Extreme Weather and Civil War: Does Drought Fuel Conflict in Somalia through Livestock Price Shocks?

Jean-François Maystadt and Olivier Ecker

A growing body of evidence shows a causal relationship between extreme weather events and civil conflict incidence at the global level. We find that this causality is also valid for droughts and local violent conflicts in a within-country setting over a short time frame in the case of Somalia. We estimate that a one standard deviation increase in drought intensity and length raises the likelihood of conflict by 62%. We also find that drought affects conflict through livestock price changes, establishing livestock markets as the primary channel of transmission in Somalia.

Key words: Civil war, conflict, drought, Horn of Africa, livestock, pastoralism, price, Somalia.

JEL codes: D74, O12, Q11, Q54.

Extreme weather events have grown more frequent since the middle of the 20th century, and their frequency will likely increase throughout the 21st century due to global climate change (Intergovernmental Panel on Climate Change 2012). In particular, the number and length of warm weather spells and the frequency of extreme precipitation events have increased globally, as well as in the Horn of Africa, causing more and more intense droughts. In 2011, after consecutive years of irregular and failing seasonal rainfall, Somalia experienced its most destructive drought in 50 years (Maxwell and Fitzpatrick 2012).[1] At the peak of the resulting famine, four million Somalis were in need of emergency assistance, with 750,000 people at imminent risk of starvation (Food Security and Nutrition Analysis Unit and Famine Early Warning Systems Network 2011).

Somalia has also been shaken by an ongoing civil war since 1991, and since 2002 violent disputes have become more frequent (Armed Conflict Location and Event Dataset 2011). The coexisting trends of increasing civil war intensity and increasing weather extremes in recent years (Lyon and DeWitt 2012; Omondi et al. 2013; Williams et al. 2012) raise the fundamental question about a possible relationship between violent conflict and drought in Somalia. In a recent meta-analysis, Hsiang, Burke, and Miguel (2013) found strong evidence for general causality and a substantial influence of climate on past conflicts. Globally, intergroup conflicts (such as civil war) rose by 14% with each one standard deviation change in climate

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[1] The 2011 drought was likely caused primarily by exceptional warming of the sea surface water in the Indian and western Pacific Oceans, leading to poor and failing rainfall in the Horn of Africa (Funk 2012; Lyon and DeWitt 2012; Williams and Funk 2011).

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toward higher temperatures or more extreme rainfall; projected temperatures by 2050 for most parts of Somalia correspond to an increase of three standard deviations (Hsiang, Burke, and Miguel 2013).

There is also convincing evidence that temperature extremes and rainfall variability have contributed to civil war across Africa and particularly in East Africa. Hsiang, Meng, and Cane (2011) found that El Niño/Southern Oscillation (causing warmer and dryer weather in the continental tropics) may have had a role in 21% of all civil conflicts since 1950. Burke et al. (2009) estimate that a rise in temperature of one degree Celsius increased the likelihood of internal armed conflicts in sub-Saharan African countries by 4.5% in the same year, and 0.9% in the next year. Combining these estimates with temperature projections suggests a 54% increase in the likelihood of armed conflict by 2030 (Burke et al. 2009). For East Africa, O'Loughlin et al. (2012) show that abnormally high temperatures raise the risk of violent conflict, and Raleigh and Kniveton (2012) show that the frequency of rebel and communal conflict events increases in periods of extreme rainfall variation.

Although these studies suggest that the stability of societies relates strongly to the global climate (Hsiang, Burke, and Miguel 2013; Hsiang, Meng, and Cane 2011) and indicate the urgent need to reform governmental (and development partner) policies to better cope with the impact of climate change (Burke et al. 2009), the studies nonetheless reveal little about the mechanisms that translate extreme climate conditions into conflict incidence. However, identifying the key factors that link people's motivation for conflict participation to variation in climatic variables and estimating the causal effects are critical for formulating both effective climate change mitigation and conflict prevention policies (Schreffan et al. 2012).

Economic behavior is often used to explain people's incentives to participate in violent conflict, following the seminal work by Collier and his coauthors on the causes of civil war (Collier and Hoeffler 1998, 2004; Collier and Sambanis 2002). Probably the most robust finding in the conflict literature is that slow economic growth and low per capita income contribute to civil conflict (Blattman and Miguel 2010). Collier and Hoeffler (1998, 2004) also found that economic opportunities such as expected income from being a fighter relative to ordinary labor market rates motivate people to participate in conflict rather than political and social grievances such as the repression of specific social groups and societal inequality. Findings on the roles of ethnic or religious fractionalization (Easterly and Levine 1997; Fearon and Laitin 2003), natural resource dependency (Humphreys 2005; Brunnschweiler and Bulte 2009), and degree of democracy (Elbadawi and Sambanis 2002; Hegre et al. 2001) as drivers or preventers of civil conflict are inconsistent.

The economic model introduced by Collier and Hoeffler (1998, 2004) that explains changes in conflict incidence by changes in economic conditions has been expanded by several authors to establish a link to weather shocks, assuming causality between the exogenous weather variable(s) and the endogenous economic variable(s) (e.g., Dell, Jones, and Olken 2012; Kurukalasuriya et al. 2006; Schlenker and Lobell 2010). Methodologically, this approach offers an appealing solution for addressing the endogeneity of economic variables to conflict, and for dealing with omitted variable problems in econometric estimations. Using rainfall variation as an instrument for gross domestic product (GDP) growth, Miguel, Satyanath, and Sergenti (2004) estimate that a negative growth shock of five percentage points increases the likelihood of conflict across Sub-Saharan Africa by about 50% in the subsequent year.[2] Similarly, Brückner (2010) uses rainfall-based variables as instruments to estimate the effects of GDP growth and population growth on conflict globally. The methodological approach of our analysis follows this strand of the literature.

We hypothesize that droughts fuel local violent conflict in Somalia. Given that we find causal statistical evidence for the hypothesized drought-conflict relationship, we explore the primary channel of transmission. We adopt an economic perspective and assume that opportunity costs determine conflict participation. Since the livestock sector

[2] The robustness of Miguel's, Satyanath's, and Sergenti's (2004) estimation results have been subject to an intense debate between Ciccone (2011) and Miguel and Satyanath (2011). For similar reasons, Buhaug (2010) questions Burke et al.'s (2009) estimation results. Couttenier and Soubeyran (2013) revisited Miguel's, Satyanath's, and Sergenti's analysis, and applied an improved method for identifying extreme weather shocks. Klomp and Bulte (2013) provide a comprehensive overview of the debate. The arguments of the debate have motivated some of our robustness checks.

is the mainstay of Somalia's economy and the main source of livelihood for most Somalis, we posit that civil conflict links to drought primarily through effects unfolding in the livestock market. Specifically, we hypothesize that drought-induced downturns in livestock prices explain increases in conflict incidence. The objectives of our article are to test these hypotheses, to estimate the partial effects of the hypothesized links econometrically, to predict the likely conflict impact of projected temperature increases based on the estimates, and to derive policy-relevant conclusions from the results.

Our article makes three important contributions to the literature. First, we establish that the causal relationship between weather extremes and conflict holds at the local level and for a relatively short time frame (a little more than a decade) in the case of Somalia. We analyze variation in conflict incidence at the subnational level, which has been left unobserved in most cross-country studies in the conflict literature (e.g., Collier and Hoeffler 1998, 2004; Fearon and Laitin 2003). Second, we present a possible key mechanism through which drought translates into conflict incidence in Somalia. Our article expands upon the conflict literature by examining livestock price shocks, thereby shedding light on the impact that local producer prices have as incentive factors of conflict participation (e.g., Brückner and Ciccone 2010; Dube and Vargas 2013; Maystadt et al. 2013). Such context-specific insights may help to formulate effective policies for conflict prevention and climate change adaptation. Third, our article may be conducive to understanding the drivers of Somalia's persistent civil war. Several scholars (e.g., Leeson 2007; Mubarak 1997) consider the poor socio-economic conditions resulting from the country's statelessness since 1991 to be the main cause of the continuing conflict. We emphasize the critical role of the livestock sector, which has become more profitable but also more contested and more vulnerable to market shocks after the collapse of the repressive regime in 1991 (Little 2003; Powell, Ford, and Nowrasteh 2008). We contribute to the debate by proposing that drought-caused livestock price shocks are a main driver of local conflict.

The rest of the article is organized as follows. The next section provides contextual information on the links between drought, livestock prices, and civil conflict in Somalia, and thus establishes the rationale underlying our empirical analysis. The third section explains our identification strategy and estimation framework and describes the dataset and the construction of the variables used in the estimation model. The fourth section then presents the estimation results of our preferred model specification and the results of the simulation. The fifth section discusses the results of our robustness checks and the validity of the identifying assumptions of the estimation model, and the last section concludes with policy implications.

Study Context and the Conflict-drought Relationship

Since the collapse of the Somalian national state and the outbreak of civil war in 1991, there has been no central government control over the entire territory of Somalia. The country has been divided into at least three (semi-)autonomous territories on a de facto basis: Somaliland in the northwest, Puntland in the northeast, and the remainder of Somalia in the central and southern region, with its capital Mogadishu. While violent conflicts have occurred all over the country, most of them have taken place in the central-southern regions of the country, where the Islamist Al-Shabab militia has been most active (figure 1).

Despite the absence of effective national governance since the collapse of the repressive regime in 1991, Somalia has maintained a functioning informal economy dominated by livestock rearing and exports, remittance inflows and money transfers, and telecommunications (Powell, Ford, and Nowrasteh 2008; World Factbook 2011). Traditionally, the livestock sector has been central to the economic and cultural life of Somalis. The livestock sector contributes officially to approximately 40% of GDP and accounts for almost 90% of total agricultural GDP and more than half of all exports (Knips 2004; World Factbook 2011). The sector has also been a major contributor to the thriving unofficial economy thanks to unregistered (illegal) livestock exports to neighboring Kenya and Ethiopia, which have far exceeded official exports (Jamal 1988; Little 2005). The livestock sector provides food and income to over 60% of the total population (FSNAU 2011a).

Approximately two-thirds of the Somalian population resides in rural areas

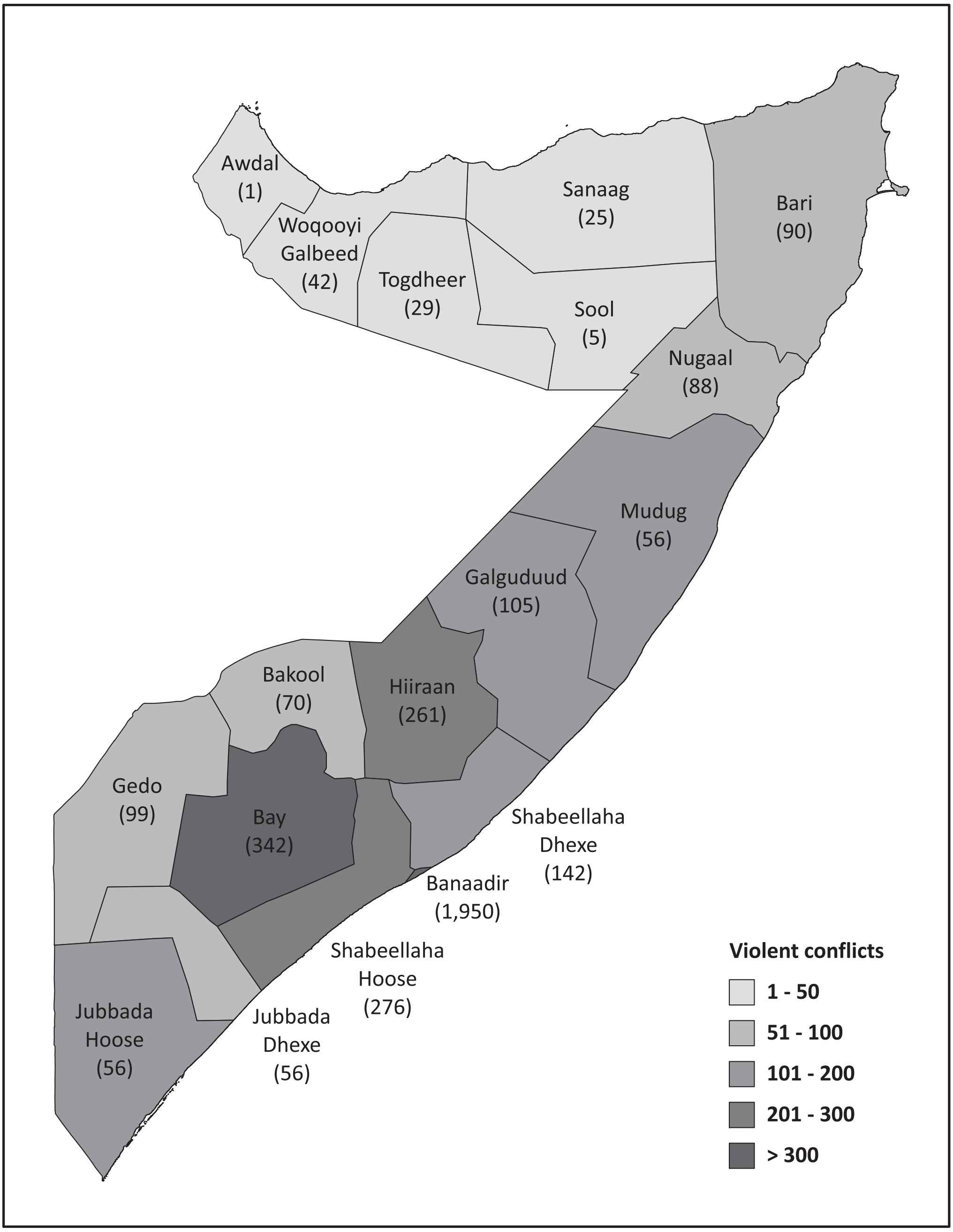

Figure 1. Number of violent conflicts by administrative region, 1997–2009

Source: Authors' presentation based on ACLED (2011).

(FSNAU 2011a). Pastoralism (nomadism) or semi-pastoralism is the main source of livelihood for most rural Somalis. Many urban dwellers earn their income as livestock traders, brokers, or laborers in related activities (Little 1992, 1996). Purely pastoral livelihoods prevail in northern and central Somalia, and agro-pastoral livelihoods are predominant in the southern part (table 1). Goat and sheep herds are more common in the northern regions than in the southern regions, whereas cattle and camel density

Table 1. Population Share by Administrative Region and Livelihood System (percentages)

	Pastoralists	Agro-pastoralists	Agriculturalists
Northwest (Somaliland)			
Awdal	38	25	0
Woqooyi Galbeed	20	10	0
Togdheer	64	5	0
Sanaag	71	0	3
Sool	74	0	0
Northeast (Puntland)			
Bari	53	0	0
Nugaal	58	0	0
Central			
Mudug	64	9	0
Galgaduud	64	18	0
South			
Hiraan	28	41	10
Middle Shabelle	43	7	31
Lower Shabelle	10	56	14
Banaadir	0	0	0
Bakool	10	70	0
Bay	0	80	0
Gedo	48	18	10
Middle Juba	22	23	32
Lower Juba	32	21	15

Source: Authors' calculation based on 2005 UNDP estimates in FSNAU (2011).

is higher in the southern regions (FSNAU 2011a).

Somalia is highly vulnerable to weather shocks—particularly droughts, but also floods—because of its geographic location and fragile environments (FSNAU 2011a). Drought is not unusual in Somalia; it is a recurring feature of the country's climate. Nonetheless, prolonged and consecutive droughts have been major threats to the local economy—particularly to the livestock sector—and to rural livelihoods in Somalia (Mubarak 2007). Moreover, weak credit and insurance markets make formal mechanisms to cope with shocks difficult to trust, and public safety nets are absent (Headey, Seyoum Taffesse, and You 2014).

Drought mitigation strategies are often limited to clan-based support, migration, and selling productive assets (Dercon and Hoddinott 2004; Lybbert et al. 2004; Mogues 2011). However, the capacity of the traditional support system is very limited when major droughts strike, since drought is a large-area disaster such that a large share of the population faces the same fate at the same time. Further, distant migration involves substantial costs such as transportation of livestock and household assets and is usually ineffective because of already overstretched rangeland resources at the destination. Destocking herds is therefore the dominant and often the only remaining strategy to avoid hunger, but all too frequently it is of limited effectiveness and pushes herder households into a poverty trap (Carter and Barrett 2006; Carter et al. 2007; McPeak and Barrett 2001).

Widespread poverty and a lack of employment create a fruitful environment for extremist groups like Al-Shabab (or other conflict parties) to recruit fighters by offering cash and other benefits (Majid and McDowell 2012). Engaging in civil conflict to earn a living at the expense of others (either directly as a fighter or indirectly as a supporter of one or the other party) may appear opportunistic for some people. Such self-seeking behavior tends to be amplified in times of unusual hardship—for example, when experiencing serious income losses from droughts—and facilitated by the political economy of the stateless order as in most parts of Somalia (Leeson 2007; Mubarak 1997; Powell, Ford, and Nowrasteh 2008). Anecdotal evidence from the 2011-2012 famine supports this notion. For example, a representative of the United Nations

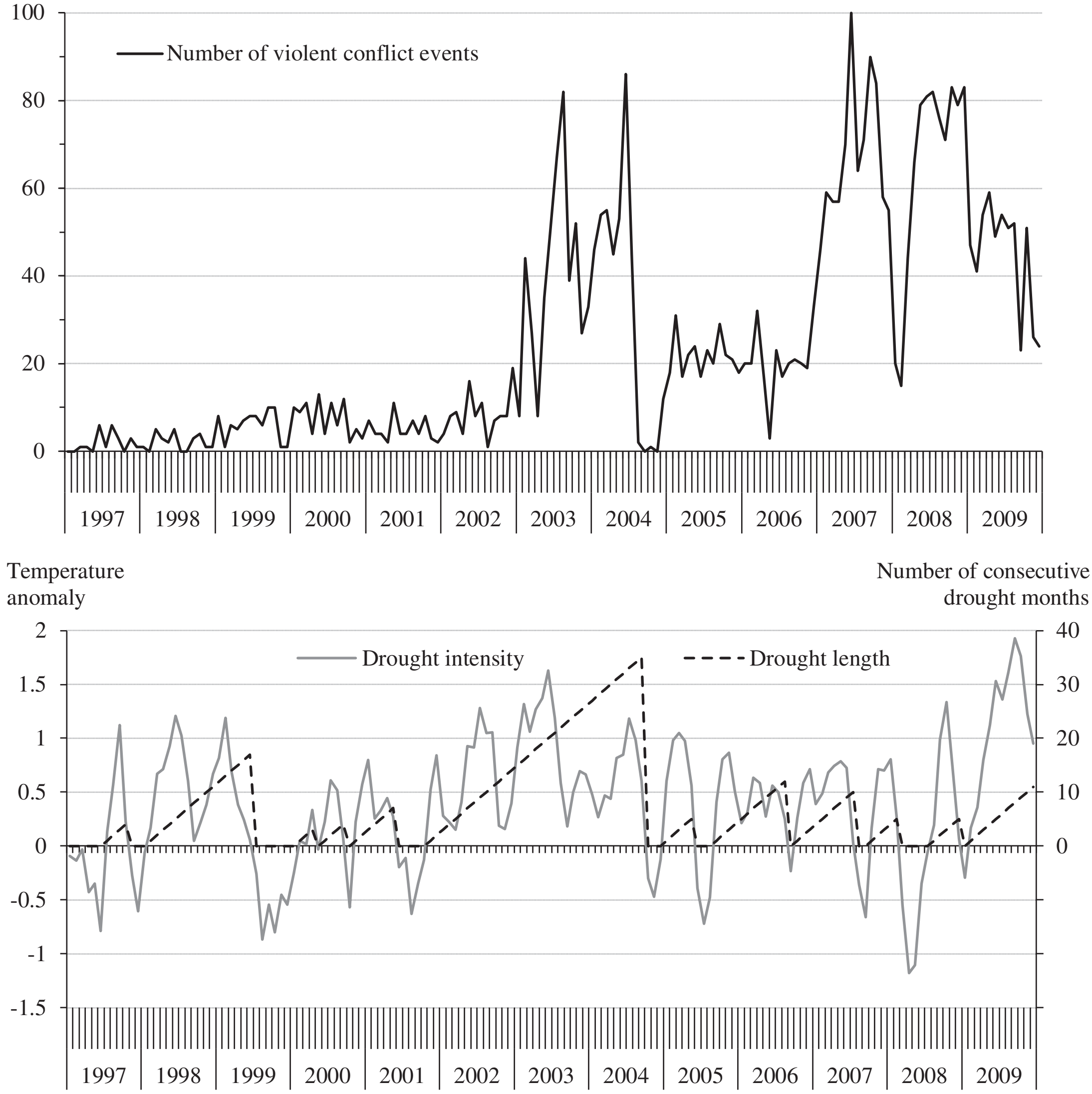

Figure 2. Frequency of conflict and drought intensity and length in Somalia, by month

Source: Authors' presentation based on own estimates.
Note: Indicators are calculated at the national level. The subsection "data and variable description" explains the methodology.

Refugee Agency in Somalia states that "This [famine] has been a boon for Al-Shabab's recruitment campaign because when you don't have purchasing power to buy the food, you will be encouraged to be recruited because then you will be saved, and you can use that salary or you could be given food" (Heilprin 2011). Interviews with Al-Shabab deserters reveal that the Islamist militia uses a combination of cash payments, promises of regular salaries, and threats of force in their recruiting tactics (Baldauf and Mohamed 2010).

Conflict and Drought Trends

Both droughts and violent conflicts have become more frequent in Somalia in recent years (figure 2). Although Somalia was frequently hit by major droughts in the 1970s and 1980s, the number of affected people was much higher in the 2000s; the 2008 famine alone affected 3.3 million people (Emergency Events Database 2012). Between 1997 and 2009, most outbreaks of violence occurred during two periods—from mid 2003 to mid 2004, and from early 2007 to late 2009.

Both periods featured several peaks of more than 80 conflict events per month. These high-intensity conflict periods overlapped with periods of major droughts, characterized by abnormally high temperatures over several consecutive months. Overall, drought intensity and drought length are correlated with the number of violent conflict events between 1997 and 2009, showing coefficients of 0.14 and 0.19, respectively.[3]

The Livestock Market Channel

Drought causes herders to sell more of their livestock than under normal conditions because of fodder and water shortages, as well as increased cash needs for fodder purchases or transporting animals to fertile grazing land (Abebe et al. 2008; Box 1971; Morton and Barton 2002). Destocking herds can be expected to follow an empirical, egoistic rationale, considering a variety of interconnected factors such as available fodder and water capacities, livestock sale prices, herd restocking requirements, and household consumption needs (Kassahun, Snyman, and Smit 2008; McPeak 2006; Morton and Barton 2002). However, the slow onset of drought (as opposed to other natural disasters, including floods) combined with the large spatial spread of its impact provoke similar, contemporaneous destocking behavior among herders, which leads to collapsing livestock prices and thereby hurts herders collectively.[4]

Drought is a recurring feature in Somalia's climate. Thus, herders know well that fodder and water shortages may kill some of their animals—usually the weaker ones first. Weaker animals may also carry less preferential genetic makeup for restocking after the drought such as lower milk and meat production, fertility, and drought resistance (Aklilu and Catley 2009; Aklilu and Wekesa 2002). Hence, selling low-productivity animals may be the first step in the herd destocking process. Considering the risk of livestock losses, herders tend to hedge against drought by keeping larger numbers of animals than are needed for production (Box 1971).

Lean animals merit lower prices than well-fed ones, whereas only well-fed, mature animals can be sold for export (Little 1992). An oversupply of low-quality animals depresses prices in local consumer markets. At the outset of drought, livestock prices for export quality may also drop due to oversupply caused by herders rushing to sell their well-fed animals before they lose weight and thus the high-quality premium. The deterioration of cattle body conditions during the 2010–2011 drought, for example, led to a drop in cattle prices in southern Somalia by 30–50% within four months (September–December 2010). The resulting loss in livestock income, in combination with cereal price spikes, reduced average purchasing power in the southern regions by 40–60% within one year (FSNAU 2011a).

Escaping plummeting local livestock prices is difficult, particularly during drought. Herding the animals to distant markets—which possibly offer higher prices—further reduces animal weights and value (and may even kill some animals), whereas transportation by truck is often unprofitable or unaffordable for most herders. In addition, given that livestock markets are empty or thin after droughts and that herders face lack of cash, they may prefer to hold on to large herds as long as possible for rapid post-drought production and herd restocking. It is important to note that herd size determines the herding system and hence the way a herder lives (Devereux 2006; Lybbert et al. 2004). In neighboring Ethiopia's Somali region, Lybbert et al. (2004) found a threshold level for cattle herds at an unstable equilibrium of 10–15 animals for a typical transhumant herder household of 6–6.5 members. Thus, two-plus cattle per household member are necessary to sustain the opportunistic, spatially flexible herding lifestyle associated with extensive pastoralism. When a household's herd size falls below this threshold level, the household effectively switches to a sedentarized herding system, but in so doing it becomes much more vulnerable to spatiotemporal variability in rainfall and provides lower returns. Hence, maintaining a herd of any size becomes exceedingly difficult, meaning that sedentarization with a small herd corresponds to dire poverty in pastoralist communities (Lybbert et al. 2004). Accordingly, agropastoralists are particularly

[3] The subsection "data and variable description" explains the construction of the drought intensity and length variable.

[4] In contrast, floods occur rapidly and the damage is much more localized. The effects on the livestock market can be expected to differ fundamentally from the effects of drought and to be less pronounced overall. This, in addition to the differing scope of the disasters' impact on Somalis' well-being, prompted us to limit our study to the analysis of droughts.

vulnerable to failing rainfall, mainly because of their inability to reach sufficient grazing land during droughts (Headey, Seyoum Taffesse, and You 2014).

A survey among pastoralist households in Ethiopia's Somali region revealed that drought, aridity, and rangeland degradation have increased over the past 40 years due to environmental degradation and the mismanagement of rangeland resources (Kassahun, Snyman, and Smit 2008). Traditional coping mechanisms were reported to be failing due to recurrent droughts and desertification. Moreover, all interviewed elderly people recognized an increase in poverty, and 60% of them perceived more conflicts (Kassahun, Snyman, and Smit 2008). In addition to competition over access to grazing land and water sources and disputes from livestock thefts, struggles for control over the livestock trade and its profits have traditionally been causes of violent conflict (Little 1996; Meier, Bond, and Bond 2007; Samatar 1992).

Methodology and Data

Identification Strategy

Our estimation of the effects of drought on local violent conflict through livestock price shocks follows a clear identification strategy. We begin by estimating cross-sectional and inter-temporal variation in conflict incidence as a function of drought (hereafter referred to as "reduced-form" estimation) to detect the hypothesized conflict-drought relationship. Given that we find a statistically significant relationship, we then explore the possible channel through which drought translates into conflict incidence, assuming that people's motivation to participate in violent conflicts is essentially driven by economic means. Along with Miguel, Satyanath, and Sergenti (2004), we adopt the opportunity costs approach according to which income losses—caused by an external shock—lower the opportunity costs of engaging in conflict-related activities. Hence, the deciding factor of an individual's behavior is the current household income from ordinary activities relative to expected income from conflict participation.

Given the large contribution of livestock rearing to (rural) income earnings and given our lack of household income (and expenditure) data, we use changes in livestock prices as a proxy for changes in household incomes. We use livestock prices for export quality (instead of prices for local quality) because the former tend to be less influenced by local demand.[5] Our hypothesis that producer prices for key exports matter for conflict is generally supported by Brückner and Ciccone (2010), who found that civil wars in sub-Saharan Africa are more likely to erupt after downturns in the international price of the countries' main export commodities. Further, Dube and Vagas (2013) show for Colombia that the sharp fall in international coffee prices during the late 1990s led to an increase in violent conflict in coffee-dependent municipalities.

We use a two-stage estimation framework to estimate the drought effects on conflict transmitted through changes in livestock prices. The challenge of our identification strategy is to isolate this livestock market channel from all other possible channels of transmission. Since we may not be able to fully exclude all other potential channels due to a lack of data, we perform a comprehensive set of robustness checks on our preferred model specification and validate our identifying assumptions.

Our estimation model requires us to deal with endogeneity and potential problems of omitted variables and measurement errors. The causality between conflict and economic well-being may actually run in both directions: income shocks increase the likelihood of conflict (as outlined above), and exposure to conflict can be a shock to income earnings. For example, conflicts may destroy transportation infrastructure or diminish productive assets through livestock thefts, thereby causing higher producer costs and income losses (Bundervoet 2010; Devereux 2006; Verpoorten 2009). A standard solution

[5] Livestock prices—especially for export quality—can be expected to be largely supply-driven in Somalia. Domestic and foreign demand for livestock is fairly stable throughout the year, except before the Muslim holidays. The number of exported live sheep and goats during the Hajj month is a multiple of the monthly exports during the rest of the year, while the increase in cattle export is less pronounced (FSNAU 2011a). Over the past two decades there have been two major demand-side shocks that had important knock-off/on effects on the livestock sector. Because of an outbreak of the Rift Valley Fever and concerns about inappropriate health screening, Saudi Arabia—the major importer of livestock from Somalia—imposed a ban on live animal and meat imports from the Eastern Africa region from February 1998 to April 1999, reestablished it in September 2000, and lifted it in November 2009, before the Hajj.

for addressing the endogeneity problem in econometric estimations is an instrumental variable approach. Weather-related variables such as changes in temperature or precipitation appear to be plausible instruments for changes in household income and prices of agricultural products in subsistence-based economies.

Omitted variable biases may arise from unobserved factors that affect both our proxy for household incomes (livestock prices) and the conflict variable. Examples include historical grievances among and between pastoralist and agropastoralist communities, social or ethnic fragmentation of the population, population density, institutional conditions, transportation infrastructure, geography, and so on. We address the potential problem of omitted/unobserved variables in a general manner by controlling for region-fixed and time-fixed effects in both the reduced-form and two-stage estimations. The region-fixed effects variables pick up time-constant, unobserved heterogeneity across regions, including region-specific factors of conflict and livestock market pricing such as colonial vestiges and ethnic composition of the population, and market structure. The time-fixed effects variables control for external shocks that affect all of Somalia similarly, for example Saudi Arabia's livestock import ban (imposed in 2000 and lifted in 2009). We also introduce a set of interaction terms in both the reduced-form estimation and the two-stage estimation that control for region-specific month-fixed effects such as locally differing patterns of conflict seasonality that are unexplained by the independent variables.

Estimation Framework

The reduced-form regression of our preferred model specification has the following estimation equation:

$$\text{(1)} \qquad conflict_{i,m,y} = c + \alpha\, TA_{i,m,y} + \beta\, PA_{i,m,y} + \gamma\, DL^{TA}_{i,m,y} + \mathbf{\Phi}_i + \mathbf{\Psi}_{m,y} + \mathbf{\Omega}_{i,m} + \varepsilon_{i,m,y}.$$

The dependent variable in equation 1 is the number of violent conflict events in Somalia's administrative region during the month-year (m, y) time period $(conflict_{i,m,y})$. The main deterministic variables identify region- and time-specific temperature and precipitation anomalies $(TA_{i,m,y}, PA_{i,m,y})$ and drought length is defined based on temperature anomaly $(DL^{TA}_{i,m,y})$.[6] Region-fixed effects are captured by a vector of region-identifying dichotomous variables $(\mathbf{\Phi}_i)$. Time-fixed effects enter the function through a vector of dichotomous variables for each time period in the sample $(\mathbf{\Psi}_{m,y})$, and region-specific month-fixed effects enter through a vector of dichotomous variables for each region-month pair $(\mathbf{\Omega}_{i,m})$. The constant term is c, and $\varepsilon_{i,m,y}$ is a disturbance term. The disturbances are allowed to be correlated across time periods for the same region and over space between neighboring regions.

The preferred level of analysis is administrative regions, which is the highest subnational administrative level. Given an insufficient number of upper-level administrative units for clustering standard errors, we adjust standard errors for spatial and time dependency of an unknown form (Conley 1999) by adopting Hsiang's (2010) procedure. We assume that spatial dependency disappears beyond a cutoff point of 263 kilometers, which corresponds to the maximum distance between the centroids of any pair of neighboring regions.[7] We also allow for time dependency for up to four months, which corresponds to approximately the number of time periods raised to the power of 0.25, as recommended by Green (2003) and Hsiang (2010).

To explore the livestock market channel, we decompose the conflict-drought relationship implied by equation 1 into two stages, using livestock prices as the variable of transmission. Technically, we estimate an instrumental variable, two-stage least-squares fixed-effect (IV-2SLS-FE) model with standard errors that are robust to spatial and temporal correlation. Along with previous works applying similar estimation frameworks (e.g., Brückner 2010; Brückner and Ciccone 2010; Miguel, Satyanath, and Segenti 2004), we use a linear 2SLS specification. Linear models are preferable to non-linear

[6] The subsection "data and variable description" explains the construction of the main deterministic variables and gives the rationale of their inclusion.

[7] The equivalent cutoff point of the alternative district-level estimation is 163 kilometers. The region-level estimation yields similar results using cutoff points of 158 kilometers (which is the average distance between neighboring regions) and 597 kilometers (which is the average distance between all regions).

approaches, since the latter require unrealistically strong model assumptions (Angrist and Krueger 2001; Wooldridge 2002).[8] To adjust standard errors for spatial and temporal correlation, we apply the same method as in the reduced-form estimation.

The first-stage equation estimates the effects of abnormal temperatures and drought length on livestock prices and thereby provides statistical evidence on the strength of these drought-identifying variables as instruments of livestock prices. The first-stage equation of our preferred model specification is:

$$(2)\qquad \ln P^{L}_{i,m,y} = c_1 + \alpha\, TA_{i,m,y} + \beta_1\, PA_{i,m,y} + \gamma\, DL^{TA}_{i,m,y} + \boldsymbol{\Phi}_{i_1} + \boldsymbol{\Psi}_{m,y_1} + \boldsymbol{\Omega}_{i,m_1} + \varepsilon_{i,m,y_1}$$

where $P^{L}_{i,m,y}$ denotes the region- and time-specific price index of livestock L. The second-stage equation, which yields the effects of livestock prices on the number of conflict events, is then:

$$(3)\qquad conflict_{i,m,y} = c_2 + \delta \ln \widehat{P^{L}_{i,m,y}} + \beta_2\, PA_{i,m,y} + \boldsymbol{\Phi}_{i_2} + \boldsymbol{\Psi}_{m,y_2} + \boldsymbol{\Omega}_{i,m_2} + \varepsilon_{i,m,y_2}.$$

Both the first-stage and second-stage equation include precipitation anomaly ($PA_{i,m,y}$) to control for potential additional weather effects that arise from abnormal rainfall and are not captured by the temperature-based drought variables.

The reduced-form and two-stage estimation work in differences and therefore explain variations within regions over time (i.e., deviations from the region means) rather than cross-region differences in levels. Hence, these estimations explain what *drives* changes in conflict incidence rather than what *causes* conflict.

In addition to interpreting the results of our estimations, we use the estimated coefficients of the preferred model specification to simulate the effects of increasing drought on conflict incidence. We run two simulations: The first simulation assumes increases of temperature anomaly and drought length by one standard deviation each. The second simulation yields a range of changes in conflict incidence due to increases in temperature anomaly that correspond to temperature changes as projected by global climate models for Eastern Africa by 2030 under established climate scenarios.[9] We keep the drought length constant—which yields lower-bound estimates of the combined effect of drought intensity and length—and assume no adjustment in the response of conflict incidence and livestock prices to a trend of increasing temperatures, which results in higher estimates with lower variance, as if some sort of adaptation is assumed.

Data and Variable Description

Our estimations are based on monthly panel data distinguished by administrative region for the preferred model specification (and distinguished by district for an alternative model specification as a robustness check). Somalia has 18 administrative regions (and 74 districts), and the time frame of our analysis ranges from January 1997 to December 2009, yielding a total of 2,808 (and 11,544) panel observations (in the reduced-form regression). Our dataset is compiled from three different data sources.

The conflict variable is constructed as the sum of violent conflict events in each administrative unit per month, using the Armed Conflict Location and Event Dataset (ACLED 2011). A conflict event is defined as a single altercation, where force is used by one or more groups for a political end (Raleigh et al. 2010). The ACLED reports 4,260 conflicts in Somalia between 1997 and 2009, of which 3,870 events were violent (including battles between conflict groups and violence against civilians).

The weather variables—temperature and precipitation anomaly and drought length—are constructed from climatic data provided

[8] In addition, Imbens and Angrist (1994) show that using a non-linear model instead of a linear 2SLS specification does not lead to any improvement in identifying the average partial effect that we are interested in. Non-linear models may also yield biased estimates in a panel framework setting with relatively rare events such as conflict incidence in our analysis. The method to account for the bias—proposed by King and Zeng (2001)—is difficult to implement because of convergence problems (Arezki and Brückner 2011). Furthermore, a procedure for adjusting standard errors for spatial and temporal correlation in non-linear panel data models is still unavailable.

[9] Table 1 of the online appendix shows the projected temperature changes and the corresponding temperature anomaly changes (which we estimated from the temperature projections) by climate model and scenario.

by the University of East Anglia Climatic Research United (UEA-CRU 2011). The UEA-CRU time-series datasets, version 3.1, report average temperatures and total precipitation by months at data points of a high-resolution grid (of 0.5×0.5 degree or approximately $56\,\text{km} \times 56\,\text{km}$ at the equator), which are based on measurements from weather stations distributed around the world (Harris et al. 2012; Mitchell and Jones 2005). Consistent with most climate simulation studies (e.g., IPCC 2012), we use monthly averages of daily maximum temperatures in our preferred model specification, which capture temperatures at daytime when evaporation is highest (and monthly averages of daily mean temperatures in an alternative model specification). We transform the gridded UEA-CRU temperature and precipitation data to one (centered) data point by administrative unit, using a spatial interpolation method ("kriging") inbuilt in ESRI ArcGIS.

Drought differs from aridity and must be distinguished from high temperatures and low rainfall as such. Drought is a temporary weather aberration, whereas aridity is a stable climatic condition. Hence, drought is characterized by a deviation from normal weather conditions. Drought is a phenomenon of (at least) abnormally high temperatures that cause unusually high evaporation, combined with abnormally low or failing rainfall.[10] Therefore, we include both temperature- and precipitation-based variables in our estimations, but we focus on temperature-based variables as indicators of drought and use a precipitation-based variable to control for potential additional effects that might arise from abnormal rainfall alone. Temperature variations have been shown to better explain spatial and temporal variation in economic output and agricultural income on the African continent (e.g., Dell, Jones, and Olken 2012; Lobell, Schlenker, and Costa-Roberts 2011; Schlenker and Lobell 2010). Moreover, available time-series precipitation datasets are based on fewer measured data from weather stations and tend to have more measurement errors than temperature datasets (Aufhammer et al. 2013; Lobell 2013; Mitchell and Jones 2005), particularly in the case of Somalia.

Our preferred model specification incorporates two dimensions of drought: the drought intensity measured over a constant time interval and the length of the drought period. Drought intensity is determined by temperature anomaly, which is calculated consistently with the precipitation anomaly (controlling for additional rainfall effects) as:

$$(4) \qquad TA^{n}_{i,m,y} = \frac{1}{n}\sum_{n}\frac{T_{i,m,y} - \mu^{T}_{i,m}}{\sigma^{T}_{i,m}} \quad \text{and}$$

$$\mathrm{PA}^{n}_{i,m,y} = \frac{1}{n}\sum_{n}\frac{R_{i,m,y} - \mu^{R}_{i,m}}{\sigma^{R}_{i,m}}.$$

The temperature anomaly takes positive values in drought months and negative values in non-drought months, whereas months that are drier than normal have a positive precipitation anomaly and months that are wetter than normal have a negative precipitation anomaly. In equation 4, $T_{i,m,y}$ and $R_{i,m,y}$ denote the monthly average temperature and monthly total rainfall in administrative unit i during the month-year (m, y) time period. The long-term monthly mean is $\mu_{i,m}$, and the standard deviation is $\sigma_{i,m}$. The time frames for the temperature and precipitation anomaly in the preferred model specification are 1980–2009 and 1983–2009, respectively (and 1950–2009 for the temperature anomaly in an alternative model specification). Temperature and precipitation anomalies are standard indicators of the intensity of abnormal weather and account for spatial differences in (temperature) variability that tend to be larger in more arid areas (Nicholson 1986, 1993). To capture the cumulative nature of weather extremes, we average temperature and precipitation anomalies over successive months. In equation 4, n denotes the number of months comprising the current month m and previous $(n - 1)$ months, while $n = 3$ in the preferred model specification.

The drought length $(DL^{TA(n)}_{i,m,y})$ is defined as the number of consecutive months with positive temperature anomalies during the current drought period, and is zero for non-drought months.

[10] Drought is also influenced by various other factors including vegetation, soil characteristics, surface water availability, and wind. However, data on these factors are lacking for Somalia or incomplete for the framework of our analysis. In addition, we searched for drought indicators that cannot be influenced by human activities—including conflict—to exclude any potential source of endogeneity from our model. This condition makes most common drought indexes such as the Palmer Drought Severity Index (Palmer 1965) unsuitable for our analysis.

Table 2. Descriptive Statistics and Unit Root Test Statistics

	Observations	Mean	Standard deviation	Minimum	Maximum	Fisher unit root test statistics
Number of violent conflict events (ACLED)	2,808	1.378	4.956	0	79	564.9***
Temperature anomaly (3-month average) †	2,808	0.313	0.593 (0.587)	−2.395	1.944	620.5***
Precipitation anomaly (3-month average)	2,808	0.241	0.434	−1.469	3.317	603.2***
Drought length (based on †)	2,808	4.741	5.848 (5.730)	0	35	193.7***
Cattle price (log)	2,335	5.250	0.480	3.305	6.978	211.7***

Source: Authors' calculation based on ACLED (2011), FSNAU (2011a), and UEA-CRU (2011).
Note: Asterisks *** indicate that coefficient is statistically significant at the 1% level. Within-region standard deviations are reported in parentheses.

Monthly market price data for livestock and key commodities are available by region (and district) from the Food Security and Nutrition Analysis Unit database (FSNAU 2011b). For the two-stage regression, we use prices for cattle of export quality in the preferred model specification (and prices for cattle of local quality, goats and sheep of export quality, and camels of local quality in alternative model specifications). We replace missing price data by the price of the nearest administrative unit (up to a maximum of the three nearest units). Tests confirm that the imputation does not considerably alter our estimation results.[11] To control for regional price inflation and thus obtain a better measure of local purchasing power, we normalize livestock prices by dividing them with gasoline prices for the preferred model specification (and by imported red rice and sugar as robustness checks). The normalization also eliminates potential price distortions between regions that may arise from trading in different currencies and applying flawed currency conversion rates in the compilation of the database. Tests reveal no evidence of biased estimates due to the normalization.

Descriptive statistics of the variables used in the preferred model specification are reported in table 2. Given the relatively high number of time periods in our dataset (of 156 months), one may be concerned that the time series in the variables are non-stationary, which can lead to spurious estimation results in the sense that relationships between variables are falsely indicated as statistically significant. Yet the statistics of the Fisher test for unit roots in panel data (Maddala and Wu 1999) allow us to reject the null hypothesis of non-stationarity in all variables at the highest confidence level.

Estimation and Simulation Results

Our estimation results provide strong evidence that more intense and longer-lasting droughts lead to more violent conflicts in Somalia, and that drought-induced cattle price shocks drive conflict outbreaks. The reduced-form regression estimates of our preferred model specification suggest that a one-point increase in temperature anomaly and an increase in drought length by one month raise the likelihood of conflict by 0.71 points and 0.08 points (at the sample mean), respectively (table 3). Hence, an increase in temperature anomaly and drought length by one within-region standard deviation each (0.59 and 5.73) increases the conflict likelihood by 62%, where the temperature anomaly increase accounts for 30%, and the drought length increase accounts for 32% (table 4). The two-stage regression estimates imply an even higher combined drought effect on conflict of 72%, associated with a decline in cattle prices of 6%. The statistical

[11] The interpolation of missing price data improves the efficiency of our point estimates and therewith the strength of the regression on the first stage. However, our estimation results do not depend on that interpolation. We can show that the results are robust to waiving the interpolation and that they are unaltered when controlling for the imputed observations (using a dichotomous variable for identification).

Table 3. Estimation Results of the Preferred Model Specification

		Two-stage	
Regression	*Reduced-form*	*First*	*Second*
Dep. var.	Conflict	Cattle price (log)	Conflict
Temperature anomaly	0.711***	−0.072**	
	(0.247)	(0.029)	
Precipitation anomaly	−0.468**	0.003	−0.391
	(0.200)	(0.033)	(0.264)
Drought length	0.077***	−0.003**	
	(0.012)	(0.002)	
Cattle price (log)			−16.15***
			(3.052)
Observations	2,808	2,335	2,335
Regions	18	18	18
R-squared	0.168	0.340	
RMSE[a]			5.964
Underidentification[b]			13.31***
Weak identification[c]			6.017
P-value (Hansen test)[d]			0.221

Source: Authors' estimation.
Note: Asterisks ***, ** indicated that coefficient is statistically significant at the 1% and 5% levels, respectively. Standard errors robust to spatial and temporal correlation are reported in parentheses. Region-fixed, time-fixed, and region-specific month-fixed effects are included in all models.
[a]Root-mean-square error.
[b]Kleibergen-Paap rank LM-statistic (Baum, Schaffer, and Stillman 2007; Kleibergen and Paap 2006): The test statistic strongly rejects the null hypothesis of underidenfication.
[c]Kleibergen-Paap rank Wald F-statistic (Baum, Schaffer, and Stillman 2007; Kleibergen and Paap 2006): The test statistic rejects the null hypothesis of weak identification, at least at the 15% level, based on the critical values provided by Stock and Yogo (2005).
[d]Hansen J-statistic (Baum, Schaffer, and Stillman 2007): The test statistic does not reject the null hypothesis of zero correlation between the instrumental variables and the error term.

Table 4. Simulation 1: Conflict and Cattle Price Changes (percentages) due to Temperature Anomaly and Drought Length Increase by One Within-region Standard Deviation

		Two-stage	
Regression	*Reduced-form*	*First*	*Second*
Dep. var.	Conflict	Cattle price (log)	Conflict
Temperature anomaly	30.3	−4.2	
Drought length	31.9	−1.9	
Combined drought effect	*62.1*	*−6.2*	
Cattle price (log)			71.6

Source: Authors' estimation.

significance of the precipitation anomaly coefficient in the reduced-form regression suggests that there is an additional effect of rainfall on conflict, which is not captured by the temperature-based drought indicators (table 3). However, the precipitation anomaly coefficient is statistically insignificant in both stages of the two-stage regression, which indicates that the additional rainfall effect is irrelevant for the livestock market channel.

The magnitude of the drought effect on conflict is within the range found in comparable studies—though at the upper end (Hsiang, Burke, and Miguel 2013). This is consistent with Hsiang, Burke, and Miguel's finding that stronger responses of conflict to climate shocks are more likely in poor countries with vulnerable populations. In their meta-analysis, Hsiang, Burke, and Miguel replicate Theisen (2012)'s estimation for Kenya, and find that a temperature increase by one (within-cell) standard deviation translates into an increased conflict likelihood of 71%. Using a temperature shock of similar magnitude, Calderone, Maystadt, and You (2013) estimated an effect of 31% for North and South Sudan.

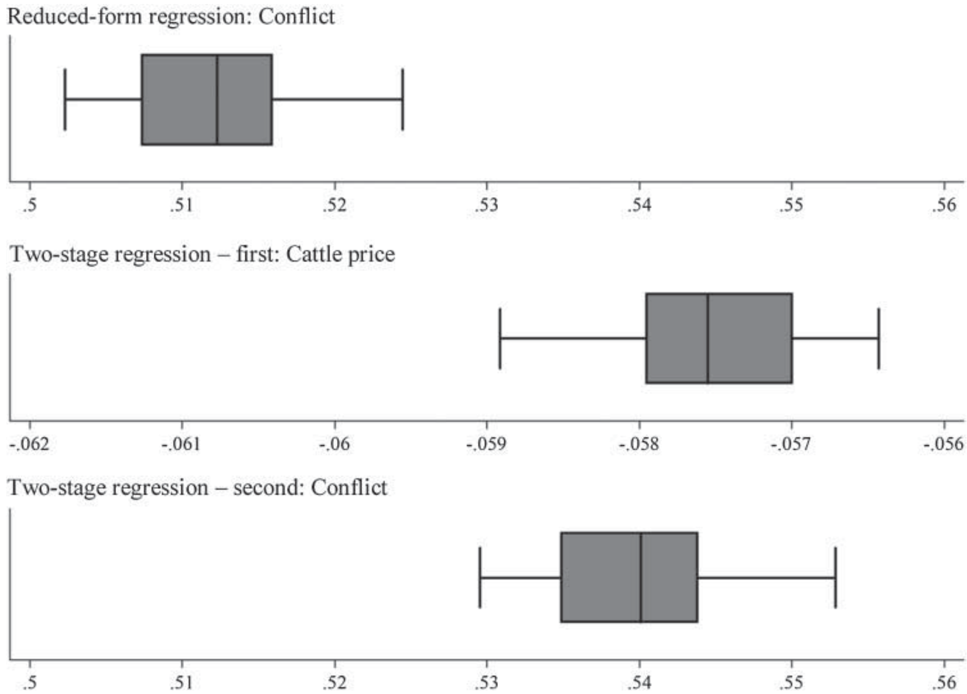

Figure 3. Simulation 2: Conflict and cattle price changes (percentages) due to temperature increases projected for 2030

Source: Authors' presentation based on own estimates.

Global climate models project temperature increases of around 0.92 degrees Celsius by 2030 that correspond to increases of our temperature anomaly by 0.70 on average (which exceeds the within-region standard deviation used in the first simulation). According to our model estimates, this increase in drought intensity is associated with an increased likelihood of conflict in Somalia of between 50% and 56%, at constant drought length (figure 3). This simulation result should be taken with some caution, since we assume no adjustment in the response of conflict and livestock prices to warming. One may expect adaptation through breeding more drought-resilient livestock, for example, but less adaptation capacity in the future because of factors such as increasing rangeland degradation is also likely.

Robustness Checks and Validity Tests

Robustness of Estimation Results

The results of our estimation may be sensitive to the model's specification. Therefore, we check the robustness of the estimation results from our preferred model specification by comparing them with estimation results from various alternative model specifications. We modify the reduced-form and two-stage regression in terms of (*a*) the level of spatial aggregation, (*b*) alternative specifications of the dependent conflict variable, (*c*) alternative specifications of the exogenous weather variables, (*d*) alternative specifications of the endogenous price variable, and (*e*) alternative specifications of the functional form. In this section we discuss the main findings from these robustness checks in detail. Table 5 summarizes the (combined) partial effects calculated from the estimates of the preferred model specification and a selected set of alternative specifications.[12]

The level of spatial aggregation does not considerably alter the estimation results of the preferred model specification. Applying the data aggregated at the district level instead of at the region level for the

[12] The regression results of all alternative specifications are shown in the supplementary appendix online.

Table 5. Partial Effects (percentages) Derived from the Estimates of the Preferred Model Specification and Selected Alternative Specifications

			Two-stage	
Regression		*Reduced-form*	*First*	*Second*
Dep. var.		Conflict	Cattle price (log)	Conflict
Preferred model specification		62.1	−6.2	71.6
Alternative model specifications with modified …				
(1)	*Level of spatial aggregation*			
	District-level estimation	53.4	(−3.4)	54.1
(2)	*Dependent variable*			
	ACLED data (all conflict types)	68.4	−5.9	76.7
	UCDP data (violent conflicts)	70.7	−6.1	84.8
(3)	*Exogenous variables*			
	NASA POWER temperature data	54.5	−11.7	68.9
	Drought length jointly defined by temperature and precipitation anomaly	57.6	−4.8	49.9
(4)	*Endogenous variable*			
	Cattle price for local quality		−5.7	71.5
	Cattle price normalized by sugar price		−4.2	67.3
(5)	*Functional form*			
	Dry seasons	72.3	−7.1	58.0
	Rainy seasons	54.4	−5.0	40.8

Source: Authors' estimation.
Note: Percentage changes in conflict incidence and cattle prices are due to an increase in temperature anomaly and drought length by one within-region standard deviation each. The partial effects for the reduced-form regression and the first stage of the two-stage regression are the combined partial effects of both drought variables. The partial effects are reported in parentheses, if all underlying coefficient estimates are statistically insignificant at the 10% level.
The online appendix presents the regression results for the alternative model specifications in table 2 (1), table 3 (2), table 5 and 6 (3), table 7 and 8 (4), and table 9 (5), respectively.

reduced-form and two-stage regression yields similar but somewhat lower partial effects (table 5).[13] The explanatory powers of both district-level regressions, however, are much lower. The two-stage regression shows no statistically significant effects of the drought variables on cattle prices, which likely arises from lower variation in the district-level sample. Due to missing market price data, the two-stage regression is based on only 69% of the maximum number of panel observations, where more than half of all price observations are imputed with the (equivalent) price of a neighboring district. Even with the interpolation, price data are completely missing for two districts. Moreover, estimations at lower spatial aggregation levels accompany substantially increased probabilities of spatial dependency between neighboring units. When augmenting the district-level regression on the first stage with spatial lags of the drought variables, their coefficients become statistically significant, indicating spatial spillover effects. This is not the case for the region-level estimation.

The results of the preferred model specification are quite robust to alternative conflict definitions and conflict data. Using all types of conflict events reported in ACLED (2011) for constructing the dependent variable instead of violent conflicts only yields similar—but slightly higher—partial effects of the response in conflict incidence for both the reduced-form and two-stage regression

[13] Table 2 of the online appendix shows the regression results.

(table 5).[14] In addition, transforming the discrete conflict variable into a dichotomous variable of conflict occurrence does not change the significance of any variable in the regressions. Other conflict data are available from the Uppsala Conflict Data Program (UCDP 2011). The UCDP adopts a more restrictive definition of violent conflict events than ACLED, and therefore reports fewer conflict events. According to the UCDP definition, violent civil conflict events result in at least one death as a direct consequence of an (armed) intra-state strife (Sundberg, Lindgren, and Padskocimaite 2011). Nonetheless, the partial effects estimated based on this dataset are moderately higher for the response in conflict incidence than those based on the ACLED data (table 5).

The construction of the temperature and precipitation anomaly variables does not compromise the estimation results. The partial effects derived from the reduced-form and two-stage regressions with modified anomaly variables vary within a reasonable range around the partial effects under the preferred model specification (table 5). The tested modifications include different lengths of the period over which the anomalies are averaged (i.e., from one to six months), and, for the construction of temperature anomaly, use of an extended time-series for calculating the long-term average (i.e., 1950–2009), the daily mean instead of daily maximum temperatures, and temperature data from an alternative source.[15] The alternative temperature data are taken from the Prediction Of Worldwide Energy Resource (POWER) project of the United States' National Aeronautics and Space Administration (NASA) and are available from 1997–2009. Comparisons of the partial effects based on the NASA POWER data and the UEA-CRU data provides evidence on the reliability of the UEA-CRU dataset as the preferred data source for identifying extreme weather events in two respects. The methodologies underlying the compilation of the two datasets are fundamentally different. The NASA POWER data are computed based on solar radiation derived from satellite observations in combination with meteorological data from an assimilation model (NASA POWER 2011). A particular weakness of the UEA-CRU data—which makes it prone to measurement errors—is the application of interpolation techniques to obtain spatially and temporally consistent coverage of temperature data even across areas with few or no weather stations and for time periods with differing numbers of measured temperature observations (Aufhammer et al. 2013; Lobell 2013; Mitchell and Jones 2005). The finding that the partial effects obtained from the regressions based on the NASA POWER data and the UEA-CRU data differ from each other within a reasonable range suggests that the potential bias of our estimation results due to possible measurement errors in the UEA-CRU dataset is minor (table 5). Additionally, the fact that the NASA POWER data have a lower resolution than the UEA-CRU data allows us to assess our results with respect to a "modifiable areal unit problem" in the weather data. This implies that substantially different results are obtained due to various levels of spatial aggregation (Harari and La Ferrara 2012; Maystadt et al. 2013). Again, similar magnitudes of the partial effects allow us to reject the possibility that our estimates are considerably biased by this scaling problem.

The estimation results are also robust to alternative specifications of drought length, including modifications using precipitation anomaly as an identifying indicator (instead of temperature anomaly), as well as temperature and precipitation anomaly combined. In the two-stage regression, drought length defined based on precipitation anomaly only shows no statistically significant effect on cattle prices, as the insignificance of the precipitation anomaly coefficient on the first stage presages.[16] The regressions with drought length jointly determined by both anomalies yield somewhat lower partial effects than those of the preferred model specification, and the coefficient estimate is statistically insignificant in the first stage of the two-stage regression, possibly because of a much lower variance of the drought length variable (table 5).

The choice of the livestock price does not compromise the results, though cattle price variations better explain variations in the drought variables than do variations in the

[14] Table 3 of the online appendix shows the regression results.

[15] Table 4 and 5 of the online appendix show the regression results.

[16] Table 6 of the online appendix shows the regression results.

prices of other common livestock. The two-stage regressions with cattle prices of export and local quality yield almost identical partial effects (table 5), which confirms that both the export and domestic market are similarly responsive to drought, as we argued in the second section of this article.[17] Similarly, alternative normalizations of cattle prices by prices of other (solely) imported basic commodities such as sugar or red rice (instead of gasoline prices) change the partial effects only marginally but considerably reduce the explanatory power of the first-stage regression (table 5).[18] Although the two-stage regressions having goat and sheep prices as endogenous variables show statistically significant effects for one of the drought variables in the first stage (i.e., for drought length on goat prices and for temperature anomaly on sheep prices), as well as for these livestock prices on conflict incidence in the second stage, weak identification tests fail. Therefore, we cannot draw strong conclusions on the validity of the hypothesized channel of transmission for the goat and sheep markets. The two-stage regression with camel prices for local quality reveals no statistically significant effect of drought on camel prices. A possible explanation for the weak identification in the case of goats, sheep, and camel is that these animals are more resilient to drought. Unlike cattle, these animals perform fairly well in milk and meat production under moderate fodder and water shortage (Kassahun, Snyman, and Smit 2008), which enables herders to smooth herd destocking over time. Camels are not sold as readily as other livestock since they serve as means of savings and a sign of prestige, are the main source of marriage payments, and are generally held by the clan rather than by individuals (Box 1971).

The estimation results are robust to various modifications of the functional forms of the reduced-form and two-stage regression. The modifications test for potential effects of seasonality, time lags, and spatial dependency, as well as for the sensitivity of the results to alternative definitions of drought and imposed non-linearity. Drought may affect conflict differently during dry and rainy seasons. For example, one may expect that the effects of drought are amplified during the dry seasons, when—even under normal conditions—income-earning opportunities are reduced and competition over rangeland and water resources is increased. Estimation results of the two-stage regression augmented with interaction terms between a dichotomous variable for the seasons and temperature anomaly and drought length each point to such seasonality effects.[19] The partial effects of drought on cattle prices are indeed higher during the dry seasons and lower during the rainy seasons than those under the preferred model specification–notwithstanding that the drought length coefficient turns statistically insignificant (table 5).

Furthermore, conflict and livestock prices may fully respond to drought only after a certain time span. Gradually introducing month lags of the drought variables in the reduced-form regression and the two-stage regression on the first stage provide some—albeit inconsistent—evidence for time lag effects.[20] Despite the statistical significance of some coefficients of the lagged drought variables, the second-stage coefficient estimates are quite similar to the estimate of the two-stage regression of the preferred specification. Adding variables in lags to the regressions of the preferred specification unduly restricts the degree of freedom of the model, increases multicollinearity, and weakens the first stage of the two-stage regression, thereby compromising the causality implied by the preferred specification.

Another area of concern is spatial dependency (Anselin 2002; Florax and Folmer 1992). Drought in one area may fuel conflict in another area through an influx of herds and the associated increased competition over scarce grazing land and water sources, for example. Ignoring such spatial dependencies can lead to underestimating the drought effects even when controlling for spatial and temporal correlation. The modified two-stage regression provides no evidence for such spatial spillover effects in the drought-cattle price relationship, but the coefficient of spatially lagged drought length is statistically significant in the reduced-form regression.[21]

[17] Table 7 of the online appendix shows the regression results.
[18] Table 8 of the online appendix shows the regression results.

[19] Table 9 of the online appendix shows the regression results.
[20] Table 10 of the online appendix shows the regression results.
[21] We test spatial dependency by augmenting the reduced-form regression and the two-stage regression on the first stage with the drought variables in spatial lags. These are constructed using distance-based spatial matrices that weight the values of the drought variables for one region by the inverse of the quadratic Euclidean distance to the geographical centers of all other regions.

Hence, the effect of drought on conflict seems to be underestimated by the reduced-form regression differently than by the two-stage regression, which may explain the differences in the partial effects shown in table 4.

There are several plausible alternatives for capturing drought in the model, all of which are less suitable than the preferred specification. Both the incidence and length of drought are important determinants of the conflict impact.[22] Dropping drought length from the regressions substantially reduces the explanatory powers and the magnitudes of the partial effects. Nevertheless, temperature anomaly changes continue to explain changes in conflict incidence and cattle prices in a statistically significant manner. On the other hand, there is no significantly amplified response in conflict incidence and cattle prices due to the interaction between drought intensity and length, as the regressions augmented by respective interaction terms suggest. Instead, the interaction term introduces a mitigating effect into the two-stage regression on the first stage and considerably reduces the explanatory power. Conceivably, the model could be also specified as having precipitation anomaly as an additional drought variable instead of treating it as a control variable. However, although the coefficient of precipitation anomaly is statistically significant in the reduced-form regression of the preferred model specification, the partial effect is small compared to that of the temperature anomaly, and the coefficients in the two-stage regression are statistically insignificant at both stages. Removing the precipitation anomaly from the regressions does not alter the estimates substantially, but does reduce their explanatory powers. Thus, variations in the temperature-based variables explain variations in conflict incidence and livestock prices independent of accounting for precipitation variation. The finding that temperature-based indicators perform better at predicting conflict incidence and socio-economic outcomes is consistent with previous studies (e.g., Burke et al. 2009; Dell, Jones, and Olken 2009; Marchiori, Maystadt, and Schumacher 2012), as well as a stronger responsiveness of livestock prices to changes in temperatures than in rainfall (e.g., Seo and Mendelsohn 2007).

Finally, adding temperature anomaly and drought length in squared terms to the reduced-form and two-stage regression provides insufficient evidence for non-linearity, so that the specification of the model in linear terms remains our preferred one.[23]

Validity of Identifying Assumptions

The second hypothesis of this article is that drought fuels conflict in Somalia primarily through price shocks in the livestock market: we used an econometric approach to identify this channel of transmission. Our identification strategy rests upon the assumption that the drought variables are valid instruments of livestock prices. Identification test statistics—shown in table 2—provide supportive evidence of the validity of this assumption for both temperature anomaly and drought length. The Kleibergen-Paap rank LM-statistic strongly rejects the null hypothesis of model underidentification, and the Kleibergen-Paap rank Wald F-statistic rejects the null hypothesis of weak identification at the common confidence level, thus confirming the strength of the instruments (Baum, Schaffer, and Stillman 2007; Kleibergen and Paap 2006; Stock and Yogo 2005).[24]

Furthermore, the identification strategy is based on the assumption that drought—precisely, drought as determined by temperature-based variables—increases conflict only through changes in livestock prices. As shown above, precipitation-based variables do not affect livestock prices significantly, so we can note that the exclusion restriction holds with respect to the definition of drought. Next, there may be additional drought-conflict links other than through the livestock market, which may compromise our identification strategy. Unfortunately, the lack of data does not allow us to perform comprehensive checks for excluding all plausible channels. We therefore adopt a less desirable approach: we acknowledge the possibility that economic factors other than household livestock income deteriorate because of drought and may incentivize

It should be noted that this indicator is a crude proxy of the distance between origin and destination of cross-region migration. More accurate approximations are impossible, given the lack of geo-referenced data of livestock migration both under normal conditions and in times of drought. Table 11 of the online appendix shows the regression results.

[22] Table 12 of the online appendix shows the regression results.

[23] Table 13 of the online appendix shows the regression results.

[24] We performed the tests by applying a Limited Information Maximum Likelihood estimator which is approximately median-unbiased for overidentified models (Angrist and Pischke 2009).

Table 6. Partial Effects (percentages) Derived from the Estimates of the Preferred Model Specification Based on Different (sub-)Samples

Regression	*Reduced-form*	*Two-stage*	
		First	*Second*
Dep. var.	Conflict	Cattle price (log)	Conflict
Full sample [18]	62.1	−6.2	71.6
Subsamples			
No Banadir [17]	51.4	−5.7	43.9
Pastoralism [9]	93.9	−8.8	(85.0)
Agro-pastoralism [9]	20.9	−4.8	(16.1)
Agriculture [6]	(−10.6)	−4.6	(−15.2)
No agriculture [11]	43.5	−7.3	35.8

Source: Authors' estimation.
Note: The number of regions included in the (sub-)samples is reported in box brackets.
Percentage changes in conflict incidence and cattle prices are due to an increase in temperature anomaly and drought length by one within-region standard deviation each. The partial effects for the reduced-form regression and the first stage of the two-stage regression are the combined partial effects of both drought variables. The partial effects are reported in parentheses, if all underlying coefficient estimates are statistically insignificant at the 10% level.
Table 14 of the online appendix shows the regression results.

conflict participation. Hence, we augment the two-stage regression of our preferred model specification by variables capturing the hypothesized channels, and show that our main estimation results are robust to the inclusion of these variables, implying that the potential existence of these channels does not jeopardize the findings of our analysis.[25]

An obvious plausible channel that transmits drought into increased conflict incidence is through (non-livestock) farm income losses. If the farming channel exists, we expect it to be of little relevance, since farming contributes only around 10% to total agricultural GDP in Somalia (Knips 2004). To assess the significance of this channel, particularly compared to the livestock market channel, we conduct robustness checks based on subsamples of regions grouped by the dominant livelihood system.[26] First, we exclude Banadir—the administrative region of Mogadishu—from the total sample, since it is the only all-urban region with minor agricultural production. Excluding Banadir does not change the significance of the coefficients of the drought and livestock price variables, but it does lead to lower coefficient estimates, which is due to the high number of conflict events that took place in the capital city. We then use the rest of the sample to create subsamples of regions where the highest shares of the regional population draw their livelihood from pastoralism, agro-pastoralism, and agriculture (farming), as reported in table 1. The cutoff level for inclusion is the median population share within each livelihood group.[27] In addition, we create a subsample that contains only regions where pure agricultural livelihoods are (virtually) absent, and hence where livestock rearing is the main economic activity of almost every rural household.[28] Table 6 shows a clear pattern of the strength of the partial effects across subsamples, which confirms that the livestock market channel prevails, whereas the hypothesized farming channel is irrelevant in Somalia overall. Although a reduction of the sample size accompanies lower efficiencies of the point estimates of the regressions, the combined partial effects of the drought variables on conflict incidence and cattle prices is statistically significant and highest for the subsample of pastoralism-dominated regions, followed by the (larger) subsample of regions

[25] The regression results are shown in the supplementary appendix online.

[26] Table 14 of the online appendix shows the regression results.

[27] The pastoralism subsample includes regions where 43% of the total population or more are pastoralists; the agro-pastoralism subsample includes regions where 18% of the total population or more are agro-pastoralists; and the agriculture subsample includes regions where 10% of the total population or more are agriculturalists. Although the median regional population share in the agriculture livelihood group is less than 3%, we excluded Sanaag from the agriculture subsample because the share of agriculturalists (3%) is very small, particularly compared to the 71% of pastoralists in this region. Hence, the region is dominated by pastoralism and shows only some pockets of agriculture (probably around some urban areas), while agro-pastoralism is absent. Nonetheless, the results are robust to the inclusion of this region.

[28] This subsample is the counterfactual subsample to the agriculture subsample, excluding Banadir and Sannag.

lacking agriculture. The explanatory powers of the regressions are low in the subsample of agro-pastoralism-dominated regions, and are particularly low in the subsample of regions with notable agriculture, meaning that the regressions produce no meaningful coefficient estimates. An additional indication that agricultural income is not a valid transmitting factor of drought effects on conflict incidence is that the impact during rainy seasons—when crops grow and so agricultural income is largely generated—is 18 percentage points lower than during dry seasons, as the robustness check for seasonality shows (table 5).

Another plausible channel of transmission is through labor income changes in weather-dependent sectors (including agriculture). Incorporating a variable for average wages for casual labor (available from FSNAU 2011b) at the first and second stage of the two-stage regression does not considerably alter the coefficient estimates of our main variables of interest.[29] The coefficient estimate of the casual labor rate is negative in the first stage, and it is not statistically significantly different from zero in the second stage. The negative correlation between wages and cattle prices appears counterintuitive at a first glance and therefore prompts us to perform an additional check for a potential relationship between extreme weather events and casual wages. Regressing temperature and precipitation anomaly and drought length on the casual labor rate reveals a statistically significant effect for both anomalies, which is positive for temperature anomaly and negative for precipitation anomaly.[30] Indeed, these effects are the reverse of those on livestock prices, and indicate that wages for casual labor tend to increase with hotter and dryer weather. Given a lack of information, we can only speculate on the economic activity that drives the casual labor rate and responds to extreme weather in such a way: it might be charcoal production (mainly for export), which is an important additional source of cash income, especially during droughts (FSNAU 2011a; Kassahun 2008). Since the casual labor rate may be driven by such an economic activity of last resort (when income from livestock is failing), the observed effects of extreme weather on wages for casual labor may reflect a general equilibrium condition. At any rate, we consider this channel to be of minor relevance, particularly as compared to the livestock market channel, given that the relationship between the casual labor rate and conflict incidence is statistically insignificant.

Moreover, conflict participation may be motivated by soaring staple food prices and resulting losses in purchasing power. The validity checks of potential channels on the consumption side follow the procedure of the validity check of a labor market channel as outlined above. The estimated effects for staple food prices should be expected to have the reverse direction to those for livestock prices, because most Somalis are net buyers of staple foods and sell livestock to generate income. Maize, red sorghum, and red rice are the main staple foods in Somalia (FEWSNET 2011).[31] Augmenting the two-stage regression with the prices of each staple food yields statistically significant effects for rice prices in the first stage and rice and sorghum prices in the second stage. Still, all these modifications do not considerably change the coefficient estimates of our main variables of interest. There is also no obvious explanation for why only the price of rice and of no other staple food shows up as a potential factor of transmission in the conflict-drought relationship. Indeed, the rice price is positively correlated with drought length but is uncorrelated with temperature and precipitation anomalies at any reasonable level of statistical significance.[32] At any rate, we do not believe that the statistical significances of the rice price coefficients in the two-stage regression constitute a credible threat to our identification strategy, considering that the combined partial effect of the drought variables on rice prices (1.4%) is much smaller than the one on cattle prices (−6.2%).

Another plausible channel in the case of Somalia is through emergency food aid. Food aid delivered to mitigate the impact of drought-caused famines may violate the exclusion restriction of our identification strategy. Two possible effects of opposite direction are of particular concern in this regard. First, food aid may disincentivize conflict participation as a means of

[29] The variable enters the regression lagged by one month to avoid potential problems of simultaneity. Table 15 of the online appendix shows the regression results.

[30] Table 17 of the online appendix shows the regression results.

[31] Table 16 of the online appendix shows the regression results.

[32] Table 17 of the online appendix shows the regression results.

economic opportunity for satisfying basic needs (Abdulai, Barrett, and Hoddinott 2005; Stewart 1998). Second, food aid has been seized by aggressive conflict parties and misused to feed and recruit fighters, to buy loyalty among the needy population, and to exchange or sell it for acquiring weapons, which all fuel conflict (Anderson 1999; Collier and Hoeffler 2007; Nunn and Qian forthcoming). Assuming that both effects are relevant for our estimation results, if the former disincentive effect dominates the latter fueling effect, our analysis provides lower-bound estimates of the impact of drought on conflict, and reversely upper-bound estimates. Unfortunately, we cannot check the potential effects of food aid due to insufficient data.

Finally, we cannot definitely rule out the possibility that extreme temperatures affect people's motivation to engage in conflict because of psychological factors. Psychologists have observed enhanced aggressive behavior among criminals, car drivers, and baseball players in the United States during heat spells (Kenrick and MacFarlane 1986; Larrick 2011; Ranson 2012). However, the transferability of these findings to the context of Somalia's civil war is questionable, since the evidence has been experimentally validated exclusively for low-intensity violence (such as crime) and for individuals in high-income countries (particularly the United States).

Conclusions

As a result of climate change, extreme weather events have become more frequent in recent decades and are predicted to further increase throughout the 21st century Intergovernmental Panel on Climate Change (IPCC 2012). The frequency and intensity of droughts in the Horn of Africa are likely to rise as a consequence. In addition to the human suffering resulting from the immediate impacts of climate change, weather extremes—and therefore climate change—increase the risk of civil conflict, thus posing an additional threat to human well-being and economic development.

Several recent studies consistently found a causal relationship between civil conflict incidence and extreme weather events at the global and regional level in the long term (e.g., Burke et al. 2009; Hsiang, Meng, and Cane 2011; O'Loughlin et al. 2012). In this article, we first show that causality is also valid for a single country (Somalia) at the local level, and for a relatively short time frame (of only 13 years).

This finding has important policy implications. Recognizing the conflict-drought relationship implies that policies and investments for drought impact mitigation and resilience building are critical for both climate change adaptation and conflict prevention in Somalia. Such measures should be primarily targeted to drought-prone areas that are at particular risk of civil conflict. The costs of inaction go beyond the immediate economic and environmental costs of climate change and may involve substantial costs from intensified conflict activities, including civilian casualties, destruction of infrastructure, and loss of economic growth potential; all of which have been largely ignored in estimations of climate change costs.

The second main finding of our study contains two aspects: factors of economic well-being are key determinants of individuals' conflict participation, and, in consequence, poverty alleviation is an effective strategy for conflict mitigation in Somalia. However, if no action is taken, the poverty-conflict trap is likely to deepen in the course of increasing climate change. Pointing to the importance of economic conditions as drivers of violent conflict, our results are consistent with previous studies on the motivations of conflict participation (e.g., Brückner and Ciccone 2010; Collier and Hoeffler 1998, 2004; Fearon and Laitin 2003).

As a new contribution to the literature, our analysis suggests that local livestock markets are the primary channel through which droughts fuel conflict in Somalia, and that livestock price downturns and hence losses in herders' income lower one's resistance to engage in conflict activities. Therefore, increasing the opportunity costs of conflict participation among pastoralists and semi-pastoralists by fostering growth in the livestock sector, providing alternative income earning opportunities, and establishing social safety nets reduces the risk of civil conflict. Furthermore, developing formal insurance mechanisms and credit systems as well as investments in livestock sector marketing and infrastructure can help to reduce the pressure to liquidate herds and to smooth herd destocking. This in turn may prevent livestock price collapses and hence rapid deterioration of household incomes. Other potentially effective interventions include financial and technical support to adapt herds toward more drought-resilient and more quickly marketable animals and to prevent the overuse of rangeland resources.

Yet this list of possible actions also reveals the limitations of our analysis for proposing specific policy recommendations. Critical knowledge gaps remain regarding the effectiveness of feasible policies and investments to strengthen resilience in pastoralist and agro-pastoralist livelihoods in the case of Somalia and other countries facing similar vulnerabilities. Quantitative research in this direction suffers from the absence of standard socio-economic data. Another limitation of our analysis may be related to the external validity of the results. Our estimates of the drought effect on conflict (adding up to 62% in the reduced-form regression due to increases in the drought variables by one standard deviation) are within the range found in comparable studies, although they are at the upper end (Hsiang, Burke, and Miguel 2013). Somalia may be seen as an extreme case in terms of length and intensity of civil war and droughts, but Sahel countries such as Mali, Chad, Niger, (Northern) Nigeria, and Sudan have also experienced increasing civil conflicts and droughts and can serve as study sites for validating our findings in future studies. Nonetheless, this article provides strong evidence of the relationship between local violent conflict and climate change and the relevance of economic behavior in this context.

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