Transitory Economic Shocks and Civil Conflict

by

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Abstract

To determine the effect of economic shocks on civil conflict, the empirical approach must be tailored to the shocks' persistence. I illustrate this point by revisiting Miguel, Satyanath, and Sergenti (2004). MSS argue that lower rainfall levels and negative rainfall shocks increase the probability of civil conflict in Sub-Saharan Africa over the 1979-1999 period. I find MSS's approach and conclusion to be incorrect. For example, according to MSS's data, lower rainfall levels and negative rainfall shocks (droughts) actually decrease the probability of civil conflict outbreak. The 1979-2009 data also reject that civil conflicts are more likely to start following lower rainfall levels or negative rainfall shocks.

Key words: Transitory shocks, mean reversion, rainfall, conflict

JEL codes: O0, P0, Q0

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Does poor economic performance cause violent civil conflict? Collier and Hoeffler's (1998, 2004) and Fearon and Laitin's (2003) empirical work suggests this is the case. Their findings are not based on exogenous changes in the economic environment however, and could reflect feedback from conflict to economic performance or omitted social and political factors. To address these concerns, Miguel, Satyanath, and Sergenti (MSS, 2004) examine the link between (exogenous) rainfall and civil conflict in Sub-Saharan Africa. Their empirics lead them to the conclusion that *higher levels of rainfall are associated with significantly less conflict* (MSS, page 737; also page 745). Or, equivalently, lower rainfall levels are associated with significantly more conflict. MSS explain this association by negative rainfall shocks reducing incomes and thereby increasing conflict risk. Their focus on exogenous rainfall shocks is an important step forward, and MSS's conclusion has therefore become a cornerstone of the literature on the economics of civil conflict (e.g. Collier and Hoeffler, 2005; Collier, Hoeffler, and Rohner, 2009; Hegre and Sambanis, 2006; Fisman and Miguel, 2009; Miguel and Satyanath, 2010). In fact, MSS's study already has more than 400 Google Scholar citations and is the 12th most cited of more than 8800 journal articles on the topics *civil conflict* or *civil war* in history, economics, political sciences, or sociology.[1]

A point overlooked by the literature is that to determine the effect of shocks on civil conflict, it is critical to tailor the empirical approach to the persistence of shocks.[2] I illustrate the importance of this point by revisiting MSS's (2004) study. I find their approach to be inappropriate and their conclusion to be incorrect. Lower rainfall levels are actually followed by significantly less—not more—conflict outbreak in MSS's data, and negative rainfall shocks (droughts) actually reduce the risk of conflict outbreak. Moreover, according to the conflict

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[1] According to the ISI Web of Knowledge http://isiwebofknowledge.com/.

[2] For example, there is no mention of this issue in Blattman and Miguel's (2010) survey.

dataset employed by MSS, there is no evidence that civil conflict incidence—which subsumes conflict outbreak and conflict continuation—is more likely following lower rainfall levels or negative rainfall shocks. Table 1 summarizes the effect of rainfall levels on civil conflict outbreak (onset) and conflict incidence using the datasets employed by MSS. It can be seen that there is no instance where the data support MSS's claim that civil conflict outbreak or incidence follows lower rainfall levels. Nor do the data indicate that civil conflict follows negative rainfall shocks (droughts). [3]

MSS's (2004) analysis employs UCPD/PRIO conflict data and GPCP rainfall data for the 1979-1999 period.[4] The latest versions of these databases have been extended to 2009. The 1979-2009 data also reject that civil conflict outbreak or incidence follow lower rainfall levels or negative rainfall shocks when civil conflict is defined as in MSS. When the definition of civil conflict excludes participation in extraterritorial civil conflicts, as in Jensen and Gleditsch (2009), there is some evidence that civil conflict incidence follows lower rainfall levels when I control for lagged incidence and shocks to the probability of civil conflict that are common to all Sub-Saharan African countries (these controls are not included by MSS). But the data always reject that civil conflicts are more likely to start following lower rainfall levels or negative rainfall shocks.

MSS's (2004) conclusion that lower rainfall levels are associated with significantly more civil conflicts and that civil conflicts follow negative rainfall shocks is based on their finding

[3] Miguel and Satyanath (2010) deemphasize MSS's conclusion that civil conflict is more likely following lower rainfall levels and more likely following adverse rainfall shocks. Their preferred interpretation of MSS's finding of a statistically significant, negative effect of rainfall growth between year *t*-1 and *t*-2 on conflict risk in year *t* is that MSS demonstrate that falling rainfall levels increase conflict risk. If this interpretation was correct, lower *t*-1 rainfall levels should translate into a statistically significant increase in civil conflict risk when rainfall in *t*-2 is held constant. MSS's data reject this hypothesis.

[4] For details on these databases see Adler et al. (2003) and Gleditsch, Wallensteen, Sollenberg, and Strand (2002).

that civil conflict is more likely following lower lagged year-on-year rainfall growth (MSS, page 737) and their assumption that rainfall growth is a measure of rainfall shocks (MSS, page 733). But years where rainfall levels are below the previous year need not be years where rainfall levels are low. And because rainfall shocks are transitory, low year-on-year rainfall growth may be due to mean reversion rather than negative shocks (droughts).[5] As a result, MSS's approach can lead to the conclusion that lower rainfall levels and negative rainfall shocks lead to more civil conflict when this is incorrect. I propose answering the question whether lower rainfall levels or negative rainfall shocks cause civil conflict by looking directly at the effect of rainfall levels and rainfall shocks on civil conflict.[6]

To see that MSS's (2004) empirical approach is inappropriate for answering the question whether lower rainfall levels or negative rainfall shocks cause civil conflict, consider the predicted probability of civil conflict $PPconflict_t$ in year t according to MSS's (linear probability) model

$$PPconflict_t = a^{LS} RGr_t + b^{LS} RGr_{t-1}, \quad (1)$$

where RGr_t is rainfall growth between year t and t-1, and a^{LS}, b^{LS} are least-squares estimates. (MSS control for country fixed effects and country-specific linear trends, but I omit them here for simplicity). My first point is that the statistically significant, negative value for b^{LS} found by MSS may reflect that civil conflict is less likely following higher rainfall levels in t-1 or less likely following lower rainfall levels in t-2. Hence, $b^{LS} < 0$ may capture that civil conflict is less likely following lower t-2 rainfall levels, which would contradict MSS's conclusion that civil conflict is more likely following lower rainfall levels. My second point is that as rainfall

[5] See Buhaug (2010) for a related point.

[6] Burke, Miguel, Satyanath, Dykema, and Lobell's (2009) investigation of the effect of global warming on civil war risk in Africa also adopts this approach, as does Buhaug's (2010) related study.

shocks are transitory, $b^{LS} < 0$ may reflect that civil conflict is less likely following negative *t*-2 rainfall shocks, as negative *t*-2 rainfall shocks tend to be followed by positive rainfall growth due to mean reversion. Hence, $b^{LS} < 0$ may reflect that civil conflict is less likely following negative *t*-2 rainfall shocks (droughts), which is the opposite of the conclusion if low year-on-year rainfall growth did in fact reflect negative rainfall shocks as assumed by MSS (page 733).

These points can be seen most clearly when rainfall levels are distributed identically and independently over time (which implies that rainfall is strongly mean reverting[7]) and the true conflict probability $Pconflict_t$ depends on current and lagged log rainfall levels ($\log R_t$),

(2) $$Pconflict_t = \alpha_0 \log R_t + \alpha_1 \log R_{t-1} + \alpha_2 \log R_{t-2}.$$ [8]

If $\alpha_i > 0$ for $i = 0,1,2$, lower rainfall levels at all lags decrease the conflict probability. Moreover, $\alpha_i > 0$ also implies that conflict is less likely following negative rainfall shocks (rainfall levels below the mean) than following positive rainfall shocks.[9] But the approach in (1) may yield that lower rainfall growth increases the probability of conflict. This follows from the usual two orthogonality conditions determining the least-squares coefficients in (1): $\text{cov}(Pconflict_t - a^{LS} RGr_t - b^{LS} RGr_{t-1}, RGr_t) = \text{cov}(Pconflict_t - a^{LS} RGr_t - b^{LS} RGr_{t-1}, RGr_{t-1}) = 0$. Making use of (2) and $RGr_t = \log R_t - \log R_{t-1}$ in these orthogonality conditions, solving for a^{LS} and b^{LS}, and substituting in (1) yields

[7] Empirically, rainfall levels are strongly mean reverting. Regressing log rainfall levels on lagged log rainfall levels using MSS's data and controlling for country fixed effects, yields a system-GMM coefficient on lagged log rain of 0.17 with a standard error of 0.04. Accounting for the empirical persistence of rainfall does not affect the conclusion but complicates the coefficient formulas in (3).
[8] Following MSS, I will focus on linear probability models.
[9] For an insightful theoretical analysis of the link between transitory economic shocks and civil conflict see Chassang and Padró i Miquel (2009).

(3) $$PPconflict_t = \frac{2\alpha_0 - (\alpha_1 + \alpha_2)}{3} RGr_t + \frac{(\alpha_0 + \alpha_1) - 2\alpha_2}{3} RGr_{t-1}.$$ [10]

Hence, the parameters α_i capturing the effect of rainfall levels and rainfall shocks on civil conflict in (2) cannot be recovered from a regression of civil conflict on current and lagged rainfall growth. Moreover, the least-squares coefficients in (3) cannot be interpreted as the effect of rainfall levels or rainfall shocks on civil conflict. For example, the coefficient on lagged rainfall growth will be negative as long as $2\alpha_2 > \alpha_0 + \alpha_1$. Hence, a negative effect of lagged rainfall growth on conflict is consistent with lower rainfall levels and negative rainfall shocks reducing conflict at all lags, i.e. $\alpha_i > 0$ for $i = 0,1,2$ in (2). It is also possible that both current and lagged rainfall growth enter (3) negatively, although lower rainfall levels and negative rainfall shocks reduce the probability of conflict at all lags. To see this, note that both coefficients in (3) will be negative if and only if $\alpha_0 - \theta < \alpha_1 < \alpha_0 + 2\theta$ where $\theta = \alpha_2 - \alpha_0$.[11] Hence, if $\alpha_2 > \alpha_0 > 0$, both current and lagged rainfall growth can enter (3) negatively, although lower rainfall levels and negative rainfall shocks (droughts) decrease the conflict probability at all lags, i.e. $\alpha_i > 0$ for $i = 0,1,2$ in (2).[12]

[10] The assumption that log rain is i.i.d. implies that $\text{cov}(Pconflict_t - a^{LS} RGr_t - b^{LS} RGr_{t-1}, RGr_t)$ simplifies to $(\alpha_0 - \alpha_1 - 2a^{LS} + b^{LS})V$ and that $\text{cov}(Pconflict_t - a^{LS} RGr_t - b^{LS} RGr_{t-1}, RGr_{t-1})$ simplifies to $(\alpha_1 - \alpha_2 + a^{LS} - 2b^{LS})V$ where V is the variance of log rain. Hence, (3) can be obtained by solving $\alpha_0 - \alpha_1 - 2a^{LS} + b^{LS} = \alpha_1 - \alpha_2 + a^{LS} - 2b^{LS} = 0$ for a^{LS}, b^{LS}. In practice one does not observe the probability of conflict but only whether there has been a conflict or not. This does not affect (3) however, see Wooldridge (2002), page 454.

[11] Lagged rain growth will enter negatively if and only if $2\alpha_2 > \alpha_0 + \alpha_1$, or equivalently $\alpha_1 < 2\alpha_2 - \alpha_0 = 2\theta + \alpha_0$. Current rain growth will enter negatively if and only if $2\alpha_0 < \alpha_1 + \alpha_2$, or equivalently $\alpha_1 > 2\alpha_0 - \alpha_2 = \alpha_0 - \theta$. Combining inequalities yields $\alpha_0 - \theta < \alpha_1 < \alpha_0 + 2\theta$.

[12] $\alpha_2 > \alpha_0$ implies that $\theta > 0$ and hence that there are values for α_i $i = 0,1,2$ that satisfy the inequality $\alpha_0 - \theta < \alpha_1 < \alpha_0 + 2\theta$. $\alpha_0 > 0$ implies that these values can all be strictly positive.

The intuition for why one may find lower year-on-year rainfall growth to be associated with greater civil conflict risk, although negative rainfall shocks decrease conflict risk is the following. Imagine an economy experiencing a negative rainfall shock (drought) and that this actually decreases the probability of civil conflict in the following year. Now consider the year following the drought. Because of last year's drought, civil conflict will be unlikely by assumption. Moreover, because of last year's drought and mean reverting rainfall levels, rainfall growth will tend to be positive. Imposing the restriction that civil conflict can be related to rainfall growth only, as in (3), will therefore yield that civil conflict is less likely following positive rainfall growth. If one goes a step further and also assumes that rainfall growth is a measure of rainfall shocks, as in MSS (page 733), the conclusion becomes that civil conflict is less likely following positive rainfall shocks. But in fact civil conflict is less likely following negative rainfall shocks.

So far I have assumed that the true model has the probability of civil conflict depend on rainfall levels, while the estimating equation links conflict to year-on-year rainfall growth. Suppose now that the true model is as suggested by MSS's (2004) finding that there is a statistically significant, negative effect of lagged rainfall growth on civil conflict risk. That is, assume the true model is

$$Pconflict_t = \beta(\log R_{t-1} - \log R_{t-2}) \tag{4}$$

with $\beta < 0$. In this case, a least-squares regression of civil conflict on log rainfall levels would yield the following prediction for conflict risk,

$$PPconflict_t = \beta \log R_{t-1} - \beta \log R_{t-2}\,. \tag{5}$$

Hence, (4) with $\beta < 0$ implies that civil conflict risk should be increasing in *t*-2 rainfall levels and also that civil conflict risk should be decreasing in *t*-1 rainfall levels. MSS's data support that conflict risk is increasing in *t*-2 rainfall levels but reject that conflict risk is decreasing in *t*-1 rainfall levels.

While linking civil conflict to year-on-year growth of the driving variable, as in (1), is an inappropriate way of assessing whether conflict is caused by transitory (rainfall) shocks, it is the correct way of assessing whether conflict is caused by permanent shocks. This is why examining the link between conflict and commodity price shocks—which are typically very persistent, see Cashin, Liang, and McDermott (2000) and Brückner and Ciccone (2010)—requires a different approach than examining the link between conflict and rainfall shocks.

The remainder of the paper estimates the effect of year-on-year rainfall growth and rainfall levels on civil conflict. Additional empirical results can be found in the Web Appendix available at www.antoniociccone.eu.

II. Does civil conflict follow lower rainfall levels or negative rainfall shocks?

The conflict data come from the UCPD/PRIO Armed Conflict Database.[13] The rainfall data come from the Combined Precipitation Dataset of NASA's Global Precipitation Climatology Project (GPCP; these data are only available since 1979).[14]

UCPD/PRIO defines conflict as "a contested incompatibility which 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."[15] MSS's (2004) definition of

[13] See Gleditsch, Wallensteen, Sollenberg, and Strand (2002). For the conflict data see http://www.prio.no/CSCW/Datasets/ Armed-Conflict/UCDP-PRIO/.
[14] Which in contrast to the datasets covering the period before 1979 employs both gauge and satellite measurements. See Adler et al. (2003) and http://precip.gsfc.nasa.gov.
[15] UCDP/PRIO Armed Conflict Dataset Codebook (2010), page 1.

civil conflict includes all internal armed conflicts without any intervention from other states and all internal armed conflicts with intervention from other states. [16]

As pointed out by Jensen and Gleditsch (2009), MSS's definition of civil conflict implies that some countries are classified as experiencing a civil conflict although there is no civil conflict on their territory. This is the case when these countries participate in civil conflicts in other states (participate in extraterritorial civil conflicts). As an illustration, Jensen and Gleditsch describe the case of Zimbabwe. The Zimbabwean government sent troops to the civil conflict in the Democratic Republic Congo in 1998-99. During this period, Zimbabwe did not experience a civil conflict on its own territory. Still, according to the definition of civil conflict employed by MSS, Zimbabwe experienced a civil conflict 1998-99. Jensen and Gleditsch argue that this example, and participation in extraterritorial civil conflicts more generally, does not fit MSS's narrative where adverse economic shocks make it easier to recruit fighters for civil conflicts. Jensen and Gleditsch therefore focus on the determinants of civil conflicts fought on the country's territory (i.e. exclude participation in extraterritorial conflicts).[17]

In response to Jensen and Gleditsch (2009), Miguel, Satyanath, and Sergenti (2007) argue that sending fighters to other countries fits the proposed causal mechanism in MSS (2004). Still, I find Jensen and Gleditsch's focus on civil conflicts on a country's own territory compelling and also use their civil conflict definition when I look at the link between civil conflict and rainfall in the latest data.[18]

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[16] UCDP/PRIO Armed Conflict Dataset Codebook (2010), page 9.

[17] Jensen and Gleditsch's main finding is that the link between economic growth and civil war incidence found by MSS becomes statistically insignificant when they focus on civil wars fought on the territory of the country.

[18] For additional results using Jensen and Gleditsch's definition of civil conflict, see the Web Appendix.

My empirical results are based on least-squares regressions and, following MSS (2004), control for country-specific intercepts and country-specific linear time trends. (MSS do not control for shocks to the probability of civil conflict that are common to Sub-Saharan African countries, like the end of the Cold War for example (Fearon and Laitin, 2003).[19])

I report results on the effect of rainfall on both civil conflict onset and civil conflict incidence. Civil conflict onset is an indicator variable that captures conflict outbreak. The onset indicator in year *t* is 1 if there is a civil conflict at *t* but there was no conflict at *t*-1; 0 if there is no conflict at *t* and there was no conflict at *t*-1; and not defined if there was a conflict at *t*-1. Conflict incidence, on the other hand, is an indicator variable that is 1 if there is a conflict at *t* and 0 if there is not. Hence, the conflict incidence indicator may be 1 because of the outbreak of a new conflict or the continuation of an existing conflict. Rainfall in year *t* is calculated as average annual rainfall.

All tables report two standard errors for each least-squares estimate. The standard errors in parentheses are consistent for arbitrary heteroskedasticity and time-series correlation within each country cluster. The standard errors in square brackets also make a small-sample adjustment. The statistical theory behind hypothesis tests using the small-sample-adjusted standard errors assumes normally distributed and homoskedastic residuals (e.g. Greene, 1990, page 161). Both the normality assumption and the homoskedasticity assumption are violated in (my) linear probability models, where the left-hand-side variable is either 0 or 1 (e.g.

[19] For results controlling for common, time-varying shocks to conflict risk, see the Web Appendix.

Wooldridge, 2002, page 454). Still, I report standard errors incorporating the small-sample adjustment to facilitate comparison with MSS (2004) and Miguel and Satyanath (2010).[20]

II.A. Civil conflict onset (outbreak)

I first examine the effect of rainfall on civil conflict onset in MSS's (2004) data and then turn to the latest versions of the databases employed by MSS.

II.A.1. Conflicts do not start following lower rainfall levels in MSS's (2004) data

Table 2, columns (1)-(2) contain results using MSS's (2004) data for the 1979-1999 period, which come from UCPD/PRIO and the GPCP. (As MSS control for contemporaneous and lagged year-on-year rainfall growth and the GPCP rainfall data start in 1979, the earliest civil conflict onset observations employed correspond to 1981.) Column (1) shows that *t*-1 rainfall growth has a significantly negative effect on conflict onset at *t*. The effect is significant at the 90% confidence level, no matter which standard error is used. According to MSS's interpretation, this empirical result implies that conflict onset is more likely following lower rainfall levels and that negative rainfall shocks are a cause of conflict outbreak. But column (2) contradicts this conclusion using the same data. Regressing conflict onset on current and lagged log rainfall levels, yields that conflict onset is less likely following lower *t*-2 rainfall levels according to the only statistically significant estimate. The result in column (2) also implies that civil conflict outbreak is less likely following negative *t*-2 rainfall shocks. The estimate indicating that conflict onset is less likely following lower rainfall levels and negative rainfall shocks is significant at the 95% confidence level, no matter which standard error is used. The rainfall growth specification in column (1) yields an incorrect conclusion because it

[20] Miguel and Satyanath mention that STATA's technical service recommended the small-sample adjustment but not why this adjustment improves inference in linear probability models.

relates civil conflict to year-on-year rainfall growth and not rainfall levels, and because it confounds (transitory) rainfall shocks and mean reversion.

Summarizing, MSS's (2004) claim that civil conflict follows lower rainfall levels is not supported by their data on conflict onset. Nor do their data support that conflict onset follows negative rainfall shocks. Their data actually point to the opposite conclusion: lower rainfall levels and negative rainfall shocks are followed by significantly less conflict onset.

II.A.2. Conflicts do not start following lower rainfall levels in the latest data

The latest UCDP/PRIO conflict dataset, the Armed Conflict Database Version 4-2010,[21] contains conflict data until 2009. The latest version of the GPCP rainfall data set, the Combined Precipitation Dataset Version 2.1,[22] contains rainfall data until September 2009. These datasets allow me to examine the effect of rainfall on civil conflict onset for the 1979-2009 period. The lack of rainfall data for the last three months of 2009 is unlikely to affect results. For this to be the case, civil conflicts starting at the end of 2009 would have to be caused by rainfall in the last three months of the year. This seems unlikely, especially as the empirical results in Table 2 indicate that contemporaneous, annual rainfall levels do not affect civil conflict risk. Still, I will also comment on the results for the 1979-2008 period (which are very similar to results for 1979-2009).[23]

Table 3 presents results for both the MSS (2004) definition of civil conflict, which includes participation in extraterritorial civil conflicts, and the Jensen and Gleditsch (2009) definition, which excludes participation in extraterritorial civil conflicts. There is no evidence

[21] See UCDP/PRIO Armed Conflict Dataset Version 4-2010, Version History and Know Errata (2010).

[22] See Huffman and Bolvin (2009).

[23] The full set of 1979-2008 results are in Web Appendix II.

of statistically significant effects of rainfall levels on civil conflict onset.[24] Hence, the civil conflict onset and rainfall data for the 1979-2009 period also fail to support that civil conflict follows lower rainfall levels or negative rainfall shocks. This continues to be the case when I control for shocks to the probability of civil conflict onset that are common to all Sub-Saharan African countries,[25] and when I focus on the 1979-2008 period.[26] I conclude that, at present, there is no evidence that civil conflicts in Sub-Saharan Africa start following low rainfall levels or negative rainfall shocks.

II.B. Civil conflict incidence

I now turn to the link between rainfall and civil conflict incidence. Civil conflict incidence subsumes conflict onset (outbreak) and conflict continuation. Hence, the implicit assumption when using conflict incidence instead of conflict onset as the dependent variable is that rainfall affects conflict onset and conflict continuation in the same way.

II.B.1. Conflict incidence and rainfall in MSS's (2004) data

Table 4, column (1) uses the UCPD/PRIO and GPCP datasets employed by MSS (2004) to reproduce their result that *t*-1 rainfall growth has a significantly negative effect on conflict incidence for the 1979-1999 period. Columns (2) and (3) add lagged incidence to MSS's specification because the probability of civil conflict may depend on whether there already was a conflict in the previous year (MSS do not control for lagged conflict incidence). Column (2) reports least-squares results while column (3) reports system-GMM results.[27] Not

[24] Nor is there evidence of statistically significant effects of rainfall growth.
[25] See Web Appendix Tables I.B.1 and I.C.1, Panel B, columns (3)-(4) and (7)-(8).
[26] See Web Appendix Tables II.A.1, II.B.1, and II.C.1, columns (3)-(4) and columns (7)-(8).
[27] Least squares is inconsistent for a fixed time-series dimension (number of years), while system-GMM is consistent as the cross-sectional dimension goes to infinity even when the number of years is fixed, see Wooldridge (2002), page 304. There is no small-sample

surprisingly, there is significant persistence in conflict incidence: civil conflict is 28 percentage points more likely when there was a conflict in the previous year. The effects of current and lagged rainfall growth are similar to column (1).

Does the negative effect of lagged rainfall growth on civil conflict incidence in columns (2) and (3) imply that conflict incidence is associated with lower rainfall levels and that conflict follows negative rainfall shocks? The only statistically significant estimate in columns (4) and (5) sheds doubt on this conclusion. Relating conflict incidence to current and lagged log rainfall levels yields that conflict is less likely following lower *t*-2 rainfall and that the effect is statistically significant at the 90% confidence level according to the system-GMM result and the least-squares result with and without the small-sample adjustment. Put differently, the only effect that is statistically significant at the 90% confidence level indicates that conflict incidence is less likely following negative rainfall shocks. Hence, the datasets employed by MSS (2004) do not support their claim that conflict incidence is more likely following lower rainfall levels or negative rainfall shocks.

MSS's (2004) claim that civil conflict follows low rainfall levels is also found to be incorrect by Miguel and Satyanath's (2010) empirical analysis, as Miguel and Satyanath's preferred estimation method yields no link between rainfall levels and conflict incidence using MSS's datasets. The preferred estimation method of Miguel and Satyanath is least squares (rather than system-GMM) with a small-sample adjustment to the standard error (see page 9 above for more on the theory behind this adjustment). As can be seen in column (4) of Table 4, I find that even with Miguel and Satyanath's preferred estimation method, conflict incidence is less likely following lower *t*-2 rainfall levels and that the effect is statistically

adjustment for system-GMM, which is why only one standard error is reported for these results.

significant at the 90% confidence level. The explanation for the discrepancy with Miguel and Satyanath is that they lose 41 of the 743 observations in MSS's sample for civil conflict incidence, while my sample has 743 observations just like MSS's sample. The reason why Miguel and Satyanath lose 41 observations is best illustrated with an example. The first observation in MSS for Nigeria relates civil conflict incidence in 1981 to rainfall between 1981 and 1979 (their rainfall data only starts in 1979). To keep this observation when controlling for lagged civil conflict incidence, one has to use data on civil conflict incidence in Nigeria in 1980 from the UCDP/PRIO Armed Conflict Database Version 1.2a employed by MSS. I use these data and keep the observation, while Miguel and Satyanath do not use these data and therefore lose this observation. The result is that Miguel and Satyanath lose one observation for each of the 41 countries in MSS's sample. Avoiding this loss of 41 observations and using all 743 observations in MSS's sample results in a positive effect of *t*-2 rainfall levels that is statistically significant at the 90% confidence level even with Miguel and Satyanath's preferred estimation method.[28] (With the other estimation methods, the estimate is always statistically significant at the 90% confidence level. See Table 4, columns (6)-(7) for the civil conflict incidence results when I reestimate columns (4)-(5) after dropping the 41 observations not used by Miguel and Satyanath.)

[28] The civil conflict data that need to be used to avoid the loss of 41 observations and maintain a sample of 743 observations are for 1980, except in the case of Namibia where the data is for 1990. MSS do not use data for Namibia in the 1980s as Namibia was not yet independent. Because Namibia became independent in March 1990, there might be a case for dropping the civil conflict data for Namibia in 1990. The same would be true for the civil conflict data for Zimbabwe in 1980 because Zimbabwe became independent in April 1980. The case is unclear however because MSS do use pre-independence rainfall data for Namibia and Zimbabwe on the right-hand side of their estimating equation and the civil conflict observations for Namibia in 1990 and Zimbabwe in 1980 are used on the right-hand side of the estimating equation only. In any case, dropping these two civil conflict observations does not affect the statistical significance of the positive effect of *t*-2 rainfall levels.

II.B.2. Conflict incidence and rainfall in the latest data

Table 5 examines the link between civil conflict incidence and rainfall over the 1979-2009 period using the UCDP/PRIO Armed Conflict Database Version 4-2010 and the GPCP Combined Precipitation Dataset Version 2.1. The table presents results for both the MSS (2004) definition of civil conflict, which includes participation in extraterritorial civil conflicts, and the Jensen and Gleditsch (2009) definition, which excludes participation in extraterritorial civil conflicts. Using the MSS definition of civil conflict in columns (3)-(4) yields no evidence that conflict incidence follows lower rainfall levels or negative rainfall shocks (the estimates that are statistically significant at the 90% confidence level point in the opposite direction).[29] Hence, the civil conflict incidence and rainfall data for the 1979-2009 period also fail to support that civil conflict follows lower rainfall levels or negative rainfall shocks. This continues to be the case when I control for shocks to the probability of civil conflict that are common to all Sub-Saharan African countries,[30] and when I focus on the 1979-2008 period (to avoid employing the rainfall data for 2009, which is based on January to September rainfall only).[31] Using Jensen and Gleditsch's definition of civil conflict in columns (7)-(8), the effect of rainfall levels on civil conflict incidence is statistically insignificant. However, with Jensen and Gleditsch's definition, there is some evidence that conflict incidence follows low rainfall levels and negative rainfall shocks when I also control for lagged incidence and shocks to the probability of civil conflict that are common to all Sub-Saharan African countries.[32]

[29] Nor is civil conflict incidence related to rainfall growth, see columns (1)-(2).
[30] See Web Appendix Tables I.B.3 and I.C.3, Panel A, columns (8)-(10).
[31] See Web Appendix Table II.A.2, II.B.2, and II.C.2, Panel A, columns (8)-(10).
[32] For these specifications, the system-GMM estimation method yields a significantly negative effect of *t*-2 rainfall levels at the 90% confidence level for the 1979-2009 period, see Web Appendix Tables I.B.3 and I.C.3, column (8). The evidence using least-squares estimation and

III. Civil war and rainfall in the latest data

UCPD/PRIO defines civil war as a civil conflict with more than 1000 annual battle-related casualties (UCDP/PRIO Armed Conflict Dataset Codebook, 2010). MSS (2004) argue that this threshold is arbitrary. Miguel, Satyanath, and Sergenti (2007) add that the 1000-casualties definition gives a restrictive view of the data as it eliminates many conflicts that should be counted in the African context; they therefore defend using the civil conflict indicator employed so far rather than the civil war indicator. The threshold may also affect empirical findings as shown in Buhaug's (2010) comment on Burke, Miguel, Satyanath, Dykema, and Lobell's (2009) work linking Sub-Saharan African civil wars to global warming.

Still, Table 6 examines the link between rainfall and civil war onset and incidence using the 1979-2009 data from the UCDP/PRIO Armed Conflict Database Version 4-2010 and the GPCP Combined Precipitation Dataset Version 2.1. Using the MSS (2004) definition of civil war, which includes participation in extraterritorial civil wars, yields no evidence that civil war follows low rainfall levels of negative rainfall shocks, see columns (1)-(3) (the only estimate that is statistically significant at the 90% confidence level points in the opposite direction). This continues to be the case when I control for shocks to the probability of civil war that are common to all Sub-Saharan African countries,[33] and when I focus on the 1979-2008 period (to avoid employing the rainfall data for 2009, which is based on January to September rainfall only).[34] Using Jensen and Gleditsch's (2009) definition of civil war, which excludes participation in extraterritorial civil wars, the effect of rainfall on civil conflict incidence is

the evidence for the 1979-2008 period is somewhat weaker, see Tables I.B.3 and I.C.3, columns (9)-(10) and Tables II.B.2 and II.C.2, Panel B, columns (8)-(10).

[33] See Web Appendix Tables I.B.4 and I.C.4, Panel B, columns (3)-(4) and Tables I.B.6 and I.C.6, Panel A, columns (8)-(10).

[34] See Web Appendix Tables II.A.3, II.B.3, and II.C.3, columns (3)-(4) and Web Appendix Tables II.A.4, Table II.B.4, Table II.C.4, Panel A, columns (8)-(10).

also statistically insignificant, see columns (4)-(6). However, there is some evidence that civil war onset, although not incidence, follows low rainfall levels and negative rainfall shocks when I use Jensen and Gleditsch's definition and control for shocks to the probability of civil war that are common to all Sub-Saharan African countries.[35]

III. Conclusion

I have argued that to estimate the effect of economic shocks on civil conflict, it is critical to tailor the empirical approach to the shocks' persistence. To illustrate my point I have revisited Miguel, Satyanath, and Sergenti's (2004) study of the link between civil conflict and rainfall in Sub-Saharan Africa over the 1979-1999 period. They argue that *higher levels of rainfall are associated with significantly less conflict* (e.g. MSS, page 737). Put differently, MSS conclude that lower rainfall levels are associated with significantly more civil conflict. MSS explain this association by negative rainfall shocks reducing incomes and thereby increasing conflict risk. However, I find that according to MSS's data, lower rainfall levels and negative rainfall shocks (droughts) actually decrease the probability of civil conflict outbreak. Moreover, MSS's data also reject that civil conflict incidence—which subsumes conflict outbreak and conflict continuation—follows lower rainfall levels or negative rainfall shocks. MSS reach incorrect conclusions because their empirical work relates civil conflict to year-on-year rainfall growth and not rainfall levels, and because their empirical approach confounds (rainfall) shocks and mean reversion.

[35] See Web Appendix Tables I.B.4 and I.C.4, Panel B, columns (7)-(8) and Tables I.B.6 and I.C.6, Panel B, columns (8)-(10) for the 1979-2009 period. For the 1979-2008 period, see Web Appendix Tables II.A.3, II.B.3, and II.C.3, columns (7)-(8) and Tables II.A.4, II.B.4, and II.C.4, Panel B, columns (8)-(10).

MSS's (2004) analysis employs UCPD/PRIO conflict data and GPCP rainfall data for the 1979-1999 period. The latest versions of these databases have been extended to 2009. When I examine the link between rainfall and civil conflict incidence for the 1979-2009 period, results depend on the definition of civil conflict and the controls employed. Using MSS's definition of civil conflict, which includes participation in extraterritorial civil conflicts, there is no evidence that conflict incidence follows lower rainfall levels or negative rainfall shocks. Using Jensen and Gleditsch's (2009) definition of civil conflict, which excludes participation in extraterritorial conflicts, yields some evidence that civil conflict incidence follows lower rainfall levels and negative rainfall shocks when I control for lagged incidence and shocks to the probability of civil conflict that are common to all Sub-Saharan African countries. However, the 1979-2009 data always reject that civil conflict outbreak in Sub-Saharan Africa is more likely following lower rainfall levels or negative rainfall shocks.

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Tables

Table 1. Is it the case as argued by MSS (2004), that civil conflict is more likely following lower rainfall levels in MSS's datasets (which cover 1979-1999)?

Using civil conflict onset or civil conflict incidence?	**Is civil conflict more likely following lower rainfall levels?**
Civil conflict ONSET With consistent standard errors	NO Conflict is actually less likely following lower rainfall levels; see Table 2, column (2) in this paper
Civil conflict ONSET With consistent standard errors plus a small-sample adjustment	NO Conflict is actually less likely following lower rainfall levels; see Table 2, column (2) in this paper
Civil conflict INCIDENCE, without controls for lagged incidence With consistent standard errors	NO No statistically significant link; not shown
Civil conflict INCIDENCE, without controls for lagged incidence With consistent standard errors plus a small-sample adjustment	NO No statistically significant link; see Miguel and Satyanath (2010) Table R2 column (1)
Civil conflict INCIDENCE, with controls for lagged incidence and largest conflict sample Least-squares estimation with consistent standard errors	NO Conflict is actually less likely following lower rainfall levels; see Table 4, column (4) in this paper
Civil conflict INCIDENCE, with controls for lagged incidence and largest conflict sample Least-squares estimation with consistent standard errors plus a small-sample adjustment	NO Conflict is actually less likely following lower rainfall levels; see Table 4, column (4) in this paper
Civil conflict INCIDENCE, with controls for lagged incidence without civil conflict observations for 1980 Least-squares estimation with consistent standard errors	NO Conflict is actually less likely following lower rainfall levels; see Table 4, column (6) in this paper
Civil conflict INCIDENCE, with controls for lagged incidence without civil conflict observations for 1980 Least-squares estimation with consistent standard errors plus a small-sample adjustment	NO No statistically significant link; see Table 4, column (6) in this paper and Miguel and Satyanath (2010) Table R2 column (2)

Note. The small sample adjustment is explained on p.9 in the main text. Estimating the specifications with lagged incidence using system-GMM also rejects that civil conflict is more likely following lower rainfall levels (see Table 4, columns (3) and (7) in this paper).

Table 2. Rainfall and civil conflict onset: reexamining MSS (2004) using their data (which are for 1979-1999)

	(1)	(2)
Rainfall Growth, t	-0.063 (0.044) [0.048]	
Rainfall Growth, t-1	-0.120* (0.062) [0.068]	
Log Rainfall, t		-0.073 (0.078) [0.086]
Log Rainfall, t-1		-0.026 (0.069) [0.075]
Log Rainfall, t-2		0.156** (0.068) [0.074]
Country FE	Yes	Yes
Country Trend	Yes	Yes
Observations	555	555

Note: The left-hand-side variable is an indicator variable capturing civil conflict onset (see p.9 in the main text). The method of estimation is least squares. Standard errors in parentheses are robust for arbitrary heteroskedasticity and clustered at the country level. Standard errors in square brackets also apply the STATA small-sample adjustment (see p.9 in the main text). The civil conflict and rainfall datasets are those employed by MSS, and civil conflict is defined as in MSS (including participation in extraterritorial civil conflicts). *Significantly different from zero at 90 percent confidence, ** 95 percent confidence, *** 99 percent confidence. When the asterisks are next to the least-squares point estimate, the confidence level applies no matter which of the two standard errors is employed. When the asterisks are next to the standard error, the confidence level applies to that standard error only.

Table 3. Rainfall and civil conflict onset 1979-2009

	with participation in extraterritorial conflicts		without participation in extraterritorial conflicts	
	(1)	(2)	(3)	(4)
Rainfall Growth, t	-0.037 (0.029) [0.031]		-0.006 (0.026) [0.028]	
Rainfall Growth, t-1	-0.052 (0.033) [0.036]		-0.047 (0.029) [0.031]	
Log Rainfall, t		0.005 (0.041) [0.044]		0.017 (0.036) [0.038]
Log Rainfall, t-1		0.023 (0.042) [0.044]		-0.03 (0.039) [0.042]
Log Rainfall, t-2		0.074 (0.052) [0.056]		0.05 (0.049) [0.052]
Country FE	Yes	Yes	Yes	Yes
Country Trend	Yes	Yes	Yes	Yes
Observations	837	837	906	906

Note: The left-hand-side variable is an indicator variable capturing civil conflict onset (see p.9 in the main text). The method of estimation is least squares. Standard errors in parentheses are robust for arbitrary heteroskedasticity and clustered at the country level. Standard errors in square brackets also apply the STATA small-sample adjustment (see p.9 in the main text). The conflict data come from the UDCP/PRIO Armed Conflict Database Version 4-2010 and the rainfall data from the GPCP Combined Precipitation Dataset Version 2.1. Participation in extraterritorial civil conflicts is included in MSS's (2004) definition of civil conflict but excluded in Jensen and Gleditsch's (2009) definition (see p.8 in the main paper for details). *Significantly different from zero at 90 percent confidence, ** 95 percent confidence, *** 99 percent confidence. When the asterisks are next to the least-squares point estimate, the confidence level applies no matter which of the two standard errors is employed. When the asterisks are next to the standard error, the confidence level applies to that standard error only.

Table 4. Rainfall and civil conflict incidence: reexamining MSS (2004) using their data (which are for 1979-1999)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	LS	LS	GMM	LS	GMM	LS	GMM
						Dropping the first observation for each country	
Rainfall Growth, t	-0.024 (0.040) [0.043]	-0.025 (0.040) [0.043]	-0.017 (0.043)				
Rainfall Growth, t-1	-0.122** (0.048) [0.052]	-0.129** (0.048) [0.051]	-0.123** (0.049)				
Log Rainfall, t				-0.053 (0.060) [0.065]	-0.033 (0.063)	-0.062 (0.067) [0.073]	-0.026 (0.071)
Log Rainfall, t-1				-0.102 (0.069) [0.074]	-0.094 (0.066)	-0.074 (0.071) [0.077]	-0.069 (0.069)
Log Rainfall, t-2				0.128* (0.067) [0.072]	0.125* (0.064)	0.124 (0.069)* [0.074]	0.135** (0.067)
Lagged Incidence		0.277*** (0.077) [0.083]	0.282*** (0.077)	0.274*** (0.078) [0.084]	0.280*** (0.078)	0.276*** (0.082) [0.089]	0.285*** (0.083)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	743	743	743	743	743	702	702

Note: The left-hand-side variable is an indicator variable capturing civil conflict incidence (see p.9 in the main text). The method of estimation is least squares or system-GMM. Standard errors in parentheses are robust for arbitrary heteroskedasticity and clustered at the country level. Standard errors in square brackets also apply the STATA small-sample adjustment (see p.9 in the main text). The civil conflict and rainfall datasets are those employed by MSS, and civil conflict is defined as in MSS (including participation in extraterritorial civil conflicts). Columns (6)-(7) reestimate columns (4)-(5) after dropping the first observation for each of the 41 countries in the sample to obtain the sample employed by Miguel and Satyanath (2010) (see p.13 in the main text), *Significantly different from zero at 90 percent confidence, ** 95 percent confidence, *** 99 percent confidence. When the asterisks are next to the least-squares point estimate, the confidence level applies no matter which of the two standard errors is employed. When the asterisks are next to the standard error, the confidence level applies to that standard error only.

Table 5. Rainfall and civil conflict incidence 1979-2009

	with participation in extraterritorial conflicts				without participation in extraterritorial conflicts			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	LS	GMM	LS	GMM	LS	GMM	LS	GMM
Rainfall Growth, t	-0.044 (0.048) [0.050]	-0.047 (0.05)			-0.034 (0.049) [0.051]	-0.034 (0.053)		
Rainfall Growth, t-1	-0.04 (0.034) [0.036]	-0.045 (0.038)			-0.055* (0.03) [0.032]	-0.052 (0.033)		
Log Rainfall, t			0.04 (0.067) [0.071]	0.039 (0.07)			0.002 (0.057) [0.059]	0.000 (0.057)
Log Rainfall, t-1			0.059 (0.048) [0.051]	0.061 (0.05)			-0.015 (0.044) [0.046]	-0.017 (0.044)
Log Rainfall, t-2			0.076 (0.044)* [0.046]	0.084* (0.05)			0.049 (0.042) [0.044]	0.04 (0.047)
Lagged Incidence	0.369*** (0.057) [0.06]	0.369*** (0.057)	0.367*** (0.055) [0.058]	0.367*** (0.055)	0.352*** (0.062) [0.065]	0.352*** (0.062)	0.352*** (0.062) [0.065]	0.352*** (0.062)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Country Trend	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1179	1179	1179	1179	1179	1179	1179	1179

Note: The left-hand-side variable is an indicator variable capturing civil conflict incidence (see p.9 in the main text). The method of estimation is least squares or system-GMM. Standard errors in parentheses are robust for arbitrary heteroskedasticity and clustered at the country level. Standard errors in square brackets also apply the STATA small-sample adjustment (see p.9 in the main text). The conflict data come from the UDCP/PRIO Armed Conflict Database Version 4-2010 and the rainfall data from the GPCP Combined Precipitation Dataset Version 2.1. Participation in extraterritorial civil conflicts is included in MSS's (2004) definition of civil conflict but excluded in Jensen and Gleditsch's (2009) definition (see p.8 in the main paper for details). *Significantly different from zero at 90 percent confidence, ** 95 percent confidence, *** 99 percent confidence. When the asterisks are next to the least-squares point estimate, the confidence level applies no matter which of the two standard errors is employed. When the asterisks are next to the standard error, the confidence level applies to that standard error only.

Table 6. Rainfall and civil war onset or incidence 1979-2009

	with participation in extraterritorial wars			without participation in extraterritorial wars		
	(1) Onset LS	(2) Incidence LS	(3) Incidence GMM	(4) Onset LS	(5) Incidence LS	(6) Incidence GMM
Log Rainfall, t	-0.029 (0.03) [0.032]	-0.039 (0.045) [0.047]	-0.048 (0.053)	-0.028 (0.022) [0.024]	-0.052 (0.04) [0.042]	-0.06 (0.049)
Log Rainfall, t-1	0.051 (0.03)* [0.032]	0.039 (0.032) [0.034]	0.038 (0.032)	0.024 (0.026) [0.027]	0.016 (0.028) [0.029]	0.016 (0.027)
Log Rainfall, t-2	-0.006 (0.026) [0.026]	0.02 (0.035) [0.036]	0.024 (0.04)	-0.023 (0.023) [0.024]	-0.007 (0.03) [0.032]	-0.006 (0.034)
Lagged Incidence		0.416*** (0.051) [0.054]	0.416*** (0.051)		0.335*** (0.074) [0.078]	0.334*** (0.066)
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Country Trend	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1036	1179	1179	1070	1179	1179

Note: The left-hand-side variable is an indicator variable capturing civil war onset or incidence (see p.9 in the main text). The method of estimation is least squares or system-GMM. Standard errors in parentheses are robust for arbitrary heteroskedasticity and clustered at the country level. Standard errors in square brackets also apply the STATA small-sample adjustment (see p.9 in the main text). The conflict data come from the UDCP/PRIO Armed Conflict Database Version 4-2010 and the rainfall data from the GPCP Combined Precipitation Dataset Version 2.1. Participation in extraterritorial civil conflicts is included in MSS's (2004) definition of civil conflict but excluded in Jensen and Gleditsch's (2009) definition (see p.8 in the main paper for details). *Significantly different from zero at 90 percent confidence, ** 95 percent confidence, *** 99 percent confidence. When the asterisks are next to the least-squares point estimate, the confidence level applies no matter which of the two standard errors is employed. When the asterisks are next to the standard error, the confidence level applies to that standard error only.