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Hunger Games: Food Security and Strategic Preemptive Conflict*

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Abstract:
A growing number of studies draw linkages between violent conflict and food scarcities. Yet, evidence suggests that at the subnational level conflict is likely to revolve around food resources abundance. In focusing on conflict waged by groups to prevent their rivals from securing food resources, this paper offers a theory to understand the relationship between food security and violent conflict. I develop a formal model that incorporates three actors: civilian producers who grow crops, raiders, and defense forces. Equilibrium and comparative static results show that violent conflict is more likely in regions with an abundance of food resources. The model is validated at the subnational level using new high specificity spatial data on staple crop production for the years 1998-2008, and used to forecast conflict for 2009- 2010. In line with theoretical expectations, food resources have a positive and statistically significant effect on the strategic behaviors of different actors.

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Violent conflict is arguably most prevalent in the developing world (Fearon and Laitin, 2003; Miguel, Satyanath and Sergenti, 2004). This paper focuses on one key mechanism that can drive different actors to instigate violence in these regions: food security. Understanding how this mechanism operates is important given that evidence from countries as diverse as Uganda (Mkutu, 2001), the Democratic Republic of the Congo (Vlassenroot and Raeymaekers, 2008), Peru (Gitlitz and Rojas, 1983), and India (Wischnath and Buhaug, 2014) suggests that conflict dynamics are closely associated with food resources. It is therefore not surprising that a growing number of studies draw links between environmental conditions such as the variability in temperature or precipitation and violent conflict, hypothesizing that these factors, among others, affect conflict by negatively impacting food production (Burke et al., 2009; Miguel, Satyanath and Sergenti, 2004; Bagozzi, Koren and Mukherjee, Forthcoming).

Despite these contributions, little analysis concerning *how* food security mechanisms affect violent conflict has been conducted. Some scholars of the climate-conflict nexus argue that rising temperatures decrease food production locally, in turn leading different actors to fight with increasing frequency over a shrinking pool of resources (Burke et al., 2009; O'Loughlin et al., 2012). However, the focus on scarcity alone cannot predict where conflict over food will arise *within* the state. For example, a close examination of violent conflict data at the *disaggregated* within-country "grid-cell year" level in Africa (Raleigh et al., 2010),[1] reveals that violent conflict *predominately* arises in regions where at least some food is grown (92% of all incidents). This empirical evidence counter-intuitively suggests that, at the local level, violent conflict is associated with food resource *abundance*, and not scarcity. Fitting explanations for the relationship between food and conflict should therefore account for how food resource abundance, in addition to food scarcities, affects local conflict frequency (Koren and Bagozzi, 2016; Butler and Gates, 2012; Adano et al., 2012).

What impact does food security have on patterns of conflict within developing states? Does increasing local food security levels exacerbate or help to quell violence in these areas?

[1] I.e., "cells" of approximately 55km x 55km around the equator (Tollefsen et al., 2012). Data on all staple food crops was estimated for the year 2000 (Ramankutty et al., 2008).

To answer these questions, I advance a complementary explanation to scarcity-centric theories, which emphasizes the strategic incentives of actors not only to secure food resources, but also to *prevent* them from being consumed by others. To achieve strategic advantage, some groups might seek to cut off the supply of other armed actors in order to weaken them. This incentive should give rise to violence not only between rebel and government troops, but also between different ethnic communities (Adano et al., 2012; O'Loughlin et al., 2012; Bagozzi, Koren and Mukherjee, Forthcoming). In the developing world, where the majority of armed groups are unlikely to receive regular logistic support (Koren and Bagozzi, 2016) and must rely on the local population for food, such a possibility is especially likely.

Reducing rival groups' access to food resources is a powerful strategy to increase strength and guarantee survival, as being deprived of food support significantly reduces an organization's fighting ability (Hendrix and Brinkman, 2013). When an organization—be it the military, a rebel group, or an ethnic militia—has access to more local food resources, it can easily recruit individuals and use income from agriculture to purchase weapons (Jaafar and Woertz, 2016). Most importantly, because the majority of armed actors in the developing world must frequently rely on locally-grown food to support their operations, by securing access to such resources an armed actor can operate for longer periods of time and venture further away from its base of operations, increasing its durability. Local food resources are therefore vital to this group and its chances of victory (Koren and Bagozzi, 2016). Correspondingly, to increase its probability of defeating the first group, a second group might seek to *preemptively* conquer areas that have more food resources to weaken its opponent. In doing so, it deprives the first group of these essential resources, thus reducing its durability, fighting capability, and size. This in turn will push the first group to stage stronger resistance in these food abundant areas to guarantee continued availability of food resources.

I develop this argument in three phases. First, I derive a formal model to show how food security concerns affect the strategic calculi of (i) the first group, or defense forces, (ii) the second group, or raiders, and (iii) the civilian producers that provide local food support to the defense forces. This model posits that when the local civilians increase their level of food support, they correspondingly increase the probability that the defense forces will win in combat. Moreover, this level of support cannot be known to the raiders in advance. In equilibrium, the raiders anticipate that if more food support is available to the defense forces, their own chances of victory will diminish. The implication is that above a certain probability threshold of the defense forces' victory, the possibility of high food support levels becomes a grave threat. I find that in the model, this incentivizes the raiders to *preemptively* target regions with more food resources in order to cut the defense forces off from these sources of support, and increase their (the raiders') overall probability of victory. Moreover, this formal analysis provides a set of comparative statics that show when the civilian producers are more likely to increase their level of food support in anticipation of this possibility, which makes it more likely that the defense forces will defeat the raiders. I then corroborate my formal model's predictions on high resolution data on conflict and local food production for the years 1998-2008 (Ray et al., 2012; Ramankutty et al., 2008) using a *statistical strategic* model that corresponds to the formal model's derivations. Finally, I use the model to forecast conflict on out-of-sample data for 2009-2010.

Overall, my empirical model provides new and nuanced evidence that locally-grown food resources have a strong influence on the strategic calculi of different groups, which generates intensified *preemptive* competition over areas with more food resources. Specifically, I show that raiders strategically attack local communities where more access to food resources exists, while higher availability of food also makes a response by defense forces more likely.

Background Discussion

The notion that climatic variability affects armed conflict has received much consideration in recent years. On the one hand, a number of scholars emphasize that climatic variations might lead to decreases in food production, which presumably pushes groups to actively fight over a shrinking pool of food resources (Burke et al., 2009; Bagozzi, Koren and

Mukherjee, Forthcoming). In many cases, the linking mechanism is hypothesized to be food security, i.e. variations in local food production. So, for instance, Burke et al. hypothesize that, "[t]emperature can affect agricultural yields both through increases in crop evapotranspiration (and hence heightened water stress in the absence of irrigation) and through accelerated crop development...reducing African staple crop yields by 10%-30% per °C of warming" (ibid. 20672). Other scholars focus on distributional asymmetries to explain the relationship between scarcity and conflict. For instance, Buhaug claims that "[e]xposed societies that lack necessary capacity and knowledge to adapt successfully may face increasing asymmetries between demand and supply of subsistence resources (e.g., freshwater, pasture, crops)" (2010, 16481), which explains why conflict is associated with decreases in food production. Similarly, recent studies draw linkages between food price variations and social unrest (e.g., Hendrix and Haggard, 2015; Weinberg and Bakker, 2015; Bellemare, 2015).

On the other hand, an increasing number of studies that focus on the *subnational* level now emphasize that *within* scarcity-prone countries, conflict might be more likely to arise in areas with *more* food resources (e.g., Koren and Bagozzi, 2016; Butler and Gates, 2012; Adano et al., 2012). These studies focus on the importance of locally grown resources to maintaining and improving the fighting capacity of different groups in many (rural) regions of the developing world. Case-based evidence confirms this argument. For instance, in their analysis of conflict in Kenya and Ethiopia, Adano et al. find that "more conflicts and killings take place in wet season times of relative abundance, and less in dry season times of relative scarcity, when people reconcile their differences and cooperate" (2012, 77). Similarly, during the Civil War in Sierra Leone, for instance, regular Sierra Leone Army (SLA) troops were paid not with money, but with bags of rice, a meager payment usually appropriated by generals located back in the capital, Freetown. This lack of support pushed the SLA to fight over areas with higher levels of food resources to secure local access to food and sustain its operations (Keen, 2005).

The potential importance of locally grown food resources is not unique to groups that partake in government vs. rebel conflicts. Indeed, ethnic and tribal militias and other irregular forces representing local communities and different ethnic groups might be even more likely to initiate conflict over food resources. These communities are likely to be especially dependent on locally grown food resources, more susceptible to the adverse effects of the distributional asymmetries between the core and the periphery (Buhaug, 2010; Wischnath and Buhaug, 2014), and more affected by local variations in precipitation or temperature (O'Loughlin et al., 2012; Food and Agriculture Organization of the United Nations, 2008).

Despite these valuable insights into the motivations governing armed actors' imperatives to secure food resources by violent means provided by the studies discussed above, we are still missing an interactive model that (i) is focused on *food resources* (rather than environmental conditions or production and price shocks); and (ii) explains when these interactions are more likely to give rise to violence locally—between communities as well as between different armed actors—rather than simply shape conflict patterns more broadly. To explain these interactions and the trend that violent conflict concentrates in areas with more food crops, I design my model around competition over food resources. In this context, food (in)security relates to the (in)ability of actors, armed groups and communities, to secure adequate amount of and/or access to food (Barrett, 2010). Correspondingly, to weaken one's rivals, possessing and even destroying food sources is a beneficial strategy that increases the opponents' levels of food insecurity,[2] negatively affecting their fighting ability (Hendrix and Brinkman, 2013).

For instance, in Sierra Leone, troops of the Revolutionary United Front (RUF) burned and destroyed villages not only to secure food resources for their own consumption, but also to strategically hurt the government and prevent its troops from accessing these important resources (Keen, 2005). Similarly, in South Sudan, where "[e]thnic groups have fought each other over cattle—a vital part of the indigenous economy—for centuries" (Reuters, 2011), livestock raiding is frequently used to humiliate and weaken the enemy. Although analyzing

[2]"Food insecurity" refers to situations where food security levels are dangerously low, and there are not enough food resources, due to either distributional or production shortages, to guarantee sufficient dietary intake for all individuals in the region (Barrett, 2010).

every incidence of preemptive conflict over food security is beyond the scope of this paper, a partial evaluation of more recent evidence—which, due to space constraints, is presented in Table A.1, Supporting Information—shows that preemptive conflict over food resources occurs relatively frequently.

The raiders' strategy of expropriating and destroying the civilians' food resources to weaken their rivals combined with the civilians' strategy of providing their defense forces with varying levels of food support produce a "commitment problem" in my game model.[3] This commitment problem suggests that as long as the raiders cannot know in advance how much food support the civilians will provide to their defense forces, they might decide to attack and conquer areas with more food resources in order to control these focal points and cut the defense forces off from these resources. The value of the civilians' land is observable by all actors, which allows the raiders to estimate how much food is available in the region (e.g., in open stockpiles, granaries, and cattle pens). The importance of local food support to the defense forces' war efforts creates strong incentives for the raiders to *preemptively* target and initiate conflict in areas that offer *more* access to food resources, because doing so would substantially weaken the defense forces, who require these resources to improve their own chances of victory. Preemptive conflict is thus about regulating the supply of food available to enemy groups.[4]

The Model

Model Primitives

Assume three actors interacting in an agricultural region of a developing country: a set of civilians b (i.e. producers) who work the land to grow crops and livestock; raiders r

[3]Commitment problems arise when two actors know that they will prefer to renege on their agreement in the future, meaning that even a mutually beneficial agreement cannot be struck at present (e.g., Fearon, 1995). In the context discussed here, because the civilians decide their levels of food only after the raiders attack, neither side has a strong enough incentive to commit to finding a peaceful solution in advance.

[4]Note that this is not (necessarily) the same as "scorched earth" tactics, which involve the complete destruction of all means of production in a given area, whether the raiders conquer the region or not. As discussed here, "scorched earth" tactics are one extreme type of preemptive conflict, but they are neither the only one nor the most prevalent.

(consisting of political or ethnic militias, rebels, etc.); and defense forces d (ethnic militias, civil defense forces, government troops, etc.). If attacked, the civilian producers decide the level of food support they provide to their defense forces $\theta \in [0,1]$, which is not revealed to the raiders until they invade the region. Thus, the civilians face a commitment problem; because they decide their level of food support only after being attacked, the raiders will always be concerned that areas with higher levels of food resources are going to improve the defense forces' chances of victory if the latter decide to open hostilities.[5]

Let ρ be the total probability that the defense forces defeat the raiders if conflict arises *taking the effect of food support into account*, such that $Pr(victory) \equiv \rho = p[1+(1-\delta)\theta\omega]$. In this probability function, $p \in [0,1]$ is the baseline probability of the defense forces' victory not accounting for the role played by local food support, i.e., based on the resources currently available to d. Additionally, let $\delta \in [0,1]$ denote the effect of violence on reducing θ, for example because targeting a food resource-abundant region enables the raiders to capture a high number of food stockpiles, kill civilians producers, or—in extreme cases—to employ "scorched earth" tactics. In this function, $\omega \leq \frac{1}{p} - 1$ denotes how important food support is to the defense forces' overall probability of victory. Both δ and ω guarantee that $p \in [0,1]$. Setting ρ in this fashion thus incorporates the effect of local food support into conflict dynamics in the region.

The raiders r seek to target locations where food resources are grown and stockpiled to control these areas and prevent the defense forces d from gaining access to these resources. Let η be the costs the raiders incur from waging conflict M, which includes the costs of mobilizing and recruiting individuals and obtaining firearms, such that $\eta > 0$. If r initiates conflict and wins with probability $(1-\rho)$ it obtains the benefit $R + s$, because controlling the region provides r with the access to both taxation and resource rents R, *and* the value

[5] In the model developed here, *how* food resources are provided and whether they are obtained using coercion or enticement is irrelevant. Because it revolves around a commitment problem, which relates to the sequential moves of different actors, the model is agnostic with respect to apportionment dynamics as highlighted by, e.g., Kalyvas (2006).

of the land s, which includes the food produced and stockpiled by b.[6] If the raiders initiate conflict and lose, they receive no benefits, but still face the costs of conflict. If they do not initiate conflict, they simply maintain the status quo and gain a utility of zero. The raiders r's utility function from initiating conflict (i.e., when $M = 1$, denoted simply as M for convenience) is thus: $U_r(M) = (1-\rho) \times (R+s) + \rho \times 0 - \eta$, which can be rewritten as:

$$U_r(M) = (1-\rho)(R+s) - \eta \tag{1}$$

Let θ be the amount of locally produced food the civilians b allocate to supporting their defense forces. Correspondingly, κ is the cost the civilians incur if the raiders initiate conflict, e.g., through targeted killings. In addition, $c(\theta)$ is the opportunity costs of allocating food resources to support armed groups rather than keeping them for other uses, such that $c(\theta)\prime > 0$; $c(\theta)\prime\prime > 0$. For convenience, let $c(\theta) = \frac{1}{2}\theta^2$. Because ρ denotes the total probability with which the defense forces successfully protect the civilians and their land against the raiders, the civilians' benefit from victory is the total value of land (and the food produced and stored therein) in the region, which they get to keep, $\rho \times s$. If conflict occurs and the defense forces lose, then the civilians forfeit the entirety of their land, such that $(1-\rho) \times 0$. The civilians' b utility function is thus expressed as:

$$U_b(M) = \rho s - \frac{1}{2}\theta^2 - \kappa \tag{2}$$

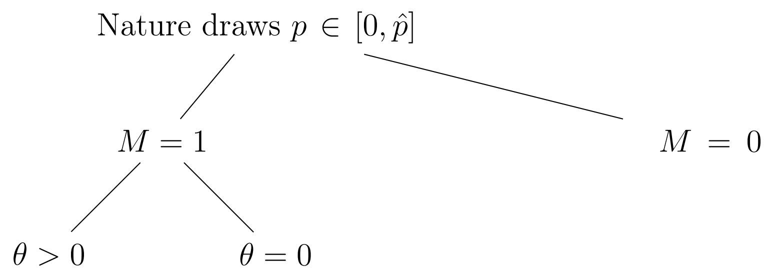
The civilian producers' optimization problem is to maximize Equation 2 with respect to θ, subject to the constraint $\theta \in [0, 1]$.

The sequence of play is as follows. Nature draws the baseline probability of the defense forces' victory $p \in [0, \hat{p}]$, which is revealed to all actors. The raiders then need to decide whether or not to initiate conflict in the region, $M \in \{0, 1\}$. Finally, the civilians determine the level of support they provide the defense forces, $\theta \in [0, 1]$. This order of play thus sets

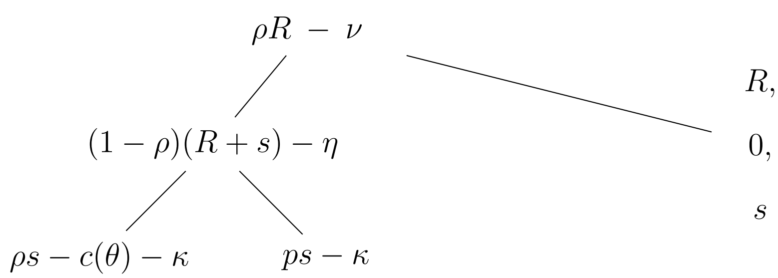
[6] Because this paper is focused on food support, the land's value s corresponds to its fertility and hence to the total amount of food that can be grown and stored on this land.

up the commitment problem.[7]

Order of Play



Utilities



Equilibrium Results

- **Lemma 1:** *In the subgame perfect Nash equilibrium of the game between r, d, and b:*

(i) In case of conflict the civilians b will always choose to provide some level of food support θ, considering its effect on improving the defense forces $d's$ overall probability of victory

(ii) The optimal agricultural food resources that the civilian producers b will allocate for the defense forces' consumption is $\theta^* = (1-\delta)\omega ps$

(iii) The utility of the raiders from (a) waging conflict, taking θ^* into account, is $U_r(M|\theta^*) = [1 - p(1 + (1-\delta)^2\omega^2 ps)](R+s) - \eta$, and consequentially (b) the raiders will initiate conflict if $U_r(M) = [1 - p(1 + (1-\delta)^2\omega^2 ps)](R+s) \geq \eta$

[7] Because the defense forces are not a strategic actor in this model and their behavior is assumed to reflect the civilians' actions, their utility function is discussed only in the Supporting Information file.

Proof: See Supporting Information.

Lemma 1 establishes that in regions with some food resources, violent conflict might arise *endogenously*, as a consequence of the equilibrium choices between the civilian producers on the one hand, and the raiders on the other. The intuition is straightforward in cases of linearly increasing food support θ: eventually food support levels will be high enough as to guarantee the defense forces' d victory. However, as shown in Proposition 2 below, the stronger the effect of violence on reducing this support δ is, the more inclined the raiders will be to use it and initiate conflict. For instance, in South Sudan, some tribal militias routinely engage with the military and civil defense forces of ethnic groups associated with the regime over cattle theft, which frequently involves abuses against civilians (Reuters, 2011). These interactions are even more evident in Ethiopia, where large farms and food producers, which are defended by forces trained and managed by the state or by their own sponsored militias, experience frequent raids both by pastoralist groups—whose traditional space has been appropriated by these farms—and rebel groups who seek to challenge the state and its presence in the region (Mkutu, 2001).

The equilibrium results from Lemma 1 can be used to derive two sets of comparative statics to explain when the civilians will increase their level of food support, and when the raiders will prefer to target regions with more food resources. The first set of comparative statics is discussed in Proposition 1 below.

Proposition 1: *The level of food support θ^* provided by the civilians will, (i) increase with a higher baseline probability of defender victory $p > 0$, (ii) increase when the marginal importance of food support to the defense forces d's victory is higher, and (iii) increase when the value of the food producing cropland in the region s is higher*

Proof: See Supporting Information.

Proposition 1 serves as the basis for the ensuing comparative static prediction developed in Proposition 2, which explains *why* the raiders choose to target regions with more food resources. The rational behind Proposition 1 is intuitive. Recall that more access to food resources provided by the local civilians increases the ability of troops to operate for longer periods of time and attract more recruits. Additionally, θ is a finite resource because the civilian producers b cannot provide more food than they can physically produce and stockpile due to limitations in infrastructure that force communities and individuals across the developing world to rely on food produced locally (Paarlberg, 2000).

Importantly, military and civil defense forces across the developing world are also frequently forced to rely on food produced and grown locally, due to the relative lack of guaranteed logistic support provided by the state (Koren and Bagozzi, 2016). If the defense forces are strong and have a high probability of victory as captured by the *exogenous* parameter p, providing food support is more likely to "pay off" because the civilians will be able not only to keep their remaining resources for consumption, but also avoid potential retribution. Correspondingly, if local food support is important to ensuring the defense forces' victory (as captured by the ω parameter), it follows that the civilian producers will allocate support simply because, bushel to bushel, and all else equal, they gain higher marginal returns with respect to improving the defense forces' chances of victory for the same amount of food.

The model's finding that the civilians will provide higher levels of food support when the land is more valuable is also intuitive. Valuable land is more fertile, and allows for more food to be produced. This in turn means that the civilians not only have a higher incentive to defend this valuable land, but also that they can increase their levels of food support and gain a higher marginal utility from investing in defending these resources.

As a result, in equilibrium, the raiders will realize that the civilians residing in regions with more arable land will always allocate some of these resources to support the defense forces, and that hence higher levels of food support θ are a credible threat. Higher allocations of θ decrease the raiders' overall probability of victory, and it is this intuition that explains *why* the raiders would choose to initiate conflict in areas with more food crops. This intuition is formalized in Proposition 2 below.

Proposition 2: *the higher the effect of conflict is on reducing the level of civilian food* *support δ (i) the utility of the raiders r from conflict will increase; and (ii) the baseline probability of defender victory above which the raiders will chose to initiate conflict $\bar{p}$ will increase*

Proof: See Supporting Information.

Targeting regions with more food resources allows the raiders to reduce the levels of food support available to the defense forces. This becomes an especially attractive strategy for the raiders if violence has a strong effect on reducing this support. Indeed, Proposition 2 explains why the raiders might choose to *initiate* conflict, and hence why preemptive violence over food resources might be more prevalent, perhaps, than initially expected. The first part of this proposition establishes that preemptively targeting regions with more food resources is an effective strategy to increase the raiders' chances of victory. The second part of Proposition 2, however, shows that—if the use of violence to reduce food support is highly effective—conflict might erupt even in cases where the defense forces are relatively strong, which would otherwise serve to deter potential raiders from initiating it. Thus, the more effective preemptive conflict is in reducing food support, the more prevalent it will be.

This does not necessarily mean that targeting regions where violence has a strong effect on reducing food support will involve a high number of *combatant* casualties. Some wars involve a relatively low number of armed combatants' deaths, yet a high number of civilian casualties (Valentino, Huth and Balch-Lindsay, 2004). The raiders might prefer to use atrocities to directly hurt the defense forces' channels of food support in cases when the latter are too strong to be defeated militarily (Wood, 2010). Atrocities can also be used as a strategy designed to subdue or influence the local population to keep θ at low or zero levels (Kalyvas, 2006), especially in cases where conflict occurs between different ethnic groups (Fjelde and Hultman, 2014). In both cases, preemptive violence results from the fact that the raiders must choose the timing and the location for the attack before the civilians decide on the levels of food support θ they provide. I thus consider civilian victimization alongside other forms of more traditional armed conflict, both in the theoretical model and in the empirical section.

Proposition 2 suggests that higher levels of food support θ will be associated with a higher incidence of violent conflict, which in turn builds on the logic that civilians will habitually provide some level of food support to the defense forces if the raiders attack. Note that the exact levels of θ that the civilians b might eventually provide to the defense forces d cannot be observed *ex ante* by the raiders r. The raiders, however, can observe the value of the land s and extrapolate from this value whether the civilians are likely to provide θ, and whether food support levels are likely to be high.

The framework of preemptive conflict therefore provides one explanation for why within the state conflict is likely to arise in areas with an abundance of food resources and not where food is scarce. Rather than thinking of conflict over food resources as a pressure on consumption, which is the focus of numerous studies of the food-conflict nexus (Burke et al., 2009; O'Loughlin et al., 2012; Bagozzi, Koren and Mukherjee, Forthcoming), it might therefore also be useful to theorize it as a weapon. Under this framework, actors seek to possess food resources not for consumption to improve their own dietary energy availability or to reward supporters, but rather to worsen their opponents' fighting capabilities by denying them access to food. Food denial has been used repeatedly to weaken and defeat one's opponents throughout history, with some notable instances including the Allied blockade of Germany during World War I (Downes, 2008), the Soviet *Holodomor* famine in Ukraine (Snyder, 2010), and the Ethiopian Derg regime's intentional starvations of Tigre and Eritrea (Keller, 1992). These instance, which show that planned famines can be used as a *macro* level strategy to destroy one's opposition, complement my model and the campaigns documented in Table A.1 of the Supporting Information, which show that the destruction of food producing lands can also be initiated as *micro* level tactics to achieve the same aim at the subnational level.

Building on Propositions 1 and 2, my model suggests that the civilians b are likely to provide at least some food support to d to increase the latter's overall probability of victory, which prompts the raiders r to preemptively target these regions in order to weaken the defense forces. The raiders cannot know *ex ante* if the civilians will provide food support to the defense forces, or—if they do decide to allocate support—how much food will they provide. However, because the raiders can observe s, i.e., the value and fertility of the land in the region, they are more likely to target areas where there are some food resources, and especially regions where food is abundant, assuming that in these regions more food is likely to be available to support the defense forces, and hence that (a higher level of) food support is more likely. They might be especially likely to attack these areas if conflict has a strong effect on reducing food support levels. This accordingly suggests the following expectation:

- **E1:** The raiders' utility from violent attacks increases in regions where more food crops are grown

Moreover, the higher the baseline probability of the defense forces' victory, the greater the marginal benefits the civilians gain from providing food support. Higher levels of food support thus increases the probability that the defense forces will be willing or able to respond to attacks by raiders. This suggests the following expectation:

- **E2:** The defense forces will be more likely to respond to raider attacks in areas and years with more available food for consumption

Empirical Analysis

The equilibrium and comparative static results derived above are statistically evaluated on a subnational sample of countries for the years 1998-2008. Moreover, to verify that any identified effect is also substantively sizable (Greenhill, Ward and Sacks, 2011), I use the resulting estimates to forecast conflict on a second sample for the years 2009-2010 and show that local food production is also a significant *predictive* indicator of localized conflict.

The tree game presented above can be expressed in statistical terms. This statistical strategic model ensures that the interactive nature of preemptive conflict over food resources is adequately captured and—importantly—that strategic misspecification issues are avoided (Signorino and Yilmaz, 2003; Carter, 2010). The strategic logit equivalent of this game necessitates making the plausible assumption that all actors operate rationally within limitations (i.e. bounded rationality), and that hence they play with some error (Signorino, 1999; Signorino and Yilmaz, 2003). This allows me to implement the logit quantal response equilibrium solution concept (LQRE) to analyze the strategic dynamics in this game (Signorino, 1999; Carter, 2010). A special case of the LQRE in which there is no uncertainty is used to solve the theoretical model. This empirical model is thus structurally consistent with the theoretical model but also accommodates errors to be made by the different actors. This statistical model captures the idea that the raiders and civilians each make decisions in the game by weighing their expected utilities for each possible action. In this case, it is useful to begin with the last step in the game, the decision of the civilians to provide food support or not, and then move up the tree following each player's calculations. For each observation, $i = \{1, 2, 3...n\}$, the civilians need to decide the level of food support they provide if they observe the raiders invading. If the raiders preemptively attack, i.e., if $M = 1$, then—as illustrated in the proof of Lemma 1— the civilians make the following comparison:[8]

$$p_{b,i|F} = U_b^*(F|A) \geq U_b^*(\neg F|A) \tag{3}$$

$$= U_b(F|A) + \epsilon_F \geq U_b(\neg F|A) + \epsilon_{\neg F} \tag{4}$$

Assuming the error terms are independent and identically distributed (i.i.d.) Type 1 Extreme Value yields:

[8]Note that F stands for feed and A for attack.

$$p_{b,i|F} = \frac{exp^{U_b(F|A)}}{exp^{U_b(F|A)} + exp^{U_b(\neg F|A)}} \tag{5}$$

$$p_{b,i|\neg F} = 1 - p_{b,i|F} \tag{6}$$

The raiders make their decision to attack or not by comparing, with some error, their utility from the status quo, $U_r(SQ)$, i.e., the utility they gain from not initiating conflict, to their utility from attacking, which is calculated by multiplying each of the two possible outcomes with the probability that each is realized. Assuming, again, that the error terms are i.i.d. Type 1 Extreme Value:

$$p_{r,i|A} = \frac{exp^{(p_{b,i|F})U_r(A,F)+(p_{b,i|\neg F})U_r(A,\neg F)}}{exp^{(p_{b,i|F})U_r(A,F)+(p_{b,i|\neg F})U_r(A,\neg F)} + exp^{(p_{r,i|\neg A})U_r(SQ)}} \tag{7}$$

Model Specification and The Dependent Variable

To specify the statistical version of the game with regressors, identification issues must satisfy theoretical expectations. The utility of at least one possible outcome at the initial information set for both civilians and raiders, which can thus influence their utilities, is normalized to zero (Signorino, 1999). As no regressor can be included in every utility estimation, all coefficients are evaluated with respect to an outcome where the raiders attack, but the civilians decide *not to provide food support*, which is correspondingly normalized to zero (see, Signorino and Yilmaz, 2003). So, for example, a positive coefficient on, say, food crops means that attacking more fertile land increases the raiders' utility when the civilians decide to provide food support compared with a situation when they decide not to do so.

The model derived above is tested on subnational data for all countries in Africa encompassing 11 years (1998-2008) for which information on all variables was available. Africa was chosen as the focus of empirical analysis for three reasons. Firstly, the Armed Conflict and Location and Event Data (ACLED) Version 6 dataset (Raleigh et al., 2010), which provides one of the most exceptional coverages of a wide variety of violence types at the highly localized level, covers almost exclusively African countries. Moreover, the ACLED dataset includes a broad spectrum of dyadic interactions that go beyond the traditional government vs. rebel logic, which allows my statistical model to capture manifestations of violence that are more likely to characterize localized conflict, such as the killing of civilians or intercommunal attacks. Secondly, the focus on Africa as the world region currently most susceptible to the effects of food insecurity—through climatic variability or otherwise—corresponds to previous studies on climatic variation, food security, and conflict, which similarly focus on the same region (Burke et al., 2009; Buhaug, 2010; O'Loughlin et al., 2012). Finally, considering the size of the dataset and the necessity to rely on computer simulations for deriving statistical estimation, any larger sample would have presented significant—and insurmountable, based on available resources—computational challenges.

The dependent variable must capture the decisions made at each node, by the raiders on the one hand, and the civilians on the other, which—in respect to food support—is reflected by the actions of the defense forces. The ACLED dataset draws on (i) information from local, regional, national and continental media reviewed daily; (ii) NGO reports used to supplement media reporting in hard to access cases; and (iii) Africa-focused news reports and analyses integrated to supplement daily media reporting. Building on the formal model, the defense forces' actions reflect the civilians' decision to allocate varying levels of food support. The defense forces can thus either defend the civilians against raids (play D) or not (play $\neg D$). The defense forces—defined as state forces, or as pro-government or ethnic militias—are coded as playing Defend if they are involved in any type of *violent* conflict[9] against the raiders—where the raiders are coded as the *initiating* actor—in a given cell during a given year, not Defend otherwise. Correspondingly, there are two discrete actions

[9] I.e., events *not* coded by the ACLED Version 6 dataset as: "Headquarters or base established" or "Non-violent activity by a conflict actor" or "Riots/Protests" or "Non-violent transfer of territory" or "Strategic development" (Raleigh and Dowd, 2015).

for the raiders: to attack (play A) or not attack (play $\neg A$).[10] The raiders are defined as having played Attack if they are recorded to *initiate* a conflict (including one sided attacks against civilians) in a given cell during a given year, whether it was responded to by a group identified as defense forces or not, not Attack otherwise. For summary purposes, the frequencies of raider attacks and defender responses for the years 1998-2008 are reported in the Supporting Information file.

The violent conflict data from the ACLED Version 6 dataset and all other indicators are structured into a cell-year level dataset wherein cells—my cross-sectional unit of interest—are measured at the 0.5 x 0.5 decimal degree resolution[11] for all African land areas annually (t) (Tollefsen et al., 2012). There are approximately 10,674 cells observed for any given year within the 1998-2008 sample period, with the average country containing roughly 201 cells.

Regressors

The specification of the raiders' utility for the status quo must include the key variables that influence their decision to initiate preemptive conflict over food security. First, potential attackers are likely to employ violence in response to previous provocations, or in locations where they have attacked previously (e.g., Buhaug, Gates and Lujala, 2009). Second, lagged indicators of development and political openness have been shown to be consistent predictors of conflict (Fearon and Laitin, 2003). Therefore, to model the raiders' utility from the status quo, historical context indicators impacting the raiders' propensity to initiate conflict are included in this equation. These indicators include: the number of all political violence-related events by all types of actors, state and nonstate, that occurred in a given cell the previous year (Raleigh et al., 2010); the gross domestic product (GDP) per capita for the previous year (World Bank, 2012); and the level of political openness in the previous year as measured by the Polity2 indicator (Marshall, Jaggers and Gurr, 2013). Cubic, binary, and

[10] In line with theoretical expectations, the raiders were defined as actors "who seek the replacement of the central government, or the establishment of a new state" or as " armed agents supported by political elites of various types, seeking to influence political processes but not change the government" or as "groups engaged in local political competition, often traditionally based contests between ethnic, community or local religious groups" (Raleigh and Dowd, 2015, 16-17).

[11] I.e., cells of approximately 55 x 55 kilometers at the equator (3025 square kilometer area).

linear time polynomials are then added to capture the effect of time trends more broadly (Carter and Signorino, 2010). The expectations is that the raiders will be more likely to attack in territories previously lost and following battlefield loses, as well as in countries with lower levels of state capacity and more politically restrictive regimes. The raiders' utility from the status quo is thus modeled as:

$$U_r(SQ) = \beta_{SQ,0} + \beta_{SQ,1} Conflict_{t-1} + \beta_{SQ,2} GDPPerCapita_{t-1} + \beta_{SQ,3} Polity2_{t-1} + \beta_{SQ,4} Time + \beta_{SQ,5} Time^2 + \beta_{SQ,6} Time^3 + \alpha_{SQ} \quad (8)$$

To measure s—i.e. the value of land that is observed by all actors—in the *raiders*' utility function, I employ a highly localized food access indicator, *Cropland* (Ramankutty et al., 2008). This indicator measures the total area of a pixel—i.e., a cell the size of 0.08 x 0.08 degrees—covered by any type of staple cropland, which was then aggregated to the 0.5 x 0.5 degree level. Approximating the actual levels of food support provided by the civilians is more complicated, as such an indicator should, at the very least, closely approximate the actual amounts of food that could be *consumed or stored* in a given region during a given year. This means that more perishable resources such as vegetables are less than ideal for this purpose, and that an adequate indicator of θ should—at the very least—be based on a more durable food crop. Moreover, the value of θ is, to some extent, dependent on s, so an effective parametrization should capture this relationship, again considering that no one regressor can be present in all utility functions (Signorino and Yilmaz, 2003).

Therefore, to approximate θ I rely on an indicator measuring the annual yields of wheat by grid cell (Ray et al., 2012). Wheat was chosen because as a staple food for about 35% of the world's population, it provides more calories and protein in the world's diet than any other crop, and can be stored for relatively long periods of time (Food and Agricultural Organization of the United Nations, 2016). Moreover, in Africa—and especially sub-Saharan

Africa—wheat is in exceptionally high demand, which cannot be met by production supply (Asfaw Negassa et al., 2013), making this crop an especially valuable food resource to measure the responsiveness of different defense forces. The focus on yields, specifically, approximates better the amounts of food that are immediately available (e.g., in stockpiles) for consumption. This indicator thus provides an exceptional coverage of the annual variation in food availability at the highly localized level ($\sim 0.08°$ grids, averaged to the $0.5°$ grid level), which is a major improvement over past studies of this sort that have favored static measures of cropland at comparable levels of geographic resolution (e.g., Koren and Bagozzi, 2016; O'Loughlin et al., 2012). For summary purposes, the collapsed values of *Cropland* and *Wheat Yield* by grid cell for the entire 1998-2008 period are reported in the Supporting Information file.

Several additional variables (some of which are not explicitly discussed above) that might influence parameters in the theoretical model are also included in the utilities of both actors from conflict. These indicators are all measured at the *cell* rather than country level, which adequately accounts for the effects of these variables at the highly localized level. First, an indicator denoting gross cell product in a given year (measured in billion USD), *GCP* (Nordhaus, 2006), is included to account for the potential effect of valuable rents R, which—as the formal model shows—might provide added incentives for violence. Second, the number of people in a given cell, *Population* (Nordhaus, 2006), is included to account for the potential effect of population density on the raiders' propensity to employ violence. Thirdly, because attacks might be more likely in grid cells that were recently conquered by rival groups (Raleigh et al., 2010), an indicator denoting whether territorial change has occurred, *Terr. Change*, is also included. Fourth, considering that conflict might be more likely in rural areas or regions closer to the border (Buhaug, Gates and Lujala, 2009), indicators measuring the distance from each cell to the nearest city with more than 50,000 inhabitants (*Travel Time*) and to the nearest border (*Border Distance*) are also added. Fifth, indicators measuring average annual temperature (*Temperature*) and rainfall (*Precipitation*) levels are included to control for the effect of these factors on food production and correspondingly on conflict; and because these indicators are used by many studies on the climate-conflict nexus (e.g., Burke et al., 2009; O'Loughlin et al., 2012; Miguel, Satyanath and Sergenti, 2004). Finally, similarly to Equation 8, time polynomials are included to account for time trends in both equations. Thus, the utilities for conflict outcomes are:[12]

$$
\begin{aligned}
U_r(AF) = {} & \beta_{r|AF,0} + \beta_{r|AF,1} Cropland + \beta_{r|AF,2} Population + \\
& \beta_{r|AF,3} GCP + \beta_{r|AF,4} TerritorialChange + \beta_{r|AF,5} TravelTime + \\
& \beta_{r|AF,6} BorderDistance + \beta_{r|AF,7} Temperature + \beta_{r|AF,8} Precipitation + \\
& \beta_{r|AF,9} Time + \beta_{r|AF,10} Time^2 + \beta_{r|AF,11} Time^3 + \alpha_{r|AF} \qquad (9)
\end{aligned}
$$

$$
\begin{aligned}
U_b(AF) = {} & \beta_{b|AF,0} + \beta_{b|AF,1} WheatYield + \beta_{b|AF,2} Population + \\
& \beta_{b|AF,3} GCP + \beta_{b|AF,4} TerritorialChange + \beta_{b|AF,5} TravelTime + \\
& \beta_{b|AF,6} BorderDistance + \beta_{b|AF,7} Temperature + \beta_{b|AF,8} Precipitation + \\
& \beta_{b|AF,9} Time + \beta_{b|AF,10} Time^2 + \beta_{b|AF,11} Time^3 + \alpha_{b|AF} \qquad (10)
\end{aligned}
$$

Results

The regression estimates in Table 1 provide strong support for the expectations derived from the theoretical model. One issue with standard errors in strategic statistical models is that the use of a choice-based sample might introduce bias, while the assumption of independence across within-group observations is violated (Carter, 2010). To account for these potential heterogeneities and other issues, I use bootstrapping undertaken based on 1,000 draws, with

[12]Because including lagged measures without theoretical justifications can introduce inferential biases (Bellemare, Masaki and Pepinsky, Forthcoming), these variables were not lagged. My findings are robust to this decision, as demonstrated in the Supporting Information file.

sampling clustered by each player.

Table 1: **Player Utilities for Raids and Defenses, 1998-2008**

	$U_r(AF)$	$U_b(AF)$	$U_r(SQ)$
Cropland	1.661*	–	–
	(0.342)		
Wheat Yield	–	0.173*	–
		(0.072)	
Population[1]	-2.193*	-0.096*	–
	(0.599)	(0.016)	
GCP[1]	-6.862*	-0.152*	–
	(1.485)	(0.025)	
Terr. Change	25.486*	0.576*	–
	(3.111)	(0.202)	
Travel Time[1]	-2.538*	-0.056*	–
	(0.879)	(0.022)	
Border Distance[1]	-1.114*	-0.019*	–
	(0.360)	(0.008)	
Temperature	0.551*	0.014*	–
	(0.118)	(0.004)	
Precipitation[1]	-4.345*	-0.122*	–
	(1.080)	(0.021)	
Conflict_{t-1}	–	–	-0.145*
			(0.022)
$\text{GDP Per Capita}_{t-1}$[1]	–	–	0.116*
			(0.056)
Polity2_{t-1}	–	–	0.067*
			(0.008)
t	6.006	-0.106	6.617
	(5.071)	(0.096)	(5.124)
t^2	0.225	-0.007	0.124
	(0.692)	(0.017)	(0.676)
t^3	-0.043	-0.001	-0.039
	(0.034)	(0.001)	(0.032)
Constant	-90.452*	2.817*	-93.224*
	(28.427)	(0.325)	(26.247)

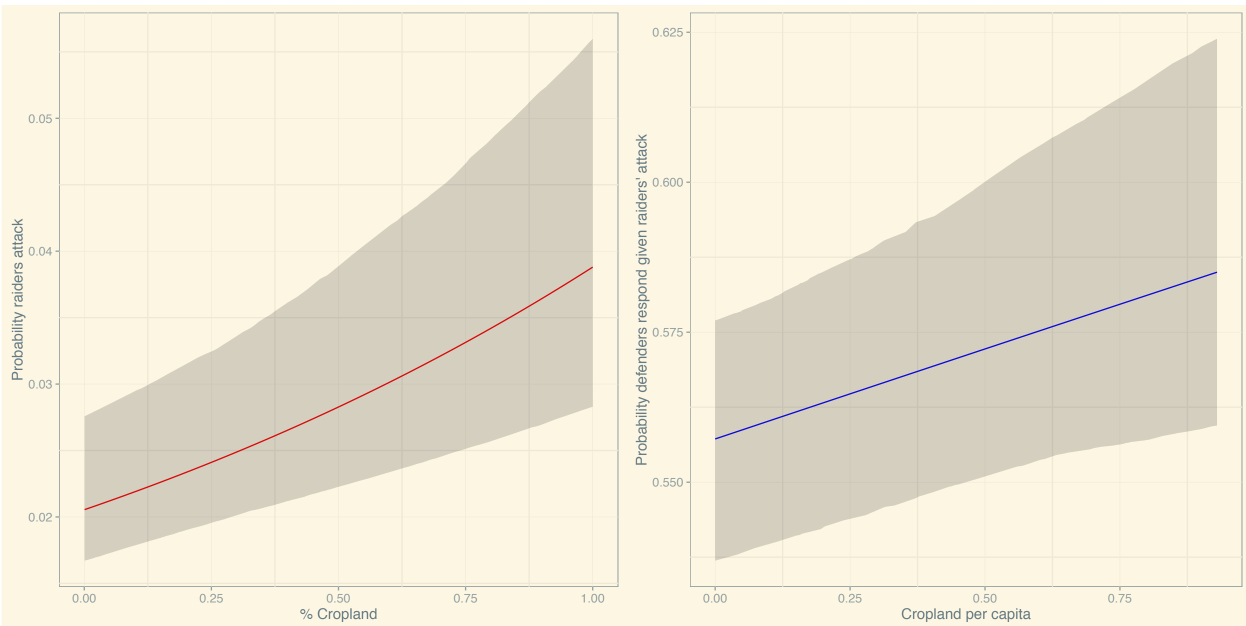
Number of observations: 63,218
Akaike Information Criterion: 20,831.61
* indicates $p < 0.05$.
Values in parentheses are standard errors clustered by player and bootstrapped using 1000 iterations.
$U_b(A\neg F)$ is the reference node and was normalized to zero.
[1] Natural log

In line with E1, the likelihood of raider attacks significantly increases in areas with more staple cropland. Because the raiders cannot know the levels of food support the defense forces will receive in advance (if any), attacking areas with more cropland is a significantly preferred strategy according to the model. These results hold even with the inclusion of relevant controls. The coefficients of *Terr. Change* and *Temperature* are positive and significant while the coefficients of *Population*, *Travel Time*, *Border Distance*, *GCP*, and *Precipitation* are negative and significant, suggesting that these factors also have an observable effect on the utilities of the raiders from initiating localized conflict. The coefficients in the raiders' utility from the status quo also follow theoretical expectations. The raiders will gain from the status quo in locations and years where there is little history of conflict, which lessens the pressures on groups to initiate preemptive conflict to weaken their rivals as a defensive strategy; in countries with higher average income, where it is not necessary for food to be grown locally because it can be easily obtained via alternative means (e.g., refrigeration, improved transportation due to better infrastructure); and in countries with more political participation, which allows different groups to resolve potential conflicts in peaceful ways.

In line with E2, the probability of defense forces responding to attacks significantly increases in areas and years with higher values of *Wheat Yield*. Higher yields correspond to higher levels of food support (as shown in the formal model), which allow the defense forces to operate freely and for longer periods of time, and attract more recruits if needed. By capturing the civilians' incentives to provide food (as derived in Proposition 1) in addition to the levels of food available in a given grid cell during a given year, this indicator provides a close approximation of θ levels. This suggests that providing higher levels of food support is a significantly preferred strategy by the civilians according to the model. Again, these results hold even with the inclusion of climatic variables. The coefficients of *Precipitation*, *Population*, and *GCP*, *Travel Time*, and *Border Distance* are negative and significant, while *Terr. change* and *Temperature* are positive and significant.

The predicted change in the probability of raids in based on staple cropland availability, and the predicted change in the probability of defenders responding to attacks based on wheat yield values are presented in Figure 1, with bootstrapped 95% confidence intervals. As illustrated by these plots, the utility of raiders from attacking a given region increases by 2.5% on average across the range of *Cropland*. Similarly, the utility of the civilians increases by about 2% across the entire range of *Wheat Yield*, as this suggests that higher levels of food support mean that the defenders are more likely to respond. These quantities are relatively quite sizable considering the large sample size, and suggest a substantive impact of locally grown resources on localized conflict.[13]

Figure 1: Predicted Probabilities From Conflict



Effect of Cropland on Raids | Effect of Wheat Yields on Defenses

Robustness Analyses

To verify the robustness of these findings to alternative mechanisms, I reestimate this model using different specifications in the Supporting Information file. First, I take the effect of urbanization more thoroughly into account by including cell level indicator of urbanization in the utilities of both the raiders and the civilians. Second, to account for the effect of state capacity on conflict, I reestimate the main model with the inclusion of distance to capital and the percentage of a given cell that is mountainous, in a manner used in past studies

[13]For a comparative example, the coefficient for *GCP* have almost no effect on the decision of the raiders to attack a given location.

(e.g., Fearon and Laitin, 2003; Fjelde and Hultman, 2014). Third, I include spatial lags of raider attacks in the raiders' utility function to account for the possibility that conflict in a given cell is caused by spillovers from neighboring cells. Forth, I reestimate a model where all time varying indicators are lagged by one year to show the robustness of the findings my decision not to lag variables without theoretical justification (Bellemare, Masaki and Pepinsky, Forthcoming). Fifth, I estimate a model that includes lagged military expenditure in the raiders' utility from the status quo to account for the effect of the defense forces' size on the raiders' decision to attack. Finally, I estimate a baseline specification of Table 1 with only a small number of variables to show that the results are not driven by my choice of controls or the number of indicators included in the model. Crucially, my findings hold across these different specifications and conceptualizations.

Predictive Analysis

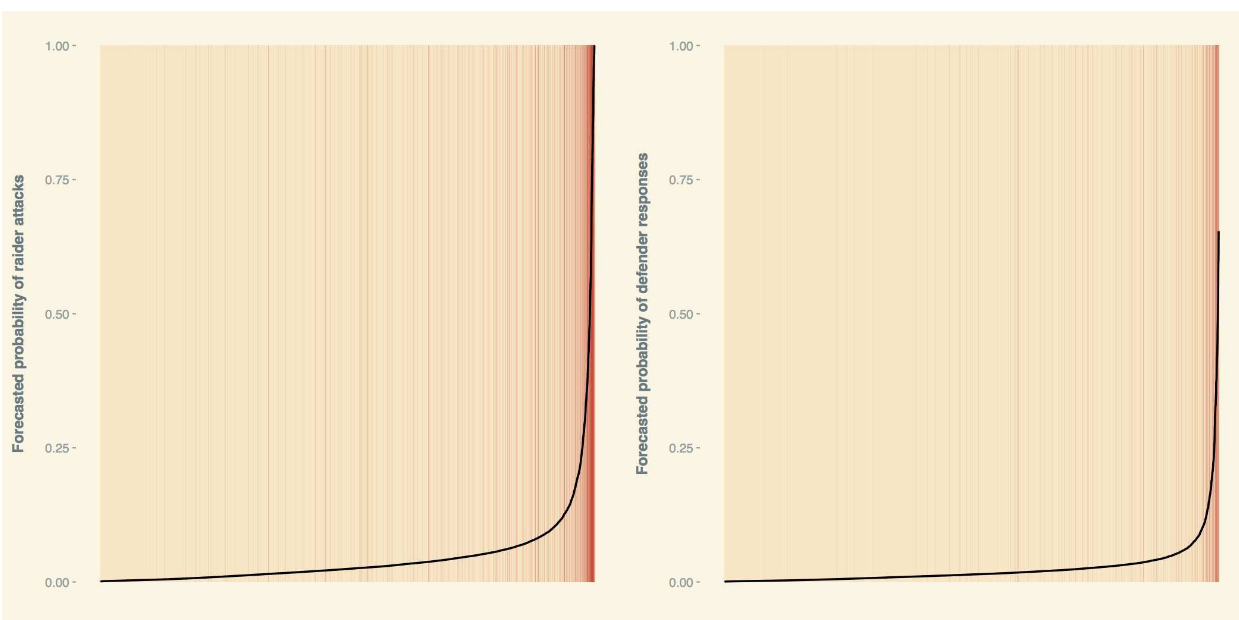
Statistical results can provide evidence about the incentives governing the strategic behavior of different actors, but these estimates in-and-of-themselves tell us little about the generalizability of this strategic model to out-of-sample situations, and whether the effects identified are truly substantively meaningful in a broader context (Greenhill, Ward and Sacks, 2011). Given the growing importance of forecasting to the study of political violence (Brandt, Freeman and Schrodt, 2011), a valid strategic model should also possess some *predictive power* that makes it preferred to a "coin-flip" model (i.e., a model that has a completely random chance of predicting a given conflict event). I evaluate the forecasting strength of the estimates derived by my strategic model for the years 1998-2008 on out-of-sample data for 2009-2010.[14] To this extent, the separation plots in Figure 2 illustrate the strategic model's ability to forecast raids and defenses, respectively. These plots evaluate the model's predictive fit by showing the extent to which the actual instances of events (dark colors in these graphs) are concentrated on the right side of the plot, while instances of no-events (light colors) are concentrated on the left side (Greenhill, Ward and Sacks, 2011).

[14]For summary purposes, the frequencies of raider attacks and defender responses for 2009-2010 are shown in the Supporting Information file.

As these plots show, the strategic model does a reasonably good job of predicting conflict given that most of the events are clustered on the right-hand side of the graph. The ROC curves (reported in the Supporting Information file) of this model show that it correctly predicts approximately 84% of raider attacks (with a 95% confidence interval of 83% $\Leftrightarrow$ 86%) and 86% of defender responses (with a 95% confidence interval of 84% $\Leftrightarrow$ 88%) for the years 2009-2010. Moreover, as additionally shown in the Supporting Information file, this model provides a statistically significant better predictive fit for both in *and* out-of-sample data compared with standard logit models that ignore the *strategic* nature of preemptive conflict fought over food security (i.e., include all the regressors in one equation).

In sum, the empirical model makes correct prediction for the vast majority of violent conflict events. Along with the theoretical model and qualitative evidence provided in the Supporting Information file (Table A.1), this provides strong indication that preemptive conflict over food resources is an important aspect of violence in the developing world.

Figure 2: The Forecasting Accuracy of the Statistical Strategic Model on Out-of-Sample Data, 2009-2010



Foreasting Accuracy: Raids

Foreasting Accuracy: Responses

Conclusion

The use of food denial as a weapon is not recent. Throughout history and well into the 19th century, armies living off the land have been a regular characteristic of warfare, and—correspondingly—the preemptive destruction of food resources. By incorporating the insight that food support is crucial in facilitating military operations in these contexts and using a statistical estimator that is the structural equivalent of my theoretical model, I confirm these expectations at the highly localized level. These interesting findings diverge from current conceptualizations of food and violence in some prominent studies (e.g., Burke et al., 2009), but are consistent with a broad historical narrative and other studies of such attacks (Butler and Gates, 2012; Adano et al., 2012; Koren and Bagozzi, 2016). They also suggests ways where the framework of localized preemptive conflict could be generalized to other types of resources, such as drugs and diamonds, and even political votes.

These conceptualizations could also prove instrumental in cases where measures of local wealth are poorly captured by GDP per capita and related constructs, as is the case for areas where populations earn little income but own large amounts of crop or livestock (e.g., rural Rwanda). In shifting the focus towards the importance of alternative ways of conceptualizing wealth, my theory points to new ways in which the political, economic, and geographic approaches to conflict can be synthesized. This can have potential implications not only to scholars concerned with the study of political violence, but also policymakers working to ameliorate conflict and prevent renewal locally. Increasing food security can also have particular and important implications for peacebuilding globally, but this effect is magnified by the existence of efficient institutions that help promoting peaceful conflict resolution.

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