Climate Change and Civil War in Somalia: Does Drought Fuel Conflict through Livestock Price Shocks?

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Abstract

Climate change leads to more intense and more frequent droughts in Somalia. In a global context, weather shocks have been found to perpetuate poverty and fuel civil conflict. By relating regional and temporal variations in civil violence outbreaks and drought incidence, we demonstrate that this relationship also holds for Somalia at the local level. We find that livestock price shocks drive drought-induced conflicts through reducing the opportunity costs of the pursuance of violence. Our estimation results indicate that an additional drought month associated with a temperature rise of 0.62 degree Celsius lowers cattle prices by 8.2 percent and goat prices by 13.9 percent and, in turn, raises the number of conflict by 1.28 and 1.55, respectively. Thus, climate change will further aggravate Somalia's security challenges and calls for urgent action to strengthen both drought and conflict resilience, especially in pastoralist livelihoods.

Introduction

Extreme weather events such as droughts and floods become more frequent and more extreme due to climate change (IPCC 2011). After consecutive years of irregular or failing seasonal rainfall, Somalia experienced the most destructive drought over the last 50 years in 2011. The resulting famine has pushed the number of Somalis in need of emergency assistance to about four million people (FEWSNET & FNSAU 2011). It has also caused the deaths of over 200,000 people and internal displacement of 1.46 million people in Somalia during the first half of 2011; the number of malnourished children surged from 476,000 in January to 780,000 in July (UNICEF 2011). Though the 2010/11 drought was largely a result of the prevailing climatic phenomenon La Niña leading to poor rainfall performance in the Horn of Africa, seasonal rainfall failures combined with high temperatures have generally occurred more often in Somalia in recent years, compared to the 1980s and 1990s (FSNAU 2011b). At the same time, Somalia has been rattled by an ongoing civil war since its outbreak in 1991, while violent disputes have become more frequent recently, too, especially after 2002 (ACLED 2009). This overlap poses an important question about the potential relationship of extreme weather events and the risk of civil conflict in the light of progressing climate change.

Historical data indeed suggest that there are strong linkages between warming and civil war in sub-Saharan Africa, with warmer years leading to increased likelihood of war. Burke et al. (2009) find that an increase in temperature of one degree Celsius leads to a 4.5 percent increase in conflict incidence in the same year and a 0.9 percent increase in the next year. Likewise, Hsiang et al. (2011) investigate the relationship between changes in global climate and global patterns of civil conflicts and shows that the probability of civil conflict outbreaks arising throughout the tropics doubles during El Nino years (leading to warmer and dryer in the continental tropics) relative to La Niña years. Thus, given strong scientific evidence that global warming continues in the foreseeable future (IPCC 2011, Boko et al. 2007), the finding that warming contributes to civil conflict has crucial implications in the debate on both the costs of climate change and appropriate conflict mitigation strategies.

Central to the search for effective mitigation strategies is knowledge of the causes and drivers of civil conflicts and the channels through which weather shocks and climatic stresses increase the risk of violence outbreaks. Behavioral economics theory has been frequently consulted to explain people's motivation to participate in armed strife. Much of the recent empirical literature on conflict causes and drivers builds upon Collier's and Hoeffler's early works on civil war (1998, 2004). The authors find that economic opportunities such as the expected income of being a fighter relative to (formal) labor market income drives civil conflict rather than political and socioeconomic grievances such as repression against particular social groups and inequality . By far, the most robust finding throughout the literature is that low per capita income and slow economic growth are linked to civil war (Blattman & Miguel 2010). In contrast, there are inconsistent findings about the roles of ethnic or religious fractionalization (Easterly & Levine 1997, Fearon & Laitin 2003), natural resources dependency (Humphreys 2005, Brunnschweiler & Bulte 2009) and democracy (Elbadawi & Sambanis 2002, Hegre et al. 2001) as causes of conflict and factors of conflict prevention.

Given the empirical evidence from previous studies, the opportunity cost approach has been increasingly prominent for estimating the effects of economic shocks on the incidence of civil conflict (e.g., Miguel et al. 2004, Bruckner & Ciccone 2010, Ciccone 2011). It also offers an appealing framework for analyzing the effects of weather shocks and climatic stresses on conflict, precisely, the economic channels through which shocks and stresses may affect people's incentives to newly participate in organized violence (as opposed to maintaining engagement in conventional economic activities). The opportunity cost approach appears to be ideally suited for studying the case of Somalia, where extreme poverty and hunger is widespread and more frequent extreme weather events make it increasingly difficult for people to recover from one shock before the next one strikes. Under conditions of generally poor income opportunities due to a malfunctioning economy and limited human and livestock mobility, such shocks further disrupt economic activity and leave young people vulnerable to unemployment and recruitment into extremists groups like al-Shabaab, promising a life free of hunger and opportunity for advancement.

In this paper, we therefore hypothesize that droughts fuel violent civil conflict in Somalia through lowering the opportunity cost for engaging in conflict. Given that the livestock sector is the mainstay of the country's economy, we analyze the role of drought-induced shocks on livestock prices as the driver of conflict onsets. The objective is hence to provide analytical evidence supporting this hypothesis, estimate the effects of droughts and related livestock price shocks on conflict econometrically, and derive policy implications for conflict prevention strategies from the estimation results.

Our hypothesis is generally supported by a study of Miguel et al. (2004) who estimate the impact of economic conditions on the likelihood of civil conflict in Africa. The authors find that, in economies which largely rely on rain-fed agriculture (like most sub-Saharan African countries), a negative income growth shock of five percentage points—induced by rainfall deficiency—increases the likelihood of conflict by one-half in the following year. However, the cross-country nature of this and other previous studies limits the ability to draw causal inferences and derive context-specific recommendations for national policy and development support on conflict prevention from the analytical results. Our study narrows this gap in the conflict literature.[1] Furthermore, we contribute to the literature on the Somali civil war by providing a quantitative assessment of a major potential driver for joining the ongoing war, whereas previous works have been only focused on explaining the consequences of the collapse of the central state in 1991. In consideration of widespread, extreme poverty in Somalia, we focus our analysis on changes in the opportunity cost as the main incentive to participate in organized violence. Innovatively, we use changes in livestock prices as proxy for household income growth (instead of GDP per capita growth as in previous, cross-country studies). We thereby analyze the transmission of weather shocks through the income channel in greater detail thus providing a new perspective and suggest revised policy implications in which the functioning of local markets play a central role.

[1] According to our knowledge, there is only one paper that analyzes the effects of weather anomalies on the incidence of civil conflicts based on regional data. In a very different context, using change in rainfall as an instrument for economic growth, Bholken et al. (2010) find that growth decreases the outbreak of Hindu–Muslim riots in 15 Indian states between 1982 and 1995.

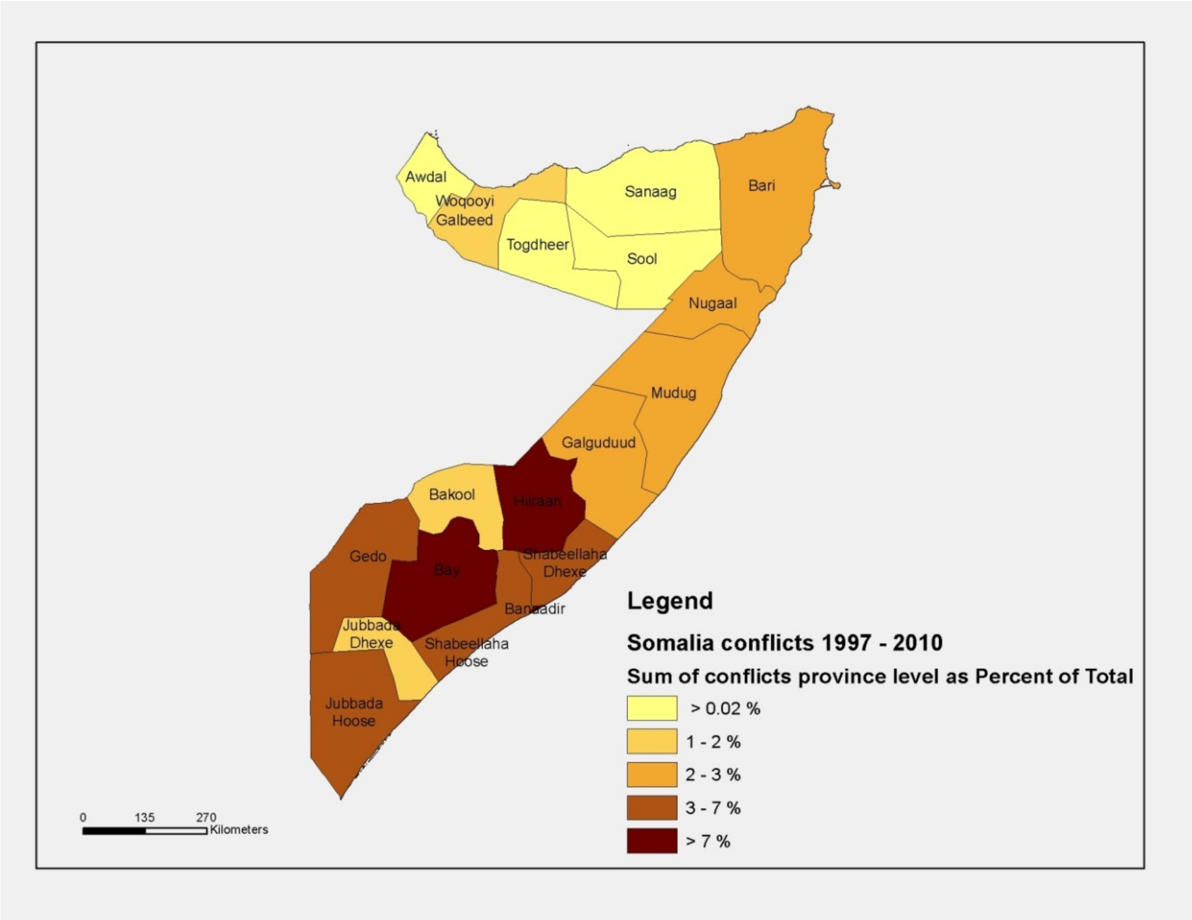
The rest of the paper is organized as follows. The next section establishes the conceptual framework underlying our empirical analysis and explains the links between droughts, livestock prices, and the likelihood of civil conflict in the context of Somalia. We then turn to the analytical identification strategy applied to isolate the effects of droughts from other potential effects and the empirical model of estimation. The results are presented in the subsequent section, followed by a section which describes the results of our robustness checks and discusses the validity of the exclusion restriction which is fundamental to our identification strategy. The last section concludes and discusses policy implications.

Linkages between Drought, Livestock Prices, and Civil Conflict in the Context of Somalia

Country context and the role of the livestock sector

From 1969 to 1991, Somalia was ruled in an autocratic manner by Mohammed Said Barre, with strong external support from the Soviet Union until 1978 and the United States afterwards. Following the end of the Cold War, the external support faded away and led to a violent civil war and collapse of the national government in 1991. Since then no central government has controlled the entirety of the country. Somalia has been frequently described by such terms as state failure, anarchy, and warlordism economy. The country is now divided into (at least) three (semi)autonomous regions on a de facto basis: Somaliland, which comprises the northwestern part of the country, has declared itself as a sovereign state (“Republic of Somaliland”), but its independence has not been recognized by any government yet. Puntland covers the northeastern part and has been self-governing since 1998 but does not seek independence. Large parts of southern Somalia have been control by the Islamist Al-Shabaab militia, while the internationally recognized Transitional National Government controls the capital Mogadishu and some territory in the center of the country at present, which is currently (re)expanding with the support of the African Union and other foreign forces. While violent conflicts occurred all over the country during the past two decades, most recent conflict outbreaks have taken place in the central and southern parts and in particular in the Bay and Hiiraan regions (Figure 1).

Figure 1: Conflict incidence by region



Source: Based on ACLED (2011) dataset.

During the two decades of effective national governance absence, Somalia has maintained a functioning informal economy dominated by livestock rearing and exports, remittances inflows and money transfers, and telecommunications (World Factbook 2011). Traditionally, the livestock sector is central to the economic and cultural life of Somalis. Prior to the civil war, Somalia was the world's largest exporter of live goats (Headey et al. 2011). The livestock sector still accounts for about 40 percent of GDP, almost 90 percent of total agricultural GDP, and more than half of all exports earnings (Knips 2004, World Factbook 2011). The main importers of Somalia's exports are the Arab countries on the Arabian Peninsula, especially of live goats and sheep for the week of the Haij.[2] Pastoralists (nomads) and semi-pastoralists, who are dependent on livestock for their livelihood, constitute a large share of Somalia's population. In a country with a rural population share of 63 percent (WDI 2011), the livestock sector provides food and income to over 60 percent of the total population (FEWSNET & FNSAU 2011). Thus, pastoralism or semi-pastoralism is the source of livelihood for most of all Somalis in the rural areas, and

[2] See graph in Figure A1. The main livestock export ports are Berberra in Somaliland and Bossaasso in Puntland.

a significant number of urban dwellers are also engaged in livestock related activities including livestock and livestock product trade. Purely pastoralist livelihoods are prevailing in the northern and central part of Somalia, and agropastoral livelihoods are predominant in the southern part and some pockets in the Northwest and Central (FSNAU 2011b).

To some extent, the structural causes of the civil insecurity are to be found in the deficiencies of the dictatorship imposed by Siad Barre, including the lack of overall development, the neglect of the rural economy and in particular the livestock sector (Mubarak 1997, Powell et al. 2006, Little 2003), and the exclusion of certain clans to land and water rights (Besteman 1996) in a context of increasing competition over natural resources (especially water and grazing and farm land) between different stakeholder groups such as various pastoralists clans, nomads and (dispossessed) farmers, and residents and refugees (Elmi 2010, Shraeder 1986). Although such structural causes may explain social fractionalization among the Somali population, they are insufficient to inform about people's motivation to engage in civil strife and explain local violence over a relatively short period of time.

The Civil Conflict-Drought Relationship

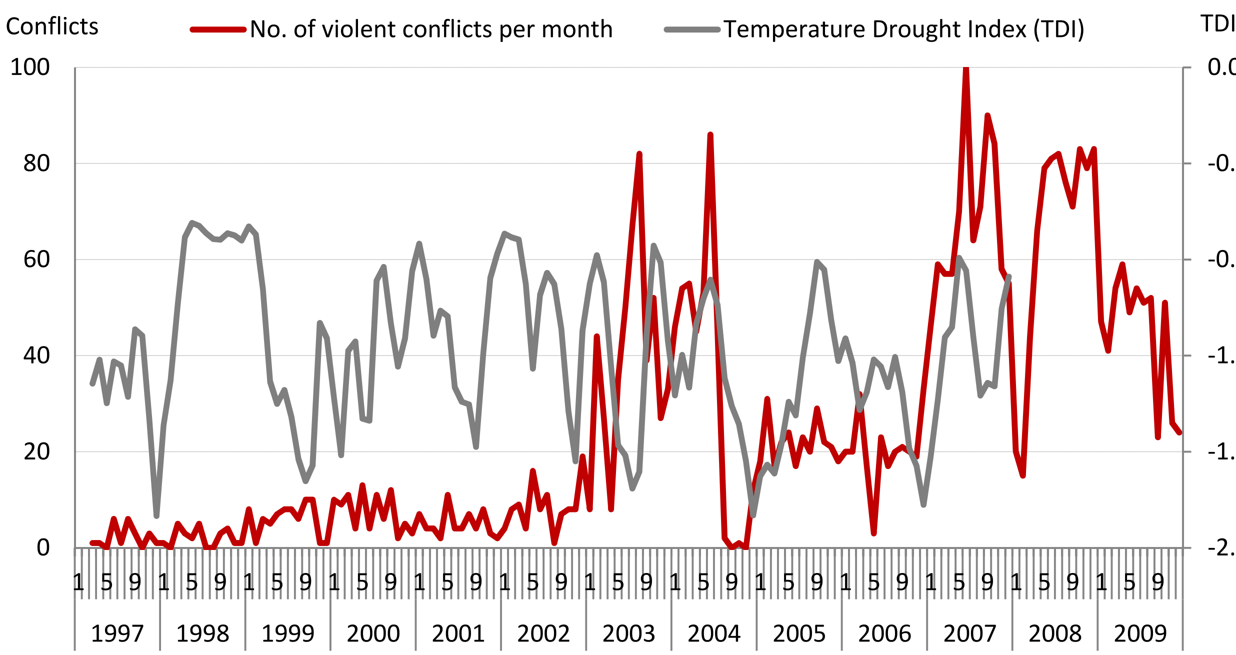
Prolonged and recurring periods of drought constitute a major constraint to development in rain-fed agrarian systems and may fuel civil conflict particularly in the absence of alternative income earning opportunities outside agriculture. Somalia is highly vulnerable to weather shocks, especially droughts (but also floods), because of the country's geographical location and fragile environments and climate (FSNAU 2011b). Most of the areas typically affected by droughts are arid and semi-arid areas that are low in resources and already under substantial ecological pressure under normal circumstances (Mutua & Zoltan 2009). In addition, the lack of credit and insurance markets make formal mechanisms unavailable to cope with shocks, and public safety nets are absent. Thus, the reduced availability of water, food, and farm income opportunities forces people to seek alternative coping strategies during droughts, including selling of productive assets (Dercon & Hoddinott 2004, McPeak & Barrett 2010, Mogues 2011), clan-based support, and migration. However, the capacity of the traditional support systems is very limited when major disasters strike, and migration involve an amplified competition over meager available resources.[3] As a consequence, long-lasting droughts and successive shocks lead to poverty traps, increasing household food insecurity, and ultimately humanitarian disasters (Carter & Barrett, 2006). In contrast, engaging in civil conflict to make an own living at the expense of others may

[3] Mutua and Zoltan (2009) note that there is a history of pastoral communities fighting (with arms) for scarce resources in parts of Somalia and its neighboring countries. The likelihood of local conflicts surge particularly during droughts, when nomad communities move on the lands of non-mobile communities and when different pastoral clan groups move to the same place in order to use the same scarce resources (Mutua & Zoltan 2009). Increasing competition for water and land resources is likely to be a driver of localized civil conflicts in Somalia and expected to partially reflect in livestock prices. Yet our identification strategy of the drivers of conflict does not capture the pure effect of climate-induced displacement. We therefore discuss in the section on robustness checks and exclusion restriction how the results of our empirical model may change when human and animal mobility is taken into consideration.

appear opportunistic for some people (Miguel et al. 2004; Mutua & Zoltan 2009). The political economy of the stateless order facilitates such self-seeking behavior (Mubarak 1997, Powell et al. 2006, Leeson 2007, Leonard 2009).

Both droughts and civil conflicts have drastically increased in Somalia in recent years. Since the dawn of the new millennium, the country has experienced already five major droughts (in 2000/01, 2004, 2005, 2008/09, and 2010/11), compared to no major drought in the 1990s (EM-DAT 2011). The last time when major droughts occurred more frequently was in the 1980s (with a drought in 1980, 1983, 1987, and 1988), while the number of affected people was significantly less than in the 2000s. Recently, civil conflict has escalated too, with two coherent periods of extreme incidence of violent conflict events from mid-2003 to mid-2004 and throughout 2007 and 2008, respectively (Figure 2). The former period correspond to major fights between the Transitional National Government and militias loyal to the Islamic Court Union, including Al-Shabab. The latter one is due to an invasion of the Ethiopian military that ousted the ruling Islamic Court Union and the control by Al-Shabab in 2007, which regained control in 2008 over most parts under Ethiopian occupation (ACLED 2009). Overall, there is an upward trend in violent conflict outbreaks, especially after 2002. The number of civil conflicts peaked in August 2003, June 2004; June, September, and October 2007; and June and July 2008 with more than 80 violent events per month.

Figure 2. Violent civil conflicts and droughts



Source: Based on ACLED dataset (2011) and NASA POWER data (2011).

Note: For more information on the variable construction, see the section on data and measurement.

In general, drought is a recurring feature of climate in Somalia, and affects all forms of rural livelihoods and all regions of the country. The number of drought months for the period of 1997-2007 is very similar across regions (Table 1). Yet, the characteristics and impacts of drought vary significantly from one region to another depending on its severity, political and economic stability, level of preparedness and resilience of the affected communities, and access to humanitarian assistance (FSNAU 2011b). Between 1997 and 2007, the incidence of violent conflict events was highest in the southern regions, while there has been no administrative region in Somalia without armed clashes, except Awdal in the very Northwest bordering Djibouti (Table 1). The simple comparison of the prevalence of pastoral and agropastoral livelihoods and the number violent conflict events across regions does not reveal a clear pattern of higher risk of conflict associated with one or the other form of pastoralism, although there is a slight tendency toward more conflict onsets in the (central and southern) regions where agropastoralism is more common.

Table 1. Pastoral and agropastoral livelihoods, drought months, and violent conflicts by administrative region

Administrative region	Rural population (percent of total)	Pastoralists (percent of rural population)	Agropastoralists (percent of rural population)	Number of drought months, 1997-2007	Violent conflicts (numbers of events), 1997-2007
Northwest (Somaliland)					
Awdal	64	60	39	62	0
Woqooyi Galbeed	30	66	33	64	28
Togdheer	69	93	7	66	21
Sanaag	79	90	0	64	20
Sool	74	100	0	66	4
Northeast (Puntland)					
Bari	53	100	0	66	56
Nugaal	58	100	0	64	70
Central					
Mudug	73	88	12	66	77
Galgaduud	82	78	22	66	59
South					
Hiraan	79	35	52	62	157
Middle Shabelle	81	53	9	62	62
Lower Shabelle	80	12	71	62	185
Banaadir *	0			66	1,299
Bakool	80	12	88	63	47
Bay	80	0	100	62	236
Gedo	75	64	24	64	72
Middle Juba	77	28	30	63	36
Lower Juba	68	47	31	58	131
National	**61**	**50**	**39**	**107**	**2,560**

Source: Based on FSNAU (2011a), NASA dataset (2011), and ACLED (2011) datasets.

Note: * Banadir is the administrative region of Mogadishu and surroundings. Population and livelihood data are from 2005. 'Drought months' are defined as months with temperatures above monthly long-term averages (see 'data and measurement' subsection); they do not capture drought severity.

The Livestock Prices-Drought Relationship

Drought-conflict relationships are complex but may be traced—within certain limits—through price effects associated with production/supply changes, which often result from weather variation. While some of these relationships appear obvious, there are some that are quite intricate with nuances worth noting for explaining price movements during drought and famine (von Braun et al. 1998). This holds for livestock prices in particular. Beforehand, the domestic and foreign demand for livestock in Somalia can be expected to be fairly stable throughout the year, except before Eid al-Adha celebrated after the Hajj.[4] Thus, changes in livestock prices are largely supply driven.[5] Market supply of livestock varies in terms of quantity and quality within the same species and across species depending on the regional severity and progression of the drought.

Overall, drought is a slow-onset and large-area disaster. Movements of livestock prices partly reflect herders' responses to systematically cope with drought.[6] Drought causes a significant reduction in the availability of water and livestock feeding resources, which in turn leads to market disequilibrium toward an oversupply of thin animals that significantly depresses livestock prices due to high quantities and poor quality (that is, less fattened animals) in the short-run. The difficulty to restock in the long run, after the drought is over, and missing markets for water, fodder and veterinary services in the short run can also explain why herders will increase supply of low quality livestock leading to a decrease in prices. These separate long-term and short-term effects help explain why herders will typically try to keep well-fed, vigorous animals since they are more likely to survive fodder shortages and preserve genetic material of higher quality (Aklilu and Catley 2009, Aklilu and Wekesa, 2002).[7] The process of liquidating

[4] Eid al-Adha is the Muslim 'Festival of the Sacrifice', and Hajj is the annual pilgrimage to Mecca.

[5] Over the past two decades, there were two major demand-side shocks that had important knock-off/on effects on the livestock sector in the Horn of Africa. Following an outbreak of the Rift Valley Fever and concerned about lack of proper health screening, Saudi Arabia imposed an import ban on livestock imports from the east African region February 1998 to April 1999, reestablished it in September 2000, and lifted it in November 2009, before the Hajj.

[6] In contrast, the impacts of floods develop much more rapidly and are localized. The effects on livestock trade and prices can therefore be expected to fundamentally differ from the effects of drought and may be less pronounced overall. This in addition to the scale of the impacts in the Somali context induced us to limit our study to the analysis of drought shocks.

[7] Restocking the herds may take even several years because the local livestock market is usually too small to restock quickly, and/or pastoralists lack cash liquidity because of missing credit and finance markets (Headey et al. 2011). This problem of missing markets exacerbates the decline in livestock prices during drought periods by inducing pastoralists to over-accumulate livestock in an effort to hedge against restocking risks associated with missing markets. In the short run, lack of veterinary services and markets for fodder and water during droughts rapidly reduce the quality of livestock and lead to rapidly decreasing livestock prices. In the long run the lack of restocking markets and the associated overstocking by all pastoralists creates immense pressure on water and land resources, negatively impacting the environment and also ultimately reducing the quality of livestock products, which too leads to lower livestock prices. Related to this is that, when drought occurs pastoralists will shed lower quality cattle in large numbers first in an effort to obtain cash for grain purchases, whose prices will have increased drastically during drought, to mitigate the long-term livestock price risk (as livestock become expensive at the time

assets—including livestock—during drought appears to follow a particular order (Morton, 2006; McPeak and Little, 2006) with more liquid assets such as cereal stocks and small livestock being shed first, and less liquid assets such as cattle and camels last (Mogues 2011).[8] Discharging more liquid assets first is rational from an individual perspective, since markets for these products exist locally so that destocking and restocking is more practicable, and more liquid assets can usually be better patched up into smaller tranches so that only the minimum amount needed for survival can be sold and the liquidation process stretched as long as possible. Yet, at the same time, the systematic liquidation of herds from many owners simultaneously leads to depression of livestock market prices, thereby implying that households forced to sell off their animals at much lower prices during drought and in turn have much reduced food purchasing power to cope with the drought. The downward price movement is further amplified by strong market information asymmetry during times of crises of which exploitive livestock traders may take advantage by offering undervalued prices.

Herders try to anticipate droughts in order to mitigate the impact on their herds and family livelihoods. Since drought is a recurring event in Somalia, herders know well that the next drought may kill at least some of their animals so that they maximize pre-drought herd size and therewith post-drought herd size (Headey et al. 2011). Another strategy to cope with more frequently recurring droughts is to adapt the composition of herds towards more drought resistant and earlier marketable animals that will also reflect in livestock prices. Herder households often rear different meat and dairy animals. Yet there are regional differences in the composition of herds which mainly result from the local availability of water and grazing land resources, suitability to the practiced pastoralist system, and wealth of the herders. Goats and sheep are most common, followed by cattle and camels. In northern Somalia, sheep are prevailing and goats in the rest of the country, except in the very South where cattle are predominant (particularly in the Lower Juba region). The share of camels is highest in the central and southern part of the country. Recurrent droughts over three consecutive years in 2008-2010 have almost ousted cattle in the central regions (FSNAU 2011b). Likewise, recent data from neighboring Southern Ethiopia (CSA & FAO 2011) show that the number of goats and sheep increases at a faster rate than cattle and camels which is likely in response to more frequent droughts.

However, such strategies have been found to be too limited to fully cope with persistent droughts, ineffective to cushion price effects, and partly even price reductive if realized by many herders contemporary. Though, important to understand herders' rationale behind the sequential liquidation process is the fact that there is a critical herd size defining the herding system (Devereux 2006, Lybbert et al. 2004). For example, a threshold level for cattle herds seems to exist at an unstable equilibrium of 10-15 animals for a typical transhumant herder household of 6-6.5 members, which corresponds to two-plus cattle per household member necessary to sustain the opportunistic, spatially flexible herding associated with extensive pastoralism (Lybbert et al. 2004). When a household's herd size falls below

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of restocking after the drought)–this combination of long term and short term factors contributes significantly to reduced livestock prices during droughts.

[8] Livestock and cattle in particular are the most important assets in rural areas of the Horn of Africa. The size of the herd is considered as the ultimate indication of wealth, is critical for paying the bride price, and functions as insurance mass in the absence of post-drought restocking markets.

the threshold level, it effectively switches to a sendentarized herding system that, however, is much more vulnerable to spatiotemporal variability in rainfall and provide lower returns. Hence maintaining a herd of any size becomes then exceedingly difficult so that sedentarization with a small herd indicate dire poverty in pastoralist communities (Lybbert et al. 2004).

Given this context, we expect livestock prices to decrease as a result of drought, following a particular pattern. Goat and sheep prices respond to drought onset first and foremost, followed by cattle and camel prices at last. And, considering the size of the total livestock stock in Somalia, we expect that price effects are highest in magnitude for goats and sheep, too.

The Civil Conflict-Livestock Prices Relationship

In the case of rural Somalia, livestock prices are an important economic indicator and can be used as proxy for household income. Accurate data on household income and regional income sources are missing due to lacking representative household budget surveys and national accounts statistics; yet regional surveys suggest that the poor in purely pastoral livelihood usually generate 50-80 percent of their income from livestock and livestock product sales (FSNAU 2011b).[9] The high income dependency of rural people on livestock prices entails a substantial loss in household incomes during drought. At the same time, staple food prices surge that further diminish purchasing power. For example, the deterioration of cattle body conditions during the 2010/11 drought led to a drop in cattle prices in southern Somalia by 30-50 percent within four months (September – December 2010), and cereal prices hiked by 50-60 percent during the same period of time. As a result, the purchasing power plummeted by 40-60 percent at the end of 2010 from the previous year level (FSNAU 2011b).

In addition to the already high prevalence of poverty, such income shocks are devastating and make fighting and support of turmoil financially more attractive under the prevailing conditions of lacking alternative income opportunities. Anecdotal evidence supports that drought-induced losses in purchasing power eased the recruitment of fighters such as for Al-Shabab.[10] In short, drought may fuel civil conflict.

[9] Comparably, almost 70 percent of all households in the neighboring Somali region of Ethiopia engage in livestock rearing (Devereux 2006).

[10] For example, a Somalia Representative of the UN Refugee Agency (UNCHR) states that “this [the drought] 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” (The Hufftington Post, 08/05/2011). Furthermore, interviews with Al-Shabab deserters reveal that *Al-Shabab* uses cash payments and promises regular salary for recruitment in combination with threats of force (Baldauf & Mohamed 2010).

Identification Strategy and Empirical Model

Analytical approach

Our analysis of the relationships between violent civil conflict and drought and livestock prices as driver of conflict follows a clear identification strategy. We begin by modeling the incidence of violent conflicts as a function of drought frequency and intensity across regions and over time (hereafter 'reduced-form' function) to assess the strength of the conflict-drought relationship in Somalia implied by our data.[11] Given that we find a statistically significant relationship, we then explore a possible channel through which more frequent and more severe droughts translate into more conflict onsets, assuming that people's motivation to participate in conflict is essentially driven by economic means, as argued in the previous section. Hence, the decisional factor is household income earnings from ordinary activities relative to the expected 'income' sought from engaging in violent conflict activities. Because of the central role of livestock husbandry for (rural) income earnings and lacking income (and consumption expenditure) data, we use changes in livestock prices as proxy for changes in household incomes. To coherently estimate the effects of drought on civil conflict events transmitted through changes in livestock prices, we use a two-stage estimation framework. The challenge of our identification strategy is to isolate this livestock price channel from all other potential channels of transmission. We perform a comprehensive set of robustness checks and present their results together with a discussion on the validity of our identifying assumptions in a separate section after the presentation of the estimation results.

Our empirical model requires dealing with common problems of identification, particularly potential omitted variable, simultaneity biases, and measurement errors. Biases from variables omitted in the estimation functions may arise from unobserved factors that affect both our proxy for household incomes (livestock prices) and conflict. For example, such omitted variables may relate to historical grievances among pastoralist communities, the ethnic composition within arid and semi-arid areas, or geographic characteristics such as altitude, access to markets, availability of transport, population density, and so on. Additionally, our conceptual framework points to a causality running from changes in economic conditions to the incidence of violent conflict events, but the reverse causality is possible, too. For example, armed conflicts may diminish or destroy productive assets such as livestock stocks through theft or sabotage of transportation infrastructure which contributes to rising sales prices (Bundervoet 2009, Annan et al. 2010, Verpoorten 2009). For instance, looting of livestock by armed fractions has been stressed by Devereux (2006) for the Somali region in neighboring Ethiopia. Potential measurement errors in the data are a general concern of model specification and particularly in the case of Somalia.

[11] In a two-stage estimation framework, the regression of the dependent variable of the second stage on the exogenous, deterministic variable of the first stage (that is, the instrument) is often termed 'reduced-form' regression (Angrist & Krueger 2001). In a fixed-effect regression, the reported intercept is actually the average value of the fixed effects. Excluding the intercept does not change the estimated coefficients but would underestimate the standard errors of the regression (Wooldridge 2002).

To deal with the methodological challenges of omitted/unobserved variables in a general manner, we control for region and time-fixed effects as well as time trend effects in both the reduced-form and two-stage regressions. Region-fixed effects pick up time-constant, unobserved heterogeneity across regions, and time-fixed effects capture external changes over time that affect all regions similarly. More specifically, region-fixed effects control for regional-specific factors of conflict onsets and livestock price changes, which are assumed to be constant over the investigated period; examples include historical grievances, social and ethnic fragmentation, governance, market structures and geographic factors. Time-fixed effects control for non-weather related, external shocks. Saudi Arabia's long-lasting livestock import ban imposed in 2000 and lifted in 2009 and other external demand shocks therefore should not bias our estimation results.

Finally, instrumenting changes in livestock prices by changes in the drought variable in our two-stage regression serves to identify the hypothesized channel of transmission in the conflict-drought relationship and account for possible endogeneity biases associated with the price variable. We apply an instrumental variable, two-stage, fixed effect (IV-2SLS-FE) estimation with robust standard errors.

Estimation framework

The reduced-form regression has the following estimation equation:

$$conflict_{i,t} = c + \alpha_i + \phi_t + \eta\, weather_{i,t} + \varphi\, trend_t + \varepsilon_{i,t} \ . \qquad (1)$$

The dependent variable in Eq. (1) denotes the number of conflict incidences in the administrative region i and month t ($conflict_{i,t}$). The main deterministic variable identifies weather shocks ($weather_{i,t}$), while a positive value indicate a drought month. Location-fixed effects are captured by a vector of region-specific dichotomous variables (α_i), and time-fixed effects enter through a vector of dichotomous variables specific to each month and year in the sample (ϕ_t).[12] Time trend effects are included by an integer variable taking an individual value for each time period ($trend_t$). The term $\varepsilon_{i,t}$ is a disturbance term; the disturbances are allowed to be correlated across months for the same administrative region. This model specification aims at explaining the variation in changes in the data over time between regions (that is, deviations from the regional means) rather than cross-regional differences in levels or trends.

The general relationship implied by Eq. (1) is decomposed into two stages, focusing on livestock price changes as the main channel of transmission. The first-stage equation estimates the effect of droughts on livestock prices and thereby yields statistical evidence of the strength of the weather variable as instrument of the livestock price variable. It is:

$$\ln price_{i,t} = c + \alpha_i + \phi_t + \beta\, weather_{i,t} + \pi\, trend_t + \varepsilon_{i,t} \ , \qquad (2)$$

[12] Somalia has 18 administrative regions, and our sample includes data from January 1997 to December 2007, comprising 132 monthly time periods.

where $price_{i,t}$ denotes a livestock price index in region i. The second-stage equation, which estimates the effects of livestock prices on the incidence of conflict events, is then given as:

$$conflict_{i,t} = c + \alpha_i + \phi_t + \gamma \ln price_{i,t} + \tau \, trend_t + \varepsilon_{i,t} \ . \qquad (3)$$

We estimate the two-stage regression with goat, cattle, and camel prices separately to explore expected differences in livestock price responsiveness, as discussed in the previous section. Finally, we calculate two sets of semi-elasticities from the estimated coefficients of the two-stage regressions, which report the change in the incidence of conflict events and livestock prices due to an increase in the drought severity and/or intensity by one standard deviation and one additional drought month associated with an average temperature, respectively.

Data and measurement

Our estimation is based on monthly panel data from different sources. The time horizon is eleven years, starting from January 1997 and running through December 2007. The dependent variable is constructed as the sum of violent conflict events per month and by administrative region, using the Armed Conflict Location and Event Data (ACLED) dataset (Raleigh et al. 2010). For Somalia as a whole, the dataset reports 2,675 conflicts of which 2,560 events were violent between 1997 and 2007.

The deterministic, exogenous variable identifying droughts is constructed from the agro-climatologic data provided by the POWER project of the National Aeronautics and Space Administration (NASA) of the United States. Following Mutua's & Zoltan's (2009) climate study for Somalia, in our preferred model specification we use daily maximum air temperature parameters at two meter above ground for constructing the drought variable. Temperatures parameters are based primarily on solar radiation derived from satellite observations and meteorological data from an assimilation model (NASA 2011). The coverage is on one degree latitude by one degree longitude grid—or about 11 square kilometers in the case of Somalia—that adds up to 80 data points for the whole country. For each administrative region, we average the daily temperature parameters from all observations within this region and over one month to obtain one temperature observation per region and month. We apply these observations to determine the occurrence of drought months. We use temperature instead of precipitation, since temperature variations appear to better explain past spatial and temporal variation in agricultural yields and economic output on the African continent (Dell et al. 2008, Schlenker & Lobell 2010, Lobell et al. 2011).

There is no universal definition of drought; it is rather defined in a differential manner. Drought needs to be distinguished from high temperature or low rainfall *per se*; it is rather characterized by successive deviations from normal weather conditions. Thus, drought differs from aridity. Drought is a temporary weather aberration, whereas aridity is a stable climatic condition, determined by generally low rainfalls. Yet, drought is not a rare and random event, it is actually a normal recurrent feature of climate that occurs in virtually all climatic zones, although its characteristics vary significantly from one region to another (Mutua & Zoltan 2009). Accordingly, we define drought months as months with temperatures above the long-term mean temperatures, while the reference period is the time horizon of our analysis. We also consider the cumulative nature of temperature excesses that makes individual temperature aberrations to become a drought, and several successive drought months a major drought. Mutua's & Zoltan's (2009) Temperature Drought Index (TDI) incorporates this cumulative effect. We slightly modify the proposed TDI to make it specific to the context of our analysis, to comply with the data availability, and to make its interpretation more intuitive. We compute the TDI for each administrative region and time period in our sample as follows:[13]

$$TDI_{m,y} = -\sqrt{\left(\frac{\frac{1}{n}\sum_{k=1}^{n} R_{m,k}^{(T)}}{R_{m,y}^{(T)}}\right)} * \frac{\frac{1}{n}\sum_{k=1}^{n}\left(\sum_{j=0}^{3} T_{k,(m-j)}\right)}{\sum_{j=0}^{3} T_{y,(m-j)}} \quad . \tag{4}$$

In Eq. (4), T denotes the maximum temperature on a monthly average basis as computed from the daily maximum temperature data provided by NASA. The parameter m indicates the current month, and y the current year.[14] The total number of years included in the reference time period, over which we average monthly temperatures to determine the 'normal,' long-term average monthly temperature, is denoted by the parameter n, while k is the running parameter of the summation, indicating the specific years. The maximum number of successive months with above long-term average temperature (that is, the 'drought months') in the period comprising the current month and the previous two months is denoted by $R^{(T)}$.[15] We choose a period of three months because it is typically the maximum lengths of the two rainy seasons and approximately half of the main dry season. When there is no drought month during this three-month period, the denominator in the first component of the TDI in Eq. (4) would take the value of zero, which would produce missing values for the TDI. Following Mutua & Zoltan (2009), we replace the denominator by 0.5 to avoid dividing by zero, assuming that there was a drought during one half of the month which is leveled off by the other half.[16] The running parameter *j* in the summations of the second product component in Eq. (4) indicates the specific months summing up to the three-month period. Thus, the second component of the TDI measures the aggregate deviation from average temperatures over a period of three months and so indicates the severity of the drought. It is weighted by the first component, which gives higher weights to the product when drought months are successive and frequent compared with spread and few extreme drought months *ceteris paribus*. For the average

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[13] The Precipitation Drought Index—also used by Mutua & Zoltan (2009)—is calculated identically (with reverse sign) and applied in our robustness checks. Yet the interpretation is reversed, since high temperature and low rainfall characterize droughts. In addition, we compute monthly temperature and precipitation 'anomaly' indexes and apply them to our empirical model to check its robustness in terms of the method used to construct the drought-measuring variable. The monthly temperature index is calculated as the difference of the (averaged maximum) temperature in the current month from the long-term monthly temperature average, divided by the long-term monthly temperature standard deviation. A month is a normal month if the temperature anomaly index equals zero, and a drought month if the index has positive values. The time reference period is identical with the one used to construct the TDI, and the precipitation anomaly index is constructed in the same way as the temperature anomaly index.

[14] Taken together, the month and year parameters give the time period parameter *t* in our estimation model.

[15] The total number of drought months between 1997 and 2007 is reported in Table 1.

[16] Replacing the first term of the TDI by the value one, if the denominator of this term is equal to zero, does not alter the main results of our estimation.

month, the TDI equals one; for hotter months (that is, 'drought months'), it shows values above one and below one for cooler months. The TDI directly enters our empirical model as the exogenous variable gauging weather variability ($weather$).[17]

Livestock price data, which give the deterministic, endogenous variable in our empirical model ($price$), are obtained from the Somalia Food and Nutrition Security Analysis Unit database (FNSAU 2011a). We use monthly market prices for living goat, cattle, and camels of local quality, as recorded in the main market of each administrative region. We normalize livestock prices by dividing through local market prices of (imported) petroleum to control for regional price inflation and thus obtain a better measure of local purchasing power. The normalization also makes prices reported in different currencies comparable. Depending on the location of the markets, the FSNAU database (FNSAU 2011a) reports local market prices in Somaliland Shilling and Somali Shilling. Since the stated currency conversion rates seem to be flawed, the normalization offers a practical transformation to obtain consistent price data. Livestock prices enter the empirical model in logarithmic terms, easing interpretation.

Empirical Results

Our regression results provide strong evidence that more droughts lead to more violent conflicts in Somalia and drought-induced cattle and goat price shocks drive civil conflict outbreaks. The estimated coefficients of the reduced-form regression and two-stage regressions for our preferred model specifications are reported in Tables 2 and 3, respectively. Table 2 shows that increases in drought frequency and intensity based on temperatures entail a higher number of violent conflict onsets overall. The coefficient of the TDI, which measures the effect of droughts on conflicts, is highly statistically significant. Table 3 indicates that droughts bring down cattle and goat prices, which, in turn, give rise to conflicts in consequence of substantial income losses. The effects on both stages are highly statistically significant for cattle and goat prices, but not for camel prices. The insignificance of camel prices in our model may be a result of lacking or poor markets for camel sales during droughts and is consistent with the notion that herders tend to liquidize camel herds—if at all—after having sold other household assets and livestock to smoothen the drought's impact on food consumption.

[17] Other drought indexes include the well-known Palmer Drought Severity Index (Palmer 1965) and the Vegetation Drought Index, applied by Mutua & Zoltan (2009) as well. We do not explore the performance of these indexes in this study, because these indexes include components such as soil characteristics, water availability, or biomass surface coverage which are influenced by human activities and possibly by conflict. When applied in our empirical model, the drought index would not be strictly exogenous anymore and may bias the estimation results.

Table 2. Effect of droughts on violent conflicts (reduced-form regression)

	No. of conflicts
Temperature Drought Index (TDI)	0.969***
	(0.289)
F-value	2.03***
R-squared	0.081
Observations	2,340
No. of regions	18

Source: Based on data from NASA (2011) and ACLED (2011).
Note: *** indicates that the coefficient is statistically significant at the 1 percent level. Standard errors are reported in parentheses. The specification includes region-fixed, time-fixed, and time trend effects.

Table 3. Effect of droughts on livestock prices and effects of drought-induced livestock price shocks on violent conflicts (two-stage regressions)

First stage	*Cattle price*	*Goat price*	*Camel price*
Temperature Drought Index (TDI)	-0.124***	-0.073***	0.006
	(0.035)	(0.024)	(0.033)
Second stage	*No. of conflicts*		
Cattle price	-11.13***		
	(4.984)		
Goat price		-15.69***	
		(7.460)	
Camel price			186.9
			(996.1)
F-value (of the first stage)	5.62***	5.01***	6.87***
R-squared	0.345	0.258	0.284
Underidentification test [1]	13.72***	9.80***	0.04
Weak identification test [2]	12.81	9.04	0.03
Root mean square error	5.725	5.554	59.75
Observations	1,289	1,585	1,560
No. of regions [3]	17	18	18

Source: Based on data from NASA (2011), ACLED (2011), and FSNAU (2011a).
Note: ***, ** indicates that the coefficient is statistically significant at the 1 percent and 5 percent level, respectively. Standard errors are reported in parentheses. All prices are normalized by dividing through local petroleum prices and transformed into logarithm. All specifications include region-fixed, time-fixed, and time trend effects.
[1] Kleinberger-Paap rk LM statistic, Chi-square value.
[2] Kleinberger-Paap Wald rk F statistic. The Kleibergen-Paap rk Wald statistic of the regressions with cattle and goat prices is larger than the Stock-Yogo weak ID test critical value for 15% maximal instrumental variable size.
[3] Too few cattle price data are available for Bari region. Similar results are obtained when this region is excluded in the goat/camel price regressions.

The effects of the drought-induced cattle and goat price shocks on conflicts are sizeable. Table 4 reports semi-elasticities which indicate the percent decline in cattle and goat prices due to a given increase of the TDI in level and the corresponding increases in the number of conflict onsets. Confirming the sequential process of livestock herd liquidation, goat prices are considerably more responsive to droughts than cattle prices. For example, an increase of the TDI by one standard deviation results in a drop of goat prices by 6.3 percent and only 3.7 percent in cattle prices. These price drops lead to an increase in the number of violent conflicts by 0.70 and 0.58, respectively.

Table 4. Livestock price-drought and livestock price-conflict (semi)elasticities

	Temperature Drought Index (TDI)	No. of conflicts
Increase of TDI by one standard deviation†		
Cattle price	-3.7%	0.58
Goat price	-6.3%	0.70
Increase of TDI due to an additional drought month associated with a temperature rise of 0.63°C		
Cattle price	-8.2%	1.28
Goat price	-13.9%	1.55

Source: Derived from Table 3.
Note: † The mean of the TDI equals -1.18 and one standard deviation equals 0.42

Furthermore, an additional drought month, which has been associated with an average temperature rise of 0.63 degree Celsius over our 11-year observation period, lowers cattle prices by 8.2 percent and goat prices by 13.9 percent and raises the number of conflicts by 1.28 and 1.55, respectively.[18] Relating these numbers to climate change projections suggest an alarming impact of climate change on conflicts in the future. Under its SRES A1B scenario, the Intergovernmental Panel on Climate Change (IPCC) projects a temperature rise for East Africa in the range of 1.8-4.3 degree Celsius by the end of the 21st century compared to the end of the last century (Christensen et al. 2007).[19] This corresponds to an increase in the number of drought months by three to seven and implies an increase in the number of violent conflicts by four to eleven.

[18] An additional drought month with an associated temperature rise of 0.63 degree Celsius corresponds to an increase in the TDI of about 2.21 standard deviations.

[19] The SRES scenarios refer to the scenarios described in the IPCC Special Report on Emissions Scenario (IPCC 2000). The A1 scenario family assumes rapid economic growth worldwide, a global population that peaks in the middle of the 21st century, and a rapid introduction of new and more efficient technologies. The A1B scenario group assumes technological change in the direction of a balance across all energy sources ranging from fossil intensive to non-fossil energy resources, associated with a moderate increase in climate gas emissions. Within each scenario group, three scenarios are considered that project less optimistic, medium, and most optimistic weather changes; the resultant range for temperature changes in East Africa is reported in the text.

Robustness Checks and Identifying Assumptions

Robustness of estimation results

The empirical results of our estimations may be sensitive to the specification of the regression functions and the variables used in the models. Therefore, we apply a comprehensive set of robustness checks to rule out potential disturbing effects systematically:

First, modifications of the reduced-form and two-stage regressions suggest that our results are entirely driven by changes in temperature (and not in other weather parameters) and that the used Temperature Drought Index is a good measure for identifying drought. We augmented the original reduced-form equation by incorporating a precipitation-based drought index as additional explanatory variable that turned out to have much less explanatory power than the temperature-based index (Table A1, Regression 1).[20] Although the coefficient of the Precipitation Drought Index (PDI) is statistically significant at the 10 percent level in the reduced-form regression, it does not alter the coefficient of the TDI considerably. In the two-stage regressions, the PDI coefficients are even statistically insignificant for all livestock price-differential specifications (Table A2, Regressions 1-3).[21] Therewith, we confirm findings from previous studies (Burke et al. 2009, Dell et al. 2009, Marchiori et al. 2011) according to which temperature-based indicators perform better than precipitation-based indicators in estimations of the relationships between weather shocks and conflicts and between weather shocks and economic variables. Moreover, a stronger responsiveness of livestock prices to changes in temperatures compared to precipitation has been found previously as well (Seo & Mendelsohn 2007). Finally, the TDI performs better than other temperature-based drought indicators such as temperature anomaly measures (Table A1, Regression 2; Table A2, Regressions 4-6), and, when using temperature and precipitation anomalies instead of the TDI and PDI in the augmented regressions, it holds that temperature-based indicators of weather shocks perform better than precipitation-based indicators (Table A1, Regression 3; Table A2, Regressions 7-9).[22]

Second, the estimated effects of the TDI on livestock prices and, in turn, on conflicts is robust to various alternative model specifications, controlling for potential effects of time lags, time sensitivity, and seasonality. The literature suggests performing robustness checks for a potential delay in the response of prices and conflict outbreaks to weather shocks (Miguel et al. 2004, Hendrix & Glaser 2007), potential non-linearity of the relationships of prices and conflicts to droughts (Schlenker & Roberts 2009), and differing responsiveness to weather shocks during the rainy seasons relative to the dry seasons (Lobell et al. 2011). To test for potential time lags and leads, we augmented the two-stage regression equations

[20] See Footnote 13.

[21] Furthermore, estimating the two-stage regressions with the PDI instead of the TDI yields statistically insignificant coefficients for all livestock price-differential specifications and therefore fails to reveal any second-stage effects.

[22] See Footnote 13.

with the TDI in lags of one to six months and in leads of one to three months successively.[23] We indeed found some statistical evidence for lagging effects of two to four months (comprising roughly one season) that, however, are not robust to the number of lags included (Table A3).[24] We also found a limited lead effect of one month in the cattle price-differential specification, which, again, is not robust to the inclusion of additional leads (Table A4). Due to unclear patterns of lagged and lead effects, we did not include the TDI lags or leads in our preferred regression specifications. Modifications of the TDI's reference period from three months to periods of two up to six months do not alter the estimated effects considerably and thus confirm that the length of the reference period in our preferred specifications is reasonable. Moreover, adding the TDI in squared terms to our preferred specifications provides no evidence of non-linearity in the drought-livestock price relationships, so that the specifications in linear terms remain our preferred ones. Also, augmenting the preferred specifications with an interaction term composed of the TDI and a dichotomous variable for the months of the short and main rainy seasons does not change the estimation results significantly. Accordingly, weather shocks during the dry and rainy seasons are equally serious in terms of their conflict impact overall. This robustness check also confirms that the TDI in combination with time-fixed effects performs well in controlling for seasonality.[25]

Third, neighborhood effects seem not to matter for conflict onsets, given the available data. Conceivably, droughts in one region may increase conflict onsets in neighboring (non-drought affected) regions through an influx of herds and associated livestock price shocks and other spatial dynamics that, when not taking into account, may lead to an underestimation of the drought impact. To test for such spatial dependencies (Florax & Folmer 1992), we successively augmented our preferred two-stage regression specifications with the TDI in spatial lags of order one and two.[26] The TDI in spatial lags turned out to be statistically insignificant in all livestock-price differential specifications, implying no neighborhood effect.[27] Yet it should be noted that the distance between the centers of regions is a very crude proxy of the covered distance between origin and destination of cross-region migration, given that data on the exact locations are lacking.

Fourth, the normalization of livestock prices does not compromise our estimation results. In fact, using the prices of other imported consumption goods such as rice or sugar for normalization instead of the

[23] We augmented the equations with the TDI in lags of up to six months to test for potential delays of one agricultural production cycle, comprising one dry and rainy season of approximately three months each. By augmenting the equations with the TDI in leads of up to three months, we test for the anticipation of expected drought effects during the dry season if rainfall failed in the prior rainy season.

[24] The coefficients of the lagged TDI become statistically significant for lags above five months. The reason may be that lags of six months and above pick up the effects of the previous agricultural production cycle.

[25] Estimation results for alternative reference periods, non-linearity and seasonality robustness checks are not reported but can be obtained from the authors upon request.

[26] The underlying spatial matrixes are constructed based the Euclidean distance between the geographical centers of all regions and the squared distances, respectively.

[27] Estimation results for spatial dependency robustness checks are not reported but can be obtained from the authors upon request.

price for imported fuel or abandon normalization does not change the estimated coefficients significantly.[28]

Validity of identifying assumptions

Our identification strategy of livestock prices as the driver of drought-induced conflict onsets rests on the validity of droughts as instruments of livestock price shocks. Test statistics indeed give confidence in the TDI as a strong instrument of livestock prices. The F-values of the first-stage regressions are relatively high for all our preferred model specifications, exceeding values of five, which gives a first indication of the strength of the instrument (Table 3). In addition, the weak instrumental variable tests proposed by Kleibergen and Paap (2006) reject the hypothesis of weak instruments at the 15 percent level (given the critical value provided by Stock & Yogo [2005]).

Next, our two-stage regressions are built on the assumption that droughts contribute to conflict onsets only through changes in livestock prices. As argued above, changes in livestock prices provide an accurate proxy for changes in real incomes in the case of Somalia, but we cannot completely rule out the possibility that there are other channels of transmission. Nevertheless, we believe that the existence of other channels is unlikely to jeopardize our general findings.

Besides income from livestock sales, droughts may affect non-livestock, agricultural income and, in turn, the economic incentives to participate in conflict. In the absence of data on agricultural income, we check the validity of our exclusion restriction by incorporating an additional instrumental variable in our preferred model specifications, which we expect to affect conflicts through no other channel than livestock price changes. This price index measures the exposure of Somali herders to international livestock prices.[29] As expected, the estimation results of the augmented model specifications do not

[28] Estimation results for price normalization robustness checks are not reported but can be obtained from the authors upon request.

[29] The index is constructed similarly to the seminal price index proposed by Bruckner and Ciccone (2010). Exposure is defined as the proximity (that is, the inverse of the Euclidian distance) from the geographical center of the administrative regions to the nearest, major livestock export port (that is, Berberra or Bossasso) adjusted for the livestock export share through this port. The livestock considered include goats (and sheep), cattle, and camels. The price index is constructed for each month m and year y as:

$$P_{i,l,m,y} = w_{i,l}\, p_{l,m,y}\,, \qquad \text{with } w_{i,l} = \frac{1}{dist_{ih}} \frac{export_{h,l}}{\sum_{l=1}^{3} export_{h,l}}\,,$$

where $w_{i,l}$ is the weight specific to region i and livestock species l, and p denotes the international price for beef and lamb (instead of goat meat), available from the Primary Commodity database of the International Monetary fund (IMF 2011). (We do not rerun the estimation with camel prices, since the coefficients are statistically insignificant in all specifications.) Entering the weight, the variable $export_{h,l}$ records the total number of heads of the livestock species l exported through port h between January 1994 and December 1996, provided by the FSNAU (2011a) database. We chose this time period, because it is prior to the time horizon of our estimation model and therefore strictly exogenous. We also estimated all model specifications with an extended reference period ranging from January 1994 to December 2010. Estimation results are very similar and therefore not reported for the extended reference period, but they can be obtained upon request.

reveal any channel of transmission other than livestock price shocks (Table A6). Precisely, under the assumption that at least one instrument is valid, the statistics of the Hansen J test for overidentification fail to reject the null hypothesis of zero correlation between the two instrumental variables and the error terms in all augmented specifications (Table A6).

Another possible violation of the exclusion restriction is the response of humanitarian assistance programs to drought-caused food shortages. In the case of Somalia, humanitarian assistance has been provided mostly in form of food aid (OECD 2009), and food aid can be expected to be targeted to the disaster areas in general. The distribution of (staple) foods may theoretically contribute to an increase in the demand for meat as a result of freeing up household resources destined for food purchases. However, the resulting income effect can be assumed to be minor considering that most food aid recipients are at acute risk of hunger and do not hold enough purchasing power to afford meat consumption anyway. Food aid delivered before the drought trickles down to human consumption though may smoothen the asset liquidation process and therefore may slow the decline in livestock prices. To be significant, it would require a boost in food aid, its distribution to be targeted perfectly in terms of time and space, and poor herders to be major beneficiaries. Past experiences do not support these requirements in the case of Somalia, and previous studies revealed weak links between volumes of food aid delivered and market price movements (Dorosh et al. 1995, Kirwan & McMillan 2007, Mabuza et al. 2009). Additionally, the expectation of food aid in times of emergency may hardly affect demand behavior prior to foreseeable food shortages since receiving (regular) food portions cannot be taken for granted. The supply-side effect of food aid diverted to feed livestock can be assumed to be insignificant, too, because most of all recipients are in dire need to consume the food themselves, the food in the form delivered is often not suitable for fodder, and the assumed amount diverted tends to be too small to have a significant market effect. Thus, distortions of livestock prices due to humanitarian assistance can be expected to be rather minor (if measurable at all).

Nonetheless, particularly in the case of Somalia, there has been a legitimate concern that humanitarian assistance is diverted to compensate fighters, exchange it for military equipment, attract new fighters, or buy loyalty among the impoverished population that all contribute to an expansion and intensification of conflict (Anderson 1999, Nunn & Quian 2011, Collier & Hoeffler 2007). On the contrary, humanitarian assistance has also been argued to reduce the likelihood of participating in conflicts for earning a living, which becomes particularly relevant under circumstances of lacking alternative sources of livelihood such as in times of hardship triggered by natural disasters or conflicts (Bas & Coe 2011, Gilligan & Hoddinott 2007). If the fueling effect of food aid on conflict dominates the opportunity income effect, our estimates represent the lower bound of the true impact of livestock prices on conflict. Unfortunately, due to lacking data on food aid, we were not able to test if food aid affects conflicts and, if so, into which direction.

Conclusions and Policy Implications

As a result of climate change, extreme weather events are predicted to become more frequent and more intensive in the future. Evidence for an increase of weather shocks in recent years includes the rising occurrence of major droughts in the Horn of Africa and Somalia in particular, which have led to one of the most severe famines in the region's history in 2011. In addition to the humanitarian suffering from the immediate impact, more frequent and more extreme weather events and therewith climate change further aggravate the risk of civil conflict in the longer run, as historical data on a global and regional basis suggest (Burke et al. 2009, Hsiang et al. 2011). Increasing civil insecurity puts an additional burden on the vulnerable population to adapt to climate change and on fragile states to foster economic development. Thus, understanding the relationship between civil conflict and weather shocks and estimates of the conflict impact of natural disasters is critical in the search of effective conflict mitigation strategies, the determination of the costs of climate change, and the implications for political action.

Our analysis showed that drought fuels civil conflict in Somalia. This finding reveals that the risk of violence outbreaks grows with increasing extreme weather events significantly not only at the global level and over decades—as shown in previous studies—but also at the local level and over a relatively short period of time. It also suggests that the conflict-drought trap in fragile countries will deepen in the course of progressing climate change, if no action is taken. Furthermore, we can confirm that economics matter even in a country like Somalia whose situation of repeated violence has too often been described as irrational or chaotic. More precisely, we innovatively demonstrated for Somalia that economic shocks proxied by changes in livestock prices drive civil conflict. Although the external validity of the finding that livestock price shocks are the main driver of drought-induced conflicts may be somewhat limited due to the dominance of the livestock sector as source of incomes in Somalia, it nonetheless points to the importance of markets as channel of transmission and the role of market disequilibria for violence outbreaks.

Our findings have several important policy implications for Somalia. First, increasing drought frequency and intensity and the resulting conflict aggravation call for urgent action to strengthen people's resilience to extreme weather shocks. Second, given the nexus between weather shocks, livestock price collapse, and conflict outbreaks, climate change adaptation needs to be considered as integral part of conflict prevention strategies, where pastoralist and semi-pastoralist livelihoods deserve special attention. Third, to improve people's resilience to weather shocks and lower the incentive for participating in conflict sustainably, alternative income sources and therefore economic growth and diversification is needed, in addition to social protection mechanisms. Ultimately, poverty reduction is key to conflict prevention. Yet the lack of national governance currently limits the range of feasible policy options and particularly in respect of the implementation of public safety net measures through national income redistribution. Fourth, early market interventions from the demand side and improvements in the functioning of local livestock markets to slow down the deterioration in livestock prices though offer alternative paths to reduce income loss of herders and thus mitigate the risk of conflict. For instance, market information asymmetry may be cut down through expansion of communication networks and services, realized by the private sector with support of international development partners. And, investments to better integrate and diversify Somalia's meat supply chain through investments in road infrastructure, slaughterhouses, and cold-storage warehouses, for example, may contribute to smoothen the destocking process of herds and reduce the animal death toll during droughts. Fifth, introducing and expanding credit and insurance markets may help herders to better cope with droughts through avoiding liquidation of their herds and, more importantly, easing the restocking of herds. Sixth, herders may need financial and technical support to adjust their herds toward more drought resistant and earlier marketable animals in order to be better prepared for more frequent and intense droughts in the future.

However, this list of possible actions also reveals the limitations of our analysis in terms of proposing specific policy recommendations in the case of Somalia. Critical knowledge gaps remain regarding the effectiveness of available policies and investments to strengthen resilience in pastoralist and semi-pastoralist livelihoods. Nonetheless, this paper elucidates the rational for fostering economic development in a country suffering from long-term civil war and increasingly severe consequences of climate change.

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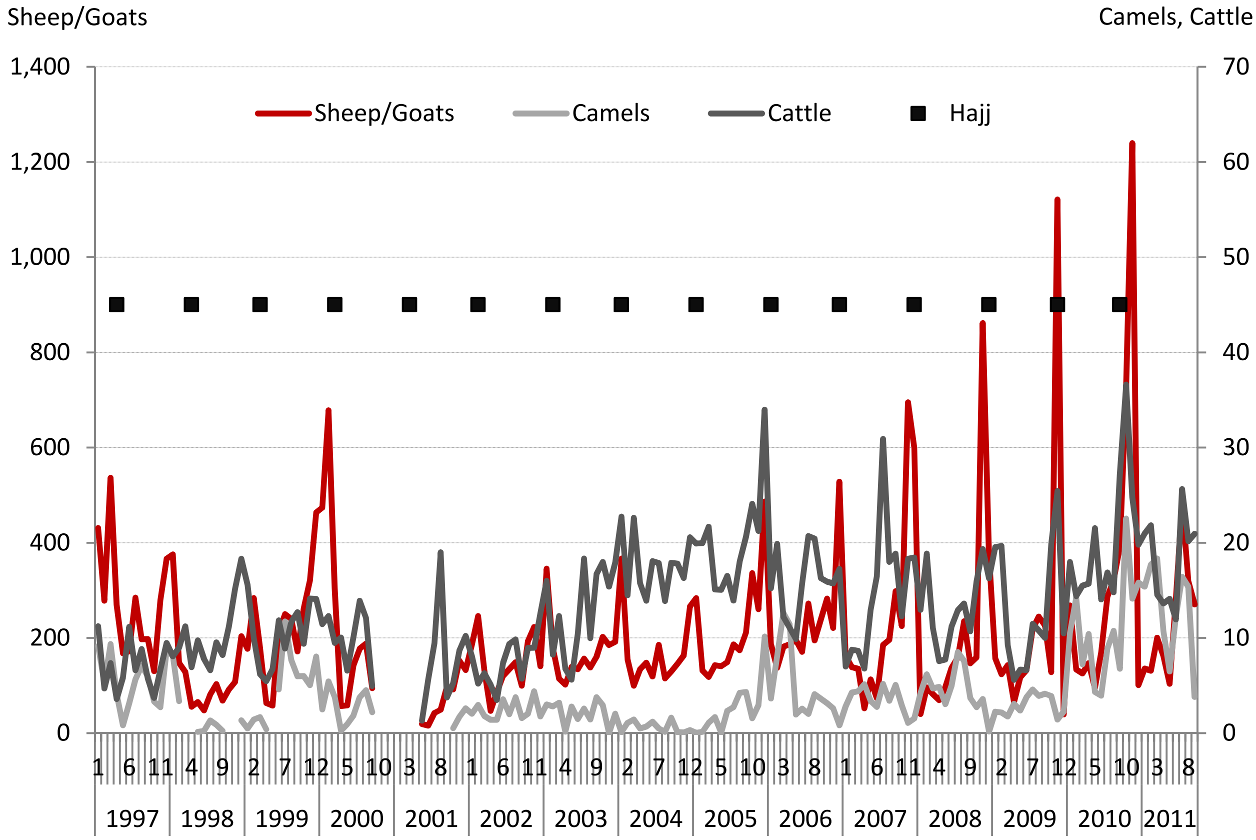
Appendix

Figure A1. Livestock exports from Berbera and Bossaasso ports (in thousand heads)



Source: Based on FSNAU (2011a) dataset.

Table A1. Robustness checks—Effect of droughts on violent conflicts (reduced-form regression modifications: temperature vs. rainfall-based indexes)

Regression	***(1)***	***(2)***	***(3)***
	No. of conflicts		
Temperature Drought Index (TDI)	0.888***		
	(0.292)		
Precipitation Drought Index (PDI)	-0.231*		
	(0.132)		
Temperature anomalies		0.609***	0.575***
		(0.141)	(0.142)
Rainfall anomalies			-0.201
			(0.129)
F-value	2.10***	2.16***	2.16***
R-squared	0.111	0.114	0.115
Obs.	2,340	2,376	2,376
No. of regions	18	18	18

Source: Based on data from NASA (2011) and ACLED (2011).

Note: ***' **' * indicates that the coefficient is statistically significant at the 1 percent, 5 percent, and 10 percent level, respectively. Standard errors are reported in parentheses. All specifications include region-fixed, time-fixed, and time trend effects.

Table A2. Robustness checks—Effect of droughts on livestock prices and effects of drought-induced livestock price shocks on violent conflicts (two-form regression modifications: temperature vs. rainfall-based indexes)

Regression	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
First stage	*Cattle price*	*Goat price*	*Camel price*	*Cattle price*	*Goat price*	*Camel price*	*Cattle price*	*Goat price*	*Camel price*
Temperature Drought Index (TDI)	-0.130***	-0.077***	0.002						
	(0.035)	(0.024)	(0.034)						
Precipitation Drought Index (PDI)	-0.022	-0.012	-0.014						
	(0.016)	(0.010)	(0.014)						
Temperature anomalies				-0.052***	-0.028**	-0.017	-0.053***	-0.029**	-0.017
				(0.019)	(0.013)	(0.019)	(0.019)	(0.013)	(0.020)
Rainfall anomalies							-0.008	-0.005	-0.002
							(0.014)	(0.011)	(0.013)
Second stage	*No. of conflicts*								
Cattle price	-7.970*			-16.27*			-14.65*		
	(4.163)			(8.845)			(8.726)		
Goat price		-12.20**			-27.97*			-24.84*	
		(6.147)			(15.26)			(14.50)	
Camel price			19.68			-47.41			-44.27
			(22.11)			(52.96)			(49.85)
F-value (of the first stage)	0.346	0.259	0.285	0.256	0.285	0.285	0.341	0.341	0.256
R-squared (of the first stage)	5.267	5.067	7.834	6.675	7.767	15.43	6.352	7.149	14.48
Observations	1,289	1,585	1,560	1,295	1,590	1,565	1,295	1,590	1,565
No. of regions [1]	17	18	18	17	18	18	17	18	18

Source: Based on data from NASA (2011), ACLED (2011), and FSNAU (2011a).

Note: ***,**,* indicates that the coefficient is statistically significant at the 1 percent 5 percent, and 10 percent level, respectively. Standard errors are reported in parentheses. All prices are normalized by dividing through local petroleum prices and transformed into logarithm. All specifications include region-fixed, time-fixed, and time trend effects.

[1] Too few cattle price data are available for Bari region. Similar results are obtained when this region is excluded in the goat/camel price regressions.

Table A3. Robustness checks—Effect of droughts on livestock prices and effects of drought-induced livestock price shocks on violent conflicts (two-stage regression modifications: TDI in lags)

Regression	***(1)***	***(2)***	***(3)***	***(4)***	***(5)***	***(6)***	***(7)***	***(8)***	***(9)***
First stage	*Cattle price*	*Goat price*	*Camel price*	*Cattle price*	*Goat price*	*Camel price*	*Cattle price*	*Goat price*	*Camel price*
TDI	-0.047	-0.020	-0.008	-0.078*	-0.038	-0.012	-0.075*	-0.035	-0.011
	(0.042)	(0.030)	(0.038)	(0.043)	(0.030)	(0.037)	(0.043)	(0.030)	(0.037)
TDI, lagged (t-1)	-0.111***	-0.077***	0.032	0.021	-0.008	0.060	-0.002	-0.024	0.057
	(0.041)	(0.029)	(0.045)	(0.051)	(0.036)	(0.052)	(0.052)	(0.037)	(0.051)
TDI, lagged (t-2)				-0.173***	-0.088***	-0.033	-0.100**	-0.039	-0.025
				(0.042)	(0.030)	(0.039)	(0.051)	(0.038)	(0.048)
TDI, lagged (t-3)							-0.096**	-0.0627**	-0.011
							(0.039)	(0.031)	(0.038)
Second stage	*No. of conflicts*								
Cattle price	-11.55***			-9.214***			-8.623***		
	(4.345)			(2.893)			(2.757)		
Goat price		-14.84**			-12.80***			-11.30***	
		(6.012)			(4.560)			(4.159)	
Camel price			42.21			17.66			16.44
			(58.22)			(17.84)			(17.08)
F-value (of the first stage)	5.625***	5.047***	6.919***	5.75***	5.75***	7.032***	5.76***	5.08***	6.97***
R-squared (of the first stage)	0.349	0.26	0.286	0.359	0.359	0.288	0.362	0.266	0.287
Underidentification test [1]	19.24***	15.33***	0.586	36.91***	22.82***	1.585	44.02***	26.99***	1.587
Weak identification test [2]	9.268	7.139	0.269	12.29	7.162	0.485	11.04	6.444	0.364
Root mean square error	5.782	5.411	14.29	5.418	5.123	7.297	5.34	4.941	6.99
Observations	1,285	1,581	1,556	1,281	1,577	1,552	1,279	1,575	1,550
No. of regions [3]	17	18	18	17	18	18	17	18	18

Source: Based on data from NASA (2011), ACLED (2011), and FSNAU (2011a).

Note: ***, **,* indicates that the coefficient is statistically significant at the 1 percent, 5 percent and 10 percent level, respectively. Standard errors are reported in parentheses. All prices are normalized by dividing through local petroleum prices and transformed into logarithm. All specifications include region-fixed, time-fixed, and time trend effects.

[1] Kleinberger-Paap rk LM statistic, Chi-square value.

[2] Kleinberger-Paap Wald rk F statistic. The Kleibergen-Paap rk Wald statistic of the regressions with cattle and goat prices is larger than the Stock-Yogo weak ID test critical value for 15% maximal instrumental variable size.

[3] Too few cattle price data are available for Bari region. Similar results are obtained when this region is excluded in the goat/camel price regressions.

Table A3 continued.

Regression	*(10)*	*(11)*	*(12)*	*(13)*	*(14)*	*(15)*	*(16)*	*(17)*	*(18)*
First stage	*Cattle price*	*Goat price*	*Camel price*	*Cattle price*	*Goat price*	*Camel price*	*Cattle price*	*Goat price*	*Camel price*
TDI	-0.073*	-0.036	-0.010	-0.073*	-0.036	-0.010	-0.076*	-0.039	-0.015
	(0.042)	(0.030)	(0.037)	(0.042)	(0.030)	(0.037)	(0.042)	(0.030)	(0.037)
TDI, lagged (t-1)	0.000	-0.023	0.052	-0.001	-0.024	0.052	0.006	-0.021	0.056
	(0.053)	(0.037)	(0.051)	(0.053)	(0.037)	(0.051)	(0.052)	(0.037)	(0.052)
TDI, lagged (t-2)	-0.123**	-0.044	-0.017	-0.120**	-0.042	-0.019	-0.125**	-0.044	-0.020
	(0.052)	(0.039)	(0.049)	(0.052)	(0.039)	(0.049)	(0.052)	(0.039)	(0.049)
TDI, lagged (t-3)	-0.019	-0.042	-0.027	-0.028	-0.048	-0.015	-0.019	-0.044	-0.014
	(0.054)	(0.039)	(0.048)	(0.055)	(0.04)	(0.048)	(0.056)	(0.04)	(0.049)
TDI, lagged (t-4)	-0.103**	-0.026	0.023	-0.065	-0.002	-0.010	-0.093	-0.015	-0.014
	(0.044)	(0.031)	(0.039)	(0.056)	(0.038)	(0.047)	(0.057)	(0.039)	(0.049)
TDI, lagged (t-5)				-0.049	-0.029	0.044	0.042	0.015	0.063
				(0.044)	(0.029)	(0.040)	(0.056)	(0.038)	(0.049)
TDI, lagged (t-6)							-0.117***	-0.055*	-0.022
							(0.044)	(0.030)	(0.039)
Second stage	*No. of conflicts*								
Cattle price	-8.607***			-9.432***			-9.717***		
	(2.730)			(2.886)			(2.939)		
Goat price		-11.83***			-13.03***			-13.52***	
		(4.33)			(4.607)			(4.664)	
Camel price			20.22			20.83			22.39
			(18.42)			(15.89)			(19.59)
F-value (of the first stage)	5.93***	5.10***	6.93***	6.01***	5.12***	6.94***	6.21***	5.21***	6.98***
R-squared (of the first stage)	0.364	0.266	0.287	0.365	0.267	0.288	0.369	0.27	0.288
Underidentification test [1]	54.74***	26.59***	1.862	55.28***	27.34***	3.116	62.78***	31.03***	2.065
Weak identification test [2]	11.55	5.085	0.344	9.855	4.36	0.479	9.928	4.312	0.516
Root mean square error	5.345	5.009	7.946	5.455	5.153	8.11	5.492	5.214	6.595
Observations	1,275	1,571	1,546	1,271	1,567	1,542	1,267	1,563	1,538
No. of regions [3]	17	18	18	17	18	18	17	18	18

Source: Based on data from NASA (2011), ACLED (2011), and FSNAU (2011a).

Note: ***, **,* indicates that the coefficient is statistically significant at the 1 percent, 5 percent and 10 percent level, respectively. Standard errors are reported in parentheses. All prices are normalized by dividing through local petroleum prices and transformed into logarithm. All specifications include region-fixed, time-fixed, and time trend effects.

[1] Kleinberger-Paap rk LM statistic, Chi-square value. [2] Kleinberger-Paap Wald rk F statistic. The Kleibergen-Paap rk Wald statistic of the regressions with cattle and goat prices is larger than the Stock-Yogo weak ID test critical value for 15% maximal instrumental variable size.

[3] Too few cattle price data are available for Bari region. Similar results are obtained when this region is excluded in the goat/camel price regressions.

Table A4. Robustness checks—Effect of droughts on livestock prices and effects of drought-induced livestock price shocks on violent conflicts (two-stage regression modifications: TDI in leads)

Regression	***(1)***	***(2)***	***(3)***	***(4)***	***(5)***	***(6)***	***(7)***	***(8)***	***(9)***
First stage	*Cattle price*	*Goat price*	*Camel price*	*Cattle price*	*Goat price*	*Camel price*	*Cattle price*	*Goat price*	*Camel price*
TDI	-0.082*	-0.071**	0.001	-0.093**	-0.068**	0.014	-0.082*	-0.064**	0.0003
	(0.045)	(0.030)	(0.043)	(0.046)	(0.031)	(0.045)	(0.046)	(0.032)	(0.041)
TDI, led (t+1)	-0.064	-0.001	0.013	-0.006	-0.006	-0.029	-0.021	-0.007	-0.002
	(0.042)	(0.030)	(0.037)	(0.054)	(0.038)	(0.051)	(0.055)	(0.040)	(0.047)
TDI, led (t+2)				-0.077*	0.003	0.053	-0.031	0.009	-0.001
				(0.045)	(0.031)	(0.046)	(0.059)	(0.039)	(0.047)
TDI, led (t+3)							-0.049	-0.008	0.038
							(0.048)	(0.032)	(0.038)
Second stage	*No. of conflicts*								
Cattle price	-10.27**			-10.11**			-11.07**		
	(4.959)			(4.877)			(5.053)		
Goat price		-16.04**			-15.89**			-16.64**	
		(7.690)			(7.804)			(8.434)	
Camel price			64.37			17.72			25.34
			(150.2)			(20.98)			(25.44)
F-value (of the first stage)	5.77***	5.01***	6.873***	5.848***	5.023***	6.847***	5.896***	5.039***	6.914***
R-squared (of the first stage)	0.348	0.26	0.284	0.352	0.26	0.286	0.356	0.261	0.327
Underidentification test [1]	16.61***	9.426***	0.225	19.555***	9.119**	1.567	18.988***	8.227*	1.67
Weak identification test [2]	7.745	4.344	0.103	6.13	2.796	0.48	4.394	1.885	0.386
Root mean square error	5.607	5.528	21.19	5.601	5.626	7.369	5.757	5.758	8.835
Observations	1,277	1,568	1,544	1,265	1,552	1,528	1,251	1,535	1,511
No. of regions [3]	17	18	18	17	18	18	17	18	18

Source: Based on data from NASA (2011), ACLED (2011), and FSNAU (2011).

Note: ***, **,* indicates that the coefficient is statistically significant at the 1 percent, 5 percent and 10 percent level, respectively. Standard errors are reported in parentheses. All prices are normalized by dividing through local petroleum prices and transformed into logarithm. All specifications include region-fixed, time-fixed, and time trend effects.

[1] Kleinberger-Paap rk LM statistic, Chi-square value.

[2] Kleinberger-Paap Wald rk F statistic. The Kleibergen-Paap rk Wald statistic of the regressions with cattle and goat prices is larger than the Stock-Yogo weak ID test critical value for 15% maximal instrumental variable size.

[3] Too few cattle price data are available for Bari region. Similar results are obtained when this region is excluded in the goat/camel price regressions.

Table A5. Robustness checks—Effect of droughts on livestock prices and effects of drought-induced livestock price shocks on violent conflicts (two-stage regression modifications: price transmission channel test)

First stage	*Cattle price*	*Goat price*
Temperature Drought Index (TDI)	-0.069**	-0.063**
	(0.034)	(0.024)
Beef price index	26,762***	
	(2,572)	
Lamb price index		316.3***
		(97.15)
Second stage	*No. of conflicts*	
Cattle Price	-6.040***	
	(1.377)	
Goat Price		-20.72***
		(5.708)
F-value (of the first stage)	7.354***	5.18***
R-squared (of the first stage)	0.388	0.263
Underidentification test [1]	78.86***	20.17***
Weak identification test [2]	63.1	9.515
Root mean square error	5.05	6.29
P-value Hansen J test	0.176	0.351
Observations	1,289	1,585
No. of regions [3]	17	18

Source: Based on data from NASA (2011), ACLED (2011), and FSNAU (2011).

Note: ***, ** indicates that the coefficient is statistically significant at the 1 percent and 5 percent level, respectively. Standard errors are reported in parentheses. All prices are normalized by dividing through local petroleum prices and transformed into logarithm. All specifications include region-fixed, time-fixed, and time trend effects.

[1] Kleinberger-Paap rk LM statistic, Chi-square value.

[2] Kleinberger-Paap Wald rk F statistic. The Kleibergen-Paap rk Wald statistic of the regressions with cattle and goat prices is larger than the Stock-Yogo weak ID test critical value for 15% maximal instrumental variable size.

[3] Too few cattle price data are available for Bari region. Similar results are obtained when this region is excluded in the goat/camel price regressions.