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Food security and conflict: Empirical challenges and future opportunities for research and policy making on food security and conflict

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ABSTRACT

During the previous decade, there has been an increased focus on the role of food security in processes of armed conflict, both in the academic and policy communities. While the policy community has pushed forward with new programs, the academic debate about the causal linkages between food security and conflict remains contested. This article examines the endogeneity that characterizes the coupling between food (in)security and conflict and makes three contributions. First, we define conflict and food security using the Uppsala Conflict Data Program and the FAO databases, and illustrate how intervening factors influence the relationship between conflict and food security at the micro and macro levels. Second, we provide a comprehensive review of the literature on the linkages between food security and conflict, focusing on findings that account for endogeneity issues and have a causal interpretation. Third, we highlight key data issues related to conflict and food security, and chart ways forward to collect new and better data that can help to fill existing academic gaps and support policymaking.

1. Introduction

Food insecurity affects the lives of millions of people across the world and is increasingly concentrated in conflict-affected regions. All 19 countries the FAO currently classifies as being in a protracted food crisis are also currently affected by violent conflict[1] (Holleman et al., 2017). Globally, 60% of the 815 million undernourished individuals and 79% of the 155 million stunted children live in conflict-affected countries (FAO et al., 2017).

Monitoring food insecurity in conflict-affected countries and understanding the linkages between food insecurity and violent conflict, as well as the positive relationships between food security and stability, is crucial to informing evidence-based interventions from local, national and international practitioners and policymakers. Yet, understanding the relationship between food security and violent conflict faces severe "endogeneity" challenges. Structural factors at macro and micro levels, e.g. state capacity and household income, are often correlated with both food security and conflict outcomes. These "confounding" factors thus complicate causal analyses of the mechanisms linking conflict and food security.

This article makes three contributions. First, we define conflict and food security using the standard Uppsala Conflict Data Program (UCDP) and the FAO databases, and descriptively illustrate how intervening factors influence the relationship between conflict and food security at the micro and macro levels. Second, we provide a comprehensive review of the literature on the linkages between food security and conflict, focusing on findings that account for endogeneity issues and have a causal interpretation. To close, we highlight fundamental data gaps that constrain policy-making and identify important new opportunities for data collection to improve the existing database and evidence. This article acts as an introduction for the Special Issue and aims to serve as a reference for future research, data collection, and policy efforts on the food security-conflict nexus.

2. Definitions and data

This section defines violent conflict and food security and emphasizes the endogeneity that characterizes their linkages. The definitions and logic presented here are what characterize the literature we will review in later sections, thus providing a basis for the review and closing analysis.

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[1] In this article we use the terms 'conflict' and 'violent conflict' interchangeably.

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2.1. Conflict

Measuring and categorizing "conflict" is not straightforward. In quantitative approaches, the event-based measures and categories developed by the Uppsala Conflict Data Program have become a standard metric of conflict at the national level (Croicu & Sundberg, 2017). We focus on the national level because high-quality FAO data on food security is collected at this level and choose the UCDP metric and data since it is the most commonly used approach in the literature. We discuss alternative datasets in Section 4.

UCDP codes and defines different types of conflict, based on the actors involved and geo- and time-coded 'battle deaths'. In general, 1000 battle deaths in a year is the threshold for a country being 'at war'. Battle deaths are verified fatalities that are a direct result of intergroup violence. We focus on three main conflict types quantitatively defined by UCDP and add a special dataset on violence against civilians (not covered by UCDP):

- "Interstate conflict" is traditional country-versus-country conflict (Pettersson & Wallensteen, 2015).
- "Intrastate conflict" is a conflict within a country where one side is the government and the other side is a non-state group (Pettersson & Wallensteen, 2015).
- "Internationalized intrastate conflict" is defined the same way as an intrastate conflict, but includes significant involvement from other countries (Pettersson & Wallensteen, 2015).
- "One-sided violence" is the direct targeting of civilians by government or non-state forces (Eck & Hultman, 2007).

Fig. 1 shows recent global trends in these measures (1993–2014), with a timeline that matches our food security indicator availability. Intrastate conflict remains the one that occurs at the highest rate. Internationalized intrastate conflicts are also increasing, as countries get involved more in the intrastate conflicts of other countries, while One-sided violence has been on the decline. Interstate conflict is rare, and increasingly represented by long-term legacy conflict such as India and Pakistan's conflict over Kashmir.

This time frame was selected for three reasons. First, our primary food security data by FAO is available for that period only (as discussed in Section 2.2). Second, the end of the Cold War is presented a structural break in the nature of intrastate conflicts (Kalyvas & Balcells, 2010), the dominant form of conflict in recent history. Third, it was also associated with a decisive shift in the *analysis* of conflict, where the increasing availability of subnational data has spurred a new empirical research agenda on the micro-level foundations of conflict (as discussed in Section 3). Nonetheless we discuss some long-term trends (based on secondary FAO data) in Section 2.3.

2.2. Food security

The FAO categorizes food security into four pillars: Food Availability, Access, Stability, and Utilization (FAO, 2017). Each pillar captures a different aspect of food security. The pillars can generally be understood thus:

- Availability: This pillar focuses on availability of necessary calories at the individual level, as well as the types of calories available nationally (e.g. cereals versus animal protein).
- Access: This pillar contains variables that measure physical infrastructure for bringing food to market, as well as individual level indicators of whether people have access to the necessary number of calories per day.
- Stability: The variables in this pillar measure dependence on food imports, domestic price variability, and variation in land equipped with irrigation.
- Utilization: This pillar captures data on primarily anthropometric indicators of whether people are able to use available calories; relevant data includes measures on wasting, stunting, and low weight among children.

FAO data on food security is available as a suite on the FAO statistics website (FAO, 2017) and predominantly describes

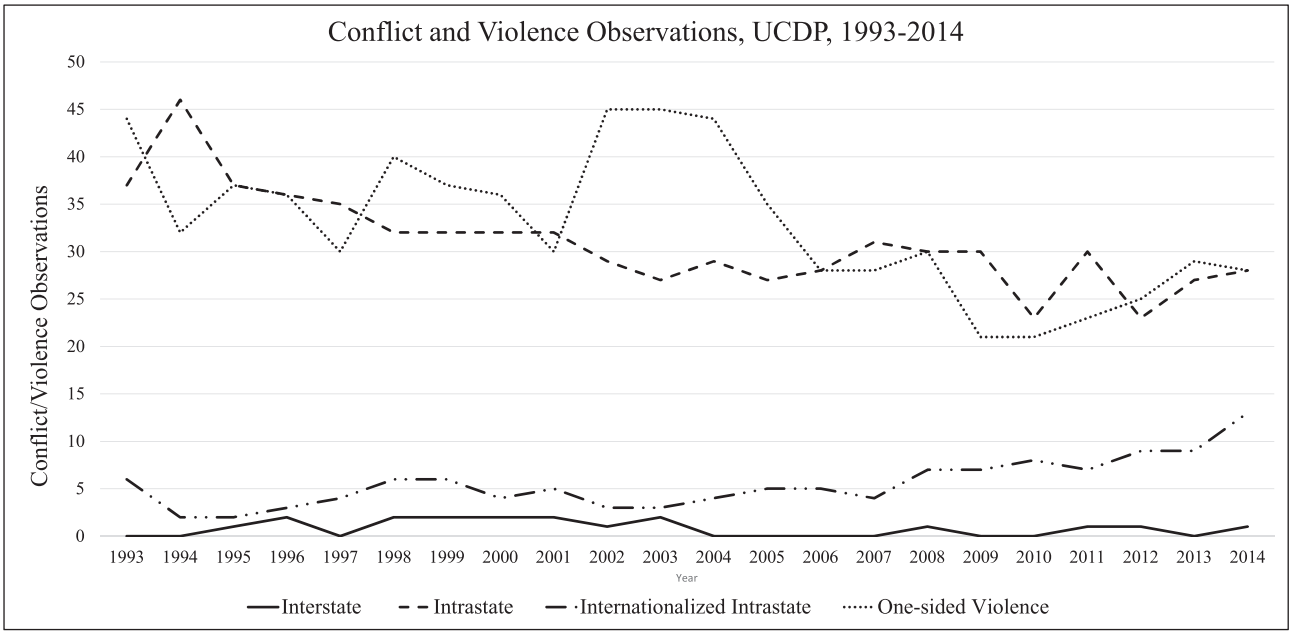

Fig. 1. Timelines of global conflict types, 1993–2014. Data from the UCDP (2017) database (Croicu & Sundberg, 2017).

outcomes reported on an annual basis. For our empirical exercise we choose five variables that are analogous to data used in previous research efforts and provide the best coverage across all countries. "Prevalence of Undernourishment", "Depth of Food Deficit", and "Share of dietary energy supply from cereals, roots and tubers" are central variables, for instance, for investigating the availability and accessibility of food, which maps on to studies that use anthropometric measures in their analysis. "Food Price Volatility" and "Cereal Import Dependency" are key variables in the large set of studies of how food prices and market shocks affect the outbreak of violence. One major problem, which we discuss later in the article, is data availability in the Utilization pillar; data coverage on percentage of children affected by wasting, stunting, and low weight is well under 50% across all countries and years. In this section, all variables are annual measures taken at the country level. The five food security variables are defined as follows:

- "Prevalence of Undernourishment" is the percentage of the population suffering from undernourishment. This data is reported from 1993 to 2014 and is a measure of the average of the previous three years' data. It is the primary food security indicator used by FAO as part of the monitoring process for Goal 1 of the MDGs, and thus should be a starting point for understanding a general relationship between food security and conflict.
- "Depth of Food Deficit" is an index number representing the difference between consumed calories and the necessary number of calories to reach an intake that would alleviate undernourishment.
- "Share of dietary energy supply derived from cereals, roots and tubers" represents the percentage of caloric intake made up of cereals, roots, and tubers. Evidence from conflict research shows that conflict can affect food production and adaption strategies.
- "Food Price Volatility Index" represents volatility of food prices domestically in a country from 2000 to 2014. This variable is important since there are many findings that tie price shocks to violence.
- "Cereal Import Dependency Ratio" represents the ratio of imports versus domestically produced cereals. Like price volatility, a country that must import food is exposed to price shocks and thus could be at higher risk of violence.

In Fig. 2 we see a generally positive pattern where food insecurity has decreased globally between 1993 and 2014. The primary indicator that the FAO used to measure success in the MDGs, Prevalence of Undernourishment, shows a distinct downward trend. We excluded Depth of Food Deficit in the graph since it uses a different scale than the other variables, and it has a trend that is derivative of Undernourishment. We will look at it later in the paper when we unpack endogeneity concerns.

2.3. Endogeneity concerns

In an ideal setup to study causal links in between food security and violent conflict, we would like to observe two identical populations simultaneously. For instance, only one of the two populations is "treated" with violent conflict, and we then compare food security outcomes between the treated and the non-treated population. As identical populations do not exist, estimations of such comparisons between treated and non-treated populations are not straightforward. Essentially, the central empirical challenge is to identify plausibly comparable populations, where treatment is "as good as random". The main statistical threat in pinning down a causal effect violent conflict to food security and vice versa is endogeneity bias.

Descriptive statistics of food security and conflict over time illustrate the fundamental challenge of intervening factors for the national level. If we look at FAO data on access to aggregate calories per day (1) globally, (2) in Least Developed Countries (LDCs) only, and (3) in Sub-Saharan Africa only, and compare the trends to the number of active conflicts globally, there is not an obvious trend (Fig. 3). Indeed, access to aggregate calories increases in the two decades following the highest number

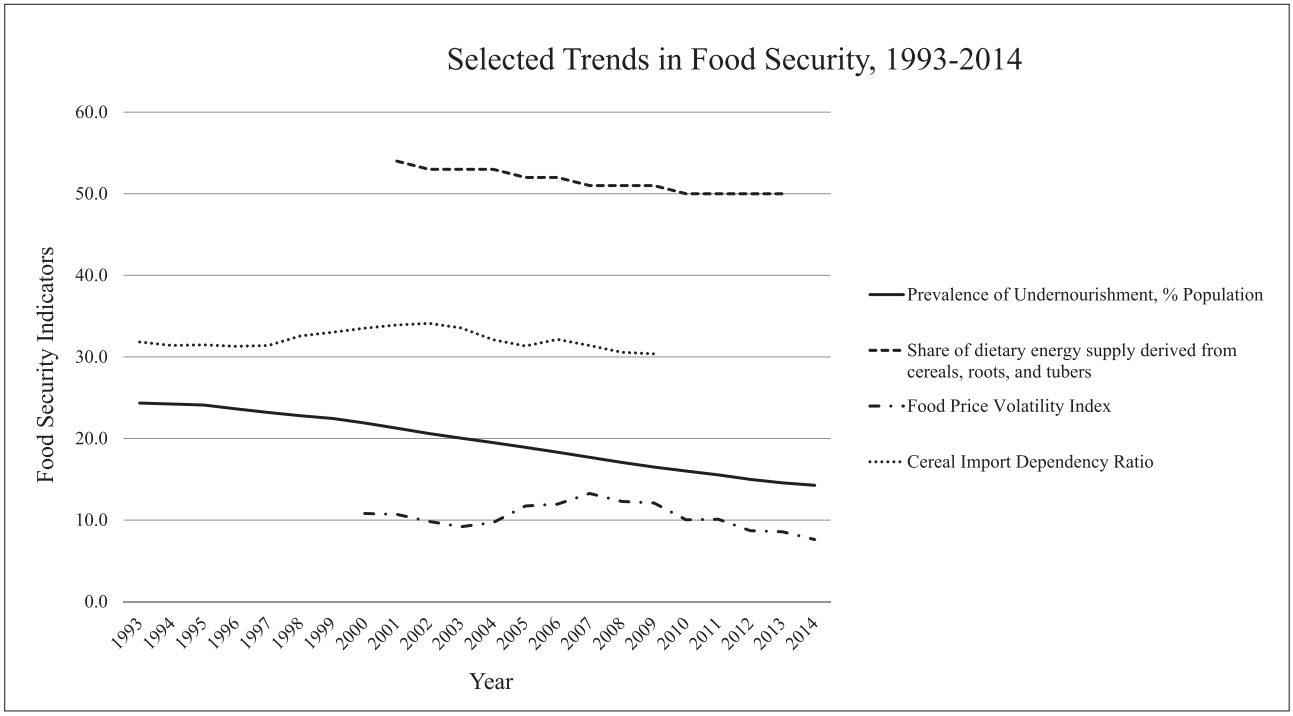

Fig. 2. Trends in selected food security indicators, 1993–2014. Data from the FAO (2017) food security database. Note that this database is a unique database of food security indicators and does not cover as wide a time span as other FAO databases.

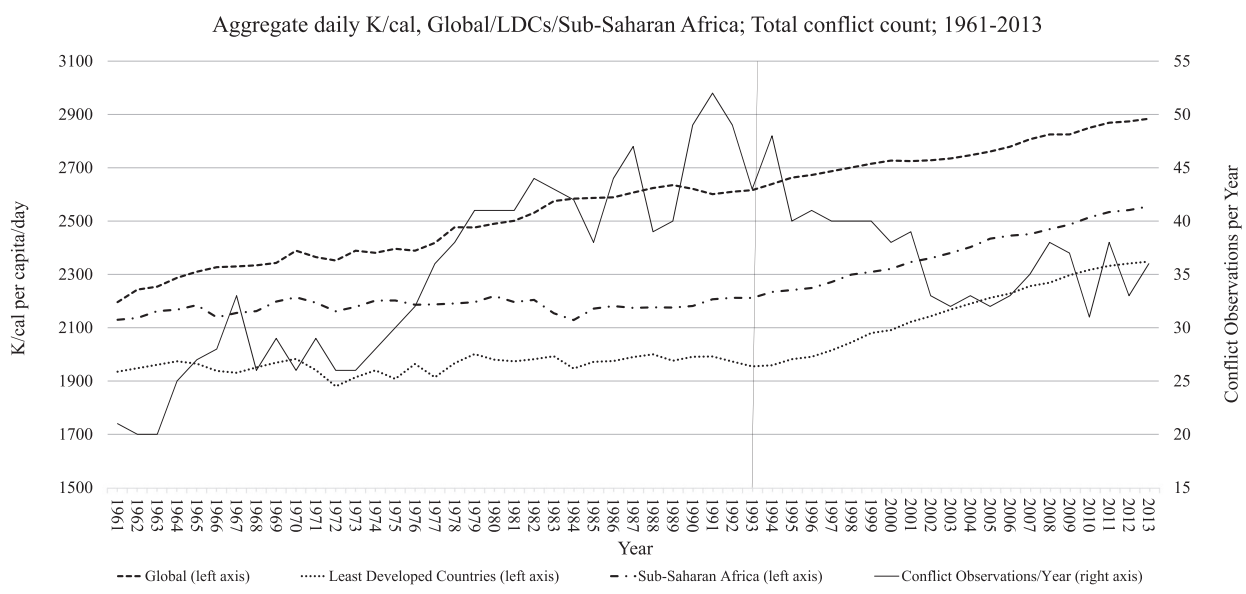

Fig. 3. Aggregate daily access to kilo calories globally, in LDCs and in Sub-Saharan Africa, across time compared to total conflict count. Sub-Saharan Africa numbers are average of FAO sub-regional data, and exclude North Africa. Sources: FAO, 2018, UCDP, 2018.

of conflict incidents increased, starting in 1993; this increase was not only global, but in LDCs and Sub-Saharan Africa, where there were a comparatively large number of civil conflicts. Still, at any given time a very small number of countries are affected by conflict, even in regions where conflicts are more common. So, a key issue going forward is unpacking the factors behind the endogeneity in the relationship between conflict and food security.

The two principal sources of endogeneity are unobserved confounding factors and reverse causality. For instance, for many forms and circumstances of food insecurity one can think of a range of factors that simultaneously drives food insecurity and the likelihood of violent conflict. If such a factor that is correlated with both conflict and food security is erroneously not included in the specified model of a food insecurity measure the estimate of the impact of violent conflict will be biased. Similarly, a snapshot of food insecurity in region X at time T may be driven by violent conflict in region X at time T, while at the same time the violent conflict may actually be the result of the food security on region X. A large body of cross-country evidence suggests that national income is negatively correlated with the incidence of violent conflict (Blattman & Miguel, 2010). Table 1 shows the food security scores for countries batched by their 2014 income group according to the World Bank (World Bank, 2017). With the exception of Cereal Import Dependency Ratio, food security improves at each progressive step from Low to High-income.

These strong patterns show that national income is not only intimately related to the incidence of conflict but also to various pillars of food security.

The function of the state goes beyond just economic performance in the form of national income, and the second factor we look at is national administrative capacity. The incidence of violent conflict is often per construction a symptom of state weakness, such as in civil wars where the state lacks the capacity to monopolize central violence and control over the whole of its nominal territory. Notably, though, some countries affected by internal conflict actually score reasonably well in the World Bank's WGI indicators.

Fig. 4 shows a basic representation of how the WGI Government Effectiveness Scores (an index of public administration quality) is related to food security outcomes in countries affected by Intrastate conflict in the year 2014. Food price volatility and prevalence of undernourishment become noticeably worse in as quality of public administration gets worse.

Fig. 4 shows that as government effectiveness increases in these contexts food security outcomes improve (on average). These strong patterns show that, like national income, state capacity is not only intimately related to conflict outcomes but also to various pillars of food security. Given that we discussed five indicators previously, it would be fair to ask why we only look at two in the graphs above. This is largely a problem of data availability and matching. For example, the timeline for Cereal Import Dependency Ration stops in 2009. In 2014, when we filter for only countries

Table 1
Averages of food security indicators by income group, 2014. Larger numbers indicate lower food security. Income groups from World Bank (2017) data, food security data from FAO (2017) database.

	Food Security Indicator Averages, FAO 2014				
	Prevalence of Undernourishment	Depth of Food Deficit	Percent of Diet that is Cereals/Roots/Tubers	Food Price Volatility Index	Cereal Import Dependency Ratio
Low-income countries	25.56%	191.71	65.21%	9.77	24.95
Lower-middle income countries	13.95%	97.88	53.64%	7.87	34.81
Upper-middle income countries	10.30%	67.55	44.50%	7.29	31.22
High-income countries	5.31%	22.16	33.17%	6.98	24.79

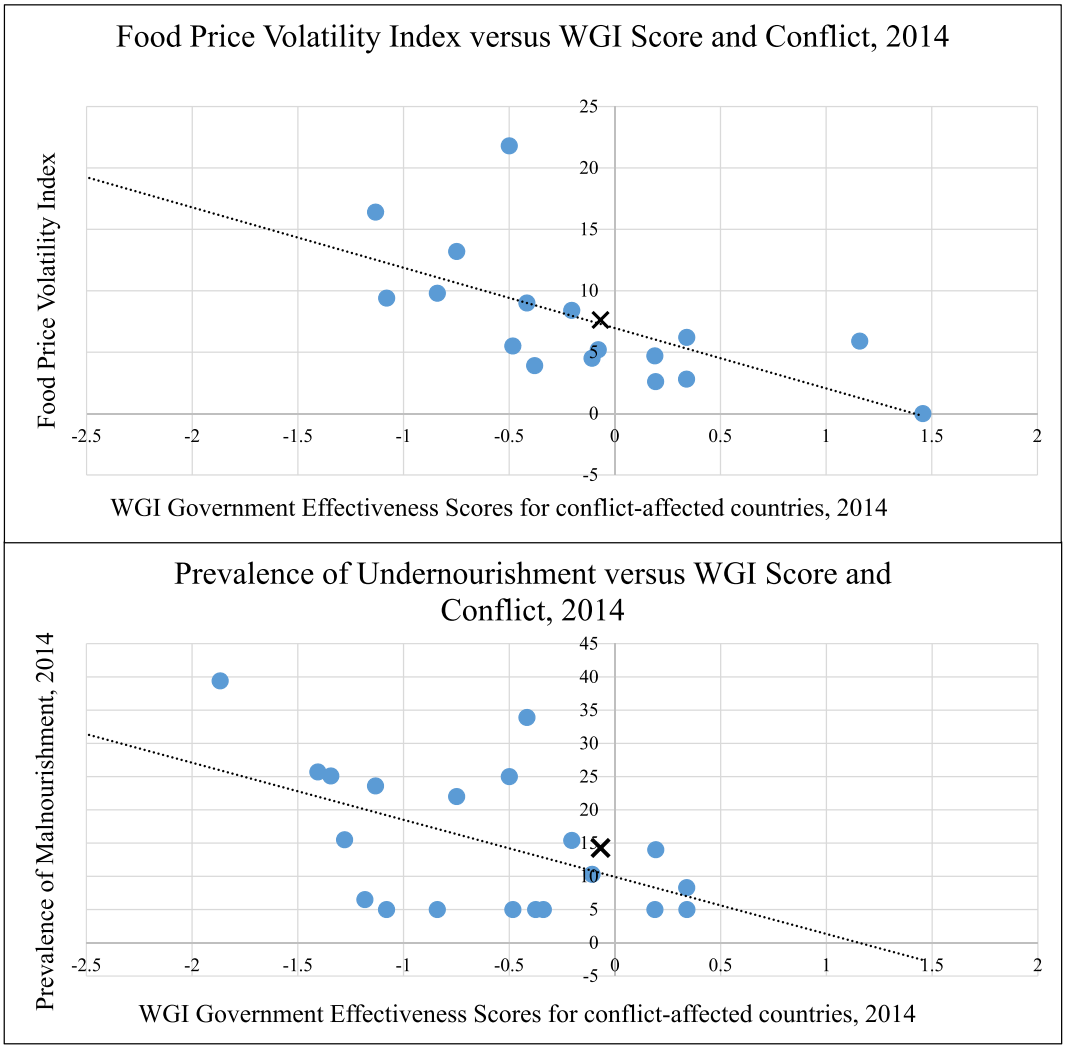

Fig. 4. The relationship between WGI score and food security among Intrastate conflict-affected countries. Larger numbers on the Y-axes indicate greater food insecurity. Data from FAO (2017) and World Bank (2017).

affected by Interstate conflict that also report food security data and have WGI scores, we are left with 17 countries reporting Food Price Volatility and 19 reporting Prevalence of Undernourishment. These kinds of missing data issues will be discussed in more detail in section four.

3. The causal relationships between food security and conflict

This section reviews robust findings from quantitative analyses of the bi-directional relationship between food security and violent conflict that account for endogeneity concerns. We summarize the existing evidence and identify limitations in both directions: (i) the impacts of violent conflict on food insecurity in Section 3.2 and (ii) the impacts of food insecurity on violent conflict in Section 3.3. The scope of the review is deliberately broad to reflect the spectra of different forms of food security and conflict and to support the wide range of topics covered in the other contributions to the special issue. While we focus on *findings* (that are supported by strong empirical evidence), we sometimes highlight specific studies in more detail if they broke new ground, introduced a technique, raised new questions or provided important or even controversial nuances to a broader finding. Sections 3.4 and 3.5 summarize the relatively recent and controversial – but highly policy-relevant – debates about the causal effects of climate conditions and food policies on food security and violent conflict and their interrelationships. Section 3.5 reflects on the dominant strategies researchers have used to identify causal relationships between food security and conflict and discusses methodological gaps.

3.1. The impacts of violent conflict on food security

It is well established that differences in food security shape short-term and long-term outcomes of health and well-being, when the ability of individuals and nations to cope with shocks and to smooth income and consumption is limited. In conflict-affected countries, many households and firms are smallholder farmers, who face a high degree of income uncertainty even in the absence of conflict, primarily through weather shocks (Townsend, 1994; Maccini & Yang, 2009). Some are commodity suppliers to local, domestic or global markets, such as cocoa or coffee farmers, who are also subject to price fluctuations in these markets (Adhvaryu, Kala, & Nyshadham, 2015; Adhvaryu, Fenske, & Nyshadham, 2018; Deaton, 1999; Kruger, 2007; Miller et al., 2010). In this case, conflict presents an additional 'shock' that affects the livelihoods and well-being of these populations. Two important points are apparent. First, the nature of this 'shock' may be quite diverse across different types and intensities of armed conflict and across the national and local institutions that

are either transformed or emerge during this armed conflict (see also Justino (2012)). Second, exposure to conflict may directly shape food security, but also interact with other fluctuations, such as those in prices and climatic conditions.

3.1.1. The impacts of violent conflict on nutritional status

A large literature has identified adverse short-term effects of exposure to conflict on children's nutritional status. Most evidence exists for anthropometric outcomes, which are directly associated with nutritional status. These are primarily the height-for-age Z-score (HAZ), i.e. height conditional on age and gender, and assessing 'stunting', which is growth failure in a child that occurs over a slow cumulative process. As stunting reflects episodes of sustained undernutrition, low scores are associated with 'chronic malnutrition'. A second indicator is the weight-for-age Z-score (WAZ), i.e. weight conditional on age and gender. Low WAZ scores are associated with 'general malnutrition'. Third, weight-for-height measures or 'wasting', are often considered the most robust indicator for 'acute malnutrition'.

Most analyses rely on a difference-in-differences approach pioneered by studies from Rwanda and Burundi. In Burundi, Bundervoet, Verwimp and Akresh (2009) show that children aged 0–5 who were born in regions affected by civil war violence, have significantly lower HAZ scores than those born in other regions. Follow-up studies report consistent, adverse effects on anthropometric outcomes among children from a range of conflict-affected contexts, including Angola, Colombia, Cote d'Ivoire, Eritrea, Ethiopia, India, Iraq and Mexico (Arcand, Rodella, & Rieger, 2015; Akresh, Lucchetti, & Thirumurthy, 2012; Akresh, Caruso, & Thirumurthy 2016; Duque, 2016; Guerrero-Serdan, 2009; Minoiu & Shemyakina, 2014; Nasir, 2016; Tranchant, Justino, & Müller, 2014). Akresh, Verwimp, and Bundervoet (2011) find very similar effects of civil war violence on child stunting in northern Rwanda and contrast the effects with those of a contemporaneous crop failure in southern regions, that was *not* induced by conflict. The analysis finds important differences between the conflict and non-conflict shocks. War exposure affected all children equally, while only girls were negatively affected in the case of crop failure. This result suggests that could smooth boys' consumption during crop failure families, while they were not able to do so during conflict exposure.

The magnitudes of the adverse effects of exposure to armed violence on anthropometric outcomes are markedly similar across case studies and contexts, despite significant differences in conflict duration, war strategies and other context-specific characteristics. Yet, two key limitations of the current literature remain. First, poor nutritional status is often directly linked to food insecurity. However, a person's nutritional status may or may not be the result of food insecurity, i.e. due to lack of access to sufficient, safe and nutritious food (access defined as physical, social and economic). Second, most of the rigorous and robust evidence documents adverse effects in chronic malnutrition, rather than acute malnutrition. However, acute malnutrition indicators in particular are critical measures. These should be closely monitored and analyzed in conflict and protracted crisis countries as well as serve as a key source of information for humanitarian interventions. Thus, more rigorous evidence on the impact on acute malnutrition is of paramount importance.

A related body of evidence shows that adverse short-term effects of conflict on children through nutritional channels may already be activated before a child is born ('*in utero*'). Pregnant women who are exposed to more conflict give birth to children of lower weight, which thus immediately transmits adverse effects of conflict across generations. The pioneering study by Camacho (2008) finds that the exposure of women to violence across Colombia during the first three months of pregnancy resulted in lower birth weights. These effects have been confirmed by findings from diverse contexts, such as Brazil, Mexico, Nepal, Kashmir and Palestine (Brown, 2018; Foureaux Koppensteiner & Manacorda, 2016; Mansour & Rees, 2012; Parlow, 2012; Valente, 2011).[2] While the relationship between conflict exposure in utero and birth weight is robust, questions about the underlying mechanisms – which are likely to be highly context-specific – and the impacts on measures such as height as a child are hitherto only inconclusively debated (Akresh, 2016).

3.1.2. Long-term consequences of early-life exposure to conflict

The famous 'fetal origins hypothesis' posits that variation in access to nutrition in the womb codes long-run differences in health and well-being. The original hypothesis has been extended to early-life nutrition after birth and confirmed by a large body of empirical evidence, which is reviewed by Almond and Currie (2011) and Currie and Vogl (2013). Conflict exposure early in life, including nutritional deficiencies and other adverse experiences, may thus pre-determine detrimental long-term impacts, which threaten food security as an adult.

A few recent studies have started to produce robust support for damaging effects on physical and cognitive development outcomes as an adult have been reported from various other conflict-affected settings, e.g. Cambodia, Germany, Mozambique and Zimbabwe (Akbulut-Yuksel, 2014; Alderman, Hoddinott, & Kinsey, 2006; de Walque, 2006; Domingues & Barre, 2013). The important study by Akresh, Bhalotra, Leone, and Osili (2012) provides convincing evidence that the magnitude of adverse impacts may vary significantly by age at exposure 40 years after the end of the conflict. For instance, they show that women who had been exposed to the Nigerian civil war in Biafra between 0 and 3 years of age are, on average, 0.75 cm shorter than non-exposed women of the same age. Women who were exposed when they were 13 to 16 years old are 4.53 cm shorter than non-exposed women of the same age. These strong heterogeneities remain to be validated across other conflicts and contexts.

Taken together, the literature has rapidly accumulated a wealth of robust micro-evidence that the exposure to conflict at a young age is causally linked to irreversible harm to short- and long-run development from nutritional disadvantages. What aspect of violent conflict causes these immediate nutritional deficits, and how, remains not well understood, and is likely to include multiple and context-specific pathways. While a recent literature demonstrates that conflict may have detrimental long-run effects, it also remains to be understood how and how strong food security is affected. Specifically, conflict exposure may push children into a reinforcing cycle of food insecurity, where food insecurity at young age may eventually causes or contribute to compounding dietary health and food insecurity issues as an adult.

3.1.3. The impacts of violent conflict on coping and consumption

To better understand reactions to conflict exposure and associated impacts on outcomes related to food security, many economists have directly studied micro-strategies to reduce conflict risk and smooth consumption (Justino, 2009).[3] Descriptive evidence suggests that these strategies are dynamic and likely to differ at conflict onset and during protracted conflict (e.g. Ogbozor, 2016).

Many of the stronger findings describe migration and forced displacement and document a wide range of adverse effects on food security. Several quantitative studies rely on refined household survey data related to the quantity and quality of consumption, despite the challenges to thorough data collection in these

[2] While the reduced-form link is very robust, it is worth noting that disentangling nutritional channels from others, such as effects of maternal stress that do not work via nutrition, empirically is very difficult.

[3] Especially for self-sufficient farmers, this obviously also concerns re-allocations of labor and capital in agricultural production, which we discuss later.

regions. Indicators include activity choices, detailed consumption diaries, resulting calorie intake data, food expenditures, food produced, and food gifts combined with local food price data. However, teasing out and quantifying causal relationships is once again daunting and robust evidence is thus rare (see review in Ruiz and Vargas-Silva (2013)).

A few convincing studies validate and confirm the correlational evidence. For instance, Kondylis (2010) exploits differences in the timing of *return* of Rwandan internal refugees to establish that returnees are significantly better off economically than those who had (still) remained displaced. Bozzoli, Brück and Muhumuza (2016) produce meaningful comparisons of residents of internal displacement (IDP) camps in post-war northern Uganda and those who had just relocated from camps voluntarily. The study finds significant differences in activity choices. While camp residents are less active overall (which may suggest their productivity is low), they are more likely to cultivate and trade. Verwimp and Munoz-Mora (2013) find similar effects on food expense and calorie intake among Burundian refugees. The study estimates that it would take 8–10 years after return for the welfare gap between displaced and non-displaced households to close. These findings suggest that displacement may have strongly adverse long-term legacies, which – without assistance – may be impossible to overcome for the poorest populations.

Beyond displaced populations, other studies have investigated food consumption patterns in conflict zones more generally and link them to conflict event data. As expected, the findings confirm that households living close to registered conflict events often experience drops in consumption levels in settings as diverse as Afghanistan (D'Souza & Jolliffe, 2013), Cote d'Ivoire (Dabalen & Paul, 2014) and Rwanda (Serneels & Verpoorten, 2015).

Beyond violence, an emerging literature offers descriptive evidence on the local presence and rule of armed state and non-state groups (Arjona, Kasfir, & Mampilly, 2015). One the one hand, such groups often invest in local public goods (Sanchez de la Sierra, 2015), which may increase local consumption levels. However, one the other hand, food is essential for the survival of armed groups (e.g. Justino & Stojetz, 2018), which may decrease local consumption levels. At the extreme end of the spectrum, these processes also include scenarios where food and hunger are used as 'a weapon of war' (Messer & Cohen, 2015). Yet, collecting microdata on these processes is difficult, and to the best of our knowledge, these effects have not been studied and quantified systematically.

At aggregate levels, both direct and indirect studies of consumption are surprisingly scant. The early study by Teodosijević (2003) reveals that the experience of conflict between 1961 and 2000 is associated with a 7% reduction in daily energy supply among 38 countries. Jeanty and Hitzhusen (2006) find similar results based on 73 countries between 1970 and 2002. Gates, Hegre, Nygård, and Strand (2012) present perhaps the most extensive set of reliable estimates of the impact of conflict on food security and underdevelopment at the cross-national level. Key findings include that a conflict with 2500 battle deaths increases the population share living on less than the minimum recommended dietary energy consumption by 3.3% and denies an additional 1.8% of the population safe access to potable water.

3.1.4. The impacts of violent conflict on agricultural production

A separate literature looks at the impact of conflict on production of food and factors that, which is fundamental to food security. A large body of studies has investigated the effects of civil war on (broad) economic production and growth across countries.[4] The impacts of violent conflict on social, political and economic institutions (including markets) are likely to be among the important factors shaping heterogeneous responses to conflict. While the long-term effects on economic performance, including food production and food security, could be positive or negative, these are still among the least understood of all impacts of violent conflict (Blattman & Miguel, 2010). Overall however, institutional change, which characterizes most violent conflicts, and the impacts on food production remain very poorly understood, both at the national and the local levels.

A few recent studies have used innovative farm-level and conflict data as well as modern techniques to analyze the causal impact of violent conflict in East Africa and Colombia on agricultural production, including livestock and a variety of crops, such as coffee. The findings suggest that production may drop substantially in regions affected by conflict, due to adverse effects on labor supply, access to land and access to credit and/or direct effects on capital such as theft and destruction (Blattman & Miguel, 2010; Munoz-Mora, 2016; Nillesen, 2007; Rockmore, 2015; Verpoorten, 2009).[5] Observing actual micro-level responses to conflict exposure in situ is particularly challenging, but there is growing empirical evidence on the coping strategies of conflict-affected individuals and households to protect their productivity, livelihoods and food security. As for instance in Africa 70 per cent of the population rely on agriculture for their food supply (Paul, Shonchoy, & Dabalen, 2015), the literature has focused on agricultural coping strategies. Well-documented strategies include shifts in crop production portfolios, labor reallocation, destroying or hiding livestock (and other visible assets), changes in land use patterns, economic cooperation with local ruling groups and other activities that minimize victimization risks and uncertainty (Arias, Ibáñez, & Zambrano, 2017; Bozzoli & Brück, 2009; Brück & Schindler, 2009; Gáfaro, Ibáñez, & Justino, 2014; Fernández, Ibañez, & Peña, 2014; Menon and van der Meulen Rodgers, 2015; Rockmore, 2011; Verpoorten, 2009).[6]

Several studies emphasize that shifts in crop, livestock and asset portfolios are often consistent with households increasing the share of low-risk, low-return activities (e.g. Justino, 2009; Paul et al., 2015; Rockmore 2015; Vlassenroot, 2008). These low-risk low-return coping strategies may obviously have adverse long-term consequences but may also provide immediate and longer-term *benefits*. In terms of benefits, Brück (2003) and Bozzoli and Brück (2009) show that subsistence farming led to improvements in the economic security of households living in extreme poverty during the civil war in Mozambique, because social and economic markets entailed limited welfare benefits. However, these effects of subsistence modes of production during conflict must be balanced against the longer-term adverse effects of low productivity. In addition, the external validity of this finding is contested. For example, Nillesen and Verwimp (2010) show that many Burundian households exposed to high levels of conflict violence shifted their portfolios towards more sustainable, and more profitable, activities, and that income shares from export crop farming were higher in violence-affected regions (even though the causality may have run from export cropping to conflict in this case).

3.2. The impacts of food (in)security leading on violent conflict

The broad field of food security and its consequences has attracted wide attention by academics and practitioners recently.

[4] For a surveys on the economic costs of conflict see, e.g., de Groot, Bozzoli and Brück (2015).

[5] We discuss the household- and farm-level decisions underpinning most of these results below.

[6] Notably, some of these strategies differ from findings from reactions to non-conflict shocks. For instance, selling – rather than hiding or destroying – livestock, is documented as a common form of coping strategy used by rural households in developing countries in times of crisis.

Analyses have predominately focused on a conceptual understanding of food insecurity, such as the lack of dietary energy availability and nutrient deficiencies, and how to alleviate these concerns. While a large body of literature has studied the impact of broad categories of economic and ethnic differences, such as in growth or religion (for a recent review see Ray and Esteban (2017)), researchers and practitioners have only recently started to study the consequential impacts of food insecurity on conflict comparatively and rigorously (for a broad overview and excellent analysis on the effects on the occurrence of conflict see, e.g., Koren and Bagozzi (2016)).

Two important points are obvious. First, food security aspects relevant for conflict zones and societies may be very diverse and vary substantially across different types and intensities of armed conflict and income levels. Second, impacts originate from and operate at very different levels. At the individual and household levels, factors such as nutrition and economic opportunity may directly affect participation in virtually any form of anti-social behavior. A range of additional mechanisms may originate at more aggregate levels, including global food prices and policies as well as domestic and local wartime institutions, markets, governance and climatic conditions.

3.2.1. The impacts of food insecurity on anti-social behavior

At the individual level, food insecurity – or the threat thereof – may create both material and non-material incentives for individuals to engage in some form of behavior that threatens peace (to which this section will refer to as 'anti-social behavior'). Pinning down a single channel empirically is extremely difficult, however, and rigorous empirical evidence at the individual level is therefore markedly thin. Two key challenges are that these motives are a) in and of itself very complex and hence difficult to measure and b) empirically extremely difficult to untangle from alternative mechanisms that are often credibly not directly related to food insecurity, such as abduction, peer-pressure, ideology, and emotions. The pioneering studies of ex-combatants by Humphreys and Weinstein (2008) provide perhaps the most compelling empirical evidence. Based on original survey data they show that armed groups sometimes target recruits via basic needs, by providing food, shelter and physical security.

More recently, a growing number of qualitative accounts have emerged that document how civilians survive and protect their livelihoods and food security through forms of support for armed groups, which may be voluntary or involuntary. These processes are endogenous to 'wartime governance' by local ruling groups and underline the centrality of shelter, food and information to the fate of armed groups (Arjona et al., 2015; Justino & Stojetz, 2018; Kalyvas, 2006; Wood, 2003). However, it is apparent that rigorous evidence beyond descriptive and qualitative analyses is very scarce.

3.2.2. The impacts of food prices shocks on violent conflict

Historical accounts are replete with descriptions of how rising food prices breed violent conflict, including insurgencies, wars and revolutions (Diamond, 2005; Goldstone, 1991; Rudé, 1964). There is now a growing body of econometric evidence – broadly in the vein of Hendrix, Haggard, and Magaloni (2009) – that supports this conjecture for the incidence of very different forms of social unrest, such as protests, riots, violence and war, with most studies relying on the FAO price index of food commodities.

Most evidence exists for urban social unrest in contemporary Africa (e.g. Berazneva & Lee, 2013; Smith, 2014), which includes studies linking the 'Arab Spring' uprisings to international food price shocks (e.g. Johnstone & Mazo, 2011; Maystadt, Trinh Tan, & Breisinger, 2014). More recent findings suggest global relevance (Bellemare 2015; Cadoret, Hubert, & Thelen, 2015). Studies of the intensive margin of violent conflict are more scarce, but point to broadly similar, positive relationships with increasing food prices (see e.g. Breisinger, Ecker, & Trinh Tan, 2015; Maystadt & Ecker, 2014). By contrast, much less is known on how and how much food prices drive violent conflict. Among the most fundamental unsettled questions is whether and when it is the level versus the volatility of food prices that breeds conflict. In this regard, the most convincing evidence is provided by Bellemare (2015), who forcefully argues that increases in food price levels cause urban unrest, while those in food price volatility do not.

The dominant explanation for the food price-conflict link are consumer grievances; higher prices essentially create or increase economic constraints and/or sentiments of perceived relative deprivation, which activates grievances that in turn lead to conflict. This causal chain is very difficult to both measure and isolate empirically, for reasons already noted above, which is why it is usually assumed rather than tested directly. In addition, most contributions have looked at the impact of international food prices on conflict at the national level, which is reasonable in principle, as many fragile and conflict-affected countries are net importers of food. However, a few recent studies emphasize the need to use country-specific food price indexes to better understand the consumption patterns and constraints faced by vulnerable populations (e.g. Arezki & Brueckner, 2014; Cadoret et al., 2015; Weinberg & Bakker, 2015). In an innovative study using such an approach based on a country's food import pattern, Van Weezel (2016) provides three statistically robust and important findings:

- The (previously documented) relationship between food prices and urban conflict is driven mainly by the prices of basic staples like wheat;
- It is also predominantly supported for high-intensity conflict;
- Interestingly, however, the magnitude of the effect as well as the predictive power of food prices are both notably moderate.

A second set of explanations for the food price-conflict link emphasizes breakdowns of state authority and legitimacy, when the state fails to provide food security, i.e. activating grievances against the state (e.g. Lagi, Bertrand, & Bar-Yam, 2011). A few recent analyses have sought to document the related impact on state-level correlates of conflict. For instance, Arezki and Brueckner (2014) argue that the cohesiveness of political institutions in low-income countries deteriorates significantly when international food prices increase, while Berazneva and Lee (2013) show that rising food prices and riots in Africa are associated with more political repression.

3.2.3. The impacts of food production on violent conflict

While many developing countries – especially in Africa – increasingly rely on food imports for domestic consumption, agriculture often remains the largest economic sector, delivering labor opportunities and sustaining livelihoods. A third large strand of literature thus focuses on the role of variation in food production on violent conflict. As food production is strongly dependent on climatic conditions in many developing countries, new evidence is emerging on food production variation induced by climatic fluctuations, which is reviewed separately in the next section.[7]

Decreases in labor demand due to shifts in agricultural production may directly lower the opportunity cost of engaging in anti-social behavior (Miguel, Satyanath, & Sergenti, 2004). For instance, Guardado and Pennings (2017) show that conflict intensity in Iraq and Pakistan is higher outside the harvest season, when demand for labor in agriculture is lower. More generally, decreases in

[7] In Africa, for instance, merely 6% of the all food production is irrigated (NEPAD, 2013).

agricultural productivity may directly activate societal grievances due to increasing destitution, famine, distress, migration or aggravated social inequalities (Barnett & Neil Adger, 2007; Kelley, Mohtadi, Cane, Seager, & Kushnir, 2015; Raleigh & Kniveton, 2012; Reuveny, 2007; Raleigh, 2010). A third source of violent conflict discussed in the literature are increased grievances against the state, when agricultural deficits at the state level result in losses of tax revenues and higher food prices, as discussed above (Homer-Dixon, 1999; Kim, 2016). In this case, associated forms of maldistribution, patronage, corruption and embezzlement of aid may then also activate or exacerbate existing grievances against the state (Benjaminsen, 2008; Hendrix & Brinkman, 2013; Nunn & Qian, 2014).

From a production point of view, increased international commodity prices – including agricultural commodities – could benefit domestic producers of the commodity and reduce conflict, for instance by an increase in opportunity costs (see e.g. Bazzi & Blattman, 2014). On the other hand, conflict could also become more likely, when, for instance, economic pay-offs to violent capture of agricultural revenues rise (see e.g. Fjelde, 2015). These basic considerations suggest that fluctuations in commodity prices may affect subpopulations and sub-regions in conflict zones very differently. While of paramount importance, researchers have just begun to develop rigorous studies and frameworks to analyze these processes empirically. A few recent contributions provide initial but statistically very sound insights. McGuirk and Burke (2017), for instance, demonstrate empirically that increases in world commodity prices can reduce the incidence of large-scale conflict over land and the control of territory ('factor conflict') for African food-producing grid-cells. Conversely, higher prices can increase the incidence of (small-scale) conflict over the appropriation of surplus ('output conflict'). The innovative study by Crost and Felter (2016) combines global market prices with spatial variation in crop intensity in the Philippines to show that increases in major export crop can causally exacerbate violence. The effects are driven by insurgents gaining strength by extorting agricultural exporters. Related, Wright (2016) shows how Colombian rebel tactics respond to fluctuations in world coffee and coca prices. Drops in coffee prices allow and cause rebels to use more intense conventional fighting (as economic opportunities outside of rebellion are argued to be low), while dropping returns to coca production lead to irregular rebel attacks (as rebels are argued to be more resource constrained). Finally, concerns of securing local food access and smoothing food security of its members can also make armed groups more likely to perpetrate violence against civilians when intergroup conflict activity is high (Koren & Bagozzi, 2017).

3.3. Climate, food security, and conflict

A related and burgeoning literature focuses on the quantitative links between variation in climatic conditions and conflict (see, e.g., the recent review by Burke, Hsiang, and Miguel (2015)). The impact may be substantiated by multiple pathways, some of which are closely related to food security and include those operating via economic conditions and outcomes. There are two broad strands of literature with differing objectives.

Following Miguel et al. (2004), a large literature has used climatic variation as an 'auxiliary' or 'instrumental' variable to identify the impact of an economic variable on outcomes of conflict and violence. Examples of these economic variables include economic growth, agricultural output and food prices (e.g. Bergholt & Lujala, 2012; Bellemare, 2015; Koubi, Bernauer, Kalbhenn, & Spilker, 2012; Maystadt & Ecker, 2014; Miguel et al., 2004). The crucial assumption is that for the study context(s) the climatic variation is not correlated with any other variables that covaries with the conflict or violence outcome variable. As the range of economic variables that may be affected by climatic variation grows rapidly (Dell, Jones, & Olken, 2014), this assumption has become increasingly contested for many contexts (e.g. Sarsons, 2015).

More recently, most attention in the literature has focused on assessing whether empirical estimates of the purported 'reduced-form' or 'net link' between climatic variation and conflict outcomes are spurious and have a causal interpretation. Studies from numerous settings find that both above-average temperatures and below-average precipitation levels are positively associated with conflict onset and duration, starting with an influential analysis on temperature and civil war incidence by Burke, Miguel, Satyanath, Dykema, and Lobell (2009). Others have contested the existence of this relationship and highlight that such a conclusion may be flawed, due to measurement error, data set selectivity and methodological strategies (Buhaug, 2010a, 2010b; Sutton et al., 2010). Yet, the leading perspective nowadays is that the climate-conflict link is real (Burke, Dykema, Lobell, Miguel, & Satyanath, 2010; Burke, Miguel, Satyanath, Dykema, & Lobell, 2010a, 2010b), which is backed up by recent meta-analyses of more than 50 prior studies documenting substantial effects of temperature increases on the likelihood of interpersonal and intergroup conflict (Burke et al., 2015; Hsiang, Burke, & Miguel, 2013). This also includes increases in conflict violence against civilians (Vanden Eynde, 2015).

Beyond the basic debate on the existence of the climate-conflict link, two observations from this relatively recent literature are worth noting. First, existing studies have nearly exclusively focused on sub-Saharan and Sahelian regions in Africa. Second, there is a very active debate about whether and how the effect of climate on conflict operates through local economic conditions. The focus on this specific pathway is partly driven by the interest in understanding the effect of economic conditions on conflict, as noted above (but of course also faces the same statistical challenges). The first step in the chain of causation via local economic conditions is that unusually high temperatures and low rainfall depress agricultural production and output (and may affect other variables), which is not disputed for Africa (e.g. Barrios, Ouattara, & Strobl, 2008; Schlenker & Lobell, 2010). While the intuitive link with an associated drop in food security is often essentially assumed, a number of studies have explicitly documented negative impacts of climatic variation on household food security (see e.g. for Ethiopia, Dercon & Krishnan, 2000; Demeke, Keil, & Zeller, 2011; Di Falco, Veronesi, & Yesuf, 2011).

In a second step, diminished agricultural yield and incomes are theorized to drive conflict by affecting local employment opportunities, prices, and grievances. Subsequent studies have thus sought to predict the consequences of climate change on violence levels by extrapolating from historical temperature and rainfall trends in rural Africa (e.g. Gleditsch, 2012; Hendrix & Salehyan, 2012; Raleigh & Kniveton, 2012; Theisen, 2012). Yet, the mechanisms substantiating this second step remain largely untested empirically. Raleigh, Choi, and Kniveton (2015) not only demonstrate the complexity of these relationships and the difficulty to untangle them empirically, but also provide rare convincing evidence of how the link from climatic variation to conflict can flow via food prices.

Recent research points to alternative mechanisms of how temperature anomalies may be related to conflict. Temperature-induced variation in agricultural yield can alter migration patterns, with potential effects on sub-state violence and conflict (Bohra-Mishra, Oppenheimer, & Hsiang, 2014; Feng, Krueger, & Oppenheimer, 2010; Feng, Oppenheimer, & Schlenker, 2012; Hsiang, Meng, & Cane, 2011; Salehyan & Gleditsch, 2006). Excessive heat may also reduce the broader supply of crops, raising the price of food (see above). Temperature anomalies also have effects on economic activity beyond agricultural production. Several studies have documented that higher temperatures may

depress economic output and growth, which may lead to conflict (Carleton & Hsiang, 2016; Dell et al., 2014; Hsiang, 2010; Jones & Olken, 2010). While these economic factors may well be linked to food security, empirical psychological research at the individual level has long established the tendency of individuals to behave more violently due to higher temperatures (Burke et al., 2015). These mechanisms are likely to interact with conflict risks due to food security and it is also possible that food security-based mechanisms are weak or even absent. The recent study by Bollfrass and Shaver (2015) provides an interesting finding. Using new global data at the provincial level they document the universal existence of a temperature-conflict link, which it also obtains in regions without agricultural production.

The bulk of the (markedly inconclusive) empirical studies linking precipitation and violent conflict aggregates rainfall during calendar years and over the totality of a country's territory. The recent paper by Maertens (2016) focuses on agricultural cells and explicitly incorporates the economics of agricultural production, i.e. that there is a non-linear relationship between rainfall and agricultural output. The study demonstrates that the hump-shaped relationship of rainfall and output in agricultural cells translates into a u-shaped relationship between rainfall and civil conflict risk at the country level. A substantial increase at comparably low levels of rainfall reduces the risk of civil war onset, while the same shift occurring above a certain threshold in levels *increases* the risk of civil war onset.[8]

3.4. Food security policies and violent conflict

With respect to policy interventions related to food security, arguably the most prominent literature is a broad body of empirical studies analyzing the impact of foreign aid and assistance on conflict outcomes. This literature is clearly very important, but it is also one of the most controversial ones in the fields of development and conflict. Theoretical models suggest that the welfare effects of material aid in fragile and conflict-affected settings is broadly ambiguous, depending on factors such as the 'cohesiveness' of political institutions and the level of government capacity, while technical assistance if effective should reduce conflict (Besley & Persson, 2011). The key empirical issue is that aid assistance is not randomly allocated. The existing evidence from both within as well as from across countries is markedly mixed. Depending on the measures used, the level of aggregation, the empirical strategy employed and the context, results range widely from very negative to very positive impacts of aid on conflict (Galiani, Knack, Lixin Colin, & Zou, 2016).[9]

The statistically most robust and most direct evidence on conflict outcomes stems from a few recent studies that use new high-quality data and exploit natural or randomized variation in certain types of foreign aid to identify its causal effects. Perhaps less intuitive findings include that conflict risks increased due to U.S. military aid in Colombia (Dube & Naidu, 2014), due to U.S. food aid to low-income countries (Nunn & Qian, 2014) and via community-driven development aid in the Philippines (Crost, Felter, & Johnston, 2014).

Beyond aid, it obvious that many subnational interventions related to food security, including in conflict-affected settings, exist, and many have successfully relieved food security stresses. While surveying these is beyond the scope of this section and deserves an entire literature review, the actual impacts of improved food security status on reducing conflict risk appear to be highly context-specific and are often assumed rather than tested rigorously. This encompasses various forms of food security and also includes innovative policies that build resilience (e.g. Breisinger et al., 2014).

3.5. Identification strategies and limitations

From a methodological perspective, various modern econometric approaches have been developed and employed to deal with concerns of statistical endogeneity affecting the relationships between food security and violent conflict. Most existing empirical strategies dealing with endogeneity concerns fall into one of four categories: First, selection-on-observables approaches, such as simple cross-sectional analysis and matching techniques, which draw on detailed observable economic, social and political information to 'control' for confounding factors (see e.g. Buhaug, 2010a). While 'bad controls' may themselves cause endogeneity issues (Angrist & Pischke, 2009), these designs are still the most dominant in the existing literature. Second, instrumental variable designs that exploit exogenous variation in a variable correlated with treatment (see e.g. Miguel et al., 2004; but also e.g. Sarsons, 2015). Third, panel data approaches, including those with lagged treatment and/or outcome variables, which have grown rapidly and use observations from the same sample or population over time (see e.g. Burke et al., 2015). Fourth, natural experiments that exploit exogenous variation in treatment (see e.g. McGuirk & Burke, 2017).

Among others, three critical, methodological gaps are apparent. First, less progress in terms of identification has been made at the macro level compared to the micro level, which, at least to some degree, has contributed to the fact that existing macro-level results are often markedly mixed and inconclusive. At aggregate levels, randomized experiments are harder to implement and natural experiments slightly more difficult to come across. Yet, natural experiments are increasingly and convincingly employed in macroeconomic studies and should be leveraged more in the study of the link between food security and conflict. Examples of historical episodes that generated natural treatments and have been 'exploited' statistically consideration range from policy intervention like changes in laws, to regime changes like abolishment of Communism, to natural disasters like earth quakes and droughts (Fuchs-Schündeln & Hassan, 2015). Additionally, methods to compute "synthetic control" groups have been developed based on a paper studying the economic costs of conflict (Abadie & Gardeazabal, 2003) but since used relatively little to analyze conflict or food security. Recent methodological innovations, such as the integration of machine learning techniques, offer a promising new avenue for understanding the food security-conflict nexus at aggregate levels, including policy interventions (Athey & Imbens, 2017; Doudchenko & Imbens, 2016; Kinn, 2018; Mullainathan & Spiess, 2017).

Second, identifying the effects of violent conflict at any level remains a central challenge. One of the reasons is that experiments where the conflict treatment itself is manipulated manually are not available. A few innovative and sometimes 'fortunate' research designs have exploited plausibly exogenous conflict shocks, some of which could be analyzed in a panel analysis, but the toolset remains limited. As a main concern is often omitted variable bias, more checks of coefficient stability would be a way of increasing confidence in standard estimates of the impacts of conflict. Examples techniques include Bayesian Model Averaging (Raftery et al., 1997) and assessments of how large the influence of unobserved confounders would have to be, relative to observed variables, to

[8] For related recent contributions on the two-step effects of precipitation anomalies, including droughts and floods, see also Buhaug, Benjaminsen, Sjaastad, and Theisen (2015), Ghimire, Ferreira, and Dorfman (2015) and von Uexkull et al. (2016). Another example of a study of a wide range of rainfall levels is Hidalgo, Naidu, Nichter, and Richardson (2010), which documents a strongly non-linear relationship between rainfall and land invasions in Brazil.

[9] For an example that demonstrates that food aid can alleviate food insecurity at the household level see, among others, Tusiime, Renard, and Smets (2013).

'explain away' an observed effect (Altonji et al., 2005; Bellows & Miguel, 2009; González & Miguel, 2015; Oster, 2017).

Third, identifying the effects of climatic conditions remains another central challenge, despite the wealth of recent scholarship. Like conflict, climatic conditions can (basically) not be randomized. In contrast to conflict exposure, the main statistical concern with differential exposure is less that certain units are 'selected' based on their pre-treatment characteristics, but rather that climatic conditions often affect a myriad of factors that could lead to conflict (Dell et al., 2014). This severely complicates (a) isolating specific pathways that undergird the reduced-form links and (b) instrumental variable approaches to identifying the impact of socio-economic variables on conflict (Miguel et al., 2004; Sarsons, 2015). This therefore emphasizes the need to improve existing techniques to identify the effect of food security on conflict. In instrumental variables approaches the exclusion restriction is untestable, but often contested. Such concerns could be mitigated by approaches that weaken the assumption of perfect instrument validity and produce estimate bounds under these new conditions, rather than recovering point estimates under the assumption of perfect validity (Clarke & Matta, 2017; Conley, Hansen, & Rossi, 2012; Nevo & Rosen, 2012; Small, 2007).

4. Building evidence and policy: data issues and possible solutions

For national and international policy-making, it is important to assess practical issues that are associated with monitoring food security and conflict and translating scientific results into practice. We highlight policy-relevant data issues as well as innovative ways that researchers and policy makers can use new technologies to navigate them.

4.1. Key data issues: food security

We illustrate different aspects of missing data at the national level based on two examples of FAO food security variables. The first variable is Prevalence of Undernourishment – the primary indicator of food insecurity selected by the FAO as the measure used to track progress toward Goal 1, Target 1.9 of the Millennium Development Goals. Thus, is it a variable that should have broad year to year global coverage, and indeed it does. However, specific cases are missing in the data, including Libya, Sudan, Somalia, South Sudan, the Democratic Republic of Congo, and Syria. These are all severely conflict-affected countries, and their exclusion means that we have no timeline to measure food security relative to changes in the intensity of their conflicts.

The second two variables we look at in the FAO's food security data are Percentage of Children Under 5 Years of Age Affected by Wasting, and Percentage of Children Under 5 Years of Age Who are Stunted – two key anthropometric measures used in micro-level empirical analyses. At the national level, the coverage for these variables is under 50%, and denies advanced analyses over time. For example, in the Democratic Republic of Congo from 2000 to 2016 there are only observations of Wasting in 2001, 2007, 2010, and 2013. This kind of sparsity exists throughout both datasets on wasting and stunting, for all countries, making cross national analysis of relationships that have proven robust at the micro level impossible.

Many important processes linking conflict and food security take place at the sub-national level. While disaggregated conflict data is increasingly available, sub-national standardized FAO data is lacking for many countries. Only recently have FAO country offices started to collect large-N, nationally representative datasets that provide important information at sub-national levels. Such shortcomings (also) reflect a state's ability to gather, process and share it. Investments in weak states' institutions of data collection and processing promises high returns for the availability of more complete and better data at the both the national and sub-national levels.

4.2. Key data issues: conflict

The battle-death based UCDP data is by some considered the 'gold standard' for dyadic data, other new datasets are now emerging that code and standardize measures of different aspects of conflict. ACLED, the Armed Conflict Location and Event Dataset, specializes in the geographic disaggregation of the nature of conflict (Raleigh, Linke, Hegre, & Karlsen, 2010). ACLED goes beyond counting battle deaths, and includes data on the location of riots, small-scale violence, and details like troop movements (Eck, 2012). Spatial data affords the ability to visualize patterns, as well as estimate geographic effects; Raleigh et al. (2010) note that ACLED's data can be used to demonstrate conflict effects beyond the specific geographic location of the violence. This is especially useful when talking about food security, since violence in one place could have knock-on effects that influence food access farther away.

The Social Conflict Analysis Database (Salehyan et al., 2012) provides alternative measures of conflict that capture riots, inter-communal conflict, and government violence against civilians. These data could prove extremely useful in understanding the socio-political dimensions that pervade both violence and food insecurity. Events of terrorism, captured in the Global Terrorism Database (START, 2017), also provide an alternative and underexplored pillar the relationship between violence and food security. The Political Instability Taskforce Problem Set (Center for Systemic Peace, 2017) captures not only data on violence, but also the nature of the conflict environment, coding details such as the ways that religion influences political positioning in Nigeria.

As conflict event data are often based on media reports, there is a risk that the reports or coded information will not be immediately available when an event of violence took place or may lack necessary geographic accuracy (Weidmann, 2013). Additional challenges arise when data teams add variables. Eck (2012) notes the differences between the ACLED and UCDP geolocated event datasets, highlighting comparative strengths and weaknesses. UCDP is more accurate in terms of event coding and geolocation, but limited to a narrow range of conflict typologies; ACLED covers a much wider range of event types, but the geolocation and coding consistency suffers as a result (ibid).

Beyond conflict event data, researchers have started to directly measure and survey conflict exposure of individuals, households and communities. There is a growing number of large-scale surveys that include such modules, which allows to match information on conflict exposure with socio-economic information at the micro level (Brück et al., 2016). Yet, this has not been implemented systematically, which limits analyses mostly to single case studies.

4.3. New technologies and innovative data collection

There are exciting new developments in collecting data on both food security and conflict, especially regarding digital technologies (e.g. Arribas-Bel et al., 2017; Jean et al., 2016; You et al., 2017). Using technologies such as mobile devices, satellite sensors and geographic information systems (GIS) can greatly improve data generation and has been shown to return reliable data.

As an example, Leo et al. (2015) show that in Afghanistan and Zimbabwe mobile phone technology allowed researchers to reach the poorest communities and that phone credit incentives minimized sample attrition. Leo and Morello (2015) demonstrate that

mobile phone-based approaches are also capable of producing high-quality information on complex measures such as individuals' policy priorities. Similarly, several pilot studies have shown the feasibility and merits of "crowdseeded" data where information to measure conflict events and exposure is reported instantly via mobile phones, even in contexts as challenging as the Democratic Republic of Congo and Syria (van der Windt & Humphreys, 2016; Baliki, 2017). These studies were not only able to monitor conflict in real time but also expose biases in traditional conflict event data from media reports (Baliki, 2017).

GIS methods allow researchers to accurately geocode conflict and food security phenomena and match it with other data sources, like georeferenced household surveys (e.g. Brück et al. (2016)). Remote imagery has now been used to identify and track food security measures, and can uncover new and sometimes counter-intuitive insights. For instance, remote sensing data allowed researchers to estimate land use and revenues from crop production by the Islamic State (Eklund, Degerald, Brandt, Prishchepov, & Pilesjö, 2017; Jaafar & Woertz, 2016) and demonstrated that Darfur vegetation growth prior to conflict outbreak had actually been higher than normal (Brown, 2017), challenging arguments that link fighting to resource shortages.

On-the-ground organizations are also actively putting new technologies to use in data gathering and service delivery. Enenkel et al. (2015) developed an application called SATIDA COLLECT, which was deployed in Central African Republic (CAR) to remotely gather data via real-time surveys from the field, as well as capturing GIS data from end-users' mobile phones. Medicins Sans Frontieres has begun using this technology in their food security work in CAR, representing a practical application of innovation in data collection (ibid). UN Global Pulse (2015) has successfully proxied food security and dietary health patterns via mobile airtime spending; this kind of day-to-day commercial behavior can be a useful proxy for tracking food security. The World Food Programme (2016) has used mobile phone-based cash transfer programs to support access to food in refugee camps in Cameroon. The meta data from this kind of program, can be vital for understanding consumption and spending patterns among conflict-affected populations.

Taken together, there are exciting new technologies for data collection. Developing these techniques further and scaling them up is thus a promising way for producing a better, faster, more complete and more cost-effective understanding food security and conflict. This can not only contribute to better policy designs and interventions, but also improve early warning systems (Lentz et al., 2018).

5. Conclusions

In the last decade, the increasing availability of more fine-grained and high-quality data, combined with modern statistical techniques, has produced a remarkable wealth of solid quantitative findings. Despite the impressive progress that has been made, our paper identifies three fundamental limitations.

First, more and better data on and from conflict zones is required for understanding and monitoring the full diversity, nature and interrelations of food security and violent conflict. At the national level, more reliable and informative data on either and related social, political, economic and institutional variables is required. At the subnational level, the local nature marking many food systems and conflicts needs to be much better accounted for and measured. There are exciting new technologies for data collection based on mobile devices and satellite imaging, which promise to produce a better, more complete and more cost-effective understanding food security and conflict.

Second, the most robust evidence to date exists on the 'reduced-form' links between food security and violent conflict. Achieving a better understanding of the causal transmission mechanisms – including both economic and non-economic channels – that underpin these links is arguably the most important next step for future research.

Third, there is a relative dearth of reliable evidence from the analysis of programmes and interventions. While designing, implementing and evaluating programmes in conflict zones present serious practical and ethical challenges, many subnational interventions related to food security and resilience have been successfully completed. Yet, impacts on food security status, and welfare outcome more broadly and downstream effects on conflict and peace outcomes, are often assumed rather than tested rigorously, and systematic learning is rare.

National and international policy-makers require results from all these directions to devise informed, effective and equitable policies. Monitoring food security, preventing the outbreak of violence, supporting individuals and groups' food security during conflict, stimulating post-conflict recovery, reacting to fluctuations in global food prices or injecting food aid, to name a few, are tall tasks when reliable data and evidence are missing. The economics and social science fields have a great deal to offer policy makers working in the food security and conflict nexus, and it is our hope that greater communication between scientists and policy makers can lead to better lives and improved safety for those facing food insecurity and conflict.

6. Conflict of interest

None.

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