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The devil is in the details: An investigation of the relationships between conflict, food price and climate across Africa☆

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ABSTRACT

This study investigates the relationship between violent conflict, food price, and climate variability at the subnational level. Using disaggregated data on 113 African markets from January 1997 to April 2010, interrelationships between the three variables are analyzed in simultaneous equation models. We find that: (i) a positive feedback exists between food price and violence – higher food prices increase conflict rates within markets and conflict increases food prices; (ii) anomalously dry conditions are associated with increased frequencies of conflict; and (iii) decreased rainfall exerts an indirect effect on conflict through its impact on food prices. These findings suggest that the negative effects of climate variability on conflict can be mitigated by interventions and effective price management in local markets. Creating environments in which food prices are stable and reliable, and markets are accessible and safe, can lower the impacts of both climate change and conflict feedbacks.

1. How food price, climate and conflict are locally bound and inter-related

In this article, we explore how mediating factors are critical components of climate security. We investigate whether food insecurity, and in particular food price, may serve as just such a mediating factor. Food price is a key indicator because it acts as a local and dynamic measure of scarcity and competition, and hence an appropriate proxy for food insecurity, and may influence the variable forms of violent collective action occurring across developing countries.

The dynamics, scale and direction of mediating relationships between climate, food price and conflict has recently caught the attention of researchers, who generally find positive links between food price increases and violence. Yet, studies differ on the type, scale and evidence of the relationship between prices and conflict: Bellemare (2014) links monthly global food price data with media reports of riots within countries between 1990 and 2011; Smith (2014) finds sudden, monthly, increases in domestic prices of 'food baskets' increases the probability of urban unrest; and Hendrix and Brinkman (2013) regard food insecurity and rising prices as a 'threat multiplier' for civil conflicts, with a focus on riots.

Previous research largely focuses on 'food riots' that occurred in 2007–2008; yet a focus on riots implies that these actions are the most obvious response to food insecurity, and limits the range of political expression that can manifest from pressure, scarcity or marginalization as experienced by groups in developing countries. It also obscures how food prices and insecurity play into a range of other conflict inducing factors, as opposed to being a solitary trigger (see Demarest, 2014). We contend that how food price and climate influence political violence is largely determined by the goals and coordination abilities of affected groups, who incorporate the experiences of marginalization and hardship into their respective conflict strategies.

Additional issues that we address here is how the scale of these phenomena is a key feature in their relationships, and how climate, conflict and food price may exhibit non-linear and interactive relationships. We posit that the key attribute of these instabilities is their local nature: the price of commodities sold in local and regional African markets are largely unaffected by global prices and shifts; a wide range of political violence is localized; and climate and environmental change is mainly experienced and adapted to on the local level. Tests on the subnational scale are therefore the main way to accommodate the reality of how these three factors interact. We suggest that future interactions between

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food price and violence can be best addressed through local political intervention, aid and state capacity.

This article is the first to model the relationship between climate, food price and conflict sub-nationally, over time and across multiple states. By concentrating on the parameters of subnational relationships, we can more accurately capture the mechanisms that underlie variation and change, and identify the ways in which endogenous factors respond to stimuli. Further, in treating these instabilities as continuous and varying, we model the presumed interrelationships that now underscore policy narratives and future directions of development aid and humanitarian assistance. Here, we aim to address whether exogenous climate shifts increase conflict rates and volatility, how and whether food price fluctuations increase conflict, and finally, if there an indirect relationship between climate change and conflict through the impact of food price.

We find that a feedback exists between food price and political violence: higher food prices increase conflict within markets, and conflict increases food price. Lower than expected levels of rainfall directly increase food price and indirectly increase conflict through its impact on food price. These results mainly suggest that conflict rates and cycles can be contained through interventions and effective price management in local markets. Creating environments in which food prices are stable and reliable, and markets are accessible and safe, can lower the impacts of both climate change and conflict feedbacks. Hence local institutions have a significant role to play in instability, environmental and food security management.

These results have a larger significance through their assertions of how governance can attend to this issue: food security is a key development priority for all African states as over 60% of Africans are episodically food insecure and one quarter are chronically food insecure, defined as situations in which people spend up to half of income on food (Barrett, 2008; Swan et al., 2010; Arndt et al., 2008). The margins for impending food price crises continue to narrow as the majority of rural and urban Africans are now food purchasers instead of solely producers (Poulton et al., 2006: 343; Barrett, 2008; Swan et al., 2010; Maxwell et al., 2010). Understanding the interaction between climate, food and political instability is critical for both governments and citizens.

The article proceeds as follows: we review the recent literature on food price and conflict, and climate's impact on both conflict and price. We then present a unique interpretation of the sequential and interactive relationships and feedbacks between these three instabilities. This is followed by a discussion of data, measures and simultaneous equations model results, and finally, a discussion centred on the implications for the African continent.

2. Existing evidence and remaining questions about the relationships between climate, food price, and political violence across Africa

A key advance of this study is the assessment and modelling of subnational patterns of, and dynamics between, instabilities. Existing literature argues that direct, linear relationships should exist between climate and conflict, food price and conflict, and climate and food price. However, there is little in the way of complementary conclusions in this literature, in part due to the different scales and mechanisms employed to test presumed relationships. Indeed, the environmental security literature is characterized by opposite and conditional results that often obscure links between physical antecedents and political consequences.

2.1. Food price and conflict

The food crisis of 2007–2008 led to a wave of research correlating global food price changes to increases in political violence, often in the forms of 'food riots'. What constitutes a food riot, and comparisons between other forms of conflict, are often not systematic in this literature (Demarest, 2014). Indeed, in some cases (see Bellemare, 2014), the number of food riot reports, instead of actual events, is the object of study Bellemare (2014), Hendrix et al. (2009), Lagi et al. (2011), and Bereneza and Lee (2013), as well as multiple aid agencies and multilateral organizations (see Pomeroy, 2008; Lacey, 2008), argue that increases in African rioting was due to high and rising international commodity prices. Smith (2014) finds the same relationship between national price indices and specifically 'urban' unrest. The correlation between international food prices and presumed 'anti-government' demonstrators is, to Arezeki and Brückner (2011), a powerful effect that is stronger in low-income countries because of the greater sensitivity of poor households to price increases. In these cases, price increases lead to conflict over price stability or volatility (see Barrett and Bellemare, 2011). The underlying presumption is that poor populations protest how governments expose them to high, unpredictable prices that create scarcity and competition for necessary, but limited, resources.

Commodities and price differences may also affect a group's willingness to engage in different forms of violence: Besley and Persson (2008) find that the risk of civil conflict grows as a country's import prices increase and erode real incomes. This correlation is confirmed in a Colombian study where Dube and Vargas (2013) report that two primary commodities alter conflict risks differently: in rural, coffee growing areas, militia violence is reduced when export prices rise for coffee. However, in resource wealthy regions where oil is a capital intensive source of income for rebels and paramilitary groups, higher export prices for oil increases violence (Hendrix and Salehyan, 2012). In studies with alternative measures of the poor's access to food, countries with lower per capita caloric intake are associated with greater probability of civil conflict (Pinstrup-Andersen and Shimokawa, 2008), even when accounting for their levels of economic development (Sobek and Boehmer, 2008). The main mechanisms linking commodity prices to multiple forms of political violence is increased grievances due to scarcity, or opportunities for income generation.

In unstable states, a feedback between food price and conflict is expected to occur as political violence exerts a negative effect on local market functioning and leads to higher food prices and volatility (Devereux and Maxwell, 2001; Auyero and Moran, 2007). Commodity prices may rise due to excessive risks and transport costs, harvest costs, and market security costs. Another possibility is that food aid found in high conflict areas will corrupt market costs and keep prices artificially low (Maxwell et al., 2010). This suggests that price volatility, rather than price increases, is more likely in conflict affected regions.

2.2. Climate, prices and conflict

A rapidly changing climate, food availability and access, increased competition and conflict are central tenets of environmental security discourse (Barnett, 2010). The direct relationship between rainfall variation and conflict has been tested on a range of spatial scales, and across multiple types of conflict. The mechanism(s) through which climate and weather affects violence is largely unsubstantiated, but scarcity, competition, and strategic opportunity are frequently presented as likely explanations. The "scarcity" perspective suggests that increased conflict follows depressed environmental conditions, creating marginalization and intense competition for resources. By contrast, the resource "abundance" perspective suggests that the rainy season encourages rent-seeking behaviour, and thereby facilitates the recruitment of people for violent acts.

Empirical results on the relationship between climate and conflict are inconsistent, and cannot affirm a scarcity or competition narrative. Higher anomalous rainfall is associated with increased communal conflict levels but decreased civil war; while drier conditions have the opposite effect (Raleigh and Kniveton, 2012). Further evidence for the impact of both high and low rainfall is found by Hendrix and Salehyan (2012) and Theisen (2012). Witsenburg and Adano (2007) argue that conflict rates in rural, vulnerable areas are strongly seasonal, and highest in periods preceding high rainfall when strategic efforts to gain territory and control of migration paths are likely to return greater benefits. Similarly, cattle raiding is more common during the wet season in pastoral areas because of favourable operating environments and healthier animals (Adano et al., 2012). Rainy months may also increase the cover necessary to launch surprise-raiding attacks (Meier et al., 2007).

Recent disaggregated climate–conflict studies consider the indirect role of climate through mediating factors. Food availability and access function as such mediators since both rainfall and temperature affect food production and yields. Climate change "affects the supply side of agriculture primarily through its impacts on productivity, yields and the availability of land and water" (Huang et al., 2011). Climate change has already worsened crop production, labour market stagnation, and price levels and competition in food insecure countries (Maxwell et al., 2010). Both long and short deviations from the climatic mean can create scarcity through limited production and/or reduced yields. Yet, there remains substantial disagreement about the sequencing and certainty of whether decreased yields correlate to scarcity, competition and violence: Rowhani et al.'s (2011) study of East Africa finds that on both regional and village levels, decreased yields are not related to violence, and conflict is more likely in areas of high vegetation.

Specifically, the presumption that food price increases create scarcities and competition for resources is an indirect assumption of neomalthusian conflict logics (Demarest, 2014). Indeed, food prices are an increasingly posited, but rarely tested, intervening variable in the climate-security literature (see Berazneva and Lee, 2013; Zhang et al., 2010; Koubi et al., 2012).

Food price can be a proxy indicator for larger economic forces, and represent how these pressures affect conflict. It is through local economic constraints that most people are coping with present climate change, as farmers manage decreased yields, crop loss, pests and commodity crises as an indirect result of changing agriculture conditions. In most African countries, over 60% of the labour force is involved in agriculture (Beintema and Stads, 2004). The majority rely on rain-fed agriculture as the basis for their livelihood on smallholder farms, and 95% of cultivated land is under rain-fed agriculture (Rockström, 2003). By associating conflict with fluctuating environmental conditions and food insecurity through income, Miguel et al. (2004) argue that nationally aggregated changes in rainfall leads to negative economic growth, and increase the risk of civil war across African states. Lower economic growth creates grievances in employable young men, and further lessens the cost of rebellion through opening avenues of recruitment. Further tests of this argument have found that lower rainfall levels actually lessen the onset of civil wars, and that the original positive effect is not robust under additional specifications (Ciccone, 2011; Jensen and Gleditsch, 2009). At present, climate variability has found to have little to no effect on the risk of violence through reduced economic growth (Koubi et al., 2012).

What emerges from this literature is that regardless of the direction or specific combination of factors, conflict patterns and risks are contingent upon political and economic characteristics of states (see Barnett, 2000; Nordås and Gleditsch, 2007; Raleigh and Urdal, 2007; Theisen, 2008). But not all places are equally vulnerable to the adverse effects of price, climate, and political and economic insecurity. Agricultural productivity, household incomes and African food prices are still primarily a function of the economic and social characteristics of local areas (Eriksen et al., 2005; Paavola, 2008; Ahmed et al., 2011; Mendelsohn et al., 2007; Jones and Thornton, 2009; Dougill et al., 2010; Badjeck et al., 2010; Hertel et al., 2010). Recent evidence suggests that environmental changes affect conflict rates only in areas with existing high violence rates (O'Loughlin et al., 2014). Further, rural areas with the most degraded environments are sites of high poverty rates and food insecurity (Gray and Moseley, 2005), often dependent on rain-fed agriculture, and subject to high levels of vulnerability to ecological shifts and resultant volatility (Kevane and Gray, 2008). Many of these same communities have a higher risk of identity-based violence between small ethnic communities (Raleigh, 2010). In contrast, areas involved in cash cropping tend to be geographically concentrated in the most fertile and politically connected areas of the state (see Kasara, 2007; Boone, 2003) and suffer less extreme consequences from climatic shifts, possibly due to preemptive measures and higher rates of development.

2.3. Local factors

From the premise establish above, we can surmise that the scale at which phenomena are studied is of paramount importance: price variation, conflict rates and vulnerability to climate anomalies vary substantially at the local level, across states and over time in Africa.

2.3.1. Food price

Local crops types, infrastructure, local climate, seasonality, and select commodity yields are the most important indicators of price stability and rates across Africa; therefore food prices for staple commodities are largely locally determined. The 2007–2008 crisis is an exception to this, as staple food prices rose 63%; although lower than the global average food price increase, this increase was an aberration from typical patterns. The vast majority of African local markets are not affected by world food prices, despite the growing number of food purchasers. Rice prices are an exception (Minot, 2010). Changes to yield expectation affects commodity price, yet depressed crop yields or higher food prices are not immediately or definitively associated with food insecurity. Several crops on the local level are 'substitutable' and price transmission is strong across multiple states (Arndt et al., 2008; Cudjoe et al., 2010). Most food price vacillation is seasonal, occurring predictably preceding a harvest and at the end of the rainy period. In these periods, food stores decline and food prices hit normal peaks (Devereux et al., 2008; Barrett, 2008). Prices are also determined by market functionality, which often depends on relative 'remoteness', as accessible markets, and those closer to the capital, are typically larger and characterized by higher and more reliable supplies of food and infrastructural benefits. Domestic upsets to farming can cause severe market problems: climate disorders, long-term political instability, or misguided government intervention (e.g. Zimbabwe's land reallocation policy) all hinder trade. Overall, evidence suggests that along with the conditions for productive yields, market health and management are key aspects of price stability.

Despite the presumption that global trends create large scale and widespread price transmission, global food prices are poor representations of African market prices for several reasons: most African states are neither major importers nor exporters. The vast majority (90%) of food consumed in Africa is from domestic producers, and poor infrastructure and policy obstacles (e.g. tariffs) dampen trade and exchange (Barrett, 2013). Yet, particular commodities and economic conditions are more likely to be volatile and negatively influenced by market fluctuations nationally and globally. In periods of crisis, such as 2007–2008, the impact of global prices did not directly affect many of the staple consumables sold in local African markets (including beans, cassava, millet and sorghum); their muted price increases came from increased demand as a substitute for rice, maize and wheat, whose prices were strongly affected (Minot, 2010; Swan et al., 2010). Tradability has a strong effect on the price increases and volatility of African staple foods, yet the vast majority of consumed goods have intra-state trading networks (Minot, 2010). Hence, African commodity price vacillation is often insulated from price transmissions (Ivanic et al., 2012; Ghosh, 2010; Minot, 2010). The exceptions are areas with a high reliance on imported food (often rice), such as port cities (Swan et al., 2010). Consequentially, African domestic food prices are often more stable than global prices (Byerlee et al., 2006), especially so in landlocked states and those otherwise removed from the global economy.

2.3.2. Local political violence

Political violence is the use of force by a group with a political purpose or motivation, and involves contests between groups at the local, regional or national level. Multiple forms of conflict are often locally clustered, as are reasons for their onset. Violent groups rarely operate across large portions of a state, even for large insurgent campaigns: Raleigh et al. (2014) show that civil war occurrence is largely clustered within 15% of a state's territory, and multiple types of political violence show high rates of repeat behaviour and near-neighbour diffusion (Behlendorf et al., 2012; Zammit-Mangion et al., 2013). Further, multiple authors have recently highlighted the essentially 'local' cleavages and nature of larger conflicts in who and where is targeted (see Kalyvas, 2006; Rustad et al., 2011).

Considering the widespread and persistent nature of modern African conflict, understanding how local factors shape conflict trajectories is of critical importance. Research on subnational variations suggest that population density and institutional structures (Raleigh and Hegre, 2009; Cederman and Girardin, 2007), wealth variation and environmental characteristics (Buhaug and Rød, 2006), political exclusion (Cederman et al., 2011) and physical factors (Herbst, 2000) are key influences in determining where civil wars are likely to occur. This research tells us about common location characteristics for one specific form of conflict, yet multiple forms of political violence are spatially distinct but temporally co-occur. Indeed, Raleigh (2014) notes that civil wars, militia actions and communal violence co-occur with limited spatial overlap, as each form is uniquely structured by the relationship between groups and governments, and the goals of the conflict agents. Hence, the form of political violence that is likely to arise in localities is endogenous to the political relationships found within.

For that reason, a focus on riots, or any other particular form of conflict, presupposes a standard reaction to local experiences of marginalization and hardship. 'Food price' riots are overwhelmingly an urban phenomenon (Barrett, 2013) and often involve middle class and wealthier citizens over the more vulnerable poor, who have limited collective action mechanisms, despite the impact of high prices on this community. Indeed, food price riots are very difficult to identify, as concerns over the price of living in a common factor in both protests and riots across Africa; furthermore, any assumption of event cause can be highly biased (Demarest, 2014).

But, the intensity and frequency of all conflicts can be exacerbated by price variations, including competition for market dominance (Minot, 2010). Market locations are areas of strategic and target interests, and violence allows for control over particularly lucrative markets or trades; a study from Nigeria confirms that "markets often become flashpoints both because they bring large numbers of people from different ethnic groups together in a congested area, and because they offer a fertile context for 'conflict entrepreneurs' to exploit conflict for business or political ends. Unemployed youth can be hired at little cost in order to escalate any small conflict that occurs" (Porter et al., 2005: 2). Further, increasing prices for commodities may influence prices for livestock, milk, etc. making cattle raiding behaviour more lucrative for communal violence contenders. Finally, blaming high prices on ineffective governance may increase support for rebel or militia groups across their supportive communities. In short, multiple forms of conflict co-exist within states, with localized expressions and logics that transcend mono-causal assumptions like 'food price'.

2.4. Interactions

In addition to testing our questions on the subnational level, we argue that the dynamics between climate, price and conflict is conditional, interactive and sequential: we propose that three direct and indirect relationships may exist between the three key instabilities, in which climate change is exogenous to food price and conflict, while food price and conflict rates are endogenous to each other: (1) climate changes can create conditions for increased conflict; (2) increased food prices can create conditions for increased conflict; (3) climate changes can lead to vacillations in food price, which in turn create conditions for a rise in conflict. We express these relationships graphically in Fig. 1.

In keeping with the subnational literature on rainfall and conflict, our first (1a) and second hypothesis (1b) is that both a positive and a negative relationship exist between rainfall and conflict.

Hypothesis 1a. *Significantly decreased rainfall increases conflict.*

Hypothesis 1b. *Significantly increased rainfall increases conflict.*

We then suggest that, across markets, increasing food price should have an immediate and localized effect on conflict rates (2a), and that price and conflict demonstrate a feedback between high rates of both.

Hypothesis 2a. *Increasing food prices lead to higher conflict event rates.*

Hypothesis 2b. *A positive feedback exists between food price and conflict levels.*

Finally, we suggest an additional mode through which price can affect violence: climate's impact on conflict should be mediated through its impact on food price.

Hypothesis 3. *Anomalous climate events will increase food price, which then increases the rate of political violence.*

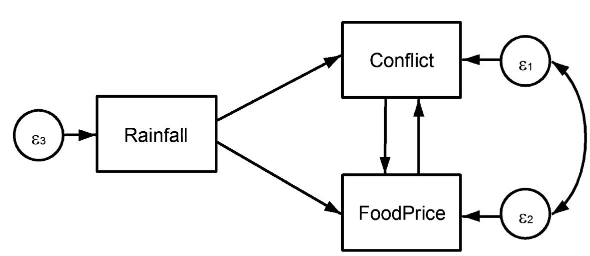

Fig. 1. A structural model of conflict, food price, and rainfall.

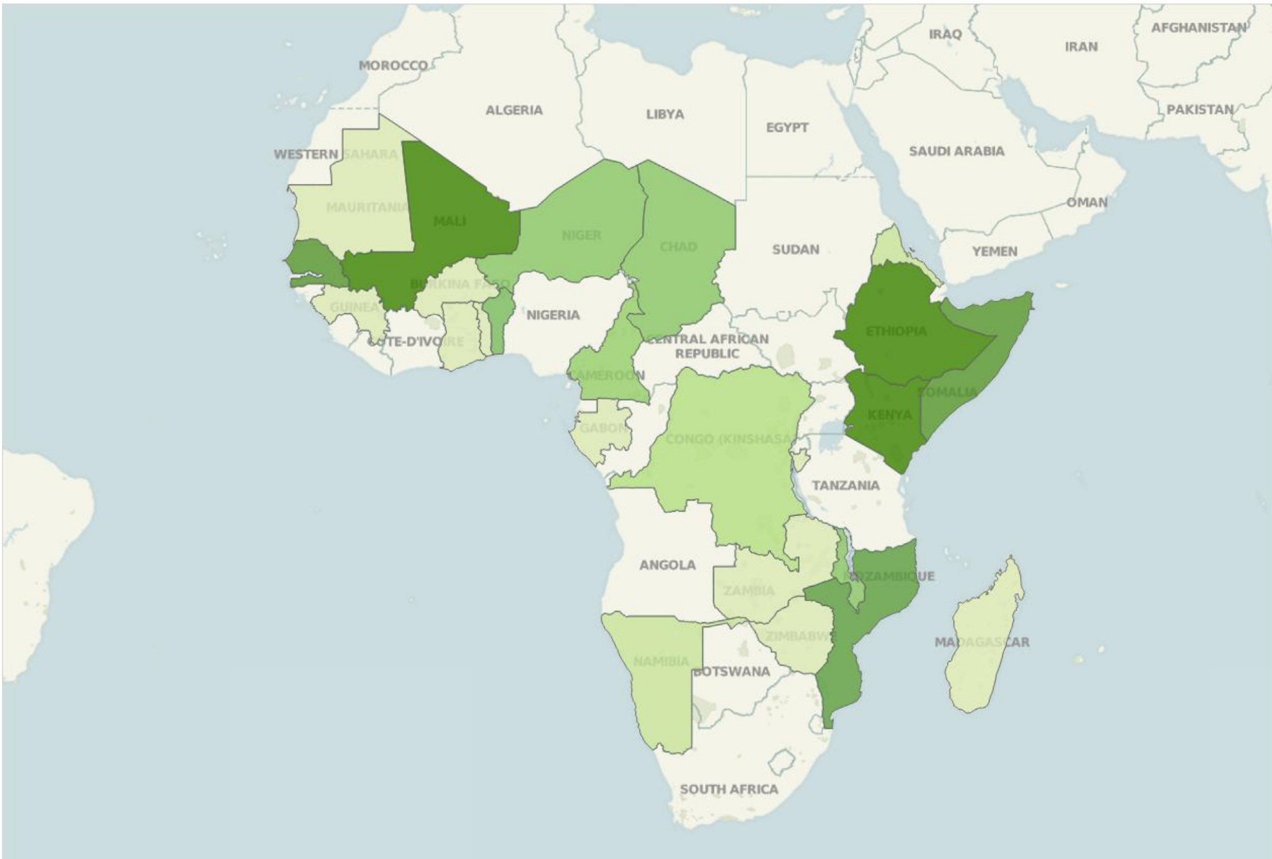

Fig. 2. Coverage of markets by African states. *Notes*: Coloured states are included in the analysis. Deeper colours reflect more markets within states.

3. Research design

The study area covers 113 markets in first level administrative regions in 24 African states (see Fig. 2). The selection is driven by the availability of commodity price information over time and across markets. This analysis covers countries with a range of political, economic, social and environmental characteristics. Of the 24 states, several have ongoing civil wars and all have some reported political violence during the dataset's time frame. Our unit of analysis is the administration-month period, clustered in county-years from January 1997 to April 2010; an increasing number of markets are incorporated throughout the timeframe. The resulting dataset includes 11,659 administrative-month units.

Markets included in this analysis and the food price data generally represent the main trading town in a first level administration district, and the patterns uncovered here can be considered broadly reflective of how food price and volatility vary within and across administrations within states. Main markets are 'price setters' in that smaller markets located within first level administration districts often follow their price signals (Renkow et al., 2004). This is largely due to intra-region price transmission and similar commodity choices therein.

Our main interests are the reciprocal relationships between food price and political violence, and the sequencing of the conflict–climate relationship. To estimate these, we specify a simultaneous-equations model with one equation for food price and another for the number of conflict events. In addition to the bi-directional relationship between food price and conflict, we also include several exogenous and predetermined variables in each equation to meet the conditions for identification. The system of two equations takes the following basic form:

$$Commodity_t = b_0 + b_1\, Conflict_t + \sum_{i=1}^{i=n}[b_2\, Rain(-)_{t-i}] + b_3\, GlobalPrice_t + b_4\, RainySeason_t + b_5\, Commodity_{t-1} \quad (1)$$

$$Conflict_t = b_6 + b_7\, Commodity_t + b_8\, CivilWar_t + b_9\, Democracy_t + b_{10}\, Growth_t + b_{11}\, Conflict_{t-1} \quad (2)$$

As such, we utilize two observed endogenous variables: $Commodity_t$ and $Conflict_t$. $Commodity_t$ is the natural log of commodity price (per kilogram) within a given market and month. Commodity data are from USAID FEWS-Net and reports commodity prices across African markets for variable time ranges. Often information on several commodities is collected, but not consistently within the same market. To rectify this, our analysis uses the monthly price of the most frequent commodity within each market; staple crops are often the most consistently reported commodity information by market. However, staple crops differ within and across countries. For example, matoke is the staple crop of southern Uganda, whereas sorghum and millet are the main consumed crops in western and northern Uganda. Price volatility varies across market administrations, although a sharp increase is displayed from 2007 to 2008 in many of the markets where mean prices for most commodities doubled. There is smaller variation thereafter. Several studies of food price and conflict operationalize commodity prices as the percentage change in price from the previous year (O'Loughlin et al., 2012; Smith, 2014). However, given the temporal unit of our analysis (month) and a strong first-order serial correlation in $Commodity_t$, this would make for many months with unusually high commodity prices have a value of near zero. For this reason, we use a standardized measure of commodity price rather than a measure of its change. Fig. 3 displays changes in the $Commodity_t$ variable in 6 selected markets.

$Conflict_t$ is the natural log of the number of violent conflict events in a given market and month. The conflict data comes from the geo-referenced Armed Conflict Location and Event dataset (ACLED) those records the date, location, actors, and types of conflict activity across all African countries between 1997 and into real time (Raleigh et al., 2010). For this study, we aggregated the number of violent events by month from 1997 to 2010 within each market administration district. We use all forms and events of political conflict for two reasons: there is no standard violent reaction to climate or food prices, and different communities engage in multiple types of violence that are shaped by political relationships and institutions instead of direct grievances (Choi and Raleigh, 2015). The $Conflict_t$ variable incorporates instances of violence against civilians (VAC) by state actors. One may argue that state-sponsored VAC is not driven by food scarcity and increased grievances. To address this potential problem, we performed robustness tests after removing the instances of state-sponsored VAC from the $Conflict_t$ variable. The results of robustness tests are reported in Appendix Table A1.

Climate is integrated into this analysis in the form of multiple parameters; each is designed to reflect how climate variations over time affect the productivity, scarcity and competition for resources. Together with temperature, rainfall primarily determines the amount of water available for crop production. However, rainfall varies over scales of tens of metres and seconds while temperatures variation is much less both spatially and temporally. Rainfall also has a complex inter-annual variability and sharp gradient, meaning that the change from excessively wet to dry can take place over a small area. High spatial variability, coupled with poor distribution of rain gauges, means that there are few continuous measurements of rainfall for much of Africa. Meteorologists and climatologists often therefore rely on satellite data that use indirect measures of rainfall. In particular, fine-grained temporal and spatial measures are necessary to capture the variation in rainfall for communities at risk.

Even in areas with high rates of rainfall, temporal variation can severely affect water supply, both from river runoff and rainfall (Vorosmarty et al., 2005). Rain-fed agriculture problems in water scarcity prone tropics are largely a function of the high intensity and spatial and temporal *variability* in rainfall, rather than low cumulative volumes (Mahoo et al., 1999; Rockström et al., 1998). The result is a high risk of meteorological drought and intra-season dry spells: the likelihood remains once every 10 years, while the occurrence of dry spells (short periods of 2–4 weeks without rainfall) are far more common.

Many studies use the amount of rainfall as a reliable indicator of climate variability (Solomon et al., 2007; Fjelde and von Uexkull, 2012; Raleigh and Kniveton, 2012). These variables use information from the CPC Merged Analysis of Precipitation (CMAP) to record monthly averaged precipitation rates (mm/day) for each 250 km × 250 km site where a market is based (Xie and Arkin, 1997). Average rainfall variation by year is relatively low, although average anomalies vary considerably over the study's time period.

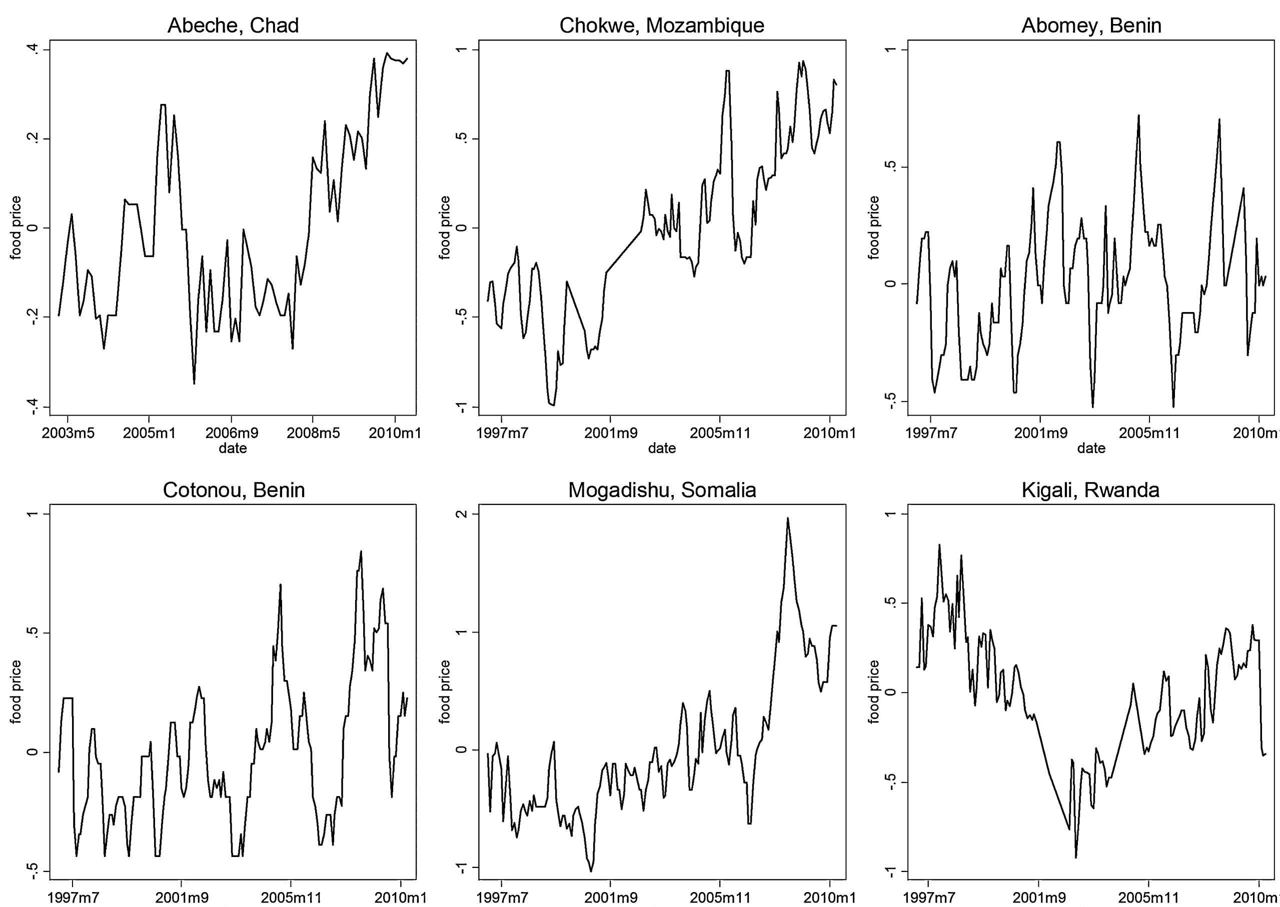

Fig. 3. Commodity prices in selected African markets. *Notes*: Prices are log transformed and centred by their respective market mean values.

Exogenous variables in the commodity equation – Eq. (1) – include positive or negative deviations of rainfall ($Rain(+)_t$, $Rain(-)_t$), the presence of dry conditions (*Drought*), a country's rainy season ($RainySeason_t$), and global food price index ($GlobalPrice_t$). These are all distinct variability measures. Following Raleigh and Kniveton (2012) and Fjelde and von Uexkull (2012), we generate the rainfall anomaly variables in the following way: for each market and month, we calculate the deviation of rainfall from the long-term average (1997–2010) and divide this score by the standard deviation of precipitation rates. Then, the variable $Rain(+)_t$ takes the value of positive rainfall deviations while setting all negative deviations to zero. On the other hand, the variable $Rain(-)_t$ takes the absolute value of negative deviations and sets all positive numbers to zero. By not imposing any parametric form on this relationship (such as a conventional quadratic function), these variables – $Rain(+)_t$ *and* $Rain(-)_t$ – more accurately measure the different effects of rainfall anomalies on conflict. As an alternative indicator of climate anomaly, we also construct a dichotomous variable *Drought* that takes the value of 1 if a market's rainfall remained considerably below average (that is, greater than one standard deviation below the long-term mean) during the four preceding months, and 0 otherwise.

Next, the $RainySeason_t$ dummy variable takes the value of 1 if a country is in the rainy season for a given month, and 0 otherwise. Rainy season months vary within and across countries, and this variable reflects the reported season for the administrative district of each market. For example, within Nigeria, the rainy season for Dandume district is a 5 month period from May to September while Bodija district's rainy season falls into two periods, March–July and September–October. Violence and commodity prices slightly vary by whether it is a rainy season; but the effects are not significant. We also include dummy variables for each month (using December as a reference category) to control for any remaining seasonal effects on commodity prices.

In addition, we utilize the International Monetary Fund (IMF)'s Global Food Price Index ($GlobalPrice_t$) as an additional exogenous variable in Eq. (1). The monthly IMF Food Price Index is the average of individual commodity price indices, weighted by their share in the volume of global food trade in 2005. The $GlobalPrice_t$ variable also serves as an instrumental variable for local commodity price in Eq. (2). We believe that $GlobalPrice_t$ satisfies the good instrument conditions suggested by Cameron and Trivedi (2010: 178): (1) it is *exogenous* because changes in food prices in local African markets are unlikely to impact global prices; (2) it is *relevant* because some of the local commodity prices may be influenced by changes in global prices (the correlation coefficient between $GlobalFood_t$ and $Commodity_t$ is 0.459); and (3) it is *exclusive* because changes in global food prices may affect conflict rates only indirectly through local prices.

Finally, we include lagged values of commodity price ($Commodity_{t-1}$) as a predetermined variable to account for a sluggish adjustment of prices to external shocks (Arezeki and Hasanov, 2009), and to address the potential problem of autocorrelation in the time-varying dataset (Wilson and Butler, 2007). According to Burkhart and Lewis-Beck (1994), the inclusion of lagged dependent variable may also help to capture the effects of omitted relevant variables.

Exogenous variables in the conflict equation – Eq. (2) – include the presence of civil war ($CivilWar_t$), the level of democracy ($Democracy_t$), and economic growth ($Growth_t$). $CivilWar_t$ is a dichotomous variable that equals 1 when a market is located in a country undergoing civil war that reaches a threshold of 25 battle-related deaths within a given month, and 0 otherwise (Gleditsch et al., 2002). Conflict events are expected to occur more frequently in markets in times of civil war.

We include $Democracy_t$ and $Growth_t$ as indicators of socioeconomic development and grievances. $Democracy_t$ is a 21-point index of democracy from the Polity IV Project (Marshall and Jaggers, 2011), and have been found to be significant predictors of civil war in previous research (see Hegre et al., 2001). $Growth_t$ is obtained from the World Bank (2014)'s World Development Indicators, and is measured by dividing the current year's GDP by the previous year's GDP. Lower levels of economic growth are expected to increase the risk of conflict by decreasing the opportunity cost of rebellion (Collier and Hoefflery, 2004). Finally, we include the lagged number of conflict events ($Conflict_{t-1}$) as a predetermined variable. The inclusion of lagged dependent variable helps account for the effects of inertia in conflict behaviour and deal with the problem of serial correlation.

A set of exogenous variables in Eq. (1) aid in the identification of the Eq. (2). At the same time, $CivilWar_t$, $Democracy_t$, $Growth_t$, and $Conflict_{t-1}$ in Eq. (2) help identify Eq. (1). That is, both equations are over-identified. All variables – except for $Rain(+)_t$, $Rain(-)_t$, and *Drought* – are centred around their respective market means to control for any unobserved differences between markets that are constant over time; these variables are already centred on the long-term average precipitation rate within each market. Centering all observations on their cluster means is equivalent to the fixed effects model, and allows us to obtain purely within-market effects of explanatory variables (Rabe-Hesketh and Skrondal, 2008: 111–112). Fig. 4 shows the distribution of two endogenous variables, while Table 1 provides summary statistics for all endogenous and exogenous variables. Lastly, we use cluster-robust standard errors in all of our regression models to account for the data structure that is clustered at the market level.

4. Results

Table 2 presents the results of maximum likelihood estimation of simultaneous equations for conflict and commodity price. Model 1 is a baseline specification that includes $Commodity_t$, $Conflict_t$, and exogenous control variables. The results in Model 1 are consistent with our expectation that food price and violent conflict are in a reciprocal relationship. The coefficient on $Conflict_t$ in the commodity equation is positive and statistically significant at the 0.05 level, indicating that higher number of conflict events contribute to higher food prices. When the number of conflict events is doubled, food price is expected to increase by about 1.6 percent in a given market and month, holding that market's other covariates fixed (when both *Y* and *X* are log-transformed, their relationship can be interpreted as the expected percentage change in *Y* when *X* increases by one percentage point). The coefficient on $Commodity_t$ in the conflict equation is also positive and significant, or increasing food prices lead to higher number of conflict events, thus supporting Hypothesis 2a. A 100 percent increase in food prices is associated with a 13 percent increase in the expected number of conflict events within a given market and month. Fig. 5 displays the reciprocal effects of food price and conflict on each other. Overall, these results demonstrate the existence of a positive feedback mechanism between food price and conflict, lending support to Hypothesis 2b.

Turning to the exogenous variables, the effects of both $Democracy_t$ and $Growth_t$ are negative and statistically significant in the conflict equation, suggesting that a market is less likely to experience violence when the state has higher levels of democracy and economic growth. The coefficient on $CivilWar_t$ in the conflict equation has the unexpected negative sign, but is not significantly different from zero. Thus, civil war onset at the country level loses its significance when the market fixed effects control the unobserved time-constant factors. The coefficient on $GlobalPrice_t$ in the commodity equation is positive and highly significant,

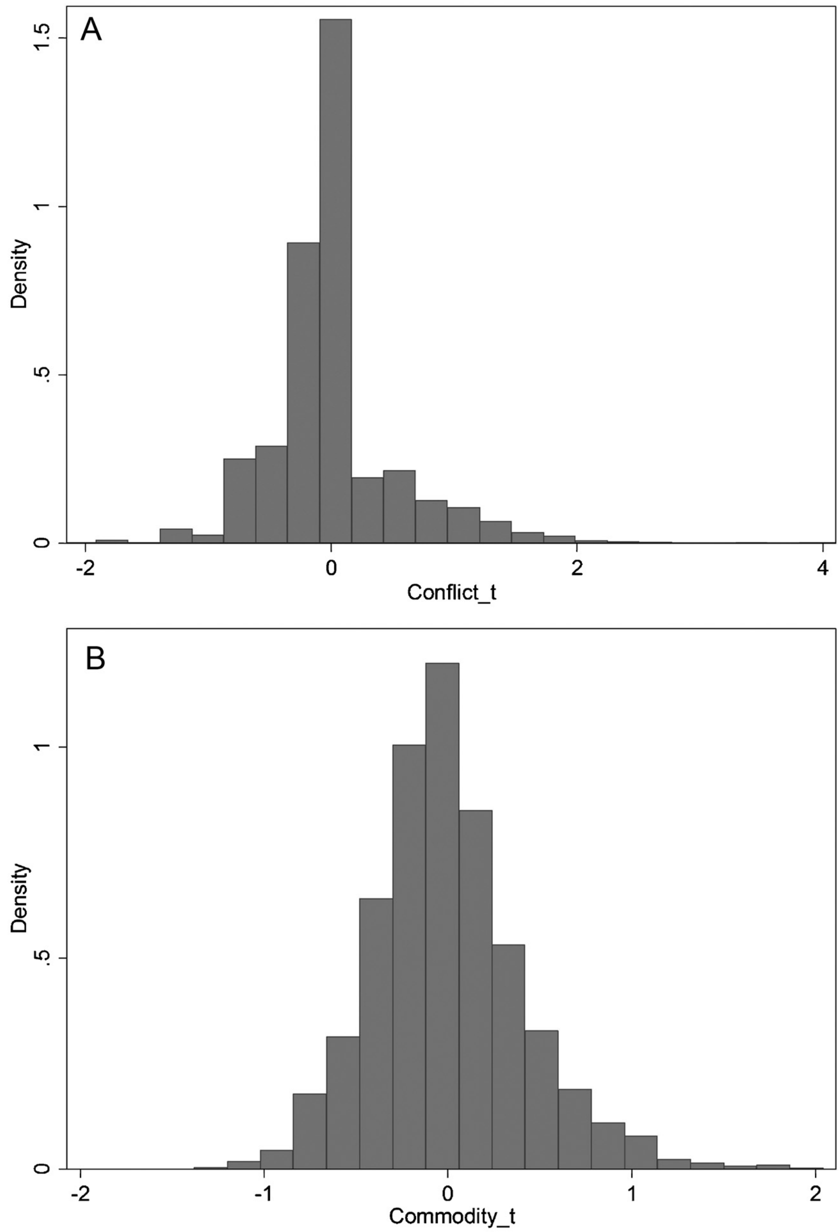

Fig. 4. Histogram plots of endogenous variables. *Notes*: Both variables are centred by their respective market mean values.

Table 1
Summary statistics for endogenous and exogenous variables.

Variable	Mean	Std. dev.	Min	Max
$Conflict_t$	0.000	0.517	−1.912	3.756
$Commodity_t$	0.000	0.414	−1.379	2.006
$Rain(+)_t$	0.395	0.722	0.000	7.038
$Rain(-)_t$	0.364	0.395	0.000	1.896
Drought	0.033	0.180	0.000	1.000
$Democracy_t$	0.000	1.717	−9.075	7.608
$Growth_t$	0.000	0.036	−0.137	0.248
$CivilWar_t$	0.000	0.137	−0.744	0.925
$RainySeason_t$	0.000	0.482	−0.842	0.882
$GlobalPrice_t$	0.000	26.152	−36.317	67.859

indicating that changes in global food prices are reflected in some of the local prices in African markets. Lastly, the coefficient on $RainySeason_t$ in the commodity equation is not distinguishable from zero.

In Model 2, we add exogenous variables for rainfall anomaly to Eq. (2). The coefficients for $Rain(-)_{t-2}$, $Rain(-)_{t-3}$, and $Rain(-)_{t-4}$ are positive and highly significant in the commodity equation; that is, negative deviations of rainfall from a market's long-term averages increase food prices at lags of two to four months. More specifically, a one standard deviation decrease in rainfall levels from the long-term average during the past 30–120 days is expected to increase food prices by about 9.1 percent, holding other covariates fixed. This finding indicates that food price's adjustment to climate change takes place after two months of low rainfall.

Table 2
Conflict, food price, and rainfall across Africa, 1997–2010.

	Model 1	Model 2	Model 3	Model 4	Model 5
Dependent variable: Commodity$_t$					
Conflict$_t$	0.016**	0.014*	0.019**	0.021**	0.018**
	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
Rain$(-)_{t-2}$		0.025***			
		(0.006)			
Rain$(-)_{t-3}$		0.034***			
		(0.006)			
Rain$(-)_{t-4}$		0.032***			
		(0.006)			
Drought			0.041***	0.039***	0.030***
			(0.009)	(0.009)	(0.010)
RainySeason$_t$	0.003	0.007	0.003	0.003	
	(0.006)	(0.005)	(0.006)	(0.006)	
GlobalPrice$_t$	0.001***	0.001***	0.001***	0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Commodity$_{t-1}$	0.903***	0.902***	0.905***	0.902***	0.904***
	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)
Monthly Dummies	Yes	Yes	Yes	Yes	Yes
Constant	−0.016**	−0.054***	−0.016**	−0.016**	−0.016**
	(0.008)	(0.007)	(0.008)	(0.008)	(0.008)
R-squared	0.891	0.896	0.896	0.891	0.891
Dependent variable: Conflict$_t$					
Commodity$_t$	0.131***	0.131***	0.134***	0.133***	0.134***
	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
CivilWar$_t$	−0.044	−0.042	−0.046	−0.046	
	(0.044)	(0.051)	(0.045)	(0.045)	
Democracy$_t$	−0.010***	−0.010***	−0.010**	−0.010***	−0.010**
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Growth$_t$	−1.078***	−1.106***	−1.090***	−1.084***	−1.009***
	(0.264)	(0.278)	(0.270)	(0.268)	(0.263)
Rain$(+)_t$			−0.002		
			(0.008)		
Rain$(+)_{t-1}$			−0.019***		
			(0.007)		
Rain$(+)_{t-2}$			−0.005		
			(0.008)		
Rain$(-)_t$				−0.032	
				(0.020)	
Rain$(-)_{t-1}$				0.054**	0.037***
				(0.026)	(0.013)
Rain$(-)_{t-2}$				0.006	
				(0.021)	
Conflict$_{t-1}$	0.349***	0.344***	0.346***	0.346***	0.349***
	(0.052)	(0.051)	(0.051)	(0.052)	(0.052)
Constant	0.005**	0.006***	0.015***	−0.005	−0.010*
	(0.002)	(0.002)	(0.005)	(0.007)	(0.006)
R-squared	0.160	0.157	0.161	0.160	0.161
N	8541	8426	8467	8502	8541
Log-likelihood	−57,130.13	−63,957.44	−75,111.72	−57,164.43	−55,010.55

Notes: Robust standard errors in parenthesis.
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$. Two-tailed tests.

In Model 3, we replace $Rain(-)_{t-2} - Rain(-)_{t-4}$ with *Drought* in the commodity equation, and add $Rain(+)_t - Rain(+)_{t-2}$ in the conflict equation. The effect of *Drought* in the commodity equation is positive and highly significant; the presence of dry conditions during the preceding months increases food prices in any given market and month, holding other variables constant. In the conflict equation, we find limited evidence for a negative effect of increased rainfall on conflict (see Fig. 6). All coefficients for positive rainfall deviations have negative signs, although only the coefficient for the immediately preceding month ($Rain(+)_{t-1}$) reaches statistical significance. This finding is contrary to the resource "abundance" perspective, which argues that increased rainfall creates conditions for violence by encouraging rent-seeking behaviour. Thus, Hypothesis 1b is not confirmed.

In Model 4, we examine the effects of significantly decreased rainfall on conflict by including $Rain(-)_t - Rain(-)_{t-2}$ in the conflict equation. The coefficient for $Rain(-)_{t-1}$ has an expected positive sign in the conflict equation and is statistically significant at the 0.05 level. Hence, one-month prior negative rainfall deviations are associated with higher rates of conflict (see Fig. 7). However, this result lends only partial support to Hypothesis 1a: coefficients for negative rainfall deviations switch signs at different lags, and the linear combination of all three coefficients fails to reach statistical significance at the 0.05 level.

Significantly decreased rainfall may affect conflict rates indirectly through the rise of food prices. We calculate the indirect effects of decreased rainfall and its associated confidence intervals using formulas presented in Sobel (1987). We find evidence for the presence of such indirect effects. When considering the feedback loop between food price and conflict, the presence of drought (*Drought* = 1) raises food prices by about 4.4 percent and this in turn produces about one more conflict event within a given market

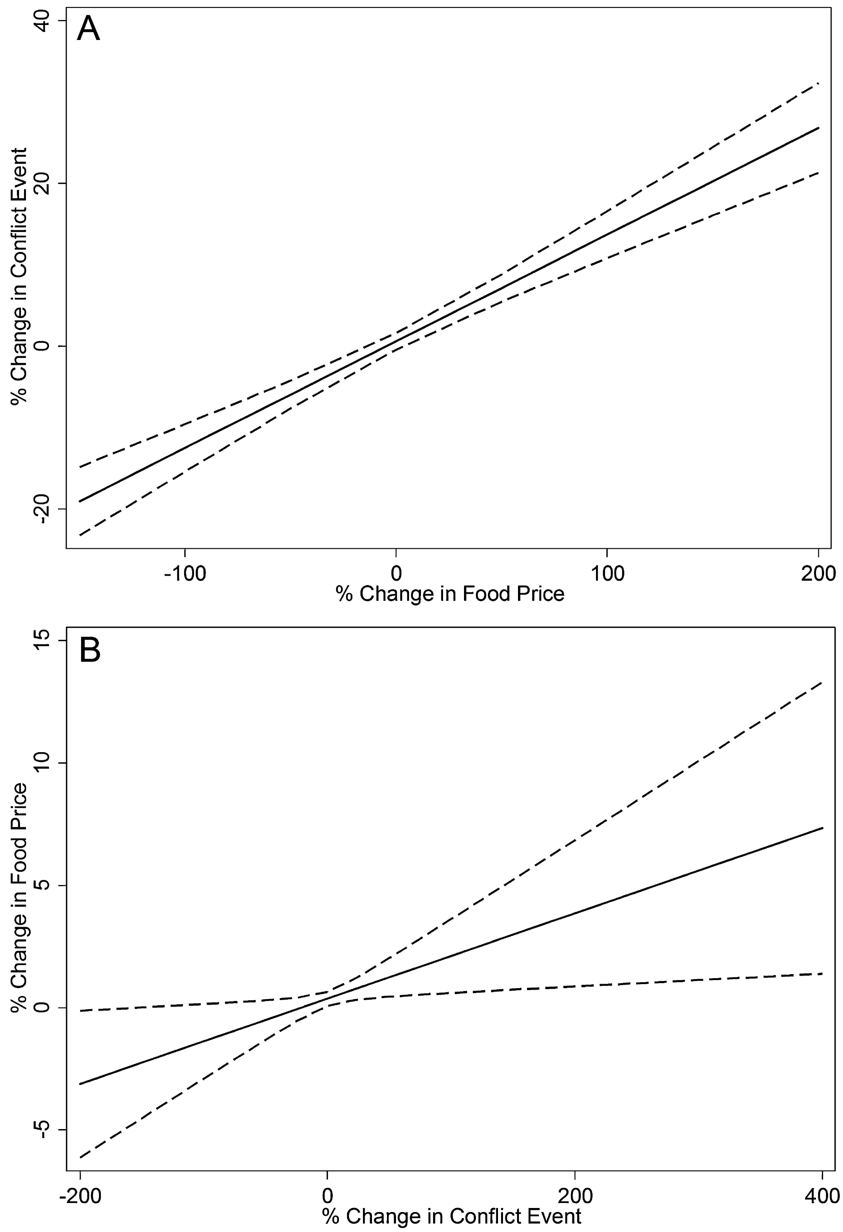

Fig. 5. Reciprocal effects between conflict and food price. *Notes*: A and B were generated using Model 1. Dashed lines represent 95% confidence intervals.

and month. Table 3 summarizes the indirect effects of rainfall anomalies on conflict. These results provide strong support for Hypothesis 3. Finally, Model 5 is a trimmed specification including only variables significant in Model 4; no substantial differences are found between the two model results.

5. Discussion

In this article, we explore the evidence for feedbacks and sequential effects between conflict, food price, and climate change. Our findings suggest that (i) higher rates of conflict are expected in markets with higher food prices; (ii) violence raises the average price of commodities in markets; (iii) anomalously dry conditions are associated with increased frequencies of conflict; and (iv) decreased rainfall exerts an indirect effect on conflict through its impact on commodity prices. Overall, we contribute to a wider set of literature on climate-security links by emphasizing the role of intervening and mediating factors linking physical change to political instability.

Our analysis uses subnational and time varying data for all three instabilities: monthly market data can more accurately capture how rainfall variations across a state affect subsistence commodities, how conflict rates affect market stability, and how the economic health of a region impacts conflict rates. Each of these factors is dynamic over time and space. Together they suggest that there exists a variation in vulnerability across markets, and alternative scenarios through which climate impacts can be addressed: urban markets in states safe from global economic shocks may be more resilient to variations in climate and food price through legislation, commodity substitution and common coping strategies. However, in rural areas without support, intervention or commodity substitution possibilities,

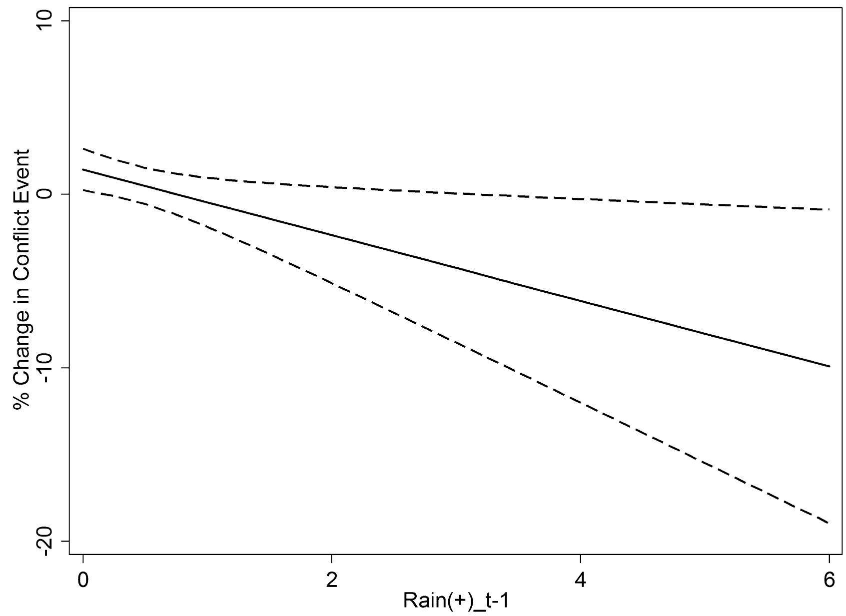

Fig. 6. Effects of positive rainfall deviations on conflict. *Notes*: Numbers on the *x*-axis represent the degree of positive rainfall deviations from the long-term market average in the previous month. This figure was generated using Model 3.

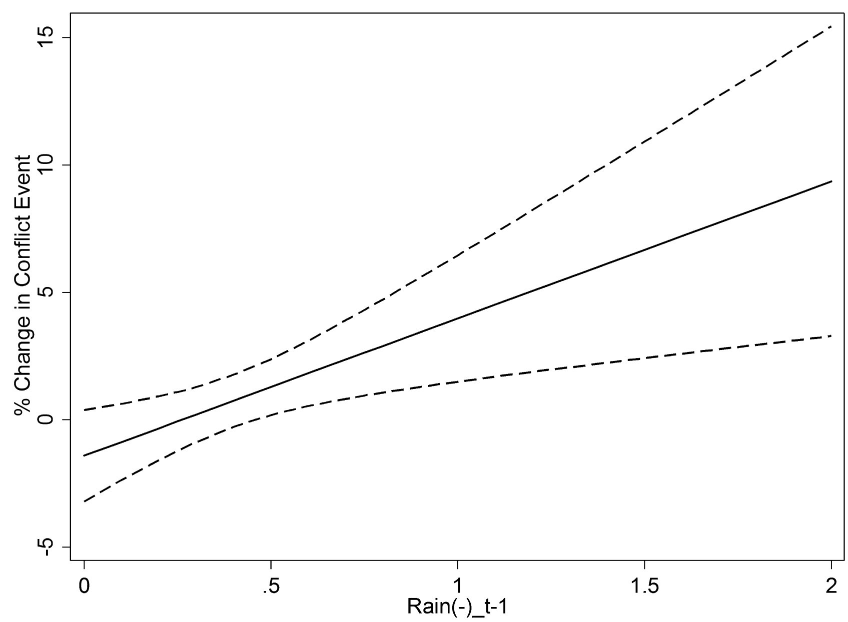

Fig. 7. Effects of negative rainfall deviations on conflict. *Notes*: Numbers on the *x*-axis represent the degree of negative rainfall deviations from the long-term market average in the previous month. This figure was generated using Model 4.

climate changes may be quite detrimental to the economic and political stability of regions. This speaks to the topography of risk and responses in how environmental security can be addressed by communities, governments and aid organizations.

Table 3
Indirect effects of rainfall anomalies on conflict.

Variable	Coefficient	Robust S.E.	$P > \|z\|$
Model 2			
$Rain(-)_{t-2}$	0.00360	0.00121	0.003
$Rain(-)_{t-3}$	0.00493	0.00162	0.002
$Rain(-)_{t-4}$	0.00454	0.00102	0.000
Model 4			
Drought	0.00578	0.00157	0.000

Notes: Effects are calculated using the formulas in Sobel (1987).

The links between economic instability and violence is suggestive, but not determinative. The differences in perceptions and consequences of the 2007–2008 commodity price increases and those of 2010–2011 underscores how political violence in any form is not a standard reaction to food price vacillation. In 2010, harvests were healthy and crucially, governments sought to influence the impact of price increases.

In choosing states experiencing a range of conflict severity over 1997–2010, we realistically capture how 'normal' market and commodity volatility is within African states. Our findings can be generalized outside of our sampled twenty-four African states to others experiencing a range of instability. Communities in states experiencing severe violence often adapt to new circumstances by engaging in normal activities within war economies; this can include farming, selling goods and incorporating the additional risk within food prices. This underscores the perception that the most vulnerable across developing countries survive through community assistance, instead of benefitting from external assistance.

Across African states, a more pressing spectre is looming: as more people become food consumers as well as producers, the influence of climate change and the health of markets is paramount for domestic stability. The ability of institutions and effective governance to mitigate the negative externalities of climate change and to dampen the likelihood of higher conflict risks is through policies on food price volatility, market development, and time-sensitive supplements to failing markets. Food price controls are a key area where governments can address environmental security, but they must be carefully attuned to the local political and economic dynamics of the locations in which they are applied.

A number of previous measures to control food price include market boards, which set prices for staples and export goods. However, these boards often acted to support and enrich the state by elevating the national price of goods regardless of local circumstance. Further, during the 1970s and 1980s, market boards supported an 'urban bias' whereby food prices were set to favour urban consumers instead of rural producers. This was to curb possible restive behaviour from urban residents who have a higher ability of collective action against the government. Political biases continue to favour of particular markets, in the form of the range of commodities available, updated infrastructure, security, and positive interventions. However, the majority of Africans may be subject to markets with limited and failing infrastructure, insecurity in a variety of forms, and negative, late interventions. This limits the ability to address the growing needs of the populations, and may create a fertile environment for anti-government sentiment, which can occur in a variety of forms and have quite serious ramifications for the stability of the state.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.gloenvcha.2015.03.005.

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