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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 1981â 1999.

Keywords: Rainfall, economic growth rate, conflict, Sub-Saharan Africa

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 countriesâ 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.

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 [1]. This data set contains

[1]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.

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) [2], whereas MSS focused on results of rainfall data from the Global Precipitation Climatology Project (GPCP) database over two other global weather sources[3], 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 [4]. 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}.

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 (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 equitation of the first-stage with a vector X'_{it} is:

$$GrGDP_{it} = a1_i + X'b_1 + d1_i year_t + e1_{it} \tag{1}$$

[2]Data assessed and retrieved from http://climateknowledgeportal.worldbank.org.

[3]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

[4]http://emiguel.econ.berkeley.edu/research/economic-shocks-and-civil-conflict-an-instrumental-variables-approach

We introduce regression analyses for SSA from 1981-1999 in Table 1, reproducing the results of MSSâ 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 MSSâ 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 (Table 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.

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 (2)):

$$Conflict_{it} = a_2 i + X\hat{a}_{it} b_2 + g_{2,0} GrGDP_{it} + g_{2,1} GrGDP_{i,t-1} + d_2 iyear_t + e_2 it \qquad (2)$$

We present results of IV 2SLS and OLS methods for both data sets in Table 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 Table 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 Table 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).

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)[5]. This link has been already examined using MSS' data by Ciccone (2011), results are reported in Table 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 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).

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

[5]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.

Table 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		.	

*f*ixed effect and specific time trends are included in all regressions

p-values in parentheses

* $p < 0.10$,** $p < 0.01$,*** $p < 0.001$

Table 2: Economic Growth and civil conflict. Dependent Variable: Civil conflict ≥ 25 deaths. For SSA, period $1981-1999$

	(1)		(2)		(3)		(4)	
	SH				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		.	

*I*nstrumental Variables for economic growth rate in regression 2 and 4 are growth in rainfall year t, and t-1.

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

p-values in parentheses * $p < 0.10$,** $p < 0.01$, *** $p < 0.001$

the difference in econometric specifications, and to the changes in data sources that use different methods of making the data available.

Table 3: Rainfall and civil conflict. Dependent variable: Civil conflict $\geq$ 25 deaths, period $1981 - 1999$

	(1)		(2)		(3)		(4)	
	SH				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

* $p < 0.10$, ** $p < 0.01$,*** $p < 0.001$

Table 4: Rainfall as an instrument for 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	

*F*ixed effect and specific time trends are included in all regressions

p-values in parentheses

* $p < 0.10$,** $p < 0.01$,*** $p < 0.001$

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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)[6].

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 [7], 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[8].

While the intensity level of a conflict in a given year distinguishes minor armed conflicts from wars based on the battle-related deaths[9], as following:

1. Minor conflicts (Intensity level 1): resulted in between 25 and 999 battle-related deaths in a given year.

[6] The UCDP/PRIO armed conflict for download http://ucdp.uu.se/downloads/.

[7] 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).

[8] 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.

[9] 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/ www.pcr.uu.se/research/UCDP/our_data1.htm

2. War (Intensity level 2): resulted in at least 1,000 battle-related deaths in a given year.

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)[10]. We observe growth in weather variables from the previous year following Miguel et al. (2004): **gr_rainfall**= $\frac{rainfall - rainfall\_lag1}{rainfall\_lag1}$

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 = (rainfall - rainfall_lag1)/(rainfall_lag1).

[10]http://climateknowledgeportal.worldbank.org.

- **gr_rainfall_lag_1:** growth rainfall lagged one year: (rainfall_lag_1 - rainfall_lag_2)/(rainfall_lag_2).
- **log_rainfall:** log of rainfall levels in country i and year t.
- **log_rainfall_lag_1:** lagged one year.
- **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)