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Food scarcity and state vulnerability: Unpacking the link between climate variability and violent unrest

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Abstract

Increased scholarly focus on climate variability and its implications has given rise to a substantial literature on the relationship between climate-induced food insecurity and violent conflict. In this article, we theorize this relationship as contingent on the institutional and structural vulnerability of the state. States' institutional and structural capabilities and constraints – such as the strength of the agricultural sector and domestic regime type – influence the probability that climate-induced food insecurity will translate into conflict, because they determine the degree to which countries are able to successfully address insecurity. We estimate the effect of food insecurity and state vulnerability on the occurrence of violent uprisings in Africa for the years 1991–2011. We find that these effects are interactive, with state vulnerability moderating the impact of food insecurity on the likelihood of violence. We also find that capable governance is an even better guarantor of peace than good weather. We conclude that a two-pronged approach that both combats the impact of climate variability on food insecurity and strengthens government institutions would be a much more effective strategy for preventing violent uprisings than either policy would be in isolation.

Keywords

Africa, civil conflict, climate change, climate variability, contentious politics, food prices, food scarcity, state capacity

When and under what circumstances does extreme weather increase the likelihood of violent unrest? Evidence in the literature has so far been piecemeal (for recent reviews, see Hsiang, Burke & Miguel, 2013; Buhaug et al., 2014). We focus on an oft-posited mechanism through which extreme weather may impact the likelihood of violent unrest: abrupt increases in the threat of food insecurity. We define the threat of food insecurity as the prospect of decreased access to food due to shocks to the price and supply of food within a state. Recent studies have argued that climate-related threats to food security have contributed to destabilizing numerous countries (see for instance Johnstone & Mazo, 2011; Kelley et al., 2015).[1]

In order to better understand and capture the relationship between extreme weather and violent unrest, it

[1] There are other possible paths through which extreme weather events, and climate variability more broadly, may impact violence and other social phenomena – for instance, natural disasters (Nel & Righarts, 2008; Slettebak, 2012; Nardulli, Peyton & Bajjalieh, 2015).

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is important to theorize and model it as a complex phenomenon. On the one hand, a sudden increase in the threat of food insecurity emerges from two distinct processes: extreme precipitation within a state, which undermines agricultural production, and international food prices, which may make food unaffordable. Therefore, we simultaneously account for the impact of both extreme weather and international food prices on the risk of food insecurity. As a result, we are able to theorize and model the extent to which each of these factors contributes to abrupt increases in the threat of food insecurity in a state. On the other hand, however, a sudden increase in the threat of food insecurity does not directly result in violent unrest. Rather, the effect of food insecurity is moderated by state (in)vulnerability to it. We argue that state vulnerability is a multifaceted concept, corresponding with economic and geographic features of a state that may magnify the impact of food insecurity, as well as with the capacity of a state to prevent or manage the ramifications of food insecurity. Thus, to understand when abrupt increases in the threat of food insecurity translate into conflict, it is important to account for the vulnerability of the state. States that are less vulnerable to the threat of food insecurity will be better able to avoid violent unrest than states that are more vulnerable.

Central to our argument is the notion that states vary *systematically* in their vulnerability to an increase in the threat of food insecurity. We follow the IPCC in defining vulnerability as 'including sensitivity or susceptibility to harm and lack of capacity to cope and adapt' (IPCC, 2014: 5). Thus, we conceptualize state vulnerability to unexpected shocks to food security as arising from two main sources: susceptibility and capacity. Susceptibility refers to economic and geographic factors that make a state more likely to experience food insecurity following extreme weather and food price fluctuations. Capacity refers to the ability of a state to respond to and manage sudden increases in food insecurity – that is, the ability of the state to govern its people (Almond & Powell, 1966; Fearon & Laitin, 2003). While many dimensions of state capacity have been explored in the literature, the most relevant to governing in the face of scarcity is institutional coherence and economic might. These two features enhance the state's ability to marshal the resources and wield the policy tools necessary to respond to the negative ramifications of an increase in the threat of food insecurity and thereby avoid violent unrest.

The pivotal role of state vulnerability can be illustrated via a comparison of the divergent experiences of Kenya and Ghana during the 2000s. Between 2003 and 2004, a severe drought – a typical instance of extreme weather whose likelihood is increased by climate variability (IPCC, 2013) – hit Eastern Africa. A similar drought affected Ghana in 2007. However, in the aftermath of these extreme weather events, Kenya experienced more widespread violent unrest (four episodes in 2004) than did Ghana (one episode in 2007) (Salehyan et al., 2012). These droughts fomented grievances, both new and pre-existing, within each state. Yet the fact that Kenya experienced far more violent unrest can be explained, we argue, by examining its relatively greater vulnerability. Kenya was unable to insulate itself economically from the effects of poor weather as its GDP per capita was below the median value for African states, and its population was more than triple the median, leaving the government with less capacity to respond to this exogenous shock.[2] By contrast, Ghana was in a comparatively stronger position to manage the consequences of an extreme drought and marshal the resources of the state to mitigate its negative consequences. Its population was much smaller, and its GDP per capita was higher, well above the median level in Africa. As a result, President John Kufuor quickly responded to the crisis by approving a $1 billion package of interventions to mitigate the impact of the drought on Ghanaians.[3]

We present two innovations to current studies of shortage-induced conflict. First, we theorize and model both food insecurity and state vulnerability as multidimensional phenomena. In so doing, we take into account multiple determinants of each phenomenon simultaneously, rather than relying on a single factor to serve as a proxy for the underlying concept. In turn, this allows us to theorize and model the individual contributions of many distinct factors to food insecurity and state vulnerability respectively. Thus, we are able to generate holistic estimates of the threat of an abrupt increase in food insecurity, as well as the vulnerability of a state to such a development. Second, we explicitly theorize and model violent unrest as the result of an interaction between food insecurity and state vulnerability. Therefore, we directly model the extent to which state vulnerability conditions the effect of food insecurity in generating violent unrest. We expect sudden increases

[2] 'Million hit by drought in Kenya', BBC News, 16 June 2004. It is important to note that Kenya experienced notable moments of violence, especially during electoral periods such as 1992, 1997, and 2007 elections. We thank an anonymous reviewer for this clarification.

[3] Michael Fleshman, Africa Struggles with Soaring Food Prices, *Africa Renewal*, July 2008 (http://www.un.org/africarenewal/magazine/july-2008/africa-struggles-soaring-food-prices).

in food insecurity to be more likely to trigger violent unrest in vulnerable states than in stronger states. Few studies have explicitly theorized and modeled this moderating effect (a notable recent exception is Hendrix & Haggard, 2015). Using data on violent uprisings in Africa in the time period 1991–2011, we demonstrate that state vulnerability dramatically increases the impact of threats to the local and global food supply on the likelihood of violent social unrest.

Climate variability and conflict

Evidence of the impact of climate-related weather disruptions on the occurrence of conflict is mixed (Salehyan, 2014).[4] These discordant results are especially noteworthy, for our purposes, as they pertain to studies of weather extremes in precipitation patterns.[5] Salehyan & Hendrix (2014) argue that droughts have a pacifying effect on armed conflict because more water enables mobilization. Similarly, Theisen (2012) studies the incidence of conflict in pastoralist communities in Kenya and finds that conflict becomes more likely following years when rain is more abundant. In contrast, Hendrix & Glaser (2007: 695), in studying interannual variability in rainfall as a trigger for conflict, find that 'positive changes in rainfall are associated with a decreased likelihood of conflict in the following year'. Yet, Hendrix & Salehyan (2012) find that both particularly dry and wet years, as identified by deviations from the long-term annual mean of precipitation, increase the probability of violent conflict. Relatedly, Raleigh & Kniveton (2012: 62) find that extreme dry conditions are conducive to rebel conflict, while extreme wet conditions are conducive to communal violence. Adopting a disaggregated research design focusing on the local level, Theisen, Holtermann & Buhaug (2011) find no effect of droughts on civil war onset, regardless of whether those droughts take place in sociopolitical contexts that are more prone to violence or not. Von Uexkull (2014), who also disaggregates at the grid level, finds that droughts, both episodic and sustained, increase the probability that battle events with at least one fatality within the context of an ongoing intrastate conflict will take place in the same grid where the drought is registered.

These mixed conclusions also appear in meta-analyses of the existing literature. Hsiang, Burke & Miguel (2013: 1212) conduct a meta-analysis of a subset of present studies, concluding that 'deviations from normal precipitation and mild temperatures systematically increase the risk of conflict, often substantially'. Engaging in a similar meta-analysis of a subset of studies, Buhaug et al. (2014: 396) conclude, in contrast, that 'research to date has failed to converge on a specific and direct association between climate and violent conflict'.

A related set of studies has sought to identify an indirect link between extreme weather events and conflict by using weather variables as instruments to capture the effects of economic growth (Koubi et al., 2012; Miguel, Satyanath & Sergenti, 2004; Ciccone, 2011) or food prices (Smith, 2014; see also Fjelde, 2015) on conflict occurrence. For example, using international prices and local rainfall scarcity as instruments, Smith (2014) finds that if, during a specific month, domestic food prices increase, so does the probability of civil unrest. Koubi et al. (2012) posit that the impact of climate variability on violence passes through the effect of climate on economic growth, but find this not to be the case.

Some of these discrepancies in findings reflect the diverse set of conceptualizations and operationalizations that researchers use to capture this effect, which, as Salehyan (2014) notes, speaks to the richness of the scholarly debate on this subject. Nonetheless, at a more fundamental level, these different results stem from difficulties associated with properly capturing the complexity of the effects of climate variability on the occurrence of conflict. As Buhaug et al. (2015: 269) argue, 'the two phenomena are not connected in the simple and direct manner as sometimes portrayed'. In particular, it is important to capture properly the moderating effect of state vulnerability on the probability that a country hit by weather-related shocks will experience episodes of conflict, given the well-established role of state capacity in predicting conflict (see for example Hegre et al., 2001; Fearon & Laitin, 2003; Collier & Hoeffler, 2004; Hegre & Sambanis, 2006).

At present, much of the literature has paid insufficient attention to the role of state vulnerability by conceiving of it as potentially impacting the propensity of states to experience violence, but not as a factor that moderates the relationship between extreme weather and conflict. Empirically, this approach entails examining the

[4] Hsiang & Burke (2014) argue instead that there is consistent support in present studies for the effect of 'changes in climatological variables and violent conflict' but Buhaug et al. (2014) dispute this claim.

[5] Other studies have sought to identify a link between destabilizing impacts of climate variability and conflict, yet mixed results persist. For example, Nel & Righarts (2008) find that natural disasters significantly increase the risk of civil conflict, but Slettebak (2012) shows that, controlling for population, the direction of that effect flips. See also Nardulli, Peyton & Bajjalieh (2015: 330).

correlation between extreme weather and violence, while controlling for indicators of state vulnerability (see, among others, Salehyan & Hendrix, 2014; Hendrix & Glaser, 2007; Hendrix & Salehyan, 2012; Raleigh & Kniveton, 2012; von Uexkull, 2014). However, this theoretical approach does not adequately capture the role of the state, which is to moderate the relationship between weather extremes and violence. That is, depending on the level of vulnerability, the effect of weather extremes on the likelihood of conflict will vary.

Several studies have focused on precisely this role for state vulnerability, but present efforts have yet to produce a comprehensive understanding of the complex way in which state capacity can moderate the impact of weather-related shocks on the probability of conflict. Some studies, for example, theorize this moderating effect but never estimate it exactly. Busby, Smith & Krishnan (2014) seek to map areas of vulnerability to climate-related events, and rely on a wide range of indicators, from the household to the national level. While this research does conceptualize vulnerability as potentially moderating the impact of climate-related weather events, it never tests the strength of this moderating effect, nor whether all of the sources of vulnerability equally moderate the impact of climate-related events (see also Busby et al., 2013).[6]

Other studies focus on the effects of weather shocks on conflict as moderated by a single dimension of state capacity. Hendrix & Haggard (2015) investigate the moderating effect of state vulnerability, arguing that the presence of a democratic regime makes states more vulnerable to food shocks and more likely to experience civil unrest. Similarly, Butler & Gates (2012) identify property rights enforcement as a key mechanism in explaining the link between droughts and pastoralist conflict in East Africa. Each of these approaches highlights the manner in which different facets of state capacity and institutionalization may potentially moderate the relationship between environmental conditions and violence. However, they do so in a relatively narrow way, focusing solely on a single element of state capacity. Yet we know that state capacity, as well as vulnerability, are inherently multifaceted phenomena (Hendrix, 2010), with dimensions ranging from economic wealth to the administrative capacity of a state to its military capacity to geographic conditions and more. Failing to account for the multi-faceted nature of state capacity risks omitting potentially crucial dimensions of a state's ability to avoid and respond to extreme weather events and the increase in food insecurity they engender.

Theory

There is a long history of sudden increases in food insecurity contributing to, or directly producing, violent protests and riots as individuals take to the streets in response to shortages, dating back at least from the famous bread shortage that ignited the French Revolution (for a series of examples in different contexts and periods, see also Brinkman & Hendrix, 2011: 7–8).[7] Indeed, during a series of violent riots in Somalia in 2008 prompted by rising food prices, one participant summarized their motivation for taking to the streets by saying: 'I've never demonstrated before, but I'm not ashamed because if you can't eat, you will do whatever you can [. . .]'.[8] Thus, our theoretical focus is on the generation of food insecurity and how it translates into violent unrest. As such, our primary theoretical interest is with food consumers.

Domestic production shortfalls and higher food prices translate into food insecurity in two ways. First, food shortages decrease *food availability*, thus imperiling the basic ability of individuals to survive. Second, food shortages highlight *food entitlements*, which Sen (1981: 459) defines as 'the ability of different sections of the populations to establish command over food using the entitlement relations in that society'. In other words, an increase in food insecurity both challenges the ability of people to procure food and emphasizes the existing differences in society between those that can and those that cannot do so.

When confronting a situation of food scarcity, individuals become more willing to participate in violent demonstrations and riots, for several reasons. First, shocks to food security act as a source of grievance by denying individuals access to basic necessities. Thus, scarcity can generate competition and animosity between societal groups and between societal groups and the state over issues of food availability. Second, these shocks can also increase existing grievances, by emphasizing food

[6] See also Bretthauer (2015) on household vulnerability. Fjelde & von Uexkull (2012: 98) only find 'some evidence' that rainfall shortages' effect on conflict is exacerbated by the socio-economic context in which they take place.

[7] Hendrix & Brinkman (2013: 3–4), however, also point to the potential for widespread food shortages to reduce the likelihood of civil war by leading individuals to prioritize finding food, rather than organizing for a rebellion.

[8] Abdullahi Mohammed, quoted in 'Clashes kill 5 when shoppers riot in Mogadishu'. Lutfi Sheriff Mohammed & Edmund Sanders, *Los Angeles Times*, 6 May 2008 (http://articles.latimes.com/2008/may/06/world/fg-somalia6).

entitlements. In this sense, abrupt increases in food insecurity will highlight existing inequalities and conflicts between different societal groups (e.g. occupational and ethnic differences). Finally, the desperation that food insecurity entails reduces the perceived costs associated with violence (see also Brinkman & Hendrix, 2011). Participating in violent demonstrations, while costly, may be a preferable alternative to not demonstrating and potentially being unable to feed oneself or family.

The effect of food insecurity is shaped by the degree to which each country is *vulnerable* to food insecurity. While these threats exacerbate grievances and inflame existing social hierarchies by both reducing food availability and highlighting food entitlements, as well as reducing the relative costs of participating in violent demonstrations, the vulnerability of the state to food insecurity plays a crucial role in moderating food insecurity's impact on the likelihood of violence. State vulnerability alters the calculations of individuals contemplating participation in violent demonstrations. When states are especially vulnerable, the ramifications of abrupt increases in food insecurity are likely to be more widespread, and grievances are more likely to trigger violence precisely because the state lacks the economic and institutional resilience necessary to address the grievances of its population and deter violence.

Threats to food security

Sudden increases in the threat of food insecurity – abrupt and dramatic reductions in the ability of individuals to access food – are a multi-faceted outcome and may result from either domestic or international processes. To understand when and why food insecurity triggers violence, it is essential to theorize individually its different sources, which we consider in turn below.

International food prices can affect the threat of food insecurity in two ways. First, the absolute level of international food prices impacts the price that local customers must pay for food. Higher food prices increase the risk of food insecurity because, ceteris paribus, higher prices make it more difficult for consumers to purchase food. Second, sudden increases in the price of food might also heighten the threat of food insecurity, by dramatically and unexpectedly reducing the ability of consumers to procure food, thus triggering shortages that are difficult for consumers to anticipate and plan for.

H1a: Higher international food prices will increase the risk of food insecurity.
H1b: Sudden increases in international food prices will increase the risk of food insecurity.

In contrast, higher international prices might, on average, be beneficial to domestic producers, by increasing their revenue. Fjelde (2015), for instance, identifies low local food prices as a factor increasing the risk of violence stemming from grievances on the part of producers. However, it is important to note that in sub-Saharan Africa most food producers are *net* consumers of food (Lee & Ndulo, 2011: 28). Therefore, while higher international prices may increase the potential revenue of producers, high prices may nevertheless make producers worse off, because as net consumers of food, the price they must pay for food is more salient. Thus, the effect of international food prices on producers is somewhat mixed.[9]

International food price fluctuations, however, tell only part of the story. Food insecurity may also originate from local conditions, most importantly from the effects of weather on food production within a state. In an agricultural system that is heavily dependent on rain-fed agriculture, as is the case in much of sub-Saharan Africa (Burke et al., 2009), adequate and regular rainfall is critical for domestic agricultural production.[10] Adverse weather conditions, by depressing local crops, challenge both producers and consumers of food. There are two characteristics of precipitation that can influence domestic agricultural production. The first is the amount of rainfall in a month. Specifically, we focus on the degree to which the amount of rainfall registered in a given month deviates from the typical amount of rainfall registered during that month – that is, monthly deviations from the long-term monthly mean of rainfall in a country. We follow Hendrix & Salehyan (2012: 46) in arguing that months that are either particularly wet or dry compared to what is normal for that month may be associated with greater production shortfalls. Extreme precipitation patterns, either in the form of flooding or droughts, can negatively impact agricultural production and increase the risk of food insecurity.

This is not to say that extremely dry and extremely wet months depress agriculture production to the same extent. For example, Buhaug et al. (2015: 1) identify a

[9] In the Online appendix, we test for whether our consumer-driven approach systematically mispredicts cases where conflict is producer-driven, finding that it does not.

[10] Though several studies also note that fluctuations in temperature may be an important determinant in the onset of violence (Burke et al., 2009), we view the effect of temperature in the generation of violence to be less central (see however Schlenker & Lobell, 2010: 6). We do, however, control for the effect of temperature in the subsequent analyses.

non-linear effect of precipitation on food production, finding that 'more rainfall generally is associated with higher yields'. Moreover, Raleigh, Choi & Kniveton (2015) find that decreased rainfall and droughts increase commodity prices, thereby affecting conflict indirectly. Thus, we expect this effect to be particularly pronounced for extremely dry months and somewhat attenuated for particularly wet months. Yet we expect both extremes to increase the risk of food insecurity compared to typical rainfall patterns.[11]

> *H2a:* Extreme deviations, especially negative ones, from the long-term average precipitation in a given month increase the risk of food insecurity.

The second characteristic is how the rainfall was distributed in a particular month, what we refer to as precipitation volatility. Whereas the previous characteristic focuses on the amount of rainfall – was a particular month atypically wet or dry – precipitation volatility focuses on how that rainfall is scattered within a given month. If precipitation is evenly distributed throughout a month (if it rains a bit every day, for example), volatility is low. If, by contrast, precipitation is concentrated (if it does not rain for weeks, and then suddenly rains a lot during a handful of days, for example), volatility is high. We argue that when volatility in a given month is higher than the typical volatility registered during that month in previous years it increases the risk of food insecurity. This is the case because weather volatility, as Buhaug, Gleditsch & Theisen (2008: 7) point out, translates into increased unpredictability and thus greater challenges to the capability of individuals to grow crops. While weather at either extreme (heat or cold, drought or flood) represents a hardship, it is nevertheless a known quantity that can be mitigated, at least to a degree (Di Falco, Veronesi & Yesuf, 2011). Day-to-day variability in rainfall, on the other hand, presents a moving target and may depress crop yields to an even greater degree (Riha, Wilks & Simoens, 1996), thereby increasing scarcity and the probability of civil strife. Therefore, when rainfall is especially volatile in a given month compared to the long-term trend for that month (that is, if rainfall is concentrated in just a few days, with most of the days experiencing no rainfall), it increases the risk of food insecurity.

[11] We model this more complex effect in Models 1 and 2 in the precipitation interaction, as can be seen in Figure 2, where especially dry months have the effect of increasing the risk of conflict the most.

> *H2b:* Positive deviations from long-term precipitation volatility increases the risk of food insecurity.

The negative effects of precipitation on food production are likely to be maximized when precipitation is most extreme, characterized by both extreme amounts of precipitation, either high or low, *and* a high degree of day-to-day volatility. The presence of unpredictability in situations where crops are already put at risk by droughts or floods will put the food production system under further duress, greatly increasing the risk of food insecurity. Accordingly, we consider cases in which there are extreme (positive or negative) deviations from the long-term mean rainfall, and we posit that in those circumstances greater weather volatility will increase the risk of food insecurity.

> *H2c:* Positive deviations from long-term precipitation volatility increase the risk of food insecurity, especially in the presence of extreme deviations from the long-term average precipitation.

The vulnerability of the state

The effect of food insecurity on the likelihood of violent unrest depends on the extent to which state structures and institutions are vulnerable. Following the IPCC, we contend that a state's vulnerability to food insecurity is determined by two features: a state's capacity to manage and mitigate sudden increases in the threat of food insecurity and the state's susceptibility to food insecurity (IPCC, 2014: 5). We conceive of state capacity as the ability of the state to respond to sudden increases in food insecurity and/or offset the societal consequences of food insecurity. In contrast, we conceive of a state's susceptibility to food insecurity as entailing those features of a state's economy and geography that exacerbate (mitigate) the ramifications of abrupt increases in food insecurity. We consider the determinants of each element of vulnerability in turn.

States are more capable of responding to sudden increases in the threat of food insecurity, and thus less vulnerable, when the central government has the capacity to manage shocks and suppress dissent (see for example Fearon & Laitin, 2003; Collier & Hoeffler, 2004). Thus, we argue that institutionally coherent regimes reduce vulnerability to food insecurity, because institutional coherence allows these states to fully tap into their resources, addressing food insecurity more rapidly and more effectively than institutionally incoherent regimes. The resources that coherent democracies and coherent autocracies will use to face threats of food insecurity are quite different. Democratic regimes will embrace economic intervention packages or redistribution, due to their more open and stable political structures that incentivize politicians to respond to the concerns of their citizens. Autocratic regimes instead will be more likely to mobilize the military and administrative capabilities of the state to suppress dissent or deter it before it materializes (see also Hendrix & Haggard, 2015). In either case, the coherence of political institutions is essential to the efficacy of such strategies.

However, as Hendrix (2010) argues, state capacity is a multifaceted concept, such that the coherence of political institutions only captures a limited dimension of vulnerability to shocks. Not all democracies will be equally effective at offering inducements to citizens in times of crisis, nor will all authoritarian regimes be able to repress dissent effectively. Rather, the capacity of a state will also vary based on the strength of its bureaucratic apparatus which is essential in identifying the sources of unrest, efficiently implementing policies to counter unrest and marshaling the resources to support those policies. Wealthier states, especially those that direct a higher level of resources toward government expenditures, are likely to possess more competent and efficient bureaucracies and will be able to increase expenditures in times of crisis. Moreover, wealthier states will have the ability to use their resources to access international commodity markets to offset domestic production shortfalls.

> *H3a:* States with a greater degree of institutional coherence are less likely to be vulnerable to food insecurity.
> *H3b:* Wealthier states are less likely to be vulnerable to food insecurity.
> *H3c:* States with higher expenditures are less likely to be vulnerable to food insecurity.

In addition to its capacity to respond to food insecurity, a state's susceptibility to abrupt increases in the risk of food insecurity significantly impacts the likelihood of observing violent unrest. We argue that a state's susceptibility to food insecurity principally depends on the structure of its agricultural system and its access to global trade. We discuss each in turn.

There are two aspects of the agricultural system that are important. First, high reliance on agricultural production is likely to increase vulnerability, for two reasons. On the one hand, because the economy of the state is primarily centered around agriculture, a shock to domestic agricultural production will displace a substantial number of workers and subsistence farmers, given that the agricultural sector is a significant source of employment. On the other hand, agrarian states may also be more reliant on subsistence farming, and extreme weather will dramatically reduce the ability of individual subsistence farmers to produce enough food. Second, high agricultural productivity will reduce vulnerability, because higher levels of productivity suggest that more food production is possible with fewer inputs. For example, highly productive agricultural systems might be more likely to rely on better irrigation systems, a feature that in turn allows them to be less susceptible to the threat of food insecurity brought about by extreme weather conditions.

Moreover, a state's level of imports may affect its vulnerability via three distinct mechanisms. First, high levels of imports might increase the risk of food insecurity resulting from increases in international food prices by exposing states to swings in international food prices to a greater degree. Moreover, higher levels of imports may also indicate an inability to rely on domestic production to offset international price increases.[12] For example, during the 'Arab Spring' states such as Egypt and Tunisia imported a considerable amount of food and thus were left vulnerable to international food price increases. Thus, reliance on food imports might increase vulnerability to food insecurity, but the effect of imports is more complex as it may in fact reduce vulnerability through two additional mechanisms. Second, therefore, high levels of imports might offset domestic production shortfalls: if the weather severely threatens domestic food production, higher levels of imports may indicate that such states are better able to compensate for those domestic sources of food insecurity by buying food from abroad than states that import less.[13] Finally, higher levels of imports afford states greater diversity of international foods. Should international food prices spike, states with more imports will have access to a larger basket of international foods than states that import less. Thus, these states will be able to substitute one commodity for another in response to rising prices (for example, importing more wheat should the price of rice increase).

[12] We thank an anonymous reviewer for their suggestion to clarify this point.

[13] It should be noted that the level of imports does not directly convey the ability of a state to import. However, we argue that the wealth of a state, in conjunction with its level of imports, does offer some insight into its ability to offset domestic production shortfalls, as wealthy states with greater access to international markets will be better able to manage domestic production shortfalls than poor states without such pre-existing access.

According to both of these mechanisms, greater reliance on imports decreases states' vulnerability to food insecurity. This prediction runs contrary to the first mechanism, which suggests instead that imports should increase a state's vulnerability. We present both logics as competing hypotheses to be empirically evaluated below.

> *H4a:* States with more land directed toward agriculture are more likely to be vulnerable to food insecurity.
> *H4b:* States with a more productive agricultural sector are less likely to be vulnerable to food insecurity.
> *H4c:* States that rely more on imports are more likely to be vulnerable to food insecurity.
> *H4d:* States that rely more on imports are less likely to be vulnerable to food insecurity.

The production of violent unrest

We have argued that the probability that sudden increases in the threat of food insecurity will translate into violence depends on the degree to which states are vulnerable to food insecurity. Abrupt increases in food insecurity will increase the risk of violent unrest. However, greater vulnerability to food insecurity – less institutional coherence, less bureaucratic capacity, and lower revenues – will amplify its effects, whereas less vulnerability will mitigate the effect of food insecurity.

> *H5:* A country's vulnerability interacts with global and local determinants of food insecurity to increase the risk of violent unrest.

Research design

We explore the relationship between increases in the threat of food insecurity, state vulnerability, and unrest in African states whose population exceeds one million in the period 1991–2011 (see Online appendix for the list of countries included). This is an important geographical area to test our theory because climate experts argue that 'Africa is one of the most vulnerable continents to climate change' (IPCC, 2007). There also exists significant variation in the level of vulnerability of African states, allowing us to better test the implications of our theory.

Our unit of analysis is the country-month, which presents at least two advantages. First, by looking at weather extremes at the monthly level, rather than the annual level (see, among others, Hendrix & Salehyan, 2012), we are better able to capture the degree to which weather extremes cause sudden and immediate disruptions to food availability. Second, by using the state level of analysis, we avoid making the assumption that there should be a one-to-one correspondence between extreme weather, food scarcity, and conflict within substate regions. Avoiding this assumption allows us to better capture the fact that, in many instances, extreme weather in a food producing region may produce food shortages in more populous, food consuming regions of the same state. As Salehyan (2014: 3) argues, 'resource scarcity drives migration to the cities, leading to conflict in urban areas' (see also findings in Bollfrass & Shaver, 2015).

Dependent variable

The dependent variable is a dichotomous measure that takes a value of 1 in any country-month in which at least one violent event in the Social Conflict in Africa Dataset (SCAD) (Salehyan et al., 2012) occurs. As we expect food insecurity to both produce new grievances and exacerbate existing ones between domestic groups and between domestic groups and the government, as well as to affect both producers and consumers, we include violent events that target either groups within the state or groups that target the government.[14] We employ a dichotomous dependent variable because our theoretical interest is in examining under what conditions food insecurity triggers violent unrest in a state.

Independent variables

We examine the determinants of state vulnerability by considering indicators of both capacity and susceptibility. To capture state capacity, we utilize three measures. First, we measure institutional coherence using data on political regime type from the Polity IV project (Marshall & Jaggers, 2002). The indicator ranges from –10 (coherent autocracies) to 10 (coherent democracies). We also include a squared polity indicator, which allows us to test for a curvilinear relationship between regime type and vulnerability. If our hypothesis is correct, the coefficients will depict a non-linear relationship between the continuous regime type variable and vulnerability, such that both the lowest (coherent autocracies) and highest (coherent democracies) values of the continuous indicator are correlated with lower levels of vulnerability (see also Hegre et al., 2001). We use data from the Penn World Tables to capture the capacity of a state to muster resources to respond to a shock (Feenstra, Inklaar &

[14] Specifically, this operationalization includes the following event types: organized violent riot, spontaneous violent riot, pro-government violence, anti-government violence, extra-government violence, intra-government violence.

Timmer, 2013): in particular, we include government consumption share of GDP per capita, to capture the amount of resources the government spends, omitting transfer payments, as an indication of the resources available to the state and its agencies, and GDP per capita, to capture how wealthy the country is as a whole.

To measure states' susceptibility to food insecurity, we also rely on three variables. First, we capture how efficient and productive a state's agricultural sector is using agricultural value added as a percentage of a state's GDP, which measures net outputs minus inputs. Second, we capture how reliant on (and thus dependent on) agriculture a state is by including a measure of the percentage of a state's land that is actively dedicated to agriculture. Finally, we include a variable for a state's imports as a percentage of the state's GDP. All these variables come from the World Bank's World Development Indicators (World Bank, 2015). We add time polynomials to control for time dependency.

We also control for other factors often found to affect vulnerability and conflict: military spending as a percentage of GDP and size of a country (World Bank data), population (Penn World Tables data), and the presence of civil war in neighboring states (data from Buhaug, Cederman & Gleditsch, 2014).

To capture the risk of an abrupt increase in food insecurity, we examine extremes of both temperature and rainfall, as measured by the Global Surface Summary of the Day (GSOD) project at the Global Observing System Information Center. We begin by calculating the average rainfall and temperature for each state and each month in our sample over time. Then, we calculate a 20-year moving average for rainfall and temperature for each state in each month to generate the long-term expectation for rainfall and temperature in each month in each state. Finally, we calculate the standardized monthly deviation from the long-term mean – the difference between the average rainfall (temperature) in a given month and the long-term average from the past 20 years in that same month, divided by the standard deviation of average monthly rainfall (temperature) in the same month in the past 20 years. This produces a standardized measure of the extent to which the rainfall (temperature) in a given month differs from the long-term average for that month.

We use the same procedure to measure volatility in rainfall and temperature within a month. Specifically, we begin by estimating the standard deviation of rainfall (temperature) within each month, before generating long-term averages of monthly volatility, and then standardized deviations from those long-term averages. Again, this procedure produces a standardized measure of the extent to which rainfall (temperature) in a given month is more or less erratic than is typically the case for that country-month. Each of these variables incorporates deviations from the average rainfall (temperature) of a particular country-month. Therefore, these measures incorporate information about both the long-term trends for a particular country (e.g. whether a particular country has a wetter/drier climate than another country) and deviations from those long-term trends.

By focusing on deviations from the long-term monthly averages and volatility, these measures allow us to capture the degree to which a month in a given country is characterized by unusual or extreme weather patterns. To capture the effect of drought, which should be most severe when precipitation is both rare and erratic, we include an interaction between the squared average precipitation and the volatility in precipitation. Because adverse weather conditions in the present undermine crop yields in the near future, which, in turn, raise the risk of food scarcity later on, we lag each of these variables by eight months.[15]

We use the IMF's monthly food price index from the Primary Commodity Price dataset, de-trended to account for non-stationarity, to measure the impact of global food prices (see Online appendix). In addition to the price level in a given month, we also code a dummy variable to measure sudden price increases that assumes the value of 1 if the change in food prices from the previous month is greater than the 75th percentile of monthly price changes.[16]

Model

To capture the above hypotheses in a statistical model, it is important to note that the argument is fundamentally interactive: the vulnerability of a state to food insecurity determines the extent to which increases of threats of food insecurity lead to conflict. Moreover, neither of these phenomena logically precedes the other – that is, states may be proactive, preventing extreme weather and high prices from translating into food insecurity, or states may be reactive, responding only after abrupt increases in food insecurity occur. Standard logit models would force

[15] In order to determine the appropriate lag length for the weather variables we estimated ten models, varying the lag length from three to 12 months. The model employing an eight-month lag for the weather variables provided the best model fit based on a comparison of AIC and BIC scores and statistical significance.

[16] We thank an anonymous reviewer for this suggestion.

us to interact each of the individual covariates associated with vulnerability with each of the covariates associated with the threat of food insecurity. Doing so would require a 21-variable interaction with 2,048 highly correlated terms in order to specify the model correctly (Braumoeller, 2004: 811), making estimation and substantive interpretation all but impossible.

Moreover, food insecurity and state vulnerability are best estimated rather than directly measured, for several reasons. First, while one might argue that we can observe food insecurity directly via, say, changes in national food prices, as Baiphethi & Jacobs (2009) demonstrate, the high degree of reliance on subsistence farming in most parts of Africa means that local food prices often fail to capture the degree to which threats to food security impact the population. We can, however, model the causes of food insecurity, as we do here. Second, by estimating food insecurity and state vulnerability, we are able to capture the multifaceted nature of both phenomena by estimating them with a wide array of variables, rather than reducing them to one dimension through the use of a single proxy variable. Finally, because we estimate these constructs using multiple variables, we can also measure the relative impact of each variable in determining them. In the case of food insecurity, for example, this approach offers an advantage over relying on an index of local food prices, because the use of such an index obscures the influence of international food prices as opposed to local weather shocks, and because local food prices are endogenous to conflict (Bellemare, 2015). While we know the likely covariates of state vulnerability and food insecurity, we avoid making a priori assumptions with respect to how much or how little each covariate should be weighted in determining the latent variables.

To model this complex system, we use a Boolean logit model (Braumoeller, 2003),[17] which in this straightforward context simplifies to a standard bivariate binary-choice model with partial observability (Poirier, 1980) or, equivalently, a split-population binary choice model (Xiang, 2010). The idea behind this model, simply put, is that 'successes' (violent events) require the presence of both latent phenomena (food insecurity and state vulnerability), while 'failures' (non-uprisings) can be expected whenever either of the two is absent. Because the zeros in the dataset are not causally homogeneous – that is, they happen for different reasons – use of standard binary-choice models such as logit or probit would violate the assumption of unit homogeneity (King, Keohane & Verba, 1994: 91–93).

[17] We utilized the R package boolean3.

Bivariate binary-choice models are designed to model precisely this sort of unit heterogeneity. When the two dependent variables (here, food insecurity and state vulnerability) are directly observed, the result is a standard bivariate logit or probit. When the dependent variables are not directly observed and must be inferred from their covariates, and an outcome of interest that occurs in the presence of the conjunction of the two (here, uprisings) can be directly observed, the result is a partial-observability model.

The main equation in the model takes the following form:

$$\Pr(y^*_{X\beta} = 1) = \Lambda(X\beta) \tag{1}$$

$$\Pr(y^*_{Z\gamma} = 1) = \Lambda(Z\gamma) \tag{2}$$

$$\Pr(y = 1) = \Pr(y^*_{X\beta} = 1) \times \Pr(y^*_{Z\gamma} = 1) \tag{3}$$

where $\Lambda(X\beta) \equiv \frac{1}{1+e^{-X\beta}}$. These equations allow us to capture the argument that the probability of social conflict $Pr(y = 1)$ is the product of two unobserved, continuous outcomes: the vulnerability of the state ($\Lambda[X\beta]$) and the shock to the system represented by food insecurity, either due to domestic shortages or volatile global prices ($\Lambda[Z\gamma]$). These quantities are independent, discounting the impact of any common independent variables. The model also assumes that the product of the y^* equals the observable probability of conflict, $Pr(y = 1)$.

Results

Table I reports the results of our models, while the Online appendix contains more models with robustness checks. Three important findings emerge from these results.

State vulnerability moderates the effect of food insecurity

First, a comparison of AIC scores between Model 1 and a logit specification with the same independent variables indicates that the Boolean specification fits the data better than a logit specification, providing support for H5: state vulnerability moderates the effect of an increase in threats of food insecurity on the likelihood of violence.[18]

In fact, as Figure 1 makes clear, low state vulnerability is an even better guarantor of peace than good weather and low food prices. While the coefficients in Table I reflect the effect of each predictor of food insecurity and vulnerability, Figure 1 plots how the effect of food insecurity on violence is moderated by state vulnerability

[18] See the Online appendix for full logit results.

Table I. Boolean logit models of the effect of food insecurity and vulnerability on violent unrest

Variables	*Model 1: Violent unrest*		*Model 2: Violent unrest*	
	State vulnerability	*Food insecurity*	*State vulnerability*	*Food insecurity*
Constant	–0.109* (–0.177, –0.048)	1.759* (1.687, 1.905)	–7.490* (–7.538, –7.451)	1.693* (1.641,1.746)
Agriculture % GDP	–0.011* (–0.016, –0.006)		–0.009* (–0.015,–0.003)	
Agricultural land, % total	0.005* (0.002, 0.009)		0.013* (0.009,0.017)	
Polity	0.035* (0.020, 0.051)		0.022* (0.005, 0.038)	
Polity^2	–0.007* (–0.011, –0.004)		–0.004† (–0.008, 0.001)	
Imports % GDP	–0.013* (–0.017, –0.009)		–0.002 (–0.007,0.003)	
Government spending % GDP	–0.013* (–0.022, –0.005)		–0.009† (–0.020,0.000)	
GDP pc, logged	–0.133* (–0.170, –0.098)		–0.005 (–0.101, 0.091)	
Population			0.483* (0.393, 0.572)	
Land area, logged			0.040 (–0.036 0.107)	
Neighboring conflict			0.119* (0.075, 0.159)	
Mean precipitation		–0.433* (–0.532, –0.329)		–2.373* (–2.428, –2.307)
Mean precipitation^2		0.095 (–0.014, 0.188)		0.897* (0.817, 0.980)
Precipitation volatility		0.125* (0.002, 0.256)		1.524* (1.478, 1.604)
Mean precipitation x Volatility		–0.077 (–0.184, 0.032)		–0.891* (–0.971, –0.806)
Mean precipitation^2 x Volatility		0.098* (0.015, 0.184)		0.231* (0.144, 0.320)
Mean precipitation x Mean precipitation^2		–0.024 (–0.092, 0.042)		–0.088* (–0.170, –0.004)
Mean precipitation x Mean Precipitation^2 x Volatility		–0.018* (–0.035, –0.002)		–0.035* (–0.064, –0.002)
Mean temperature		–0.298* (–0.422, –0.170)		–0.895* (–0.983, –0.804)
Temperature volatility		–0.019 (–0.127, 0.096)		0.076 (–0.023, 0.168)
World food prices		–0.002 (–0.012, 0.012)		–0.011 (–0.061, 0.046)
High world food prices		0.185* (0.040, 0.334)		0.717* (0.605, 1.611)
Peace months	–0.103* (–0.114, –0.094)	0.572* (0.539, 0.618)	–0.067* (–0.078, –0.056)	0.036 (–0.018, 0.105)
Peace months^2	0.199* (0.149, 0.268)	3.291* (3.204, 3.374)	0.147* (0.079, 0.271)	0.757* (0.666, 1.611)
Peace months^3	–0.011* (–0.021, –0.006)	–0.269* (–0.408, –0.195)	–0.010* (–0.030 –0.002)	–0.063* (–0.114, –0.043)

(continued)

Table I. (continued)

Variables	Model 1: Violent unrest		Model 2: Violent unrest	
	State vulnerability	*Food insecurity*	*State vulnerability*	*Food insecurity*
Observations	9,108		6,414	
AIC	7,573.770		4,932.879	
BIC	7,758.809		5,129.100	

†$p < 0.1$, *$p < 0.05$. 95% bootstrapped confidence intervals in parentheses.

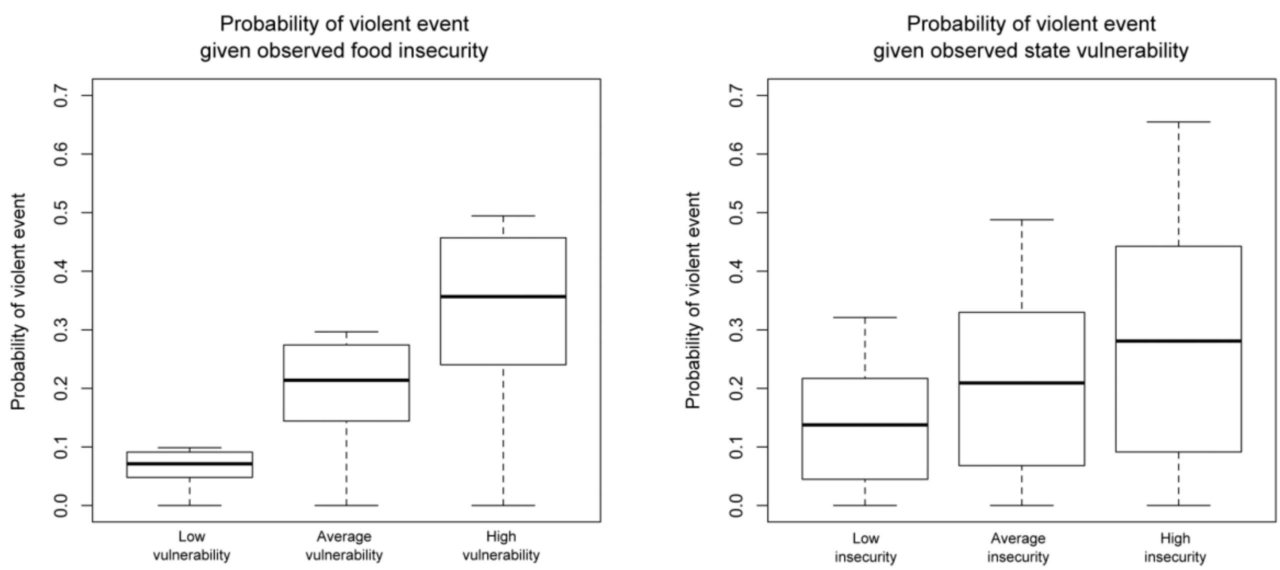

Figure 1. The probability of violent unrest across observed state vulnerability and food insecurity

(Figure 1a) and, conversely, how the effect of state vulnerability on violence changes depending on the values of food insecurity (Figure 1b). Figure 1a depicts a box plot of the density of the predicted probability estimates of violent social conflict based on the fitted values of the food insecurity equation, while varying state vulnerability from one standard deviation below the mean, to the mean, to one standard deviation above the mean. When state vulnerability is low, the median probability of observing a violent event is 0.07, indicated by the thick black horizontal line in the center of the box. Increasing state vulnerability shifts the distribution of violent event estimates considerably, such that when state vulnerability is high, the median probability of observing violent unrest quintuples, to 0.36. In contrast, Figure 1b depicts a box plot of the density of the predicted probability estimates of violent social conflict based on the fitted values of the state vulnerability equation, while varying estimates of food insecurity from one standard deviation below the mean, to the mean, to one standard deviation above the mean. Increasing food insecurity from low to high does increase the likelihood of violent unrest, but the magnitude of this change is much smaller than with state vulnerability: shifting from low to high food insecurity only increases the median probability of observing violence from 0.14 to 0.28 – a meaningful increase, but substantively smaller than the change in the probability of violence associated with changes in the vulnerability of states.

Thus, violent unrest is the product of *both* food insecurity *and* the underlying vulnerability of the state to shocks, but the substantive effect of vulnerability on unrest is even larger than that of food insecurity. While others have pointed to the relevance of vulnerability in understanding the impact of food insecurity (Busby et al., 2013), we advance such findings by demonstrating that state vulnerability is pivotal, exerting a larger substantive effect on the likelihood of violence than food insecurity.

Returning to our initial example, we can use our model to see that the probability of violent unrest in Ghana in June 2007, for example, is 0.05, whereas the probability for Kenya in June 2004 is 0.21, more than four times as high, in large part because we estimate

Kenya to be far more vulnerable than Ghana, consistent with the observed level of violence in both cases.

State vulnerability

The coefficients on the Polity variables suggest that institutionally coherent states, either fully democratic or autocratic, are less vulnerable than states undergoing transitions between regime types or those that combine elements of democratic and autocratic institutions, as per H3a. This result is consistent with the broader literature linking institutional coherence with a lower risk of internal violence (Hegre et al., 2001), while countering findings in Hendrix & Haggard (2015) that democracies are *less* capable of mitigating the impact of food insecurity than are autocratic states.

The coefficients on both GDP per capita and government expenditures are negative and statistically significant, suggesting that each component of state capacity results in lower levels of vulnerability, consistent with H3b and H3c. Wealthier states and states that spend more on resources will be less vulnerable to increases in the threat of food because they can rely on stronger, better financed administrative agencies in times of crisis, as well as more overall resources for governments to draw from to address shortages.

Agricultural productivity reduces vulnerability. States with more efficient and productive agricultural sectors can more easily shield themselves from food insecurity. Yet, controlling for productivity, greater reliance on the agricultural sector, measured as the percentage of a state's territory devoted to agriculture, translates into greater vulnerability to food insecurity.

Higher levels of imports reduce state vulnerability, consistent with H4d. Coupled with the negative effect of GPD per capita on vulnerability, this result offers an important insight. Controlling for the ability to import (as captured by GPD per capita), the more a state imports, the less vulnerable it is. This is the case because, while imports might make states more vulnerable to international food price increases, more imports suggest that states may offset domestic food shortages and substitute other goods when local food prices increase. This result is robust across multiple model specifications, suggesting that the two mechanisms linking higher imports to lower vulnerability outweigh the increased exposure to international price fluctuations that higher imports entail.

Food insecurity

Consistent with the expectations of H2c, we find a statistically significant interactive effect between deviations in monthly precipitation from the long-term monthly mean and the volatility of rainfall in a given month. Months that are especially dry increase the risk of food insecurity considerably, whereas months that are especially wet have a much smaller effect. Months that are especially dry with erratic rainfall are most likely to threaten food security.[19]

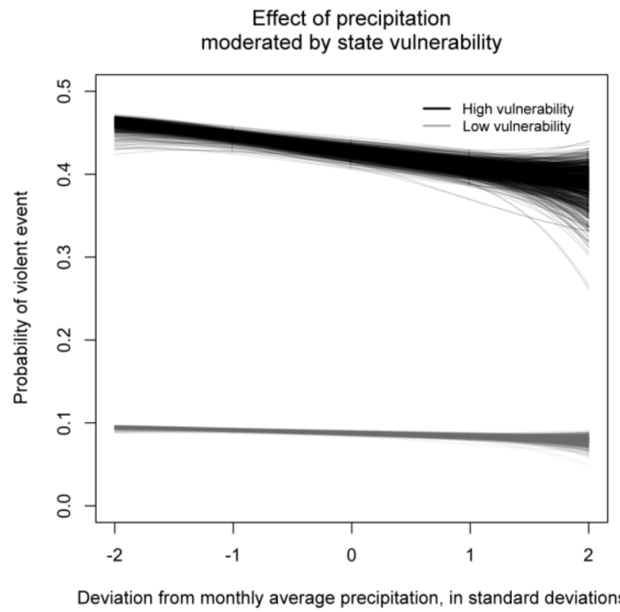

Figure 2. The moderated effect of the sources of food insecurity on violence

High and low state vulnerability refer to the 75th and 25th percentiles, respectively, of the state vulnerability distribution. All the other variables held at their median values. Each line represents the predicted probability estimate from one of the 1,000 bootstrapped estimates.

Figure 2 plots the effect of deviations in monthly precipitation from the long-term mean on the probability of violent unrest when state vulnerability is low (grey lines) and high (black lines), holding all other variables at their medians. State vulnerability significantly moderates the impact of rainfall on conflict, as vulnerable states (black lines) are significantly more likely to experience conflict across all levels of rainfall than are states that are less vulnerable (grey lines). In both high and low vulnerability states, especially dry months are associated with a higher likelihood of violence than are months with average rainfall, as the slope of the lines in Figure 2 indicates.

We also find that spikes in international food prices increase the likelihood of food insecurity, though the absolute level of international food prices fails to achieve statistical significance, providing support for H1b but not H1a. Holding state vulnerability to its median value,

[19] See the Online appendix for additional details.

a sudden increase in international food prices increases the probability of conflict by 1.52%. State vulnerability, as in the case of precipitation, significantly moderates this effect. A price increase when vulnerability is low translates into a 9% predicted probability of violence, while the same price increase when vulnerability is high translates into a 44% chance of violence.

Positive deviations from long-term temperatures – that is, especially warm months – decrease the likelihood of food insecurity, while temperature volatility does not (see Online appendix for details).[20]

Table I presents a second Boolean specification, which includes several controls. Our initial results are robust. Moreover, states with larger populations and states whose neighbors are experiencing civil wars are likely to be more vulnerable (see also Buhaug & Gleditsch, 2008).

Conclusions and implications

We demonstrate that state vulnerability shapes this relationship between food insecurity and violence substantially, a finding that has two relevant ramifications. First, addressing state vulnerability is crucial to breaking the link between food insecurity and violence. Reducing vulnerability can address the two main channels through which sudden increases in food insecurity contribute or directly produce violent protests and riots: decreasing food availability and highlighting food entitlements (Sen, 1981). Second, because our results demonstrate that vulnerability is a multidimensional phenomenon, counteracting the worst consequences of climate-induced food scarcity will entail going beyond providing food aid to offset food shortfalls in the short term (Barnett & Adger, 2007). Rather, it will require a composite approach, comprising initiatives to stabilize domestic regimes, as suggested by Hendrix & Haggard (2015). Moreover, it will also require policies to strengthen the structural resilience of vulnerable states – for example, with investments in 'green growth' policies aimed at increasing economic growth while fostering resilience to climate shocks (Michel & Yacoubian, 2013: 46). These strategies can boost the wealth of the state and provide the government with a greater capacity to respond to shocks in the future, while simultaneously reducing the likelihood of negative environmental impacts.[21]

Finally, our results also shed light on important future directions for research. For example, expanding the geographical scope of the analysis will allow for evaluating the role of the moderating impact of state vulnerability in other regions. Similarly, extending the study to other dimensions of weather variability, such as natural disasters, will illuminate the central role of state vulnerability in moderating the effect of environmental triggers for conflict.

Replication data

The dataset, codebook, and do-files for the empirical analysis in this article, as well as the Online appendix, can be found at http://www.prio.org/jpr/datasets.

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[20] We also consider an interaction between these variables as in the case of precipitation, but find no evidence that such an interactive relationship is present.

[21] See also de Serres, Murtin & Nicoletti (2010) and IPCC (2014: Chapter 22.4).

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