.75	N	41.25	E
	4	33.75	N	43.75	E
	5	36.25	N	43.75	E
61.Iran	1	26.25	N	58.75	E
	2	26.25	N	61.25	E
	3	28.75	N	51.25	E

4	28.75	N	53.75	E
5	28.75	N	56.25	E
6	28.75	N	58.75	E
7	28.75	N	61.25	E
8	31.25	N	48.75	E
9	31.25	N	51.25	E
10	31.25	N	53.75	E
11	31.25	N	56.25	E
12	31.25	N	58.75	E
13	31.25	N	61.25	E
14	33.75	N	46.25	E
15	33.75	N	48.75	E
16	33.75	N	51.25	E
17	33.75	N	53.75	E
18	33.75	N	56.25	E
19	33.75	N	58.75	E
20	36.25	N	46.25	E
21	36.25	N	48.75	E
22	36.25	N	51.25	E
23	36.25	N	53.75	E
24	36.25	N	56.25	E
25	36.25	N	58.75	E
26	38.75	N	46.25	E

**Declaration of co-authorship**

If a dissertation is based on already published or submitted co-authored articles, a declaration from each of the authors regarding the part of the work done by the doctoral candidate must be enclosed when submitting the dissertation.

**1. Doctoral candidate**

Name: Sherin Khalifa

**2. This co-author declaration applies to the following article:**

If Climate Change Can Trigger Civil Conflict, Can Good Policy Trigger Peace?  
Empirical Evidence from Cross-Country Panel Data

The extent of the doctoral candidate's contribution to the article is assessed on the following scale:

- A. Has contributed to the work (0-33%)
- B. Has made a substantial contribution (34-66%)
- C. Did the majority of the work independently (67-100%)

**3. Declaration on the individual phases of the scientific work (A,B,C)**

Extent

**Concept:** Formulation of the basic scientific problem based on theoretical questions which require clarification, including a summary of the general questions which, it is assumed, will be answerable via analyses or concrete experiments/investigations

A

**Planning:** Planning of experiments/analyses and formulation of investigative methodology, including choice of method and independent methodological development, in such a way that the scientific questions asked can be expected to be answered

B



**Execution:** Involvement in the analysis or the concrete experiments/investigation

B


**Manuscript preparation:** Presentation, interpretation and discussion of the results obtained in article form

B

**4. Signature of all co-authors**

Date	Name	Signature
02.09.2020	Dr. Svetlana Petri	
02.09.2020	Prof. Dr. Christian Henning	

**5. Signature of doctoral candidate**

Date	Name	Signature
02.09.2020	Sherin Khalifa	



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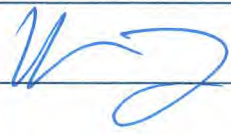
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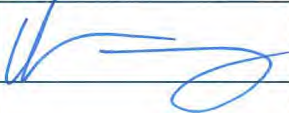
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