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ECONOMIC SHOCKS & CIVIL CONFLICT ONSET IN SUB-SAHARAN AFRICA, 1981–2010

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A number of studies have examined the link between rainfall and conflict but results so far have been inconclusive. This study examines the effect of rainfall on economic performance in different sectors and conflict onset. The empirical analysis finds no support for a strong relation between rainfall and conflict as most results are not robust to different model specifications. The results also do not provide conclusive evidence for a link between growth in specific economic sectors and civil conflict onset.

Keywords: Rainfall; Growth; Conflict onset

1. INTRODUCTION

Economic conditions are often singled out as a prime cause of conflict, and the literature provides empirical evidence for the claim that low income levels and poor economic performance are associated with conflict (Dixon 2009; Hegre and Sambanis 2006). Within this literature two patterns can be distinguished: firstly that poor countries have a higher propensity to suffer from conflict, and secondly that conflict occurs when countries suffer from negative income shocks (Chassang and Padró i Miquel 2009). One region in particular has been the centre of attention: Sub-Saharan Africa – henceforth Africa – as it harbours some of the poorest countries in the world and has experienced a lot of conflict in the past decades compared to similar developing countries in Asia and the Americas.

Although poor countries are disproportionally involved in conflict, the direction of the effect may be difficult to establish (Besley and Persson 2008). A common problem in the literature is that a lot of research suffers from endogeneity issues, particularly reverse causality issues. Other problems include omitted variable bias as well as the issue that data quality for countries of interest is generally poor (Heston 1994).

To deal with these issues, (Miguel, Satyanath, and Sergenti 2004) – henceforth MSS – used an instrumental variable approach with variation in rainfall as a source of exogenous shocks to income and they found that economic growth, instrumented by year-on-year

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growth in rainfall, is strongly negatively related to civil conflict, with low growth rates increasing the risk of conflict.[1]

Since the MSS paper, a number of other studies have examined the relationship between variation in rainfall and conflict using rainfall as a measure for climate change or to proxy economic conditions. So far, the results have been mixed with no clear consensus on the direction of the effect (Brückner and Ciccone 2010; Ciccone 2011; Fjelde and von Uexkull 2012; Hendrix and Glaser 2007; Hendrix and Salehyan 2012; Koubi et al. 2012; Raleigh and Kniveton 2012).[2]

In this paper, I re-examine the relationship between variation in rainfall, economic shocks and conflict using the latest data on Africa for 1981–2010 and by focussing on conflict onset in order to identify a possible causal link. In contrast to the existing cross-country literature, I also examine the effect that income shocks in different economic sectors have on the probability of an outbreak of conflict. As Dunning (2008) notes, the likelihood of conflict could be influenced by the sector of the economy experiencing the shock. Dal Bó and Dal Bó (2011) give a theoretical framework arguing that not all positive shocks to the economy will reduce the probability of conflict but that it is dependent on the sector and its labour intensity relative to the economy. Within this framework, positive shocks to labour intensive sectors will diminish conflict risk while positive shocks to capital intensive sectors will increase the risk. Dube and Vargas (2013) illustrate this point in a study on the effects of exogenous price shocks in international commodity prices on the intensity of violence in the Columbian civil war. Their results show that a fall in prices of labour-intensive agricultural goods increased violence in regions dependent on income from the agricultural sector due to the fact that lower wages also lowered the opportunity costs of joining armed groups. In contrast, a fall in the prices of natural resources (oil in this case) decreased violence as it lowered municipal revenue and thus the value of contestable resources.

This paper contributes to this strand of literature by examining the effect that shocks in different economic sectors have on the probability of conflict onset, focussing on the agricultural and industrial sector. Since the agricultural sector in Africa is labour intensive, negative shocks to this sector are expected to increase conflict likelihood according the the analysis by Dal Bó and Dal Bó (2011) and Dube and Vargas (2013). Where Dube and Vargas (2013) provide empirical evidence for the theoretical framework of Dal Bó and Dal Bó (2011), the main contribution of this paper is that, to the best of my knowledge, it is the first cross-country study that examines the effect of different economic sectors on conflict onset.

I solely focus on conflict onset, rather than conflict incidence, as the former approach is more appropriate to establish a causal link. The main issue with using conflict incidence as the dependent variable is that the assumption that rainfall or economic shocks affect the continuation of conflict in the same way as the outbreak of new conflict is problematic on theoretical grounds and likely to be violated (Bazzi and Blattman 2011; Ciccone 2011). Considering the costs associated with initiating a conflict, and those with joining an already ongoing conflict, it is straightforward to see that these costs will be different. Since conflict disrupts the economy and affects economic performance the opportunity costs for joining and already existing rebellion will be lower compared to those of initiating a new conflict (Collier and Hoeffler 1998).

[1]Due to the innovative approach their paper has quickly become one of the standard works in the literature. It has been cited 233 times since it was published in 2004 (number based on statistics from Web of Knowledge in July 2013).

[2]The Journal of Peace Research published a special edition on climate change in January 2012 on the link between climate change and conflict containing three papers looking at rainfall all with different results.

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Using conflict incidence as the dependent variable neglects the issue of reverse causality between conflict and economic performance and therefore one cannot make any causal claims about the examined link.

In the analysis, I find that rainfall is a viable instrument for economic growth although the effect of rainfall on aggregate economic growth becomes considerably weaker after 2000. Moreover, using year-on-year rainfall growth as an instrument gives considerably weaker results compared to using rainfall anomalies and coefficients are biased to OLS-estimates. Current shocks in rainfall are significantly and positively linked to economic growth where a standard deviation increase in rainfall on average corresponds with a 0.5 to 1% point increase in economic growth which is considerable considering the average economic growth of Africa for 1981–2010.

The effect of rainfall on productivity is strongest in the agricultural sector but there is also a positive and significant effect in the industrial sector, which might be due to the importance of hydro-electricity as well as the use of water as a cooling agent in factories (Barrios, Bertinelli, and Strobl 2010).

With regard to the link between rainfall and conflict, the results are very mixed. In a reduced form estimation, I find that lagged shocks in rainfall affect conflict onset but the coefficients are only marginally statistically significant and not robust to different model specifications. In model estimate using IV with economic growth rates predicted by variability in rainfall, the results are similar with a marginally statistical significant effect for lagged growth rates.

If I instrument economic growth with year-on-year rainfall growth, I find that lagged growth rates are negatively associated with conflict onset at 90% confidence level, but the results are again not robust to different model specifications using rainfall anomalies as an instrument or using a different dependent variable. Using a dependent variable with a 5-year intermittency period for conflict I do find that the direction of the effect is consistent – though not significant – across the various models: higher levels of rainfall reduce the likelihood of the outbreak of conflict.

The estimation results are inconclusive with regard to the effect of shocks in the different sectors of the economy on conflict onset. For both the agricultural and industrial sector, it seems that positive shocks are linked to a decreased probability of conflict onset but the estimates are characterised by large uncertainty. Moreover, the coefficients are lower compared to aggregate output and statistically insignificant. I am therefore hesitant to make any strong claims with regard to how different sectors influence conflict likelihood.

2. EXISTING LITERATURE

One of the major issues in the literature on conflict is that research results are often not robust to different model specifications, the use of different data or hampered by issues such as endogeneity (Hegre and Sambanis 2006). One of the very few findings that does seem to be robust, however, is the nexus between economic conditions and conflict (see Dixon (2009) for an overview).[3]

Within the literature there are two main patterns: one is that poor countries have a high propensity to experience civil conflict and the second is that civil conflict is more likely to occur when a country suffers from negative income shocks (Chassang and Padró i Miquel

[3]The paper by Djankov and Reynal-Querol (2010) is one of the few that contradicts the conclusion that poverty is a main determinant of conflict.

2009). A prominent example is Collier and Hoeffler (1998) who argue that poorer countries are more likely to experience conflict due to lower opportunity costs for rebellion. When a country experiences disappointing economic growth rates utility maximising arguments prevail over arguments of political marginalisation as an explanation for conflict.

Fearon and Laitin (2003) on the other hand, argued that poor economic performance is a proxy for weak state capacity. Governmental incompetence, expressed in a weak military apparatus and poor infrastructure, hampers both the deterrence of and capabilities to quell insurgencies. These are low repressive capabilities that link together poverty and civil conflict.

It is hard to establish the causality between economic conditions and conflict due to omitted variables bias and endogeneity. The paper by MSS is one of the pioneering works in addressing these issues and has quickly become one of the pillars of the literature on conflict. The authors use rainfall growth as an instrument for gross domestic product (GDP) per capita growth and show that positive rainfall growth is strongly negatively correlated with civil conflict, the effect not being significantly different for richer, more democratic or more ethnic diverse countries.[4] A number of other studies have looked at the link between rainfall and conflict, either examining the direct relationship or using rainfall to proxy for economic growth.[5] The paper by Hendrix and Glaser (2007) looks at the effect of interannual changes in rainfall and conflict onset in Africa and finds that positive shocks have a pacifying effect and reduce the likelihood of conflict, very similar to the results by MSS. Hendrix and Glaser (2007) argue that short-term shocks in rainfall (yearly growth rate) are a better predictor of conflict than changes in the overall climate over a longer period of time. In another work, Hendrix and Salehyan (2012) find that civil war and violent insurgencies are more likely to follow after a year of abundant rainfall, relative to the historical expectation. Thus, linking higher rates of rainfall with conflict, contrasting earlier results. The study by Raleigh and Kniveton (2012) of eastern Africa finds that the frequency of rebel and communal conflict events increases in periods of extreme rainfall variation and that the effect is present in both cases of negative and positive variation.

These results are somewhat similar to the study by Fjelde and von Uexkull (2012) who use a disaggregated approach combining rainfall data with geo-referenced events data on the occurrence of communal conflict in Africa between 1990 and 2008. The main difference between these two studies is the direction of the effect as Fjelde and von Uexkull (2012) find that only large negative deviations from the historical mean are associated with a higher risk of communal conflict.

Rather than focussing on the direct effects of rainfall and conflict, Koubi et al. (2012) examined the causal pathway linking climatic conditions to economic growth and violent conflict. In their analysis, they found no evidence for the claim that rainfall, or climatic variability in general, affects economic growth.[6]

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[4]A number of papers have criticised the results of MSS on basis that their model is agnostic to the sector experiencing the shock (Dunning 2008), the fact that they erroneously code the dependent variable to include countries participating in civil wars in other states (Sandholt Jensen and Skrede Gleditsch 2009), and most forcefully by Ciccone (2011) who argues that the results are driven by a positive correlation between conflict in t and rainfall in $t-2$.

[5]In this short review, I focus on the papers that have looked at the link between rainfall and conflict. For an insight into the relation between rainfall and economic growth I refer to (Barrios, Bertinelli, and Strobl 2010) and Dell, Jones, and Olken (2012).

[6]Koubi et al. (2012) looked at data for the whole world but found similar results for Africa alone.

3. DATA & DESCRIPTIVE STATISTICS

3.1. Conflict Onset

Data on conflict onset comes from the *UCDP/PRIO Armed Conflict Dataset, version 4–2011* (Themner and Wallensteen 2011) limiting the dependent variable to only instances of intrastate or civil conflict.[7] I include all cases with at least 25 battle-related deaths in a single year, I do not make a distinction between conflict and war, the latter typically classified passing the threshold of 1000 battle-related deaths in a single year.[8]

To capture the outbreak of conflict, I define a binary onset-indicator for country c in year t that is 1 if there is a conflict in year t but not in year $t-1$ and 0 if there is no conflict in both year t and $t-1$. If there is a conflict in year $t-1$, then the indicator is not defined for t:

$$\text{Onset}\begin{cases} 1 & \text{if conflict in } t \text{ but not } t-1 \\ 0 & \text{if no conflict in } t \text{ and } t-1 \\ \cdot & \text{if conflict in } t-1 \end{cases} \tag{1}$$

What difference does it make whether one uses conflict incidence or conflict onset to identify the relation between the dependent and the explanatory variables? As Bazzi and Blattman (2011) note there are both conceptual and empirical problems with the approach of using conflict incidence.[9] Conceptually, using conflict incidence one assumes that rainfall and economic growth affect the continuation of existing conflicts in the same way as the outbreak of new ones (Ciccone 2011). From the literature, we know that violence is associated with shocks as it affects wages (Besley and Persson 2011); accordingly, we would therefore expect that the effect of such shocks is larger in pre-existing conflicts than it is for new conflicts. Collier and Hoeffler (1998) note that starting an insurgency is costly as it brings with it the opportunity costs of rebel labour as well as the costs incurred by the disruption of the economy. A rebellion will therefore only occur if the benefits outweigh the costs.

So starting a conflict includes some fixed costs. In the case of an already ongoing conflict this fixed start-up cost is essentially lifted. Meaning that the opportunity costs for joining the rebellion are lower than those of initiating a rebellion. Since the costs are higher for initiating a conflict, this also means that new conflicts are less sensitive to economic shocks compared to existing ones. Therefore, by estimating the effect of economic shocks on conflict incidence one probably would overestimate the magnitude of effect.

There is also an empirical problem due to the omission of the lagged dependent variable. Conflicts are very persistent over time and often are linked to previous conflicts. Moreover, conflicts that occur in t are often affected by both current (t) and lagged ($t-1$) shocks. By omitting the lagged dependent variable, one introduces a large correlation in the model between the dependent variable, the shocks, and the error term (Bazzi and Blattman 2011).

[7]Data can be found at http://www.pcr.uu.se/research/ucdp/datasets/ucdp_prio_armed_conflict_dataset/. Civil conflicts are all observations coded as type 3 or 4 in the data-set. A type 3 conflict is defined as 'an internal armed conflict that occurs between the government of a state and one or more internal opposition group(s) without the intervention from other states'. A type 4 conflict is similar only allowing for the intervention from other states on behalf of one or both sides (Gleditsch et al. 2002).

[8]A conflict is defined as: 'a contested incompatibility that concerns government and/or territory where the use of armed force between two parties, of which at least one is the government of a state, results in at least 25 battle-related deaths'.

[9]The conflict incidence indicator is coded as: $\text{Incidence}\begin{cases} 1 & \text{if conflict in } t \\ 0 & \text{if no conflict in } t \end{cases}$

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TABLE I Congo DR during the 1st and 2nd Congo War

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Economic growth	−0.03	−0.04	−0.08	−0.04	−0.06	−0.09	−0.05	0.01	0.03
Incidence	0	1	1	1	1	1	1	0	0
Onset	0	1	–	–	–	–	–	–	0

Using conflict incidence also doesn't account for the possible reverse causality between conflict and economic growth. An example is given in Table I, where the economic performance (GDP per capita growth) is given for Congo-Kinshasa during the First and Second Congo War from 1995 to 2003. It is easy to see that the use of conflict incidence as dependent variable would give misleading results as it doesn't account for the feedback of conflict into the economy. The occurrence of conflict will affect economic conditions irrespective of changes in rainfall, which is used as an instrument to proxy for these economic conditions, thereby introducing a form of endogeneity into the model.[10] I argue therefore that conflict onset is more suited as the dependent variable as it accounts for past conflicts and also is better equipped to deal with the mentioned issues and thus better suited to uncover the causal mechanism between rainfall and conflict.

Additionally to test the robustness of the results, I will also estimate the model with a different onset-indicator which uses a 5-year intermittency period in order to even better control for any short-term carry-over effects of previous conflict. In this case, the onset-indicator is only set to 1, if there is a conflict in year t conditional on that there hasn't been any conflict in the past 5 years.

3.2. Economic Growth

Data for economic growth is taken from the *World Development Indicators* for 47 countries in Africa between 1981 and 2010 (World Bank 2012).[11] The *World Development Indicators* are used because of recent concerns with the figures for growth in the commonly used Penn World Tables data (see Johnson et al. (2009); Dell, Jones, and Olken (2012)). Income growth is measured as the interannual growth rate of real GDP per capita in constant US$.[12]

3.3. Rainfall

3.3.1. Aggregating rainfall

Time-series data on rainfall comes from the *NASA Global Precipitation Climatology Project (GPCP), Version 2.2* (Adler et al. 2003).[13] The data-set provides worldwide monthly mean precipitation given as a daily average (in mm) and covers 1979–2010. The estimates are the result of the combination of a number of sources, taking the advantage of each data type to get the best possible estimate. Values are based on the information coming from gauge stations as well as microwave, infrared and sounder data from satellites. The data sources

[10]An additional problem is the systematic measurement error in conflict countries due to the collapse of public institutions that provide the data.
[11]The data-set is weakly unbalanced due to the fact that Namibia & Eritrea gained independence in 1990 and 1993, respectively. The model estimations include 46 countries due to the lack of data for Somalia.
[12]I use GDP in constant US$ in order to capture international purchasing power.
[13]Data in ASCII format is available at ftp://rsd.gsfc.nasa.gov/pub/912/bolvin/GPCP_ASCII/. For further information on the data itself, see project page: http://precip.gsfc.nasa.gov/.

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are blended together to produce a global gridded precipitation field with the precipitation data at a 2.5 × 2.5 degree resolution, roughly 250 by 250 km at the equator.

The two main advantages of this data-set over the more traditional precipitation data are that it is less likely to suffer from classical and non-classical measurement error. Data supplied by meteorological institutes comes predominantly from gauge stations and due to the sparseness of operating gauge stations in Sub-Sahara Africa, this might lead to classical measurement error. Furthermore, the number of operating gauge stations might be affected by socio-economic conditions which could lead to non-classical measurement errors.

Aggregating the the rainfall data from the grid-level to the country level can produce coarse estimates due to the relative low resolution of the raster (Auffhammer et al. 2013). or some smaller countries aggregating will not produce an estimate at all due to the fact that their national territory does not cover enough space in a grid-box.[14] A way to overcome this problem is by assigning the value of the nearest cell to the particular country (see for instance Miguel, Satyanath, and Sergenti (2004) and Brückner and Ciccone (2010)). Although this is a pragmatic solution, it ignores the fact that if this problem affects countries of small size, it can also affect certain regions of larger countries thereby thus producing skewed estimates for these countries neglecting within-country variation in rainfall.

A simple solution for this problem is artificially increasing the resolution of the raster.[15] Figure 1 illustrates this approach for the Great Lakes region. The left panel shows a graphical representation of the grid overlay at the original resolution. It shows that countries like Rwanda and Burundi are too small, in terms of coverage of a grid-cell, to get an estimate. It also shows that this issue could occur in parts of Malawi and Congo DR.[16] The right panel in the figure shows the grid-overlay on the national boundaries after I increased the resolution. In this case, the resolution was increased from a 2.5 × 2.5 degree raster to a 0.5 × 0.5 degree raster, which is roughly 56 × 56 km at the equator.[17] Dividing the grid-boxes into smaller boxes is a purely technical solution in order to get a better fit between the raster and the national boundaries resulting in more precise estimates when aggregating the data to the national level.[18] The rainfall data are aggregated to country-year level taking into account the number of days in each month, corrected for leap years, in order to obtain a weighted yearly average for each country.[19] Although this method provides theoretical advantages, in practice the difference between the methods of aggregation is small.[20] There are some systematic differences between the two time series though, especially for the smaller countries such as Benin, Equatorial Guinea and Rwanda.[21]

[14]Typically using GIS software, a value in a grid-cell is aggregated when the cell's centre-point falls within the national boundaries.

[15]Many thanks to Robert Hall from the South East Asia Research group at Royal Holloway for suggesting this method.

[16]At the original resolution, aggregating returns no estimates for the following countries: Burundi, Cape Verde, Comoros, Djibouti, Gambia, Guinea-Bissau, Lesotho, Mauritius, Rwanda, Sao Tome & Principe. For the Seychelles, the higher resolution aggregation method does also not return an estimate.

[17]Hendrix and Glaser (2007) use a similar method, they refine the raster to 1 × 1 degree resolution and assign cells to countries on the basis of majority.

[18]Note that each of the smaller grid-cells has the same value as the larger original grid-cell. This approach does not change anything about the measurements and therefore does not take into account any within-cell variation.

[19]$\text{Rain}_{ct} = d\text{Jan}_{ct} \times 31 + d\text{Feb}_{ct} \times 28 + \ldots + d\text{Dec}_{ct} \times 31.$

[20]The time-series correlation is 0.99.

[21]The high correlation between the two methods of aggregation can be explained by the fact that most African countries have very arbitrary boundaries. At the 1884–1885 Berlin conference, a majority of borders were drawn along meridians and parallels. Fourty-four percent of African borders follow meridians and parallels while 30% follow other rectilinear or curved lines (Alesina, Easterly, and Matuszeski 2008; Posner 2006).

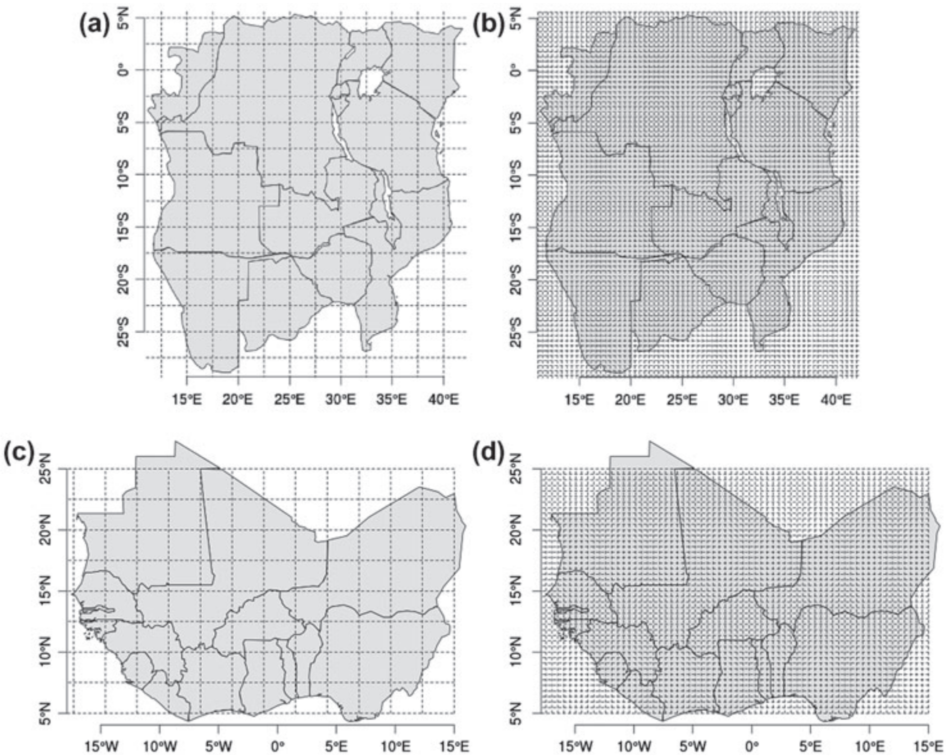

FIGURE 1 Geographic raster for Great Lakes region in Africa at 2.5° × 2.5° (left) and 0.5° × 0.5° (right), respectively.

3.3.2. Measuring rainfall shocks

To estimate the effect of rainfall on economic growth and civil conflict, I use interannual growth and anomalies as a measure for rainfall shocks. Interannual growth is measured as the percentage change in annual rainfall R for country c in year t relative to the previous year $t-1$: $(R_{ct} - R_{c,t-1})/R_{c,t-1}$. The main issue with using interannual growth as a measure is that it tells us little about the relative abundance or shortage of rainfall for a particular country in a given year, compared to the historical expectations. If for a given country c, rainfall in year t was above average, it is very likely that rainfall in year $t+1$ will be lower due to the mean-reverting nature of rainfall making rainfall shocks very transitory. Mean reverting would therefore imply that ΔR_{ct} is negative although the country could still experience above average levels of rainfall (Ciccone 2011).

Consider the example in Figure 2: the dashed line represents the country average and the spikes are the levels of rainfall for each observation in time. Using year-on-year growth as a measure, we would have a negative growth rate at $t = 4$ and a positive growth rate at $t = 6$. Looking at the country average, however, we can see that rainfall in $t = 4$ is above average and rainfall in $t = 6$ is below average. To better account for both cross-country variation in the mean values as well as within-panel variation, rainfall anomalies are used as an additional measure (Hendrix and Salehyan 2012). Anomalies are measured as the annual standardised rainfall deviation from the long-term panel mean for a given country, $(R_{ct} - \bar{R}_c)/\sigma_c$.[22]

[22]Long term is in this case the period from 1979 to 2010.

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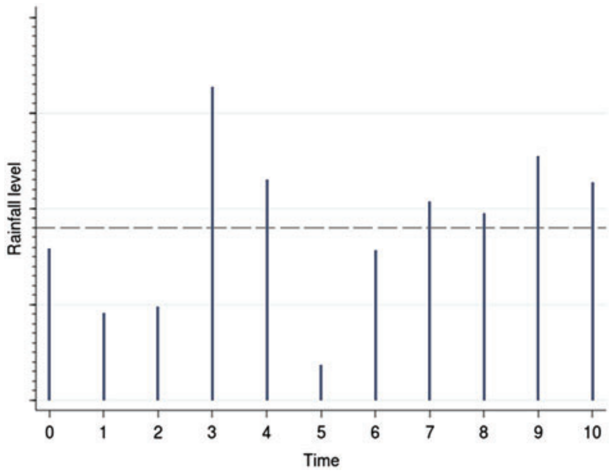

FIGURE 2 Illustration of precipitation time-series. Blue bars are level, and dotted line is long-term mean.

The data shows that the majority of observations has the same sign for growth and anomalies. For about a quarter of the observations, the signs of the two measures are different though which is a substantial part of the data-set.[23]

3.4. Control Variables

A number of controls are used to account for certain country characteristics that are commonly used in the literature (Dixon 2009; Hegre and Sambanis 2006).[24]

Peace years are included to control for the fact that the likelihood of conflict strongly depends on the occurrence of previous conflicts. This variable is measured as the number of years that have passed since the last incidence of conflict.[25] If there hasn't been any conflict, I count the number of years since the country gained independence.[26]

The size of the population is often correlated with conflict as larger populations imply difficulties in controlling local-level activity and increase the pool from which insurgents can be recruited (Fearon and Laitin 2003). Another risk of larger populations with regard to resources is that they put additional pressure on the existing resource base which could lead to both relative and absolute scarcity of essential resources such as fresh water.

I include the lagged value of the natural log of the total population in the model specification with data taken from the *World Development Indicators*.

Empirical evidence shows that there is a curvilinear relationship between regime type and conflict where both extreme autocracies and democracies are less likely to experience civil conflict in contrast with regime types that fall between these two extremes, so called 'anocracies' (Hegre and Sambanis 2006).[27] The square of the polity2 index from the *Polity*

[23]Four hundred and ninety observations (35%) are both positive and 527 observations (38%) are both negative. In 188 observations, where anomalies have a positive sign, the growth rate is negative (14%) and for 184 observations, where the deviations from the panel mean are negative, the growth rate is positive (13%).
[24]The specific set of controls that are used in this study are based on the papers by Miguel, Satyanath, and Sergenti (2004) and Fearon and Laitin (2003).
[25]Peace years are thus measured as the absence of any violence that resulted in at least 25 battle-related deaths in a given year.
[26]Or otherwise, the time since 1945 though this did not occur in the panel.
[27]Anocracies are more vulnerable due to political instability, the result of the spread of power among elitist groups constantly competing with each other for power. Kenya, Nigeria and Zimbabwe are some examples.

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IV dataset (Marshall, Jaggers, and Gurr 2013) is used to control for this relation, where the variable is lagged to deal with possible endogeneity issues.[28]

Another demographic control is the population's heterogeneity or ethnic composition for which I use the PREG index (Posner 2004). The PREG index only includes politically relevant groups and allows the values to vary per decade, giving a better representation of the political ethnic composition of a country over time.[29]

Countries with more rough terrain experience higher probabilities of conflict as this terrain provides easier shelter for insurgents and mountainous regions can be difficult to to control for governments (Fearon and Laitin 2003; Hegre and Sambanis 2006). I measure rough terrain as the percentage of total land area covered by mountains, data taken from (Montalvo and Reynal-Querol 2005).

Throughout the literature, oil-rich countries are strongly associated with conflict onset as the availability of oil can lure insurgents as it provides an extra prize when successfully contesting state power (Fearon and Laitin 2003; Lujala 2010; Ross 2004). The availability of oil revenues can also create a gap between government and population as it provides an easy source of income reducing the need for taxation and thus interaction with the population (Collier and Hoeffler 2002). This perceived distance can cause frictions if a group has the feeling that the revenues are not being equally distributed.[30]

I use a lagged oil dummy that takes value 1, if oil rents contribute to more than 33% of GDP in a given year, and 0 for all other cases, data taken from the *World Development Indicators*.

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3.5. Descriptive Statistics

Figure 3 visualises descriptive statistics for economic growth, precipitation and conflict.[31] In terms of economic growth, Africa has experienced slow growth rates over the past 30 years characterised by large fluctuations in individual countries as the spikes show (see upper left). On average GDP per capita growth has been around 1% with a standard deviation of 8% points. 1981–1999 has been characterised by large fluctuations with extremes ranging from −50 to 93%. Since 2000 growth rates have stabilised and slightly increased to an average annual growth rate of 2% and a standard deviation of 5% points.[32]

Rainfall variation is enormous (upper right): while the wettest country in the sample (Sierra Leone) has an average rainfall of 2311 mm per year and the driest country (Mauritania) has an annual rainfall of just 118 mm per year. There is no clearly distinguishable trend with regard to shifts in rainfall: on average rainfall has decreased over the past 30 years but there have been unusual spells of relatively wet years such as between 1994 and 2000.[33]

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[28]Conflict incidence is used in the measurement of regime types.

[29]Most other indices on ethnolinguistic fractionalisation are time fixed and often based on data from the 1960s. Moreover, they include all ethnographically distinct groups in a country irrespective of whether they engage in political competition.The PREG index covers 41 of the 47 countries in the panel. Data from Alesina (2003) are used to supplement for Cape Verde, the Comoros, Djibouti, Eritrea, Mauritania and Sao Tome & Principe.

[30]Examples of grievances related to oil revenues can be found in the Cabinda Province of Angola, Biafra in Nigeria and the current situation between Sudan and South Sudan.

[31]See Table VIII in Appendix 1 for summary statistics.

[32]Some countries perform exceptionally well in comparison to the average such as Equatorial Guinea & Gabon, two major oil exporters, Botswana which has large diamond and nickel deposits, Mauritius which has a successful diversified agricultural economy and South Africa which has a relative successful mixed economy.

[33]A period of 30 years is fairly short in climatic terms to distinguish clear trends. However, other research has shown that over a longer period of time rainfall in Africa has reduced (see Nicholson (2001); Buhaug (2010); Barrios, Bertinelli, and Strobl (2010)).

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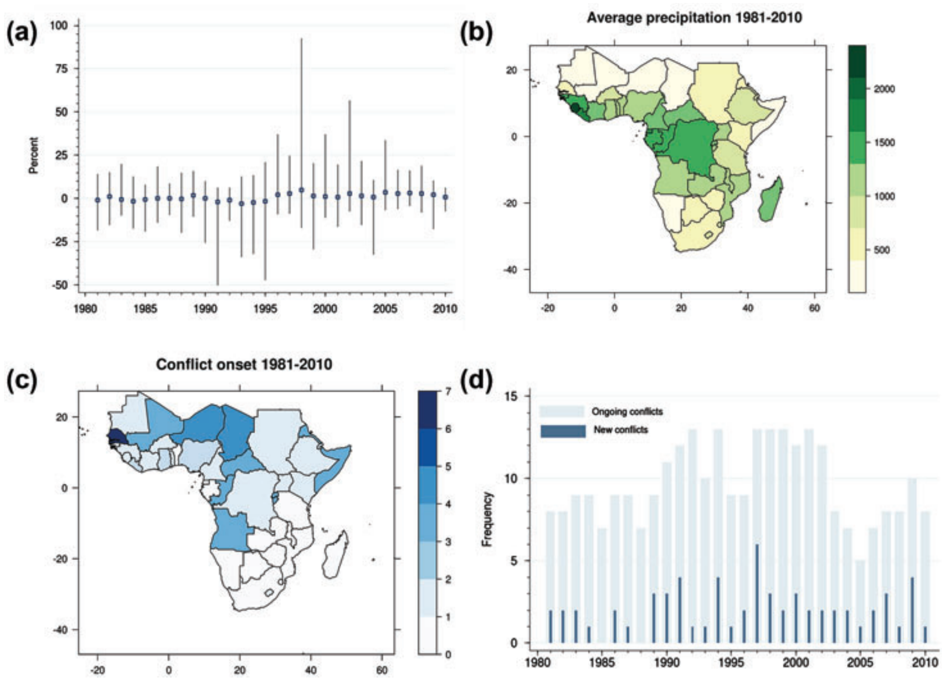

FIGURE 3 Descriptive statistics for economic growth, rainfall, & civil conflict in Sub-Sahara Africa (1981–2010). Upper left: Annual growth rate of GDP per capita, spikes represent the range of growth rates while the dots represents the averages, calculated from the World Bank Development Indicators. Upper right: Mean precipitation in mm at country-year level. Lower left: Conflict onset frequency per country, data from UCDP/PRIO Armed Conflict Dataset v.4-2011. Lower right: Frequency of occurrence and onset of civil conflict (with at least 25 battle-related deaths per year), as defined by the UCDP/PRIO Armed Conflict Dataset v.4-2011.

Compared to similar regions in the world, Africa is experiencing rather a lot of conflict although the total number of conflicts is decreasing. About 1 in 5 observations is coded for conflict while conflict onset is a much rarer occurrence with 1 in 20 observations. Since the 1990s, the number of conflicts has decreased.[34] Almost all of the conflicts are what is called ‘minor conflicts’ which are conflicts with between 25 and 1000 battle-related deaths in a given year.[35]

4. EMPIRICAL FRAMEWORK

The main estimating equation links conflict onset to per capita economic growth and other controls, where economic growth is instrumented by rainfall.

$$\text{onset}_{ct} = a_c + bX'_{ct} + c_0\,\text{growth}_{ct} + c_1\,\text{growth}_{ct-1} + d_c\,\text{year}_t + e_{ct} \tag{2}$$

[34]There has only been a noticeable spike between 2007 and 2009.

[35]Civil wars with more than a 1000 battle-related deaths in a given year are relatively rare. In the data-set, only 5 observations are coded for onset of a civil war, 2 of which followed the onset of a minor conflict. In this paper, I focus on intrastate conflict and not interstate conflicts. Between 1981 and 2010, there were only 7 cases of interstate conflict, and only one which lasted more than a year (Ethiopia & Eritrea from 1998 to 2000).

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I focus on civil conflict onset in country c in year t, where the principal onset indicator is based on the absence of conflict in the previous year $t - 1$. In most specifications, country-specific time trends (year_t) are included in order to deal with additional variation and a disturbance term (e_{ct}) that is allowed to be serially correlated. The errors are clustered at the country level. To capture some of the time-invariant country characteristics that might be related to conflict country-fixed effects (a_c) are included in some of the models. I also estimate the model accounting for country characteristics (X'_{ct}).

A reduced-form model is estimated with OLS and Rare Event Logit using the model:[36]

$$\text{onset}_{ct} = a_c + bX'_{ct} + c_0\Delta\text{rain}_{ct} + c_1\Delta\text{rain}_{ct-1} + d_c\text{year}_t + e_{ct} \quad (3)$$

In the first-stage, I regress economic growth in t on changes in rainfall in t and $t - 1$, using the same controls as in the main Equation (2). In the first-stage, I also estimate the effect of rainfall on the agricultural and industrial sector as opposed to whole economic output. In the second stage, economic growth rate is instrumented by the predicted values from Equation (3). Changes in rainfall are captured by either the interannual growth rate or anomalies.

$$\text{growth}_{ct} = a_c + bX'_{ct} + c_0\Delta\text{rain}_{ct} + c_1\Delta\text{rain}_{ct-1} + d_c\text{year}_t + e_{ct} \quad (4)$$

To test the robustness of the results, I use a different dependent variable with a 5-year intermittency period for conflict onset.

5. FIRST-STAGE RESULTS

Using the latest data for 1981–2010, I estimate the first-stage model regressing GDP per capita growth on rainfall.[37] Results are shown in Table II where column 1–3 depict the results for the model specifications, where I regress economic growth on rainfall growth and column 4–6 for rainfall anomalies.

I find a positive and significant relation between economic growth and rainfall similar to the results by MSS.[38] Focussing on interannual growth, the effect is robust to the inclusion of fixed effects, country, controls and time trends. A standard deviation increase in rainfall accounts for a difference in economic growth of 0.7% points over years t and $t + 1$, which is a substantial effect considering the average growth rate for African economies between 1981 and 2010. The uncertainty with which we can link rainfall to economic growth increases when introducing controls into the model.[39] Moreover, the strength of rainfall as an instrument is severely reduced as the F-statistic drops from 7 to 2.7, with the result that the coefficients on economic growth in the second-stage estimations will be biased towards OLS-estimates (Angrist and Pischke 2008; Bound, Jaeger, and Baker 1995). Estimating the model with anomalies also shows that current changes in rainfall are positively related to economic growth at 1% significance with the magnitude of the effect being similar to the models in columns 1–3.[40] The coefficient for lagged deviations is near 0 and statistically

[36]See King and Zeng (2001) for an explanation on Rare Event Logit.
[37]The number of countries included in the data-set is 47. The first-stage estimations are done for 45 countries due to missing values.
[38]I also re-estimated the MSS model using their data-set and changing their rainfall data with the new rainfall estimates. The results for this are in the Appendix 1 in Table IX.
[39]When using time-fixed effects to control for common shocks only current rainfall growth rates are significantly linked to economic growth.
[40]The size of the coefficient in columns 4–6 is 0.01 but this is due to rounding as the real coefficient is 0.006.

TABLE II IV-2SLS (First-stage): economic growth & rainfall 1981–2010

	Growth			Anomaly		
Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)
$Rainfall_t$	0.02***	0.02**	0.02**	0.01***	0.01***	0.01***
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
$Rainfall_{t-1}$	0.02***	0.01**	0.01*	0.00	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)	(0.00)
Peace years			0.00			0.00
			(0.00)			(0.00)
Ln $population_{t-1}$			0.00			0.00
			(0.05)			(0.05)
Square $polity2_{t-1}$			0.00			0.00
			(0.00)			(0.00)
Ln GDP per capita 1979			0.16			0.08
			(0.94)			(0.96)
Ethnolinguistic fractionalization			−0.06			−0.08
			(0.09)			(0.10)
Rough terrain (% mountains)			−0.01			−0.01
			(0.02)			(0.02)
Oil-exporting countries (dummy)			0.03			0.03
			(0.03)			(0.03)
Country FE	no	yes	no	no	yes	no
Country-specific year trend	no	yes	yes	no	yes	yes
Root MSE	0.07	0.07	0.07	0.07	0.07	0.07
Observations	1299	1299	1162	1299	1299	1162

Notes: Robust standard errors in brackets.
Errors clustered at country level.
***$p \leq 0.01$.
**$p \leq 0.05$.
* ≤ 0.1.

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insignificant while I do find that the two coefficients are jointly significant at a 99% confidence level. The results seem to indicate that anomalies are actually a stronger instrument with the F-statistic ranging from 9.4 to 12.2. All country controls show statistical insignificant effects and exhibit small coefficients sizes.

The results show that for a longer time period rainfall is still a viable instrument for economic growth, although the magnitude of the effect has diminished over time and in some cases rainfall is a weak instrument.[41] In their original work, MSS also found that rainfall was a weak instrument. Moreover, in a re-examination of their work they found that the first-stage relationship between rainfall and economic growth became weaker after 2000 as neither rainfall growth in year t or $t-1$ was significantly correlated with economic growth in year t (Miguel and Satyanath 2011). I also find that after 2000, the link between rainfall and economic growth becomes very weak. This trend might be related to the unprecedented economic growth Africa has experienced in the past decade as Miguel and Satyanath (2011) suggest.

From 1981 to 2010, the agricultural share of GDP has decreased by about 6% points, from 19 to 13%, with a very sharp decline since 2002. Taking the two economic powerhouses – Nigeria and South Africa – out of the equation the decline is even larger with

[41]See Table X in the Appendix 1 for the first-stage estimations per period.

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TABLE III OLS: growth per sector & rainfall 1981–2010

	Agricultural growth				Industrial growth			
Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rainfall growth$_t$	0.08***	0.09***			0.00	−0.01		
	(0.02)	(0.03)			(0.01)	(0.01)		
Rainfall growth$_{t-1}$	0.04**	0.03*			0.02*	0.02		
	(0.02)	(0.02)			(0.01)	(0.01)		
Rainfall anomaly$_t$			0.02***	0.01***			0.00	0.00
			(0.00)	(0.00)			(0.00)	(0.00)
Rainfall anomaly$_{t-1}$			−0.01	−0.01*			0.01***	0.01***
			(0.00)	(0.00)			(0.00)	(0.00)
Country FE	yes	no	yes	no	yes	no	yes	no
Country-specific time trend	yes	yes	yes	yes	yes	yes	yes	yes
Country controls	no	yes	no	yes	no	yes	no	yes
Root MSE	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.11
Observations	1088	964	1088	964	1058	934	1058	934

Notes: Robust standard errors in brackets.
Errors clustered at country level.
***$p \leq 0.01$.
**$p \leq 0.05$.
* ≤ 0.1.

12% points. Rainfall is vital to productivity in the agricultural sector due to the fact that in Africa most arable land is rain-fed and irrigation is almost absent. However, the relevance of rainfall to economic performance is not limited to only the primary sector as other sectors also depend on rainfall due to the prominence of water to generate electricity and as a secondary input in the industrial sector (Barrios, Bertinelli, and Strobl 2010).[42]

I regress the output from the agricultural and industrial sector on rainfall to determine the separate effects (see Table III for results).[43] As expected the agricultural sector shows the stronger relation between rainfall and productivity illustrated by the relative large coefficient size compared to GDP per capita growth. The sign for anomalies in $t-1$ is a bit counterintuitive, however, indicating that higher rainfall deviations in t reduce output in $t+1$.

There is a bit more uncertainty about the link between rainfall and industrial output. For all estimations, the coefficient for rainfall in year t is 0 – or near zero – and statistically insignificant. Rainfall in year $t-1$ does seem to be correlated with industrial output in year t according to the majority of the estimations where especially the models using anomalies show a strong link. I also estimated the effect of rainfall on output in the service sector and found some statistically significant results but in all cases the coefficient had a size that was near zero and further tests showed that rainfall would be a very weak instrument with F-values below 2.

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6. EMPIRICAL RESULTS

6.1. Rainfall & Conflict Onset

Looking at the between-country differences in rainfall for countries with conflict onset and other countries there is no clearly distinguishable trend concerning rainfall levels or variation and a higher likelihood of observing conflict onset. On average countries that had at least one observation of onset tend to be wetter although the difference with the other countries falls well within the standard deviation of rainfall in the sample.[44] Looking at growth rates and deviations the data shows that countries that had conflict onset have lower growth rates but experience larger deviations.[45]

I estimate the relation between rainfall and conflict using reduced form estimate (Equation (3)), the results for which are given in Table IV. The results provide little empirical support for the claim that variation in rainfall contributes to conflict onset at the country level. Across the various model specifications current variation in rainfall is positively linked with conflict onset; higher levels of rainfall relative to last year or the panel mean predict an increased chance of conflict. The coefficients are not statistically significant, however, and come with large uncertainty as all t-values are below 1.[46]

Lagged rainfall has the expected sign indicating that lower levels of rainfall increase conflict likelihood. These coefficients come with a bit more certainty as the t-values are consis-

[42]According to Barrios, Bertinelli, and Strobl (2010), hydro-electricity represents about 47% of total power generation in Africa. In a simple regression, I was unable to find a strong link between rainfall and electricity output (results not shown).

[43]I used the agriculture and industry value added in constant dollars from the World Bank Development Indicators and calculated a per capita measure to normalise across countries (same approach was used for the service sector).

[44]1039 mm versus 993 mm, a margin of only 47 mm.

[45]Countries that had a case of conflict onset on average have a growth rate of 1.6%, a 1.9% point difference with the countries that didn't (3.5%). In terms of anomalies, countries with conflict onset have an average yearly deviation of −0.01 against 0 for the other countries. Countries with conflict onset include 471 observations leaving 918 observations for the other countries.

[46]Z-value in case of the rare event logit estimation.

TABLE IV Reduced form: conflict onset & rainfall 1981–2010

Explanatory variable	Growth (1) OLS	Growth (2) OLS	Growth (3) RE-Logit	Anomaly (4) OLS	Anomaly (5) OLS	Anomaly (6) RE-Logit
$Rainfall_t$	0.01	0.02	0.38	0.00	0.00	0.03
	(0.02)	(0.03)	(0.69)	(0.00)	(0.01)	(0.13)
$Rainfall_{t-1}$	−0.03	−0.03	−0.49	−0.01	−0.01	−0.17
	(0.02)	(0.03)	(0.87)	(0.01)	(0.01)	(0.11)
Peace years		0.00	−0.05***		0.00	−0.05***
		(0.00)	(0.02)		(0.00)	(0.02)
Ln $population_{t-1}$		−0.09	0.01		−0.09	0.01
		(0.14)	(0.14)		(0.14)	(0.14)
Square $polity2_{t-1}$		0.00	−0.02**		0.00	−0.02**
		(0.00)	(0.01)		(0.00)	(0.01)
Ln GDP per capita1979		1.01	−0.28		1.11	−0.28
		(1.53)	(0.36)		(1.56)	(0.36)
Ethnolinguistic fractionalisation		−0.97***	0.07		−0.93***	0.06
		(0.29)	(1.03)		(0.31)	(1.03)
Rough terrain (mountains)		−0.13	0.01		−0.13	0.01
		(0.11)	(0.01)		(0.11)	(0.01)
Oil-exporting countries (dummy)		−0.01	0.83		−0.02	0.83
		(0.05)	(0.68)		(0.05)	(0.69)
Country FE	yes	no	no	yes	no	no
Country-specific time trend	yes	yes	no	yes	yes	no
Root-mean square error	0.21	0.21		0.21	0.21	
Conflict observations	63	55	55	63	55	55
Observations	1101	942	942	1101	942	942

Notes: Robust standard errors in brackets.
Errors clustered at country level.
***$p \leq 0.01$.
**$p \leq 0.05$.
* ≤ 0.1.

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tently larger than 1 and in some of the models the coefficient is one-sided significant at the 10% level giving some certainty about the direction of the effect.[47] These results are robust at the 90% confidence level when I control for temperature.[48] I also estimated the model using a dummy for extreme rainfall deviations ($\sigma \geq 1$ or $\sigma \leq -1$) but did not find any support for the claim that these extreme variations are associated with conflict.[49]

Some of the country characteristics that are used as controls show statistically significant results (col. 3 and 6) indicating that the odds ratio of conflict is reduced by longer peace spells as well as non-hybrid regime types. Moreover, OLS estimation indicates that ethnolinguistic fractionalisation is negatively associated with conflict onset at the 99% confidence level (col. 2 and 5).

[47]This is the case for columns 1, 4 and 6.
[48]Data for temperature comes from NOAA for 1981–2008 and is based on gauge stations. The downside of using this data is that it could introduce bias into the model due to measurement error (results not shown). Burke et al. (2009) find that temperature is a stronger predictor of agricultural performance and as well as that temperature has a stronger effect on conflict than rainfall. They focus on civil war incidence though not controlling for past conflicts (Burke et al. 2009).
[49]Note that in contrast with the studies by Raleigh and Kniveton (2012) and Dunning (2008) the data in this paper are aggregated to the country level instead of the use of disaggregated data which probably causes the differences.

TABLE V IV-2SLS (second stage): conflict onset & economic growth 1981–2010

	Growth			Anomaly		
Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)
Economic growth$_t$	−0.48	−0.25	−1.82	1.65	0.87	0.01
	(1.31)	(1.60)	(2.44)	(1.41)	(1.54)	(1.23)
Economic growth$_{t-1}$	−2.12*	−2.16*	−2.37	−1.27	−2.19	−1.31
	(1.22)	(1.21)	(1.42)	(1.32)	(1.53)	(1.21)
Peace years			−0.00			0.00
			(0.00)			(0.00)
Ln population$_{t-1}$			−0.23			−0.21
			(0.34)			(0.22)
Square polity2$_{t-1}$			−0.00			0.00
			(0.00)			(0.00)
Ln GDP per capita 1979			1.60			1.34
			(5.38)			(2.66)
Ethnolinguistic fractionalisation			−1.19*			−0.92**
			(0.69)			(0.37)
Rough terrain (mountains)			−0.15			−0.14
			(0.12)			(0.11)
Oil-exporting countries (dummy)			0.24			0.08
			(0.27)			(0.14)
Country FE	no	yes	no	no	yes	no
Country-specific time trend	no	yes	yes	no	yes	yes
Root-mean-square error	0.29	0.26	0.30	0.27	0.26	0.23
Conflict observations	63	63	55	63	63	55
Observations	1032	1032	911	1032	1032	911

Notes: Robust standard errors in brackets.
Errors clustered at country level.
***$p \leq 0.01$.
**$p \leq 0.05$.
* ≤ 0.1.

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6.2. Economic Growth & Conflict Onset

Table V shows the results for estimating the main model using IV-2SLS with economic growth rates predicted by variation in rainfall. For the models where economic growth is instrumented with year-on-year growth in rainfall, the coefficient shows that a 1% point drop in GDP per capita increases the risk of conflict onset in the following year by about 2% points (controlling for country-fixed effects and country-specific time trends).[50] The model thus predicts that there is a certain lag in the effect of economic growth on conflict where underperformance in year t increase the risk of the outbreak of a conflict in the following year, $t + 1$. My model estimations seem to hint more at an effect of growth in year t instrumented by rainfall on conflict onset in year $t + 1$. The sign of the coefficient for growth at $t - 1$ is robust to various model specification and also to using a different measure to capture rainfall shocks (columns 4–6), although in this case the effect ceases to be statistically significant at the traditional levels. Using a one-sided t-test shows that the sign of the

[50]MSS found a point estimate of −1.84 for lagged growth rates which wasn't statistically significant. In their model, estimation current growth rates were negatively linked to conflict onset and significant at the 90% confidence level.

TABLE VI IV-2SLS (second stage): conflict onset & economic growth per sector 1981–2010

Explanatory variable	(1)	(2)	(3)	(4)
Agricultural growth$_t$	0.02	−0.04		
	(0.88)	(0.58)		
Agricultural growth$_{t-1}$	−1.12	−0.97		
	(1.95)	(0.99)		
Industrial growth$_t$			−0.77	−0.28
			(0.58)	(2.73)
Industrial growth$_{t-1}$			−0.43	−0.99
			(0.52)	(1.68)
Peace years		0.00		0.00
		(0.00)		(0.00)
Ln population$_{t-1}$		−0.23		−0.41
		(0.25)		(0.45)
Square polity2$_{t-1}$		0.00		0.00
		(0.00)		(0.00)
Ln GDP per capita 1979		0.99		5.76
		(2.56)		(10.14)
Ethnolinguistic fractionalisation		−0.56		−0.65
		(0.69)		(1.63)
Rough terrain (mountains)		−0.13		−0.05
		(0.12)		(0.10)
Oil-exporting countries (dummy)		0.04		0.07
		(0.03)		(0.08)
Country FE	Yes	No	Yes	No
Country-specific time trend	Yes	Yes	Yes	Yes
Root-mean-square error	0.24	0.23	0.23	0.23
Conflict observations	48	41	48	41
Observations	856	747	826	717

Notes: Robust standard errors in brackets.
Errors clustered at country level.

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coefficient is marginally significant at 90% confidence level in columns 4 and 5 but not for the model including country controls, which is similar to the results in column 3.

So, although I do find that some of the models show a statistically significant link between economic growth and conflict onset, these results are not robust to the inclusion of time-fixed effects to capture shocks that are common to African countries. Including time-fixed effects heavily inflate both the size of the coefficient as well as the standard errors.[51]

The positive sign of current growth rates in columns 4–6 is unexpected especially considering that this direction of the effect only occurs in the cases where I use anomalies to predict growth.[52]

None of the country controls – see columns 3 and 6 – seem to have any predictive power except for the variable for ethnolinguistic fractionalisation which is statistically significant in both models.[53] The coefficient is significant at the 90% confidence level and indicates that the likelihood of conflict onset actually decreases when fragmentation increases. An

[51]Brückner and Ciccone (2010) also found that the results by MSS were not robust to the inclusion of time-fixed effects.
[52]It could be that this is related to some of the measurement errors in the economic growth rates but this is no more than a guess.
[53]Something that also occurred in the reduced-form OLS regressions (see Table IV).

TABLE VII IV-2SLS (second stage): conflict onset (5-year intermittency) & economic growth 1981–2010

	Growth			Anomaly		
Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)
Economic growth$_t$	−1.42	−0.92	−2.75	−0.13	−0.27	−0.33
	(1.37)	(1.40)	(2.65)	(0.99)	(0.99)	(0.90)
Economic growth$_{t-1}$	−1.16	−1.11	−1.89	−0.48	−1.29	−0.62
	(0.90)	(1.03)	(1.61)	(0.91)	(1.32)	(1.12)
Peace years			0.00			0.00*
			(0.00)			(0.00)
Ln Population$_{t-1}$			−0.49			−0.25
			(0.72)			(0.27)
Square polity2$_{t-1}$			0.00			0.00
			(0.00)			(0.00)
Ln GDP per capita 1979			3.73			2.93
			(7.01)			(2.86)
Ethnolinguistic fractionalisation			−2.12**			−2.15***
			(0.85)			(0.41)
Rough terrain (mountains)			−0.29			−0.23
			(0.21)			(0.17)
Oil-exporting countries (dummy)			0.26			0.05
			(0.34)			(0.11)
Country FE	no	yes	no	no	yes	no
Country-specific time trend	no	yes	yes	no	yes	yes
Root MSE	0.23	0.20	0.28	0.19	0.20	0.18
Conflict observations	34	34	29	34	34	29
Observations	892	892	795	892	892	795

Notes: Robust standard errors in brackets.
Errors clustered at country level.
***$p \leq 0.01$.
**$p \leq 0.05$.
* ≤ 0.1.

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explanation for this could be that when a society approaches perfect fractionalisation (value of 1 in this case) people benefit more from cooperation rather than conflict.[54]

I also estimate the effect, the different economic sectors (agricultural and industrial) have on the outbreak of conflict using rainfall to predict the growth rates (Table VI). The estimations are limited to the use of anomalies to instrument for the growth rates as these have shown to be a stronger instrument in the first-stage estimations. According to the literature, one would expect that a positive shock in the agricultural sector would have a larger effect on reducing conflict likelihood compared to the industrial sector as it is more labour intensive.[55] The results do not really support this hypothesis as the coefficients are very close to each other with the caveat that the estimates come with a lot of uncertainty given the large standard errors and very wide confidence intervals. On the basis of these estimations, I can't identify with certainty a distinct separate effect that economic shocks in the two sectors

[54]As stated in the data, section I uses a different index to measure fractionalisation taking into account the political relevance of ethnic groups and allowing it to vary by decade. This might explain the difference with the findings in the literature.

[55]In terms of total employment about 44% works in the primary sector while about 16% works in the secondary sector (data from World Development Indicators for Sub-Saharan Africa 1981–2010).

could have on conflict onset.[56] Moreover, the coefficients are considerably lower compared to aggregate economic output in the previous table.

As the literature suggests there is a strong link between conflict and economic conditions but the causality may be hard to establish as conflict feeds back into the economy influencing economic performance. In order to better control for this effect, I estimate the model using a stricter coding of the dependent variable that uses an intermittency period after the end of a conflict in order to control for the disrupitve effect of conflict on economic performance. I use a 5-year intermittency period meaning that after the last incidence of conflict I code the next 5 years as missing in order to control for any temporal effect of conflict after the conflict ended. The results that were statistically significant using the standard onset-indicator do not withstand this test and cease to be significant (see Table VII for results). However, I must note that part of this reduction in statistical significance could be due to an increase in imprecision as the number of observations drops with about 14%. Nonetheless, there is also a drop of almost 50% in the point estimates. Another noticeable change is the direction of the effect considering the models where economic performance is predicted by anomalies. Growth rates at t are now robustly negatively – though statistically not significant – related to conflict onset, confirming earlier results in the literature.[57]

It seems that this onset-indicator does a better job in modelling the temporal dependence of conflict and also improves the fit of the model as the mean-square errors are smaller, although not by a very large margin.

Another interesting find concerns the country controls where the coefficient for ethnic fragmentation is statistically significant from a 95% confidence level and a coefficient size that has increased by 50%. This shows that there is an apparent link between ethnolinguistic fractionalisation and conflict onset although not in the direction that was expected. Peace years also enters significantly in one of the models but the point estimate is near zero.

7. CONCLUSIONS

A serious challenge in the empirical literature on conflict is how to deal with issues of reverse causality. In a study on the effect of economic shocks and civil conflict, Miguel, Satyanath, and Sergenti (2004) used an innovative approach and instrumented economic performance with year-on-year growth in rainfall and found that there is a positive link between rainfall, economic shocks and conflict. Their publication has become a standard work in the literature but subsequent studies have failed to come to a conclusive result with regard to the link between rainfall and conflict.

In this paper, I have tried to address some of the issues in the literature that haven't received a lot of attention: the coding of the dependent variable and the link between rainfall, different sector of the economy and civil conflict.

With regard to the coding of the dependent variable I argue that using a binary incidence indicator does not identify the causal mechanism of interest. Based on the theoretical contribution by Collier and Hoeffler (1998), the assumption that economic shocks affect the continuation of conflict in the same way as the outbreak of a new one is not viable. Costs associated with joining an ongoing rebellion are lower than those associated with initiating a new one and therefore we should expect that conflict onset is less sensitive to economic

[56]Due to the sparseness of accurate national account data, a more disaggregated approach might be more suitable to identify the effect of different economic sectors on conflict likelihood.

[57]Although again a caveat here is that conflict influences economic performance and moreover there is also the mechanical problem of data collection in violence-struck areas.

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shocks (Bazzi and Blattman 2011). In my analysis, I find little support for the link between rainfall and conflict as the statistically significant results that I find are not robust to different model specifications or different measures of shocks. Although the analysis does show that there is some robustness in the direction of the effect.

With regard to the different economic sectors, I find that rainfall has the largest impact on the agricultural sector which is no surprise given the dependence on rainfall for irrigation. The results also indicate that rainfall has a statistically significant contribution to productivity in the industrial sector but the magnitude of this effect is relatively small and the data did not seem to support some of the strong claims made in other work (Barrios, Bertinelli, and Strobl 2010).

Over the past decades, the size of the agricultural sector in Africa has decreased although it still employs a significant amount of the total labour force. There is however no strong empirical support for the notion that a negative shock to the agricultural sector significantly increases the risk of conflict.

A caveat with regard to estimating the relationship between rainfall, economic shocks and conflict is the loss of information due to aggregation when using the country year as unit of analysis. The yearly aggregates do not give a fair representation of within-country differences for both rainfall and economic performance. An additional problem is the mechanical error in national account data due to the lack of institutions to correctly measure economic performance. A disaggregated approach could be beneficial to answer some of the questions that remain although recent work has shown that also on the local level there does not seem to be a very strong relation between rainfall and conflict (O'Loughlin et al. 2012), something that is also established in this study.

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APPENDIX 1

TABLE VIII Descriptive statistics (1981–2010)

	Mean	Std. dev.	Obs.
		A. Civil conflict	
Civil conflict (≥ 25 deaths)	0.21	0.41	1389
Onset	0.06	0.23	1101
Offset	0.24	0.43	289
Onset (5-year intermittency period)	0.04	0.19	954
		B. Precipitation	
Rainfall (mm)	1023.4	552.6	1389
Rainfall $growth_t$	0.02	0.23	1389
Rainfall $growth_{t-1}$	0.02	0.23	1389
Rainfall $anomaly_t$	−0.01	0.99	1389
Rainfall $anomaly_{t-1}$	−0.01	0.99	1389
		C. Economic growth	
GDP growth $rate_t$	0.01	0.07	1299
GDP growth $rate_{t-1}$	0.01	0.07	1288
Agricultural sector growth $rate_t$	0.00	0.10	1088
Industrial sector growth $rate_t$	0.02	0.11	1058
		D. Country controls	
Peace years	14.40	13.50	1389
Ln $population_{t-1}$	15.46	1.47	1389
Regime $type_{t-1}$	37.33	26.61	1356
Ln GDP per capita 1979	7.05	0.74	1389
Ethnolinguistic fractionalisation (PREG index)	0.40	0.24	1221
Rough terrain (% land area covered by mountains)	12.08	21.07	1389
Oil $exports_{t-1}$	0.07	0.26	1387

TABLE IX IV-2SLS (First-stage): rainfall & economic growth 1981–1999 (Data from Miguel, Satyanath, and Sergenti (2004))

	MSS		Growth		Anomaly	
Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)
$Rainfall_t$	0.06***	0.05***	0.06***	0.06***	0.01***	0.01***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.00)	(0.00)
$Rainfall_{t-1}$	0.03**	0.03**	0.04***	0.04***	0.00	0.00
	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)	(0.00)
Country-fixed effects	no	yes	no	yes	no	yes
Country-specific year trend	no	yes	no	yes	no	yes
Root MSE	0.07	0.07	0.07	0.07	0.07	0.07
Observations	743	743	743	743	743	743

Notes: Robust standard errors in brackets.
Errors clustered at country level.
***$p \leq 0.01$.
**$p \leq 0.05$.
* ≤ 0.1.

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TABLE X Economic growth & rainfall: first-stage per period

	1981–2010		1981–1999		2000–2010	
Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)
$Rainfall_t$	0.02**	0.01***	0.02*	0.01***	0.01	0.00*
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
$Rainfall_{t-1}$	0.02**	0.00	0.02**	0.00	0.00	0.00
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
Country-FE	Yes	Yes	Yes	Yes	Yes	Yes
Country-specific time trend	Yes	Yes	Yes	Yes	Yes	Yes
Root MSE	0.07	0.07	0.07	0.07	0.05	0.05
Obs.	1299	1299	796	796	503	503

Notes: Results in odd columns are for growth; and anomalies in even columns.
Robust standard errors in brackets.
Errors clustered at country level.
***$p \leq 0.01$.
**$p \leq 0.05$.
* ≤ 0.1.

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