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Violent Repression as a Commitment Problem: Urbanization, Food Shortages, and Civilian Killings under Authoritarian Regimes

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Abstract: Authoritarian regimes frequently commit systematic killings of their own subjects, yet the mechanisms governing this behavioral shift remain unclear. We address this puzzle by developing a formal model that shows authoritarian elites perpetrate systematic killing campaigns preemptively in response to an exogenous shock where urban development levels are sufficiently high. In these contexts, the civilians cannot commit not to mobilize and pose a credible threat to the regime, which often preempts these efforts using systematic killings. Statistical analyses of a global high-resolution sample within all authoritarian states between 1996 and 2008 confirm the model's predictions. This study thus explicates when elites would resort to systematic killing as a rationalist strategy, and identifies an important dynamic that explains geographical and temporal variations in systematic killings within authoritarian states.

Keywords: Mass killing; development; drought; geospatial analysis

JEL classifications: D74, Q11, Q18

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Much of the recent research on the causes systematic killing of civilians generally argues that such violence is implemented rationally as means to an end (Valentino, 2014; Kalyvas, 2006; Poe and Tate, 1994; Valentino, Huth and Balch-Lindsay, 2004). Yet, because extreme repressive violence is highly costly and potentially perilous (Chenoweth and Stephan, 2011; Valentino, Huth and Balch-Lindsay, 2004), a central puzzle is explaining why regimes ever engage in such a risky strategy.

Because systematic killings of civilians almost exclusively happen in non-democratic – i.e., authoritarian/autocratic – countries (see, e.g., Valentino, 2014; Davenport, 2007), some scholars suggest that state-led violence arises because elites are less accountable and "frequently use coercive power domestically amid potential and existing challenges and challengers" (Davenport, 2007, 1-2). Other influential studies link such systematic killings to ongoing war (Poe and Tate, 1994; Valentino, Huth and Balch-Lindsay, 2004). These arguments emphasize that campaigns of systematic violence – which we term "killing campaigns"[1] – are frequently used as part of a total war strategy designed to destroy opponents. Considering that civil war frequently concentrates in rural areas, attention has been placed primarily on mass categorical violence against rural populations (Kalyvas, 2006, 38-48). Interestingly, however, a close look at new global, *localized* data on civilian killings (PITF, 2009) shows that nearly 40% of intrastate killing campaigns (as defined below) perpetrated by authoritarian regimes occur in locations and years that did not experience active conflict. Moreover, the same data also show that a staggering 56.2% of the locations and years that experienced killing campaigns had some level of urbanization, although such locations constitute roughly only 17% of our sample. This evidence suggests that killing campaigns are not constrained solely to periods of intensified violence or rural areas. Rather, systematic killings *vary substantively* across space and time within authoritarian countries, a trend that current theories of mass categorical violence cannot adequately explanation.

Why do authoritarian regimes systematically kill civilians in some times but not others? What explains the variation in systematic killing *within* autocracies? In this article, we develop a dynamic game-theoretic model that answers both questions. Our model focuses on the incentives for violence

[1] As discussed below, in its emphasis on within-country variation in mass violence, this conceptualization diverges somewhat from studies that use terms such as "mass killing" to empirically measure acts of mass categorical violence, particularly genocide, occurring at the *country level* (e.g., Valentino, 2014; Valentino, Huth and Balch-Lindsay, 2004; Harff, 2003). Similarly to Valentino, Huth and Balch-Lindsay (2004), we still employ a quantitative definition of these campaigns, although we recognize that other definitions exist (e.g., Poe and Tate, 1994; Harff, 2003).

produced by the shadow of the future, which we conceptualize as a commitment problem. This model examines formally how and when strategic interactions between two players – the ruling elite and the civilians residing in an authoritarian state – increase the prospects of deadly repression. Specifically, under particular conditions, the civilians cannot promise not to mobilize against the elite, while the latter cannot commit not to use violent repression and killings. We test this hypothesis on a global *high-resolution* sample of the aforementioned newly released data on civilian deaths resulting from political violence at the *disaggregated* 0.5 degree grid level[2] (PITF, 2009). This highly disaggregated sample allows us to effectively identify how the likelihood of deadly repression varies within a given authoritarian country. By conceptualizing the cause of the violence as a commitment problem and showing that it is affected by the variations in the civilians' mobilization potential across space and time, we also formally explain the seemingly-puzzling conundrum of why mass killing arises as a *rational* strategy.

Our model associates the apparent centrality of urban areas as targets for systematic regime violence with the higher material capacity available for urban civilians in these locations. The positive associations between urban development and the civilians' ability to mobilize an effective opposition against authoritarian regimes was established by previous studies (e.g., Wallace, 2013), but these stop short of explaining *civilian victimization* in these areas. As a result, as Pierskalla argues, "[w]e still do not have a clear understanding of when governments can successfully deter protest, when repression of protest can be effective, and under which conditions escalating violence breaks out" (2010, 19). Indeed, effectively explaining *when* violence might escalate within an authoritarian country requires the researcher to identify an exogenous trigger.

Drawing on recent research into the linkages between food shortages and unrest (Bellemare, 2015; Hendrix and Haggard, 2015) as well as studies on linkages between droughts and civilian victimization (Bagozzi, Koren and Mukherjee, 2017), we conceptualize this exogenous trigger as a drought-induced food shortage. It is important to stress, however, that we do not argue droughts are a universal trigger of unrest and violence, only identify a *specific context* in which climatic variations can generate a

[2] I.e., "cells" of approximately 55 x 55 kilometers around the equator, which decrease in size as one moves toward the poles (Tollefsen et al., 2012).

particular political violence type, namely in developed urban areas. We explain in detail why this is the case, develop a dynamic model to explore the mechanisms leading to this contextualized hypothesis, and test our hypothesis globally on a high resolution sample. Doing so not only avoids making strong claims about highly complex and conditional relationships, but also increases the probability that the resulting statistical associations are valid.

In line with our theoretical expectations, we find that areas with more urban development per capita are more likely to experience a state-led killing campaign during drought, a conclusion additionally supported by numerous illustrative examples. For instance, as discussed in the Supplemental Appendix, when bread riots triggered by a severe drought erupted in the urban centers of Tunisia and Morocco in 1983, both regimes responded with killing campaigns to prevent these protests from evolving into a massive civil revolt. A more recent example is the onset of the civil war in Syria. The rapid breakdown of the Syrian polity seems to defy traditional explanations, and recently a new one has emerged: by impacting food availability, the severe drought that preceded the war fueled political tensions and increased the probability of social conflict (Kelley et al., 2015).

The theoretical and empirical findings that during drought, more urban development per capita can generate violent repression draw new linkages between political violence, development, and consumption shocks, which researchers only recently began to address. We build on the diverse bodies of research on political violence (e.g., Valentino, 2014; Kalyvas, 2006), authoritarian repression (e.g., Davenport, 2007; Frantz and Kendall-Taylor, 2014), and urban unrest (e.g., Wallace, 2013; Pierskalla, 2010; Chenoweth and Stephan, 2011) to situate our model within the field's current understanding of mass killing and repression more broadly. Our analysis thus allows us to both develop "the theoretical explanation for why repression takes place" (Davenport, 2007, 17), and to explore "the disaggregation of repressive behavior across time, space, and types of activity" (Davenport, 2007, 18). We additionally rely on these linkages, backed by analyses of our disaggregated *global* sample, to explore several policy implications relevant to rapidly urbanization authoritarian states and their susceptibility to food shortages. This recommendations can help policy-makers and aid workers to better anticipate the timing and location of killing campaigns and respond effectively to these calamities.

1 Urbanization, Food Shortages, and Civilian Killings

In this section we derive a dynamic formal model to evaluate how the onset of drought and the ensuing shock to consumption levels impact the probability of a killing campaign within authoritarian countries, and identify a threshold of urban development per capita above which violence is likely. We derive equilibrium conditions and relevant comparative statics, and use the latter to formulate a testable hypothesis. Due to space constraints, the model's Background section and all mathematical derivations and proofs are reported in the Supplemental Appendix.

1.1 Players, Per Period Payoffs, Timing of Game

Consider two groups in an autocratic polity populated by a continuum of measure one of individuals: an authoritarian ruling elite, e; and the civilians, c (including workers, i.e. labor). Similar to other models of authoritarian politics (e.g., Acemoglu and Robinson, 2006), the ruling elite constitute a fraction λ of the population (where $\lambda < 1/2$), while the civilians constitute the majority $(1-\lambda > 1/2)$. These two groups interact within an infinite-horizon economy (described below) in which time $t = 0, 1, 2...\infty$ is discrete. Each individual i in this economy – where $i \in \{e, c\}$ are either part of the elite or civilians – wants to maximize the present discounted value of her lifetime utility:

$$U_{i,t} = E_0 \sum_{t=0}^{\infty} \beta^t x_{i,t} \tag{1}$$

where $x_{i,t}$ denotes the per-period payoff of individual i at time t, E_t is the expectations operator conditional on information available at time t, and $\beta \in (0,1)$ is the discount factor.

In this economy, food output at each period t comes from the Constant Elasticity of Substitution (CES) production function, $D(N_t, L_t) = [\gamma_t(\alpha N_t^{\rho} + (1-\alpha)L_t^{\rho})^{\frac{\varepsilon}{\rho}}]$.[3] Agricultural land N_t and labor L_t (a subset of c) are the two factors of production; and γ_t is the "rainfall shock" parameter, assumed to be uniformly distributed as $\gamma_t \sim u[-1,1]$, which affects each factor's productivity levels. When a severe drought occurs, $\gamma_t \sim [-1,0)$, which implies a negative rainfall shock. Both e and c's food consumption is drawn from a basket of resources (defined formally below), which includes all food production output

[3] Discussed in the Supplemental Appendix.

from the CES production function.

In addition to consuming food, members of both c and e gain income $y_{i,t}(\theta)$ during every period t. This income is directly shaped by the non-negative parameter $\theta \in \Re_+$. θ captures a key feature that – to our knowledge – has not received sufficient attention in current research on civilian killings and repression in authoritarian regimes: the extent of local development and its distribution within urbanized areas. As discussed below, the civilians' ability to mobilize against e increases when urban development levels (e.g., via electricity provision, infrastructure development) rise. Such developments improve efficiency and productivity, facilitate creativity, provide the civilians with greater material and technological capacity, and are hence directly related to income (Henderson, Storeygard and Weil, 2012). Building on the work of scholars such as Henderson, Storeygard and Weil (2012), we derive and discuss in detail below a nighttime light based, time varying indicator that closely corresponds to θ. Accordingly, higher levels of the non-negative θ parameter measure higher levels of concentrated urban development available to each civilian i in c during period t. The linkages between income and the degree of urban development available per civilian suggest that $y_{i,t}$ is a continuous and weakly increasing in $\theta \in \Re_+$ in the model.[4]

Our model conceptualizes the ruling elite and the civilians as interacting in one of two possible political states. The first is the status quo (denoted S), in which the ruling elite controls political power and is *not* challenged by the civilians. The second state is that of political contest (denoted F), in which the civilians mobilize to depose the ruling elite.

Next, we proceed to define the per period payoff of members of e and c in each of these two political states. Under the status quo S during each period t, the ruling elite obtains income $y_{r,t}(\theta)$, but – as suggested by past research (e.g., De Mesquita et al., 2003) – also pays private transfers T to regime supporters. Incorporating a "divide-the-pie" environment (Gehlbach, 2013),[5] the elite also consumes a fraction of resources $R_t \in [0,1]$, including food output. The remaining share $(1-R_t)$ is distributed to c. While the civilians consume $(1-R_t)$ as allocated to them under the status quo, they also obtain at each period t income $y_{c,t}(\theta)$, but incur a cost l from labor. Combined, the payoffs per capita for both e and

[4]This means that for $\theta \in [\underline{\theta}, \overline{\theta}]$ (since $\theta \in \Re_+$), $y : [\underline{\theta}, \overline{\theta}] \rightarrow [0, \Re_+]$.

[5]We adopt this framework to maintain the parsimony of our model. The results hold when we employ a more complex structure for the allocation of consumption resources.

c during period t are respectively defined under the status quo as

$$x_{e,t}(S) = R_t\left(\frac{y_{e,t}(\theta)-T}{\lambda}\right) \quad (2)$$

$$x_{c,t}(S) = (1-R_t)\left(\frac{y_{c,t}(\theta)-l}{(1-\lambda)}\right) \quad (3)$$

Correspondingly, members of e and c also obtain different payoff during a state of political contests F. As research on political repression (e.g., DeMeritt, 2015; Pierskalla, 2010; Gregory, Schröder and Sonin, 2011; Glaeser and Shleifer, 2005) shows – and as the anecdotal examples discussed in the Background section illustrate – civilians living under authoritarian rule may challenge the ruling elite e to depose it and alter the status quo. Therefore, in the model, the civilians decide whether or not to challenge the elite, $h^c \in \{0,1\}$. If $h^c = 0$, the civilians refrain from challenging the elite. If, however, the civilians decide challenge the elite's rule (i.e., when $h^c = 1$), they must devote monetary resources $m \in \{0,1\}$ for these deposition efforts.

Let $h^e \in \{0,1\}$ denote whether or not the ruling elite responds to c's challenge by employing violent repression – i.e., resorts to a killing campaign – against c to prevent them for posing an existential threat to its rule. If the elite does *not* respond to the civilians' challenge with violent repression (i.e., $h^e = 0$), it decides whether to provide political concessions or not $P \in \{0,1\}$. Providing concessions (i.e., $P = 1$) can include extending the franchise to (a larger part of) c or increasing legislative representation at some cost to e (Acemoglu and Robinson, 2006).

If the elite resorts to violent repression (i.e., $h^e = 1$), then in addition to the transfers T described earlier, it incurs the costs of resources spent on killings $\omega \in \{0,1\}$. Since repression cost is added to transfers T cost, the total costs that the elite incurs under this scenario (repression during political contest) is $\mu = \omega + T$. The elite's total net *per-capita* return under political contest for its choice of $h^e = 1$ (accounting for $P \in \{0,1\}$) is therefore $R_t\left(\frac{y_{c,t}(\theta)-P-\mu}{(\lambda)}\right)$. Because the elite may either provide political concessions to c or choose expend ω to impose a cost on c via killings under the political contest scenario, the civilians net return *per capita* is $(1-R_t)\left(\frac{y_{c,t}(\theta)+P-l-m-\omega}{(1-\lambda)}\right)$, which can also be written as $(1-R_t)\left(\frac{y_{c,t}(\theta)+P-l-\delta}{(1-\lambda)}\right)$ where $\delta = (l+m+\omega)$.

Let $\pi(h^c, h^e)$ be the probability with which e successfully defends itself against c's challenge and remains in power under a political contest state. Accordingly, the probability with which the civilians successfully challenges e and removes the elite from office in F is $(1-\pi(h^c,h^e))$. Additionally, if the civilians challenge e, the elite might respond with violence and wage a killing campaign against the civilians.

The civilians decision to challenge e and the elite's potentially violent response reduces, even destroys, the productive capacity of an economy (Acemoglu and Robinson, 2006). If the civilians wage a serious challenge to e, then in the political contest that ensues, the fraction of the autocratic economy destroyed is given by the state variable ϕ_t. Hence, the fraction of the economy's productive capacity available for generating output and be appropriated by the respective players is $(1-\phi_t)$. Note that ϕ_t can take on two values: $\{\phi^L,\phi^H\}$. ϕ^L denotes the destructions of a low fraction of the economy's productive capacity, while ϕ^H denotes a high proportion. Since ϕ_t can be either ϕ^L or ϕ^H, $q=\Pr(\phi_t=\phi^H)$ is the probability that a high proportion of the economy's productive capacity will be destroyed.[6] Accordingly, $(1-q)=\Pr(\phi_t=\phi^L)$ is the probability that the fraction of the economy's productive capacity destroyed is low.

Building on each player's net returns per capita under the political contest state (as discussed above), the probability with which the elite successfully defends its standing, and the fraction of the economy's productive capacity available for appropriation, we can now define the payoff during period t of each member of the elite and each civilian under the political contest scenario:

$$x_{e,t}(F) = \pi R_t(1-\phi_t)\left(\frac{y_{r,t}(\theta)-P-\mu}{\lambda}\right) \tag{4}$$

$$x_{c,t}(F) = (1-\pi)(1-R_t)(1-\phi_t)\left(\frac{y_{c,t}(\theta)+P-\delta}{(1-\lambda)}\right) \tag{5}$$

Because the elite may use a killing campaign $h^e=1$ in response to a challenge by the civilians $h^c=1$, we thus define $K_t=\max\{h^c,h^e\}=1$, meaning that widespread killings occur if the elite chooses to repress when confronted by c.

Let $A^\infty(\beta)$ denote an infinitely repeated game as described above. The timing of the game within a period t is as follows:

[6] Note that $q=\Pr(\phi_t=\phi^l)$ regardless of whether or not $\phi_{t-1}=\phi^l$.

1. γ_t is realized and the state $\phi_t = \{\phi^L, \phi^H\}$ is revealed with $q = \Pr(\phi_t = \phi^H)$. γ_t and ϕ_t are observed by both e and c.

2. After the civilians observe γ_t and ϕ_t, they decide whether or not to challenge the ruling elite: $h^c \in \{0,1\}$. If $h^c = 0$, then the elite controls the allocation of R_t and $(1-R_t)$, but this control is challenged when $h^c = 1$.

3. The elite observes if the civilians challenge its hold on power and determines whether or not to resort to violent repression in response, $h^e \in \{0,1\}$. If $h^e = 0$, the elite decide whether or not to provide political concessions $P \in \{0,1\}$. If $h^e = 1$ in response to $h^c = 1$, then $K_t = \max\{h^c, h^e\} = 1$ denotes whether a killing campaign occurs.

4. Payoffs are realized.

We solve for and analyze the Markov Perfect Equilibrium (MPE) of this game. Note that in each period, the players are restricted to playing Markov strategies, each of which is a function of the current state of the game. The state of the game is decided by the state variable ϕ_t, represented by either ϕ^L or ϕ^H, and the political state J_t, which is either S or F. Due to space constraints, the formal definition of this MPE as employed throughout this article is provided in the Supplemental Appendix.

1.2 Equilibrium Result and Comparative Statics

Before stating the equilibrium result from the infinitely repeated discounted game $A^{\infty}(\beta)$, we first derive the following claim from our CES function:

Claim 1: *The marginal change in food output is* $\gamma_t \varepsilon[\alpha N_t^{\rho} + (1-\alpha)L_t^{\rho}]^{\frac{\varepsilon}{\rho}-1}[\alpha N_t^{\rho-1} + (1-\alpha)L_t^{\rho-1}]$. *The outbreak of severe drought* $\gamma_t \sim u[-1,0)$ *hence leads to a sharp decrease in food output in this authoritarian economy.*

Proof: See Supplemental Appendix.

The logic described in Claim 1 is straightforward: a severe drought adversely affects the two input factors or production, which leads to a sharp decline in food output. Building on this result we can formally characterize the Markov Perfect Equilibrium (MPE) of the infinitely repeated discounted game between e and c. This equilibrium is formally stated as:

Lemma 1: *There is a unique Markov Perfect Equilibrium,* $\{\widetilde{\sigma}^c, \widetilde{\sigma}^r\}$, *of the infinitely repeated discounted game* $A^\infty(\beta)$. *In this equilibrium,*

1. *If* $\gamma_t \sim u[-1,0)$, *then for sufficiently high* $\theta \geqslant \theta^*$ *where* $\theta^* = \frac{b(1-R_t)}{(1-\pi)(1-\phi^H)}$ (*with* $b > 0$),
   - $h^c(\phi_t) = 1$ *for* $\phi_t = \phi^H$
   - $h^e(\phi_t) = 1$, $h^c(\phi_t) = 1$ *for* $\phi_t = \phi^H$
2. *If* $\gamma_t \sim u(0,1]$, *then for* $\theta \in \Re_+$, $h^c(\phi_t) = 1$, $h^e(\phi_t) = 0$, *given* $\phi_t \in \{\phi^L, \phi^H\}$

Proof: See Supplemental Appendix.

Part 1 of this Lemma suggests that in the unique MPE,the civilians will seek to overthrow e ($h^c = 1$) during a severe drought once the level of urban development is greater than the sufficiently high threshold $\theta \geqslant \theta^*$ for $\phi_t = \phi^H$ (i.e.,a high proportion of the economy's productive capacity is damaged).[7] In the MPE, if a challenge occurs during a drought in a high urban development θ^* context , the ruling elite will respond with violent repression $h^e = 1$ for $\phi_t = \phi^H$. This is our model's "threshold effect:" once urban development is at or above the threshold level of θ^* during a drought, then both a challenge by c and violent repression by e occur in the MPE. However, part 2 shows that if a drought does not occur, then the civilians will not challenge the elite, and hence the probability of violent repression is substantively negligible . Due to space constraints, a discussion of $\theta \in \Re_+$ in the absence of drought is provided in the Supplemental Appendix.

It is worth discussing the logic behind part 1 in more detail, its centrality within our model. First, recall from Claim 1 that the outbreak of a severe drought sharply reduces food output. This implies that the fraction of resources R_t that can be allocated for consumption also decreases rapidly when a drought occurs (see "proof of Claim 2," Supplemental Appendix). The depletion of essential resources (especially food) can push the ruling elite to engage in "resource grabbing", e.g., via appropriating a

[7]Lemma 1 shows that $\phi_t = \phi^H$ given $h^c = 1$ for $\gamma_t \sim [-1,0)$, $\theta \geqslant \theta^*$. The proof (see Supplemental Appendix) also shows that $h^e(h^c = 0, \phi_t) = 0$ for $\phi_t = \phi^L$.

greater share of these resources, which means that $R_t > (1 - R_t)$. This means that a severe drought can engender distributional conflict over consumption resources between c and e. More importantly, Lemma 1 shows that since the ruling elite controls political power under the political status quo scenario ($J_t = S$), it also cannot commit *ex ante* to redistribute a higher fraction of food resources to the civilians, or even maintain existing allocation levels, e.g., via offering to empower the civilians via some political concessions P. As a result, even though c values consumption resources even more under the conditions of a drought-induced food shock, they are highly uncertain they would be allocated adequate levels of $(1 - R_t)$ under the status quo.

This, in turn, provides a *trigger* for c to mobilize against e. Yet, such a trigger is insufficient to generate mass mobilization if the civilians do not possess the capacity to both start and sustain an effective campaign for redistribution. Indeed, the decision to invest monetarily $m \in \{0, 1\}$ to challenge and depose the elite is problematic because individual citizens may lack the material or organizational capacity to make this investment. Fortunately, Lemma 1 also provides at least two reasons why civilians where the level of urban development θ (normalized per capita) reaches a sufficiently high threshold θ^* will have the capacity to invest in such mobilization.

First, as anecdotal evidence discussed in the Background section illustrates, urban development is associated with greater individual social and material capacity, including more disposable income (Henderson, Storeygard and Weil, 2012), and thus with a higher probability that the civilians will challenge autocratic regimes (Wallace, 2013), especially in response to food shortages (Bellemare, 2015; Hendrix and Haggard, 2015). Directly incorporating this logic, our model shows that higher urban development per capita levels generate more income $y_{c,t}(\theta^*)$ for individual civilians in developed urban areas, and hence for the entire civilians' share of the population within the authoritarian state $(1 - \lambda)$. Greater financial capacity generated by $y_{c,t}(\theta^*)$ provides civilians in developed urban areas with financial surplus to invest in monetary resources $m \in \{0, 1\}$ to oppose the regime. This makes it financially feasible for civilians in developed urban locations to challenge the regime, and to mobilize against the elite when a drought occurs.

Second, note that when $\theta \geqslant \theta^*$, which generates the material capacity-per-capita effect $y_{c,t}(\theta^*)$ described above, the net returns $(1 - R_t)\left(\frac{y_{c,t}(\theta^*)+P-\delta}{1-\lambda}\right)$ civilians in developed urban locations obtain from challenging the elite are not only positive but also strictly greater than their net returns $(1-R_t)\left(\frac{y_{c,t}(\theta^*)-l}{1-\lambda}\right)$ under the status quo (see proof of Claim 3, Supplemental Appendix). Hence, during drought, if the urban development threshold is $\theta \geqslant \theta^*$, then the mobilization constraint binds the civilians to overturn the status quo. Consequently, as shown formally in Proposition 1, this binding mobilization constraint combined with the positive net returns from opposing e provide stronger incentives to c in developed urban areas to invest resources m not only to challenge the ruling elite, but also *to sustain this challenge*. This remains true even if (i) the elite offers political concessions P such as extending the franchise, and (ii) the economy's productive capacity destroyed is $\phi_t = \phi^H$.

Thus, in our model's dynamic setting, the outbreak of a severe drought combined with a sufficiently-high urban development threshold level θ^* generates strong incentives for both current and future (that is, inter-temporal) mobilization against e, especially for civilians living in developed urban locations. This, in turn, ensures that the total value – this is the sum of c's expected-present and discounted-future returns (*continuation value*) – from challenging and deposing e is strictly greater than the total value of *not* challenging e ($h^c = 0$). Stated formally, these expectations are:

Proposition 1: *The value (from the Bellman equation) for the civilians from $h^c \in \{0,1\}$ given $h^e \in \{0,1\}$ for $\phi_t = \phi^H$ is*

$$V^c(h^c|h^e,\phi^H) = x_{c,t}(J_t) + \beta[qV^c(h^c|h^e,\phi^H) + (1-q)V^c(h^c|h^e,\phi^L)] \tag{6}$$

where $J_t \in \{S,F\}$. In a drought $\gamma_t \sim u[-1,0)$, if $\theta \geqslant \theta^*$, then $V^c(1|\,0,\phi^H) > V^c(0|\,0,\phi^H)$ for $P \in \{0,1\}$ and $V^c(1|\,1,\phi^H) > V^c(0|\,1,\phi^H)$.

Proof: See Supplemental Appendix.

Since the total value (including continuation value) of challenging e during a drought is strictly greater than the total value obtained from adhering to the status quo $h^c = 0$, urban civilians *cannot credibly commit* not to mobilize against e under conditions of sufficiently high urban development. The ability of c to genuinely commit not to mobilize against e therefore strongly decreases in developed urban areas.

Additionally, given that challenging and possibly removing e from office implies a change in the allocation of future political power in favor of c, the civilians, especially those residing in developed urban location, also cannot credibly promise to not use their future political power to completely capture the fraction of the consumption resources $(1-R_t)$ for their own benefit. Hence, if $\theta \geqslant \theta^*$ in the context of a severe drought, then in the model's dynamic setting, the civilians cannot make credible commitment to the elite *ex ante* that they will not appropriate all consumption resources and deprive e of accessing them *ex post* once e is overthrown.

This civilians' "commitment problem" is common knowledge to both c and e. As a result, if $\theta \geqslant \theta^*$ during drought, the elite recognizes that the mobilization constraint binds for the civilians. The elite must thus recognize that civilians in the developed urban areas have a strong potential to arrange a sustained campaign to establish control over political power and appropriate resources for both present and future consumption, such that *only the civilians benefit*. The credible possibility of losing power and access to consumption resources sharply increases the elite's fear of ceding current and future power to c, thus dramatically increasing their incentives to keep their power by any means necessary. Comparative statics from our model summarized below in Proposition 2 suggests that this incentive and the elite's rational fear of losing political power has two deleterious consequences.

First, the elite is has strong incentives to *sustain* the status quo rather than provide political concessions $P = 1$ (e.g., extension of the franchise) to c as civilians in developed urban areas cannot credibly commit not to mobilize against e even if concessions were provided. Second, as Proposition 2 shows, since the the ability to credibly commit not to mobilize against e is especially low for civilians residing in developed urban areas, the elite has a strong incentive to strategically shift to *perpetrating a killing campaign* against urban civilians if drought occurs.[8]

What constitutes a killing campaign? As mentioned in the introduction, whereas previous research tends to focus on acts of mass categorical violence, particularly mass killing and genocide, occurring at the *country level* (e.g., Valentino, 2014; Valentino, Huth and Balch-Lindsay, 2004; Harff, 2003), our

[8]This conclusion is broadly consistent the "elimination of (civilian) enemies" in dictatorial repression models suggests by Gregory, Schröder and Sonin (2011, 38).

theoretical and empirical focus is on systematic violence occurring *within* the state. As Proposition 2 illustrates, within authoritarian states, killing campaigns are likely in locations where the civilians' mobilization potential is high enough to be perceived by the regime as an existential threat if food shortages trigger mobilization, specially in relatively well-developed urban areas. Therefore, in contrast to country-level studies that define mass violence based on intent (e.g., Harff, 2003), extremist leaders (e.g., Valentino, 2014) or an exceptionally high number of civilian deaths (e.g., Valentino, Huth and Balch-Lindsay, 2004), our definition is based on a strategic shift. If the elite faces a real existential threat in specific locations, it will shift its strategy to perpetrating a *systematic* campaign of capital violence against its own citizenry, because in these locations c cannot commit not to mobilize and sustain their opposition against e.

We thus use the term "killing campaigns" to identify a specific trend of systematic killings occurring *locally*. Our model suggests that the elite's rational fear of losing political power to the civilians, who cannot credibly promise not to overthrow it, induces e to opt to expend $\omega = 1$ to conduct such killing campaigns to impose severe costs on c and thus to preempt current and future challenges to its rule. This pressure to preempt ensures that if a drought occurs when $\theta \geqslant \theta^*$, the total expected value to the elite (including continuation value) from resorting to violent repression of the civilians ($h^e = 1$) is strictly greater than the total value from *not* using repression ($h^e = 0$) for $h^c \in \{0,1\}$, which motivates e to spend ω. This is exactly why the strategic shift to a killing campaign occurs. More formally, these results from our model are stated as:

Proposition 2: *The value for the elite from* $h^e \in \{0,1\}$ *given* $h^c \in \{0,1\}$ *for* $\phi_t = \phi^H$ *is*

$$V^e(h^e|h^c,\phi^H) = x_{e,t}(J_t) + \beta[qV^e(h^e|h^c,\phi^H) + (1-q)V^e(h^e|h^c,\phi^L)] \quad (7)$$

where $J_t \in \{S,F\}$. *In a drought* $\gamma_t \sim u[-1,0)$, *if* $\theta \geqslant \theta^*$, *then* $V^e(1|\,0,\phi^H) > V^e(0|\,0,\phi^H)$ *for* $m \in \{0,1\}$ *and* $V^e(1|\,1,\phi^H) > V^e(0|\,1,\phi^H)$, which leads to $h^e(h^c = 1,\phi^H) = 1$

Proof: See Supplemental Appendix.

Most importantly, Proposition 2 shows that the elite also cannot credibly commit not to use violent repression against c when it anticipates c's challenge, which the civilians also recognize. Taken together, Propositions 1 and 2 therefore suggest that a *two-sided commitment problem* emerges endogenously in the model's Markov Perfect Equilibrium during drought if urban development levels are sufficiently high: (i) the civilians cannot credibly promise not to challenge e hold over office, and (ii) anticipating this challenge, the elite, in turn, cannot credibly commit to not resort to civilian-targeted killings given its rational fear of losing political power to c in current and future periods.

This two-sided commitment problem has several important implications. First, it reinforces the civilians' decision to oppose and overthrow e in order to weaken latter's monopoly over violence, as c recognizes the elite will use the state's security apparatus to commit violent repression. Second, it leads to a vicious cycle where both sides fail to trust each other, which ensures that under the $\theta \geqslant \theta^*$ condition during drought, "killing campaigns" emerges as a *stationary* Markov perfect equilibrium in pure strategies, where the civilians do not deviate from opposing the elite ($h^c = 1$), while the elite does not deviate from violent repression by spending ω and thus sustains its killing campaign strategy (while *not* providing political concessions to c). This can be formally summarized as:

Proposition 3: *If* $\gamma_t \sim u[-1,0)$, *then for* $\theta \geqslant \theta^*$, $K_t = \max\{h^c, h^e\} = 1$ *for* $\phi_t = \phi^H$.

Proof: See Supplemental Appendix.

The ruling elite's decision to bolster its killing campaigns serves two main goals. First, the model suggests that a sustained killing campaign leads to a decline in the share of civilians in $(1-\lambda)$, and particularly the share of citizens residing in highly developed urban areas, who pose the greatest existential threat to e's rule (see proof of Claim 4, Supplemental Appendix). More broadly, killing civilians allows the elite to assert its political control by terrorizing and forcefully evicting a share of the population from developed urban areas. This result is in line with Gregory, Schröder and Sonin (2011, 38), who demonstrate that *targeted elimination* of the regime's enemies is a crucial strategy employed by dictators to increase political security.

Second, violent killing campaigns generate extreme fear among the civilians, and induce at least some of them to desist from investing $m \in \{0,1\}$ to oppose e. This implies that harming the livelihood and physical integrity of civilians in the model's MPE reduces material capacity surplus for c, and hence lowering the possibility of current and future opposition to e's rule. This increases the probability π (as per the elite's calculation) that e will remain in office, thus further encouraging e to initiate and sustain a killing campaign during a drought-induced consumption shock where $\theta \geqslant \theta^*$ (see proof of Claim 5, Supplemental Appendix), as was illustrated by anecdotal evidence in the Background section.

Taking the above propositions, as well as anecdotal evidence, into account suggest the following testable hypothesis, which is statistically evaluated on a global sample in the next section:

- **Hypothesis:** Severe droughts will be associated with a significantly and substantively higher likelihood of killing campaigns by authoritarian regimes where the level of urban development per capita is, on average, high.

2 Empirical Analysis

2.1 Sample, Variables and Statistical Methodology

Our hypothesis critically associates the level of urban development *within* authoritarian states with killing campaigns in the context of severe droughts. Because our model focuses on *intra-state* variation of violence, data measured at the annual country level would be inadequate for evaluating our hypothesis. We accordingly use a sample of intrastate killing campaigns perpetrated by state forces measured at the 0.5 degree grid-cell year level[9] in authoritarian countries, which covers the 1996-2008 period.

This grid cell-year sample has two main advantages. First, it allows us to carefully and accurately operationalize the variation in urban development per capita within and across authoritarian states, a necessary feature for evaluating our hypothesis. Thus, this framework is sensitive enough to capture variations in the frequency of systematic killing campaigns as these are reflected in urban development patterns within a given country. Second, as mentioned in the introduction, a substantive share of killing campaigns within autocracies occur in urban areas (56%), despite their relatively small share of all autocratic grid cell years (17%). Indeed, our model relies on the assumption that the concentration of

[9] I.e. a geospatial resolution of 55km x 55km at the equator, which decreases toward the poles.

killing campaigns in developed urban areas has theoretical importance, as it relates to the civilians' higher mobilization capacity. From this perspective, our grid cell framework allows us to identify how droughts affect intrastate systematic killing dynamics across urban and non-urban cells within a given country.

Given these advantages, we develop our authoritarian regime grid-cell year sample in two main steps. In the first step, we use Geddes, Wright and Frantz's (2014) comprehensive and updated data on authoritarian regimes to identify a list of 77 countries – listed in Table A1, Supplemental Appendix – that were considered autocracies during the 1996-2008 period, and for which data to operationalize the dependent and independent variables were available. In the second step, these 16 years of data are structured into a cell-year level dataset, where cells are the cross-sectional unit of interest, and are measured at the 0.5 x 0.5 decimal degree cell resolution for the entire terrestrial globe discussed in the introduction (Tollefsen et al., 2012).

Recall that our hypothesis focuses on the likelihood of state-led killing campaigns, which implies that our dependent variable is binary. We therefore operationalize this variable, $Killing\ Campaign_t$, as incidents where the yearly (t) number of civilians killed by deliberate attacks done for political purposes by official state forces or other armed groups sanctioned by the regime within a given cell was larger than 50. The use of a binary threshold not only permits us to directly evaluate the interactive effect in our hypothesis; it is also a well-established practice in studies of mass killing and mass categorical violence (e.g., Valentino, Huth and Balch-Lindsay, 2004; Valentino, 2014). These studies usually employ a threshold of 1,000 or more intentional civilian deaths for an entire campaign, measured at the country-year level. However, considering that our data is (i) annual, and (ii) measured at the grid cell year level, we believe that a threshold of 50 civilian deaths resulting from atrocities is high enough to capture intentional, *systematic* killing campaigns by state forces; indeed, this threshold corresponds to an average of approximately 14 intrastate killing campaigns per year, which is roughly consistent with the annual number of such ongoing campaigns in extant studies of mass killing at the country level (e.g., Valentino, Huth and Balch-Lindsay, 2004; Valentino, 2014). Another advantage of using a threshold of 50 or more casualties is that it accommodates a relatively large number of cities and regions within the state where such campaigns were implemented.

The data for constructing *Killing Campaign*$_t$ were obtained from the PITF Worldwide Atrocities Dataset, which defines atrocities as "implicitly or explicitly political, direct, and deliberate violent action resulting in the death of noncombatant civilians" (PITF, 2009, 3). The PITF uses international news sources to collect and code a reasonably systematic sample of atrocities occurring worldwide between 1995 and 2014, and as such, offers two notable advantages over other extant datasets. First, it relies on human codes to record each attack's geolocation, and do not report an event if no information on location is available (PITF, 2009, 8). Second, whereas other datasets focus only on specific regions, the PITF provides *global* coverage of violence over our entire temporal period. A subset of these atrocities, which only includes incidents perpetrated by the state or auxiliary forces sanctioned by the regime, is then utilized to create the dependent variable. After merging the PITF's atrocity deaths into our cell-year dataset based upon their recorded latitude-longitude coordinates, each cell's identified number of civilians killed by state forces is summed to the yearly level. Finally, the variable *Killing Campaigns*$_t$ is operationalized, as mentioned, by employing a threshold of *at least* 50 civilian deaths by state forces in a given cell during a given year. A map showing the location and frequency of killing campaign by authoritarian regimes over the entire 1996-2008 period is presented in Figure A1, Supplemental Appendix.

We interact two explanatory variables to test the moderated effect posited above: a binary measure denoting the occurrence of a severe drought, and a continuous measure of the extent of urban development levels per capita for each autocratic regime grid-cell year in our sample. The first independent variable, *Drought*$_t$, was obtained from the PRIO-Grid dataset (Tollefsen et al., 2012). We use this variable to verify whether substantial local declines in food production that are independent of time-related trends (which we account for using year fixed effects) can impact the likelihood of a killing campaign at year t. Considering that seasonal variations are already built into the civilians' and elites' expectations, we are specifically interested in capturing annual – rather than monthly – changes in drought trends. We thus dichotomize our *Drought*$_t$ variable based on whether a given cell experienced a severe drought – i.e., precipitation levels measured at 1.5 standard deviations or more below the mean – for a consecutive streak of two months or more during year t. A value of one was given to a cell during year t if this was the case, zero otherwise.

We construct our second independent variable as a thinly disaggregated, time-varying measure of urban development per capita, *Urban Development* PC_t, in three steps, in a manner that closely corresponds to previous studies (e.g., Henderson, Storeygard and Weil, 2012). First, to verify that our indicator captures solely urban areas, we keep only grid cells denoted as urbanized according to the Globcover2009 dataset (Bontemps, Defourny and Van Bogaert, 2009), with other cells given a value of zero on this indicator. In the second step, we incorporate a variable measuring the mean annual level of nighttime light in a given cell from the PRIO-Grid dataset (Tollefsen et al., 2012). Nighttime light provides a good approximation of the degree of urban development, especially the expansion of local infrastructure including roads, telecommunication and electricity (Koren and Sarbahi, Forthcoming). Finally, although this indicator allows us to measure nighttime light levels in urbanized centers, it does not take into account how these factors are distributed with respect to the individual civilian c's ability to dedicate resources to removing R in our model. To verify that it empirically aligns with our theoretical model, we normalize this indicator by (the natural log of) population size residing in a given cell during a given year (Tollefsen et al., 2012) in the third step. The resulting indicator, *Urban Development* PC_t, is thus formally defined as

$$\Sigma_{i=1}^{n}[\frac{l_i}{lnP_i}] \tag{6}$$

where lnP_i measures the log of population size in a given grid-cell, l_i is nighttime light emissions used in this grid-cell, and n is the number of urbanized cell-years in our sample (non-urbanized cell-years are thus given a value of zero). *Urban Development* PC_t effectively captures the θ parameter as it pertains to the urban civilians' ability to coordinate and allocate sufficient resources to stage an effective and sustainable civil revolt in our formal model's derivations.

Recall that our hypothesis posits that the interactive effect of drought and urban development per capita will be positively associated with the likelihood of a killing campaign in authoritarian states. We thus introduce the interaction term $Drought_t$ × *Urban Development* PC_t and control for the individual components of this interaction term in our models.

Our models also includes a large number of variables accounting for alternative explanations. First, we include economic output levels *GCP_t* (gross cell product in billion USD) and population densities, *$Population_t$*, in a particular cell during year *t* (from the PRIO-Grid). To account for the possibility that a killing campaign is more likely where it occurred previously, we include a lagged indicator *Killing $Campaign_{t-1}$* in our models. Geospatial controls are added to account for the potential effect of some constant geographic features: distance to the nearest borders (in kilometers), *Border Distance*; travel time to the nearest city with more than 50,000 inhabitants, *Travel Time*; and distance to the capital city, *Distance to Capital*. To account for the impact of ongoing war on the killing of civilians highlighted by numerous studies (e.g., Valentino, Huth and Balch-Lindsay, 2004; Poe and Tate, 1994), we also include an annual cell level indicator, *$Conflict_t$*, denoting whether war – defined as a conflict involving 25 or more combatant casualties – afflicted a given cell during a given year (Tollefsen et al., 2012). We also use data from the Nonviolent and Violent Campaigns and Outcomes (NAVCO) Data Project to create an indicator of whether a given country already experienced a *violent* civil disobedience – specifically – the previous year, *Violent Civil $Disobedience_{t-1}$* (Chenoweth and Lewis, 2013). We also account for a country's level of political openness using the ordinal *$Polity2_t$* indicator. To account for the impact of natural resources (e.g., Valentino, Huth and Balch-Lindsay, 2004; Ross, 2011), we include annual oil and gas production by country, *Oil_t* and *Gas_t* (from Ross, 2011).Finally, to account for other economic confounders more broadly, we also include in our analysis an annual measure of gross domestic product per capita, *GDP PC_t* (Gleditsch, 2002). Summary statistics on all variables are reported in Table A2, Supplemental Appendix.

Because our dependent variable is binary, we rely on logistic regression (i.e. logit) models for statistically assessing our hypothesis. To control for time dependencies unaccounted for by these variables in the specification listed earlier, all models include yearly dummies (i.e., year fixed effects). Since we are interested in variations in repression *within* authoritarian states each model includes country fixed effects.[10] Because the data for some variables are duplicated over time, standard errors are clustered by grid cell in all models.

[10]We also estimate models with fixed effects by grid cell, our unit of analysis, in Table A5, Supplemental Appendix.

2.2 Main Results and Robustness Tests

Table 1 reports the estimates of three logit models used to test our hypothesis on a full sample consisting of all global terrestrial cells in autocratic countries for the years 1996-2008. In all models, the association between our interaction term *Drought*$_t$ $\times$ *Urban Development PC*$_t$ and *Killing Campaign*$_t$ is positive and statistically significant, which empirically corroborates our hypothesis. Model 1 reports a minimalist baseline specification to test the interactive mechanisms implied by our formal model. The effect of urban development levels during drought on intrastate killing campaigns is estimated alongside each constitutive term, controlling solely for the lag of the dependent variable, *Killing Campaigns*$_{t-1}$. The results from this baseline model suggest a highly significant (to the 1% level) and positive relationship between the interaction term *Drought*$_t$ $\times$ *Urban Development PC*$_t$ and intrastate killing campaigns by state forces. The direction, statistical significance, and magnitude of this relationship remain consistent as more control variables are added to arrive at the fully specified model.

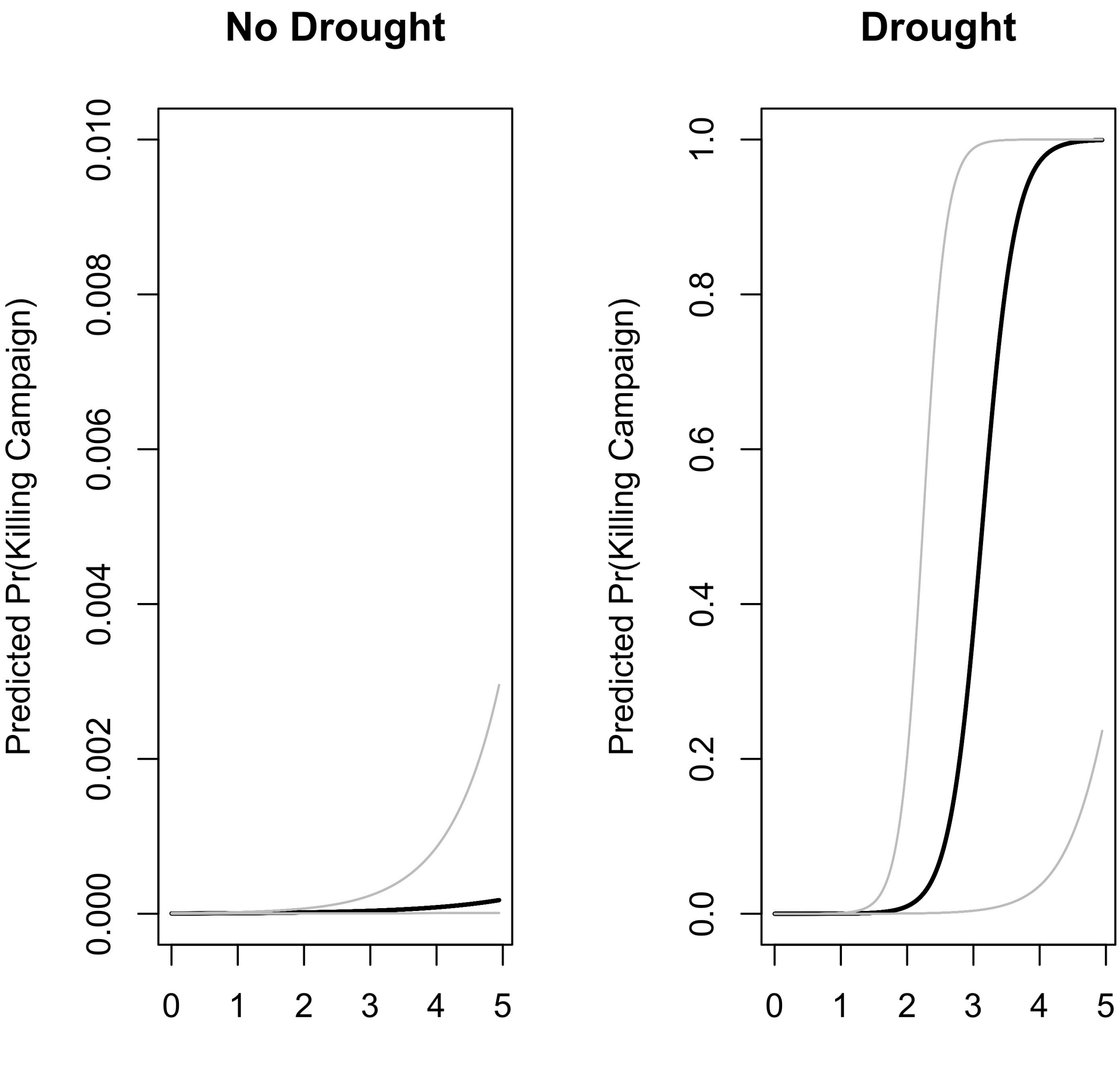
Next, we use the estimates from our full model in Table 1 to compute the marginal effect of *Urban Development PC*$_t$ on the probability of *Killing Campaigns*$_t$ for two sets of observations in the sample: those that (i) experienced a severe drought (that is, *Drought*$_t$=1), and (ii) did *not* experience a drought (i.e. *Drought*$_t$=0). As Figure 1 illustrates, in the absence of a drought, the effect of *Urban Development PC*$_t$ on *Killing Campaigns*$_t$ within autocracies slightly increases with higher values, but is substantively negligible ($\sim$ 1e-05% increase in the probability of a killing campaign). When a severe drought occurs, again the probability of *Killing Campaigns*$_t$ within autocracies is practically zero until one reaches the mid-range values on *Urban Development PC*$_t$. Once this threshold is passed, however, the average predicted probability of *Killing Campaigns*$_t$=1 increases sharply, to nearly 100% with extremely high *Urban Development PC*$_t$ values. This provides strong evidence in support of the threshold effect identified in our formal model, which associates killing campaigns not only with the incentives provided by drought, but also with the higher capacity of the civilians residing in relatively developed urban areas within authoritarian states to challenge the regime. These findings also illustrate that killing campaigns are indeed a rational strategy, used by authoritarian regimes where they face an existential threat, even if waged by unarmed civilians.

Table 1: **Killing Campaigns by Government Forces, 1996-2008**

	Baseline (1)	**Medium (2)**	**Full (3)**
Urban Development PC$_t$	1.725***	0.958***	1.122***
	(0.165)	(0.355)	(0.354)
Drought$_t$	−0.114	0.071	−0.199
	(0.768)	(0.816)	(0.816)
Drought$_t$ × *Urban Development PC*$_t$	2.759***	3.150***	3.884***
	(0.798)	(0.927)	(0.955)
Killing Campaigns$_{t-1}$	2.685***	2.547***	2.162***
	(0.327)	(0.334)	(0.335)
Violent Civil Disobedience$_{t-1}$	–	0.751**	0.075
		(0.371)	(0.400)
GCP$_t$[1]	–	−0.341	−0.316
		(0.265)	(0.267)
Population$_t$[1]	–	0.607***	0.531***
		(0.114)	(0.117)
Border Distance[1]	–	−0.338***	−0.426***
		(0.073)	(0.075)
Travel Time[1]	–	−0.890***	−0.925***
		(0.200)	(0.202)
Distance to Capital[1]	–	0.355***	0.348**
		(0.134)	(0.136)
Conflict$_t$	–	–	2.233***
			(0.256)
Polity2$_t$	–	–	0.150**
			(0.060)
GDP PC$_t$[1]	–	–	0.781
			(0.888)
Oil$_t$[1]	–	–	0.161
			(0.133)
Gas$_t$[1]	–	–	−0.097
			(0.360)
Constant	−11.131	−1.707	−5.628
	(2,472.194)	(3.564)	(6.977)
Observations	371,183	347,849	347,816
Log Likelihood	−1,000.203	−800.645	−752.084
Akaike Inf. Crit.	2,186.406	1,779.290	1,690.167

Note: * indicates $p < 0.1$; ** indicates $p < 0.05$; *** indicates $p < 0.01$.
Values in parentheses are robust standard errors clustered by cell-id.
All models include year and country fixed effects.
[1] In natural log form.

Figure 1: Change In The Effect Of *Urban Development* PC_t On *Killing Campaign* During Drought



We conduct a battery of sensitivity analyses to verify the validity of our main results and to assess whether other factors might produce the effects observed in Table 1. To this end, Tables A3–A5 in the Supplemental Appendix first report nine alternative specifications corresponding to the full model presented in Table 1. These models illustrate the robustness of our analysis to: (i) the coding standards behind $\textit{Drought}_t$; (ii) droughts occurring at the country rather than the grid cell level; (iii) limiting our sample to focus solely of urban cells; (iv) variations across different types of authoritarian regimes; (v) the theoretical assumptions underlying our $\textit{Urban Development PC}_t$ indicator; (vi) our decision not to lag our variables; (vii) our decision to rely on a binary conceptualization of $\textit{Killing Campaigns}_t$; (viii) the potential effect of spatial and serial correlations at higher levels of aggregation; and (ix) susceptibility to zero-inflation concerns. Crucially, our findings are robust to all these issues.

To illustrate that our results remain when only within-cell variations are isolated, we also re-estimate each model from Table 1 with fixed effects by *grid cell* in Table A5. The use of unit of analysis fixed effectsthat is, in this case grid cells, to capture observed and unobserved influences on an outcome of interest (the probability of a killing campaign) that are constant over time is a well-established procedure for establishing robust statistical associations. Again, the effect of the interaction term remains positive and statistically significant even in these more constrictive models. Finally, in the Supplemental Appendix we also use our statistical results to identify grid cells within countries with and without drought and with different levels of urbanization to provide specific examples behind our findings.

3 Conclusion

When are authoritarian elites more likely to resort to the systematic killing of their subjects? Our formal model suggests that the likelihood of killing campaigns under authoritarian regimes increases in developed urban areas when an exogenous shock, conceptualized here as severe drought, occurs. Such consumption shocks often trigger resentment and civilian mobilizations. While the elite may seek to address this challenge peacefully at first, its ability to do so decreases where urban development per capita levels are high, because the civilians become less able to commit to the status quo. The elite thus comes to favor systematic killings over concessions as a way of solidifying its standing and preempting the formation of a sustained opposition movement – an existential threat to its rule. Results from statistical analyses conducted on a *global*, within-country sample of all authoritarian states for the 1996-2008 period provide robust support for our main expectation, and the resulting predicted probability plots clearly illustrate this relationship empirically.

One potential objection is that rural civilians, which often live of locally grown food, might be too hungry to mobilize. Hence, urban areas might attract more systematic killing campaigns because the impact of food shortages in these locations is actually lower compared with rural area. While this is a valuable point, we believe that our analysis is robust to this concern. First, our findings that killings are more likely in developed urban areas is consistent with previous research that suggests that such violent repression is likely to be aimed at centers of political power (e.g., Frantz and Kendall-Taylor, 2014; Kalyvas, 2006). Indeed, this finding is supported by Model A3, Supplemental Appendix, which shows that even if all non-urban regions were removed from analysis, our findings hold. Second, if rural civilians are too weak to mobilize, it is because they miss sufficient material capacities to do so, an issue directly incorporated into our model. Hence, we can systematically explain how and why negative consumption shocks generate *credible* threats to the ruling elite in developed urban areas. In doing so, we emphasize that it is not the case that climatic variations *always* increase the propensity of violence, nor do we argue that drought is a *universal* cause of the violence. Rather, we identify contexts where exogenous consumption shocks can generate violence under the right conditions: in areas with more urban development per capita within authoritarian states.

Furthermore, while our model's findings that shocks to food consumption can generate civilian mobilization in urban areas are in line with past research (e.g., Bellemare, 2015; Hendrix and Haggard, 2015; Wallace, 2013), we specifically discuss in great detail why and where food shocks generate political threats to authoritarian elites and act as a driver of *systematic violence*. Moreover, particular geographical patterns of violence within autocracies are also *empirically* understudied (Davenport, 2007). Hence, by verifying the theoretical linkages between urban development, drought, and repression using both original within-country and cross-national, grid level data, these contributions represent an important step forward in advancing our understandings of state-led mass violence.

For policymakers, our theory and findings elicit important mechanisms governing the variation in systematic killings, especially in respect to development, urbanization, and economic shocks. Increases in urban development can generate intensive pressure and spell an existential threat to the regime under the right conditions. One conclusion is that authoritarian elites can intentionally target dense urban areas to maximize harm to civilian and minimize this threats. Whereas much of the current emphasis is on violence against civilians in rural areas (Kalyvas, 2006), this conclusion suggests that international organizations should devise political, and possibly military, plans to preempt and mitigate social and political pressures related to urbanization in autocratic states.

A second conclusion is that assisting developing authoritarian regimes to be better prepared and more effectively address sudden food shortages can help prevent violence and save lives. Establishing food stabilization programs and safety nets can help, but considering the commitment problem highlighted here, this alone might not be sufficient. Given that ruling authoritarian elites are rarely politically accountable, such regimes should also design economic and political states that allow them to make *credible* commitment to their subjects to stabilize food supplies *before* a food crisis occurs. This will allow these regimes, with or without the international community's assistance, to more effectively address sudden food shortages, which can help prevent violence and save lives.

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Supplemental Appendix For

Violent Repression as a Commitment Problem: Urbanization, Food Shortages, and Civilian Killings under Authoritarian Regimes

Contents

This appendix proceeds in six parts. In the first part, we provide a background discussion of our formal model. In the second part, we explain how our model results pertain to situations where urban development levels are high but in the absence of drought. The third part reports the formal model's detailed proofs and underlying economic models. In the fourth part we provide different summary statistics pertaining to our global sample, including a list of the countries analyzed. The fifth part reports a large number of robustness analyses, including grid-cell fixed effects models. Finally, in the sixth part we identify grid cells with and without drought and with different levels of urbanization across different countries and years, and illustrate the interactive effect hypothesized in the main paper in greater depth.

Background Discussion

The notion that governments employ systematic killing campaigns against civilians as a strategy when they find it both necessary and effective is firmly established in the literature (Valentino, 2014; Valentino, Huth and Balch-Lindsay, 2004; Kalyvas, 2006; Davenport, 2007*a*; Pierskalla, 2010). An increased probability of dissent thus provides one possible explanation for why and when violent repression arises. Drawing on numerous additional studies highlighting the negative impact of food consumption shocks on protests in developed urban areas (Bellemare, 2015; Hendrix and Haggard, 2015), our model assumes that elites and civilians interact in these autocratic countries, and that both players (i) are aware that higher urban development levels improve the civilians' ability to pose a serious threat to the ruling elite, and (ii) must account for the effect of negative shocks, conceptualized here a severe drought, on their consumption.

These very features have been observed, for example, in North Africa, when during the 1980s drought and its corresponding effect on food prices generated waves of protest, which resulted with strong regime-led repression. In Tunisia, the 1983 drought led to a 33% drop in grain production (Barakat and Handoufe, 1997, 11-12). This led to a "sudden doubling of bread prices," which was "a crucial factor in the outbreak of mass unrest" (Seddon, 1986, 1) in the country's developed urban areas, especially the capital Tunis, Sfax, Kariouan, and other large cities (Seddon, 1986). The regime viewed this mobilization as a "threat from 'hostile elements' concerned to overthrow the government" (Seddon, 1986, 1), and its 'response to the demonstrations was itself extremely violent. As the unrest spread, security forces opened fire on crowds in several towns, including the capital Tunis; at least 60 people were killed – as many as 120 according to some reports – and many more injured" (Seddon, 1986, 1).

In Morocco, events unfolded in a strikingly similar way. The 1983 drought led to a precipitous drop in crop output, which in turn produced inflation and created an economic crisis that the authoritarian regime – led by King Hassan – failed to adequately address. The result was, again, a "wave of mass demonstrations and street violence" (Seddon, 1986, 1), to which the authoritarian regime responded by bringing in "troops...to quell the disturbances. As social unrest spread...it was countered by heavy concentrations of state security forces; press reports suggest that at least 100 were killed (as many as 400 according to some sources) and many more injured" (Seddon, 1986, 1-2). Indeed, almost thirty years later these very dynamics were reflected in the words of a displaced Syrian farmer who – when asked if the 2011 conflict was about the drought – replied: "Of course. The drought and unemployment were important in pushing people toward revolution. When the drought happened, we could handle it for two years, and then we said, 'It's enough'"(cited in Kelley et al., 2015, 3254).

Our dynamic formal model directly incorporates the role of urban development and its impact on the civilian's capacity and, correspondingly, the ruling elite's sense of security (see, e.g., Wallace, 2013). We treat these two actors – the ruling elite and the civilians – as being in one of two states, either status quo conditions where the elite's rule is unchallenged, or a political contest scenario where the civilians choose whether to challenge the regime or not. Our model illustrates that under the political contest scenario, civilians in developed urban areas cannot commit not to mobilize against the elite, remove it from power, and appropriate all consumption resources, while the elite cannot commit not to use violent repression.[1] Systematic killing campaigns in autocracies arise under this commitment problem, which explains why such extreme violence is used even if it lowers regime's durability (Valentino, 2014).

[1]This finding is in line with studies on repression by autocrats, (Glaeser and Shleifer, 2005; Gregory, Schröder and Sonin, 2011).

Urban Development's Effects in the Lack of Drought

Part 2, Lemma 1: *There is a unique Markov Perfect Equilibrium,* $\{\widetilde{\sigma}^c, \widetilde{\sigma}^r\}$, *of the infinitely repeated discounted game* $A^\infty(\beta)$*. In this equilibrium, if* $\gamma_t \sim u(0,1]$*, then for* $\theta \in \Re_+$

- $h^e(h^c = 0, \phi_t) = 0$ *for* $\phi_t \in \{\phi^L, \phi^H\}$.

Proof: See "Proofs Section" in Supplemental Appendix.

Part 2 of Lemma 1 as stated above suggests that in the *absence* of a drought – that is, no positive rainfall shock, $\gamma_t \sim u(0,1]$ – the possibility that the regime will employ violent repression, even where urban development levels are high is substantively negligible compared with times of drought in areas with $\theta \geqslant \theta^*$. Note that when a drought does not occur, distributional conflict over consumption resources (including food) between the elite and the civilians, i.e., R_t and $(1 - R_t)$, is unlikely to become pronounced. This is because in the absence of drought R_t and $(1-R_t)$ remain strictly positive, thus reducing the possibility of "resource grabbing" by the elite. Therefore, no-drought contexts, it is more feasible for the ruling elite to commit *ex ante* to allocate at least the fraction of resources $(1 - R_t)$ to c such that it does *not* threaten the civilians' physical survival. As a result, c will have no reason to worry about being deprived of their basic needs. This, in turn, has two key effects.

First, the incentives for civilians to bear the necessary costs and take the decision to expend resources $m \in \{0, 1\}$ to challenge the ruling elite is very weak. This means that the income-effects of higher levels of urban development (or any $\theta \in \Re_+$) will matter less, as the civilians have little to no incentives to use the added financial capacity that results from higher θ to expend resources on anti-regime activities. Second, the lack of incentives for c to oppose e in the context of $\gamma_t \sim u(0,1]$ will, in effect, ensure that the sum of the civilians' current payoff and continuation value (i.e. their total value) from remaining in the political status quo and not challenging the elite ($h^c = 0$) is greater than their total value from challenging the elite. From the Bellman equations we find in this case that,

$$
\begin{aligned}
V^c(0|0,\phi_t) &= \frac{(1-R_t)(y_{c,t}(\theta)-l)}{(1-\lambda)} + \beta V^c(0|0,\phi_t) \\
&= \frac{(1-R_t)(y_{c,t}(\theta)-l)}{(1-\lambda)(1-\beta)} \qquad \text{(S.1)}
\end{aligned}
$$

$$
\begin{aligned}
V^c(1|0,\phi_t) &= \frac{(1-\pi)(1-R_t)\,(1-\phi_t)\,(y_{c,t}(\theta)-l)}{(1-\lambda)} + \beta V^c(1|0,\phi^H) \\
&= \frac{(1-\pi)(1-R_t)\,(1-\phi_t)\,(y_{c,t}(\theta)-l)}{(1-\lambda)(1-\beta)} \qquad \text{(S.2)}
\end{aligned}
$$

Therefore, when a drought does not occur $V^c(0|0,\phi_t) > V^c(1|0,\phi_t)$ for $\theta \in \Re_+$ and $\phi_t \in \{\phi^L, \phi^H\}$. Further, analysis of the Bellman equations $V^c(0|1,\phi_t)$ and $V^c(1|1,\phi_t)$[2] shows that $V^c(0|1,\phi_t) > V^c(1|1,\phi_t)$ or $\theta \in \Re_+$ and $\phi_t \in \{\phi^L, \phi^H\}$. This further reinforces the claim that for $\gamma_t \sim u(0,1]$, the civilians current payoff and continuation value from adhering to the political status quo and not challenging the elite ($h^c = 0$) will be greater than their total value from challenging the elite. The main implication of these results is that in the absence of a drought, the civilians "commitment problem "vis-a-vis the elite does *not* emerge in the MPE. Put differently, the civilians *can credibly promise* to not challenge and overthrow the elite.

Crucially, given common knowledge, the ruling elite will recognize in this case that the civilians do not pose an existential threat ot their rule. They hence rationally anticipate that for $\gamma_t \sim u(0,1]$, $h^c = 0$ for any positive level of urban development θ. Our model suggests that since higher levels of urban development provide civilians the necessary material capacity to oppose the regime[3] – a possibility recognized by the elite – e may *hedge* with some probability in equilibrium by using some (substantively low level of) repression as a strategy to credibly

[2] The derivation and description of the full functional forms of $V^c(0|1,\phi_t)$ and $V^c(1|1,\phi_t)$ is available upon request.

[3] See the proof of Claim 2 in the "Proofs Section" below.

deter any anti-regime opposition stemming from higher θ. But because in the absence of a drought, e is*unlikely* to perceive any potential dissent (from $\theta \in \Re_+$) as a serious threat, the elite will not rely on violent repression against c when drought-induced consumption shocks are *not* realized. As shown by the Bellman equations below, it is hardly surprising that when drought does not occur,the sum of the elite's current payoff and continuation value (i.e. their total value) from remaining in the political status quo and thus not using repression ($h^e = 0$) will be greater than their total value from engaging in violent repression such as killing campaigns,

$$\begin{aligned} V^e(0|0, \phi_t) &= \frac{R_t(y_{e,t}(\theta) - T)}{\lambda} + \beta V^e(0|0, \phi_t) \\ &= \frac{R_t(y_{c,t}(\theta) - T)}{\lambda(1-\beta)} \end{aligned} \tag{S.3}$$

$$\begin{aligned} V^e(1|0, \phi_t) &= \frac{\pi R_t\,(1-\phi_t)\,(y_{e,t}(\theta) - P - \mu)}{\lambda} + \beta V^e(1|0, \phi_t) \\ &= \frac{\pi R_t\,(1-\phi_t)\,(y_{c,t}(\theta) - P - \mu)}{\lambda(1-\beta)} \end{aligned} \tag{S.4}$$

Again, analysis shows that when a drought does not occur $V^e(0|0, \phi_t) > V^e(1|0, \phi_t)$ for $\theta \in \Re_+$ and $\phi_t \in \{\phi^L, \phi^H\}$. Consequently, the possibility that a killing campaign will occur in the absence of a drought, even where the level of urban development, is substantively negligible and *substantially lower* than the propensity of mass killing campaigns in a drought when $\theta \geqslant \theta^*$ (as stated above in part 2 of Lemma 1).

Formal Model Proofs

CES Production Function, Solution Concept

We first describe the Constant Elasticity of Substitution (CES) production function that generates ouput of output that is consumed by the elite and the civilians in our model. We then define our dynamic model's solution concept before stating some technical definitions that are used for analyzing the model's proofs.

CES Production Function: In the infinite horizon autocratic economy, food output at each t comes, as noted in the text, from the Constant Elasticity of Substitution (CES) production function $D(N_t, L_t) = [\gamma_t(\alpha N_t^\rho + (1-\alpha)L_t^\rho)^{\frac{\varepsilon}{\rho}}]$,[4] homogeneous of degree ε, which includes two factors of production: agricultural land N_t and labor L_t. In this CES production function, $\alpha \in [0,1]$ is the relative weight of production inputs land N_t and labor L_t (who are a part of c); $\rho \leq 1$ is the elasticity of substitution; and γ_t is the "rainfall shock" parameter – assumed to be uniformly distributed as $\gamma_t \sim u[-1,1]$ – which affects the factors' productivity. $\gamma_t \sim [-1,0)$ when a severe drought occurs, which implies a negative rainfall shock.

Solution Concept: Recall that the state of the game consists of the state variable ϕ_t represented by either ϕ^L or ϕ^H and the current state of the political environment J which is either S or F. Following from this notation, the formal definition of our game model's Markov Perfect Equilibrium (MPE) is:

Definition (Markov Perfect Equilibrium): *Let $\sigma^c = \{h^c, m\}$ be the notation for the actions taken by the civilians, and let $\sigma^e = \{h^e, P, R\}$ be the notation for the actions taken by the ruling elite in the game. The actions of the civilians σ^c consists of their decision to initiate a challenge or not against the elite, $h^c : \{\phi^L, \phi^H\} \rightarrow \{0,1\}$, and possibly invest monetary resources $m \in \{0,1\}$ when the political state is $J = F$. σ^e for the elite consists of a decision to resort to violent repression $h^e : \{\phi^L, \phi^H\} \rightarrow \{0,1\}$, or to provide political concessions $P : \{\phi^L, \phi^H\} \rightarrow \{0,1\}$ when $J = F$, and the share of consumption resources $R \in [0,1]$ it captures when $J \in \{S, F\}$. Hence, the Markov Perfect Equilibrium of the game*

[4] Developed by Arrow et al. (1961).

is a strategy combination $\{\widetilde{\sigma}^c, \widetilde{\sigma}^r\}$ *such that* $\widetilde{\sigma}^c$ *and* $\widetilde{\sigma}^r$ *are best responses to each other* $\forall\ \phi_t$ *and* $\forall E$*.*

Proofs

We first state and demonstrate the following three background claims below that serve as a foundation for completing some of the formal proofs of our model's main results in this section.

Claim A: Following the properties of Markov Perfect Equilibrium (see Acemoglu and Robinson 2006, Chapter 5), the state variable ϕ_t in our model only fluctuates after periods of peace in which the political status quo prevails between the elite and the civilians. Instead, the state variable ϕ_t stops fluctuating once $K_t\{h^e(h^c = 1, \phi_t) = 1\}$, which means that $\phi_t = \phi_{t-1}(K_{t-1} = 1)$ where $\phi_t \in \{\phi^L,\ \phi^H\}$.

Claim B: We briefly show that $\forall\ \phi^L \in [0, 1]$, it follows that $h^c(\phi^L) = 0$. Focusing on the boundary conditions of $\phi^L \in [0, 1]$, first suppose that $\phi^L = 0$. For $\phi^L = 0$, the civilians per capita per period payoff in the political contest state is $\frac{(1-\pi)(1-R_t)\left(1-\phi^L\right)(y_{c,t}(\theta)+P-\delta)}{(1-\lambda)} = \frac{(1-\pi)(1-R_t)(y_{c,t}(\theta)+P-\delta)}{(1-\lambda)}$, while their per capita per period payoff in the status quo state is $\frac{(1-R_t)(y_{c,t}(\theta)-l)}{(1-\lambda)}$. One can check that $\frac{(1-\pi)(1-R_t)(y_{c,t}(\theta)+P-\delta)}{(1-\lambda)} < \frac{(1-R_t)(y_{c,t}(\theta)-l)}{(1-\lambda)}$ for not only $P \in \{0, 1\}$ but also (i) $\forall\ \gamma_t \sim u[-1, 1]$ when $\theta \geqslant \theta^*$ (where $\theta^* =$) and (ii) $\theta \in \Re_+$. This means that $h^c(\phi^L) = 0$ in this case. For $\phi^L = 1$, the civilians per capita per period payoff in the political contest state is 0 which is also strictly less than the civilians per capita per period payoff in the status quo, $\frac{(1-R_t)(y_{c,t}(\theta)-l)}{(1-\lambda)}$ again for $P \in \{0, 1\}$ and $\forall\ \gamma_t \sim u[-1, 1]$ when $\theta \geqslant \theta^*$and $\theta \in \Re_+$. This means that $h^c(\phi^L) = 0$ in this latter case. Thus $h^c(\phi^L) = 0\ \forall\ \phi^L \in [0, 1]$ which means that the political state in which e and c interact always remains in the status quo state in the state $\phi_t = \phi^L\ \forall\ \gamma_t \sim u[-1, 1]$ when $\theta \geqslant \theta^*$and $\theta \in \Re_+$.

Claim C: From Claim B, we know that in the state $\phi_t = \phi^L$, $h^c(\phi^L) = 0\ \forall\ \gamma_t \sim u[-1, 1]$ when $\theta \geqslant \theta^*$and $\theta \in \Re_+$. Turning to the elite, we find that when $\phi^L = 0$, the elite's per capita per period payoff in the political contest state is $\frac{\pi R_t\left(1-\phi^L\right)(y_{c,t}(\theta)-P-\mu)}{\lambda} = \frac{\pi R_t\left(1-\phi^L\right)(y_{c,t}(\theta)-P-\mu)}{\lambda}$, while their per capita per period payoff in the status quo state is $\frac{R_t(y_{c,t}(\theta)-T)}{\lambda}$. Observe that

$\frac{\pi R_t\left(1-\phi^L\right)(y_{c,t}(\theta)-P-\mu)}{\lambda} < \frac{R_t(y_{c,t}(\theta)-T)}{\lambda}$ for not only $P \in \{0,1\}$ but also $\forall\ \gamma_t \sim u[-1,1]$ when $\theta \geqslant \theta^*$ (where $\theta^* =$) and $\theta \in \Re_+$. Hence $h^e(\phi^L) = 0$ in this case. For $\phi^L = 1$, the elite's per capita per period payoff in the political contest state is also 0 which is also strictly less than their per capita per period payoff in the status quo, $\frac{R_t(y_{c,t}(\theta)-T)}{\lambda}$ for $P \in \{0,1\}$ and $\forall\ \gamma_t \sim u[-1,1]$ when $\theta \geqslant \theta^*$and $\theta \in \Re_+$. Hence, from Claims B and C, it follows that there exists a MPE where for $\forall\ \gamma_t \sim u[-1,1]$ when $\theta \geqslant \theta^*$ (and $\theta \in \Re_+$), $h^e(h^c = 0, \phi_t) = 0$ in the state $\phi_t = \phi^L$. Less technically, this indicates that the elite and the civilians will always remain in the political status quo in the state $\phi_t = \phi^L$. Hence, we turn to derive and characterize in Lemma 1, our model's unique MPE in the state where $\phi_t = \phi^L$. Before doing so, we prove the following claim that we stated in our main paper's model section.

Proof of Claim 1: When a severe drought occurs – which implies a negative rainfall shock – then by construction $\gamma_t \sim -u[1,0)$. From the CES production function $D(N_t, L_t)$, we obtain

$$\frac{\partial D}{\partial N_t} = \phi\varepsilon[\alpha N_t^\rho + (1-\alpha)L_t^\rho]^{\frac{\varepsilon}{\rho}-1}\alpha N_t^{\rho-1} \tag{A.1}$$

$$\frac{\partial D}{\partial L_t} = \phi\varepsilon[\alpha N_t^\rho + (1-\alpha)L_t^\rho]^{\frac{\varepsilon}{\rho}-1}(1-\alpha) L_t^{\rho-1} \tag{A.2}$$

Because the total marginal change in food output is $\left(\frac{\partial D}{\partial N_t}L_t + \frac{\partial D}{\partial L_t}N_t\right)$, we obtain from (A.1) and (A.2) and after some algebra

$$D(N_t, L_t) = \phi\varepsilon[\alpha N_t^\rho + (1-\alpha)L_t^\rho]^{\frac{\varepsilon}{\rho}-1}[\alpha N_t^{\rho-1} + (1-\alpha)L_t^{\rho-1}] \tag{A.3}$$

From the expressions for $\frac{\partial D}{\partial N_t}$ and $\frac{\partial D}{\partial L_t}$, one can easily observe that $\frac{\partial D}{\partial N_t} < 0$ and $\frac{\partial D}{\partial L_t} < 0$ when $\gamma_t \sim -u[1,0)$. Differentiating (A.1) with respect to N gives

$$D_{N_tN_t} = \phi\left[\varepsilon\frac{D}{N_t}\left(\frac{\alpha N_t^\rho}{\alpha N_t^\rho + (1-\alpha)L_t^\rho}\right)N_t^{-2}\right]\left[(\varepsilon-\rho)\left(\frac{N_t^\rho}{\alpha N_t^\rho + (1-\alpha)L_t^\rho}\right) + (\rho-1)\right] \tag{A.4}$$

Differentiating (A.2) with respect to L gives

$$D_{L_tL_t} = \phi\left[\varepsilon\frac{D}{L}\left(\frac{(1-\alpha)L_t^{\rho}}{\alpha N_t^{\rho}+(1-\alpha)L_t^{\rho}}\right)L^{-2}\right]\left[(\varepsilon-\rho)\left(\frac{(1-\alpha)L_t^{\rho}}{\alpha N_t^{\rho}+(1-\alpha)L_t^{\rho}}\right)+(\rho-1)\right] \quad \text{(A.5)}$$

From (A.4) and (A.5), $D_{N_tN_t} < 0$ and $D_{L_tL_t} < 0$ when $\gamma_t \sim -u[1,0)$. Finally, if $\gamma_t \sim -u[1,0)$, then one can check from the expressions for $\frac{\partial D}{\partial N_t}$ and $\frac{\partial D}{\partial L_t}$ that $\frac{\partial D}{\partial N_t} < 0$ and $\frac{\partial D}{\partial L_t} < 0$. The average products of labor and land given ϕ are respectively

$$\frac{D(N_t,L_t)}{L_t} = \frac{\phi[\alpha N_t^{\rho}+(1-\alpha)L_t^{\rho}]^{\frac{\varepsilon}{\rho}}}{L_t} \quad \text{(A.6)}$$

$$\frac{D(N_t,L_t)}{N_t} = \frac{\phi[\alpha N_t^{\rho}+(1-\alpha)L_t^{\rho}]^{\frac{\varepsilon}{\rho}}}{N_t} \quad \text{(A.7)}$$

Hence, the total (average) food output is

$$\left(\frac{D(N_t,L_t)}{L_t}+\frac{D(N_t,L_t)}{N_t}\right) \quad \text{(A.8)}$$

$\frac{D(N_t,L_t)}{L_t} < 0$ and $\frac{D(N_t,L_t)}{N_t} < 0$ when $\gamma_t \sim -u[1,0)$, which means that $\left(\frac{D(N_t,L_t)}{L_t}+\frac{D(N,L)}{N_t}\right) < 0$ when $\gamma_t \sim -u[1,0)$.

Proof of Lemma 1: To start with, we know from the previous proof that $\left(\frac{D(N_t,L_t)}{L_t}+\frac{D(N,L)}{N_t}\right) <$ 0 when $\gamma_t \sim -u[1,0)$. Further, we demonstrate below in the proof of claim 2 that $R_t < 0$ and thus $(1-R_t) < 0$ when $\gamma_t \sim -u[1,0)$. Building on this, we demonstrate in SECTION B of this lemma's proof that for $\gamma_t \sim -u[1,0)$ if $\theta \geqslant \theta^* =$, then $h^c = 1$ in the state $\phi_t = \phi^H$. Hence, to complete the proof of Lemma 1, we start in SECTION A with the elite's best response in the Markov Perfect Equilibrium for $\phi_t = \phi^H$. To this end, we demonstrate that for $\gamma_t \sim -u[1,0)$ if $\theta \geqslant \theta^*$, then $h^e(h^c = 1, \phi_t) = 1$ in the state $\phi_t = \phi^L$, as claimed in Part 2 of Lemma 1 in the text. We then solve for and characterize the civilians best response in the MPE in SECTION B of this lemma's proof. Finally, in SECTION C, we prove part 2 of Lemma 1 stated in the text which posits that in the absence of a drought (that is,

$\gamma_t \sim u(0,1])$, $h^e(h^c = 0, \phi_t) = 0$ in the MPE for $\theta \in \Re_+$ and $\phi_t \in \{\phi^L, \phi^H\}$.

SECTION A

Suppose that $h^c = 1$ for $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$, as demonstrated below in Section B of this Lemma's proof. $h^c = 1$ implies by construction that $\phi_t = \phi^H$. We need to examine two cases to prove the claim that $h^e = 1$ for $h^c \in \{0, 1\}$ in the state $\phi_t = \phi^H$. In Case I, we need to show that the elite will opt for $h^e = 1$ over $h^e = 0$ in response to $h^c = 1$ in the state $\phi_t = \phi^H$ for $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$ (where $\theta^* =$). In Case II, we need to show that the elite will opt for $h^e = 1$ over $h^e = 0$ even for $h^c = 0$ in the state $\phi_t = \phi^H$ for $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$. To this end, first let the value functions to the ruling elite and the civilians in the state $\phi_t = \phi^H$ be denoted by $V^e(h^e|\ h^c, \phi^H)$ and $V^c(h^c|\ h^e, \phi^H)$ respectively where $h^e \in \{0, 1\}$ and $h^c \in \{0, 1\}$.

Case I: Given $V^e(h^c|\ h^e, \phi^H)$, the relevant Bellman equation that determines the elite's value $V^e(1|\ 1, \phi^H)$ from choosing $h^e = 1$ in response to $h^c = 1$ in the state $\phi_t = \phi^H$ is

$$V^e(1|1, \phi^H) = \frac{\pi R_t \left(1 - \phi^H\right) \left(y_{e,t}(\theta) - P - \mu\right)}{\lambda} + \beta V^e(1|1) \tag{A.9}$$

$$= \frac{\pi R_t \left(1 - \phi^H\right) \left(y_{e,t}(\theta) - P - \mu\right)}{\lambda(1 - \beta)} \tag{A.10}$$

where $\beta V^e(1|1)$ in (A.9) is the continuation value in this case. The Bellman equation that determines the elite's value $V^e(0|\ 1, \phi^H)$ from choosing $h^e = 0$ in response to $h^c = 1$ in the state $\phi_t = \phi^H$ is

$$V^e(0|1, \phi^H) = \frac{\pi R_t \left(1 - \phi^H\right) \left(y_{r,t}(\theta) - P - \mu\right)}{\lambda} + \beta V^e(0|1) \tag{A.11}$$

where $\beta V^e(0|1)$ in (A.11) is the continuation value in this case. Because the elite is deposed from office when $h^e = 0$ in response to $h^c = 1$, $\pi(h^e = 0, h^c = 1) = 0$, it implies that

$\frac{\pi R_t(1-\phi_t)(y_{r,t}(\theta)-P-\mu)}{\lambda} = 0$ in (A.11). Likewise, since the elite is out of office forever when $h^e = 0$ in response to $h^c = 1$, $\pi(h^e = 0, h^c = 1) = 0$ in future periods as well which implies that $\beta V^e(0|1) = 0$ in (A.11). Thus, $V^e(0|1, \phi^H) = 0$ in (A.11) given that $\pi(h^e = 0, h^c = 1) = 0$. Since $V^e(1|1, \phi^H)$ in (A.10) is strictly positive while $V^e(0|1, \phi^H) = 0$, it follows that $V^e(1|1, \phi^H) > V^e(0|1, \phi^H)$ which implies that $h^e(h^c = 1, \phi^H) = 1$ for $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$.

Case II: Now suppose that $h^c = 0$ for $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$. For $h^c = 0$, it is possible that $\phi_t \in \{\phi^L, \phi^H\}$. Hence, to start, the relevant Bellman equation that determines the elite's value function $V^e(1|\ 0, \phi^H)$ from choosing $h^e = 1$ in response to $h^c = 0$ in the state $\phi_t = \phi^H$ is

$$\begin{aligned} V^e(1|0, \phi^H) &= \frac{R_t\left(1-\phi^H\right)(y_{r,t}(\theta) - P - \mu)}{\lambda} + \beta V^e(1|0) \\ &= \frac{R_t\left(1-\phi^H\right)(y_{r,t}(\theta) - P - \mu)}{\lambda(1-\beta)} \end{aligned} \tag{A.12}$$

The Bellman equation that determines the elite's value function $V^e(0|\ 0, \phi^H)$ from choosing $h^e = 0$ in response to $h^c = 0$ in the state $\phi_t = \phi^H$ is

$$V^e(0|0, \phi^H) = \frac{R_t(y_{e,t}(\theta) - T)}{\lambda} + \beta[qV^e(0|0, \phi^H) + (1-q)V^e(h^e|0, \phi^L)] \tag{A.13}$$

where $\beta[qV^e(0|0, \phi^H) + (1-q)V^e(h^e|0, \phi^L)]$ is the continuation value that depends on the future realization of ϕ_t. For $\phi_t = \phi^L$in the future, it follows that,

$$\begin{aligned} V^e(1|0, \phi^L) &= \frac{R_t\left(1-\phi^L\right)(y_{r,t}(\theta) - P - \mu)}{\lambda} + \beta V^e(1|0) \\ &= \frac{R_t\left(1-\phi^L\right)(y_{r,t}(\theta) - P - \mu)}{\lambda(1-\beta)} \end{aligned} \tag{A.14}$$

When $h^c = 0$, it is plausible that $\phi^L = 0$ (or $\phi^L = \varepsilon$) as the (i) absence of a challenge from the civilians is likely to do little damage, if at all, to the economy's productive capacity and (ii) elite has strong incentives to maintain as much (preferably all) of the economy's productive capacity when resorting to $h^e = 1$ for $h^c = 0$ in the state $\phi_t = \phi^L$. For $\phi^L = 0$, $V^e(1|0, \phi^L)$ in (A.14) is given by

$$V^e(1|0, \phi^L) = \frac{R_t(y_{r,t}(\theta) - P - \mu)}{\lambda(1-\beta)} \tag{A.15}$$

The Bellman equation that determines the elite's value function $V^e(0|\ 0, \phi^L)$ from choosing $h^e = 0$ in response to $h^c = 0$ in the (possible future) state $\phi_t = \phi^L$ is

$$V^e(0|0, \phi^L) = \frac{R_t(y_{e,t}(\theta) - T)}{\lambda} + \beta[qV^e(h^e|h^c, \phi^H) + (1-q)V^e(0|0, \phi^L)] \tag{A.16}$$

In (A.16), $(1-q)V^e(0|0, \phi^L) = (1-q)V^e(0|0)$. Additionally, from (A.11), $[qV^e(h^e|h^c, \phi^H)] = [qV^e(1|1, \phi^H)]$ which implies that $[qV^e(1|1, \phi^H)] = q\frac{\pi R_t(1-\phi_t)(y_{r,t}(\theta)-P-\mu)}{\lambda(1-\beta)}$ when $h^e(h^c = 1, \phi^H) = 1$. From (A.12), $[qV^e(h^e|h^c, \phi^H)] = [qV^e(0|1, \phi^H)]$ which implies that $[qV^e(0|1, \phi^H)] = q\left(\frac{\pi R_t(1-\phi_t)(y_{r,t}(\theta)-P-\mu)}{\lambda} + \beta V^e(0|1)\right)$ when $h^e(h^c = 1, \phi^H) = 0$. We know from our analysis of (A.11) that $V^e(0|1, \phi^H) = 0$ given that $\pi(h^e = 0, h^c = 1) = 0$. The aforementioned discussion thus means that that the continuation value in (A.16) is simply $\beta[qV^e(1|1, \phi^H) + (1-q)V^e(0|0)]$. Therefore, (A.16) can be rewritten as

$$V^e(0|0, \phi^L) = \frac{R_t(y_{e,t}(\theta) - T)}{\lambda} + \beta[qV^e(1|1, \phi^H) + (1-q)V^e(0|0)] \tag{A.17}$$

Note that $V^e(0|0, \phi^L)$ is strictly greater than the elite's value, $V^e(1|0, \phi^L)$. Hence, $V^e(0|0, \phi^L) > V^e(1|0, \phi^L)$ implies that the elite will opt for $h^e = 0$ in response to $h^c = 0$ if $\phi_t = \phi^L$. Thus, for $h^e(h^c = 0, \phi^L) = 0$, it follows from (A.13) that,

$$\begin{aligned} V^e(0|0, \phi^H) &= \frac{R_t(y_{e,t}(\theta) - T)}{\lambda} + \beta V^e(0|0) \\ &= \frac{R_t(y_{e,t}(\theta) - T)}{\lambda(1-\beta)} \end{aligned} \tag{A.18}$$

When $h^c = 0$, $P = 0$ since the elite has no incentives to offer political concessions in this case. It is also plausible that $\phi^H = 0$ (or $\phi^H = \varepsilon$) for $h^c = 0$ as the (i) absence of a challenge from the civilians will do little to no damage the economy's productive capacity and (ii) elite will maintain much (arguably all) of the economy's productive capacity even if $h^e = 1$ for $h^c = 0$ in the state $\phi_t = \phi^H$. Yet for $h^e = 1$, $\mu = \omega + T$ even when $h^c = 0$. Thus, gathering this information together, we obtain the following from equation (A.12) stated earlier: $V^e(1|0, \phi^H) = \frac{R_t(y_{r,t}(\theta) - T - \omega)}{\lambda(1-\beta)}$. One can easily check that $V^e(1|0, \phi^H)$ is strictly greater than $V^e(0|0, \phi^H)$ that is defined in (A.18). This means that $h^e(h^c = 0, \phi^H) = 1$ for $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$.

SECTION B

From Section A of this Lemma's proof described above, we know that in the MPE, the elite always opts for $h^e(h^c = 0, \phi^H) = 1$ *and* also $h^e(h^c = 1, \phi^H) = 1$ for $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$and in the state $\phi_t = \phi^H$. This is recognized by the civilians who thus *anticipate* that $h^e = 1$ for $h^c \in \{0, 1\}$ when $\phi_t = \phi^H$. Hence, the civilians will assess the total value from $h^c = 1$ compared to $h^c = 0$ when $h^e = 1$ for $\phi_t = \phi^H$. They will also compare the value from $h^c = 1$ compared to $h^c = 0$ in the (potential) cases where $h^e = 0$ and thus $P = 1$ for $\phi_t = \phi^H$. Therefore, to complete the proof for Section B of the Lemma, we first demonstrate in Case 1 below that in the MPE, the civilians will opt for $h^c = 1$ even when they expect $h^e = 0$ for $\phi_t = \phi^H$ in the drought $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$where $\theta^* = \frac{b(1-R_t)}{(1-\pi)(1-\phi^H)}$. We next show in Case 2 that in the MPE, the civilians will opt for $h^c = 1$ in anticipation of $h^e = 1$ for $\phi_t = \phi^H$ in a severe drought, $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$.

Case 1: The Bellman equation that determines the civilians' value $V^c(1|\ 0, \phi^H)$ from choosing $h^c = 1$ if they anticipate $h^e = 0$ in the state $\phi_t = \phi^H$ is,

$$V^c(1|0, \phi^H) = \frac{(1-\pi)(1-R_t)\left(1-\phi^H\right)\left(y_{c,t}(\theta) + P - l - m - \omega\right)}{(1-\lambda)} + \beta V^c(1|0, \phi^H) \quad (A.19)$$

When $h^c = 1$ for $h^e = 0$, the civilians fully control de facto political power in current and future periods. As a result, c can change the allocation of consumption resources $(1 - R_t)$

completely in favor of the civilians. Hence, $R_t = 0$, which means that $(1 - R_t) = 1$ in (A.19). Additionally, for $h^c = 1$, $m = 1$ in the expression for $V^c(1|0, \phi^H)$ above and further, since $h^e = 0$, $P = 1$ and $\omega = 0$ in (A.19). Thus, $V^c(1|0, \phi^H)$ can be written as

$$\begin{aligned} V^c(1|0, \phi^H) = & \quad \frac{(1-\pi)\left(1-\phi^H\right)(y_{c,t}(\theta) - l)}{(1-\lambda)} + \beta V^c(1|0, \phi^H) \\ = & \quad \frac{(1-\pi)\left(1-\phi^H\right)(y_{c,t}(\theta) - l)}{(1-\lambda)(1-\beta)} \end{aligned} \tag{A.20}$$

The relevant Bellman equation that determines the civilians' value $V^c(0|\, 0, \phi^H)$ from choosing $h^c = 0$ in anticipation of $h^e = 0$ for $\phi_t = \phi^H$ is

$$V^c(0|0, \phi^H) = \frac{(1 - R_t)(y_{c,t}(\theta) - l)}{(1-\lambda)} + \beta[qV^c(0|0, \phi^H) + (1-q)V^c(0|0, \phi^L)] \tag{A.21}$$

Recall from the proof of Part I of Lemma 1 that $h^e(h^c = 0, \phi^L) = 0$ since $V^e(0|0, \phi^L) > V^e(1|0, \phi^L)$. Because $h^e(h^c = 0, \phi^L) = 0$, the continuation value for $\phi_t = \phi^L$ in (A.21) is $h^c(h^e = 0, \phi^L) = 0$. Thus, the expression in (A.21) is given by

$$\begin{aligned} V^c(0|0, \phi^H) = & \quad \frac{(1 - R_t)(y_{c,t}(\theta) - l)}{(1-\lambda)} + \beta V^c(0|0, \phi^H) \\ = & \quad \frac{(1 - R_t)(y_{c,t}(\theta) - l)}{(1-\lambda)(1-\beta)} \end{aligned} \tag{A.22}$$

In a drought $\gamma_t \sim u[-1, 0)$, the civilians will opt for $h^c = 1$ for $h^e = 0$ in the state $\phi_t = \phi^H$ if and only if $V^c(1|0, \phi^H) > V^c(0|0, \phi^H)$. From the equations in (A.21) and (A.22), one can check after some algebra that $V^c(1|0, \phi^H) > V^c(0|0, \phi^H)$ when $\theta \geqslant \theta^*$ where $\theta^* = \frac{b(1-R_t)}{(1-\pi)(1-\phi^H)}$ with $b > 0$ being a positive constant.

Case 2: Given $V^c(h^c|\, h^e, \phi^H)$ (defined earlier), the relevant Bellman equation that determines the civilians' value $V^c(1|\, 1, \phi^H)$ from choosing $h^c = 1$ when they expect $h^e = 1$ in the state $\phi_t = \phi^H$ is,

$$\begin{aligned} V^c(1|1,\phi^H) &= \frac{(1-\pi)(1-R_t)\left(1-\phi^H\right)\left(y_{c,t}(\theta)+P-l-m-\omega\right)}{(1-\lambda)} + \beta V^c(1|1,\phi^H) \\ &= \frac{(1-\pi)(1-R_t)\left(1-\phi^H\right)\left(y_{c,t}(\theta)+P-l-m-\omega\right)}{(1-\lambda)(1-\beta)} \end{aligned} \quad (A.23)$$

We saw in the proof of Section A in Lemma 1 that when $h^c = 0$, $P = 0$; further, when $h^c = 0$, it follows that $m = 0$. Hence, the Bellman equation that determines the civilians' value $V^c(0|\ 1, \phi^H)$ from choosing $h^c = 0$ in anticipation of $h^e = 1$ in the state $\phi_t = \phi^H$ is

$$V^c(0|1,\phi^H) = \frac{(1-\pi)(1-R_t)\left(1-\phi^H\right)\left(y_{c,t}(\theta)-l-\omega\right)}{(1-\lambda)} + \beta V^c(0|1,\phi^H) \quad (A.24)$$

where $\beta V^c(0|1,\phi^H)$ in (A.24) is the civilians' continuation value in this case. Because the elite stays in office for sure when $h^c = 0$ for $h^e = 1$, $\pi(h^e = 1, h^c = 0) = 1$ and therefore $(1-\pi(h^e = 1, h^c = 0)) = 0$ which implies that $\frac{(1-\pi)(1-R_t)\left(1-\phi^H\right)(y_{c,t}(\theta)-l-\omega)}{(1-\lambda)} = 0$ and $\beta V^c(0|1,\phi^H) = 0$ in (A.24). Hence, $V^c(0|1,\phi^H) = 0$, which means that $V^c(1|1,\phi^H) > V^c(0|1,\phi^H)$ since $V^c(1|1,\phi^H)$ is strictly positive. $V^c(1|1,\phi^H) > V^c(0|1,\phi^H)$ implies that $h^c(h^e = 1, \phi^H) = 1$ (as claimed) which holds for $\gamma_t \sim u[-1,0)$ when $\theta \geqslant \theta^* = \frac{b(1-R_t)}{(1-\pi)(1-\phi^H)}$.

SECTION C

We turn to briefly prove part 2 of Lemma 1, which states that in the absence of a drought $\gamma_t \sim u(0,1]$, $h^e(h^c = 0, \phi_t) = 0$ in the state $\phi_t \in \{\phi^L, \phi^H\}$ for $\theta \in \Re_+$. From the proof of claim 1, one can check that $\left(\frac{D(N_t,L_t)}{L_t} + \frac{D(N,L)}{N_t}\right) > 0$ when $\gamma_t \sim u(0,1]$ and thus it is plausbile (from the converse of claim 2) that $R_t > 0$ and $(1-R_t) > 0$ in the absence of a drought. For $\left(\frac{D(N_t,L_t)}{L_t} + \frac{D(N,L)}{N_t}\right) > 0$ and $(1-R_t) > 0$, it is less likely that c will oppose e which, in turn, implies that $\phi^L = 0$ and $\phi^H = 0$. For $\phi^L = 0$ and likewise, for $\phi^H = 0$, the civilians per capita per period payoff in the political contest state is $\frac{(1-\pi)(1-R_t)(y_{c,t}(\theta)+P-\delta)}{(1-\lambda)}$, while their per capita per period payoff in the status quo state is $\frac{(1-R_t)(y_{c,t}(\theta)-l)}{(1-\lambda)}$. Note that $\frac{(1-\pi)(1-R_t)(y_{c,t}(\theta)+P-\delta)}{(1-\lambda)} < \frac{(1-R_t)(y_{c,t}(\theta)-l)}{(1-\lambda)}$ for not just $P \in \{0,1\}$ but also $\forall \theta \in \Re_+$ when $\gamma_t \sim u(0,1]$. This means that $h^c(\phi_t) = 0$ for $\phi_t \in \{\phi^L, \phi^H\}$ and $\theta \in \Re_+$ given that $h^e \in \{0,1\}$ in this case. Likewise, when $\phi^L = 0$ and $\phi^H = 0$, the elite's per capita per period payoff in the political contest state is $\frac{\pi R_t(y_{c,t}(\theta)-P-\mu)}{\lambda}$, while their per capita per period payoff in the status quo state is $\frac{R_t(y_{c,t}(\theta)-T)}{\lambda}$. $\frac{\pi R_t(y_{c,t}(\theta)-P-\mu)}{\lambda} < \frac{R_t(y_{c,t}(\theta)-T)}{\lambda}$ for not only $P \in \{0,1\}$ but also $\forall \theta \in \Re_+$ when $\gamma_t \sim u(0,1]$. Hence, $h^e(\phi_t) = 0$ for $\phi_t \in \{\phi^L, \phi^H\}$ and $\theta \in \Re_+$ given $h^c \in \{0,1\}$. Therefore, it $\gamma_t \sim u(0,1]$, then $h^e(h^c = 0, \phi_t) = 0$ in the state $\phi_t \in \{\phi^L, \phi^H\}$ for $\theta \in \Re_+$, as stated in part 2 of Lemma 1 in the text.

Subgame Perfect (Nash) Equilibrium Analysis [SPE]: We briefly show below that the MPE result that we report in Lemma 1 also holds in the SPE derived from our model. To this end, note that the payoff to the civilians if they opt to not challenge the elite is equal to the present value of remaining in the political status quo (irrespective of the state ϕ_t): $V^c(0|0,\phi_t) = \frac{(1-R_t)(y_{c,t}(\theta)-l)}{(1-\lambda)} + \beta V^c(0|0,\phi_t)$ which is equivalent to $V^c(0|0,\phi_t) = \frac{(1-R_t)(y_{c,t}(\theta)-l)}{(1-\lambda)(1-\beta)}$. However, if the civilians deviate and instead choose to challenge the regime to depose e, then $V^c(1|1,\phi^H) = \frac{(1-\pi)(1-R_t)\left(1-\phi^H\right)(y_{c,t}(\theta)+P-\delta)}{(1-\lambda)(1-\beta)}$ as civilians challenge the elite in a drought for $\theta \geqslant \theta^*$ only in the state $\phi_t = \phi^H$ (see Lemma 1) but in this SPE case, they will be punished forever after deviation to $h^c = 1$. Following from the proof of Case 1 in Section B of Lemma 1 that that in this SPE case $V^c(1|1,\phi^H) > V^c(0|0,\phi_t)$ when $\theta \geqslant \theta^*$ where $\theta^* = \frac{b(1-R_t)}{(1-\pi)(1-\phi^H)}$; this is exactly the conditions—stated in Part 1 of Lemma 1—under which the civilians opt for $h^c = 1$ against e in the MPE in a drought for $\theta \geqslant \theta^*$. Turning to the elite, we know from the proof in Section A of Lemma 1 that $V^e(0|0,\phi_t) = \frac{R_t(y_{e,t}(\theta)-T)}{\lambda(1-\beta)}$. If the elite deviate and insead opt for $h^e = 1$, then $V^e(1|0,\phi^H) = \frac{R_t\left(1-\phi^H\right)(y_{r,t}(\theta)-P-\mu)}{\lambda} + \beta V^e(1|1,\phi^H)$.Because deviating to $h^e = 1$ will be punished by c forever, $V^e(1|0,\phi^H) = \frac{R_t\left(1-\phi^H\right)(y_{r,t}(\theta)-P-\mu)}{\lambda} + \beta\frac{\pi R_t\left(1-\phi^H\right)(y_{r,t}(\theta)-P-\mu)}{\lambda(1-\beta)}$. One can check that $V^e(1|0,\phi^H) > V^e(1|0,\phi^H)$ when $\theta \geqslant \theta^*$, which is (once again) the the conditions—stated in Part 1 of Lemma 1—under which the elite opts for $h^e = 1$ against c in the MPE in a drought.

Proof of Claim 2: Because R_t includes consumption of food resources, define (without loss of generality) for members in the ruling elite, $R_t = \frac{g\,+\,D(N_t,L_t)}{\lambda}$ where $\frac{D(N_t,L_t)}{\lambda}$ is consumption of food per capita among members in the ruling elite and $\frac{g\,+\,D(N_t,L_t)}{\lambda}$ includes consumption of other economic goods per capita among the ruling elite. Thus for the civilians $(1 - R_t) = \left(1 - \frac{g\,+\,D(N_t,L_t)}{\lambda}\right)$. For $\left(\frac{D(N_t,L_t)}{L_t} + \frac{D(N,L)}{N_t}\right) < 0$ during the drought $\gamma_t \sim -u[1,0)$, $R_t^{'} = \frac{g\,+\left(\frac{D(N_t,L_t)}{L_t} + \frac{D(N,L)}{N_t}\right)}{\lambda}$. Because $\left(\frac{D(N_t,L_t)}{L_t} + \frac{D(N,L)}{N_t}\right) < 0$, $R_t^{'} < R_t$ which further implies that $(1 - R_t^{'}) < (1 - R_t)$.

Proof of Proposition 1: $V^c(1|0,\phi^H)$ denotes $h^c(h^e = 0,\phi^H) = 1$ while $V^c(0|0,\phi^H)$ denotes $h^c(h^e = 0,\phi^H) = 0$. Recall from equations (A.20) and (A.22) respectively in the proof of Lemma 1

$$
\begin{aligned}
V^c(1|0,\phi^H) &= \frac{(1-\pi)\left(1-\phi^H\right)(y_{c,t}(\theta) - l)}{(1-\lambda)(1-\beta)} \\
V^c(0|0,\phi^H) &= \frac{(1-R_t)(y_{c,t}(\theta) - l)}{(1-\lambda)(1-\beta)}
\end{aligned}
\tag{A.25}
$$

As shown in the proof of Section B of Lemma 1, $V^c(1|0,\phi^H) > V^c(0|0,\phi^H)$, if $\gamma_t \sim u[-1,0)$ when $\theta \geqslant \theta^*$ where $\theta^* = \frac{b(1-R_t)}{(1-\pi)(1-\phi^H)}$. Next, from (A.23) and (A.24) respetively in Lemma 1 above, we obtain

$$
V^c(1|1,\phi^H) = \frac{(1-\pi)(1-R_t)\left(1-\phi^H\right)(y_{c,t}(\theta) + P - l - m - \omega)}{(1-\lambda)(1-\beta)} \tag{A.26}
$$

$$
V^c(0|1,\phi^H) = \frac{(1-\pi)(1-R_t)\left(1-\phi^H\right)(y_{c,t}(\theta) - l - \omega)}{(1-\lambda)} + \beta V^c(0|1,\phi^H) \tag{A.27}
$$

As noted in the proof of Section B in Lemma 1, $V^c(1|1,\phi^H) > V^c(0|1,\phi^H)$ and hence $h^c(h^e = 1,\phi^H) = 1$ holds for $\gamma_t \sim u[-1,0)$ when $\theta \geqslant \theta^*$, as claimed.

Proof of Proposition 2: $V^e(1|1,\phi^H)$ denotes $h^e(h^c = 1,\phi^H) = 1$ while $V^e(0|1,\phi^H)$ denotes $h^e(h^c = 0,\phi^H) = 0$. We saw in the proofs of part II of Lemma 1 and Proposition 1 that $h^c(h^e = 1,\phi^H) = 1$ and $h^c(h^e = 0,\phi^H) = 1$ for $\gamma_t \sim u[-1,0)$ when $\theta \geqslant \theta^*$. From equations (A.10) and (A.11) respectively in the proof of Lemma 1,

$$V^e(1|1,\phi^H) = \frac{\pi R_t\left(1-\phi^H\right)\left(y_{e,t}(\theta)-P-\mu\right)}{\lambda(1-\beta)}$$
$$V^e(0|1,\phi^H) = \frac{\pi R_t\left(1-\phi^H\right)\left(y_{e,t}(\theta)-P-\mu\right)}{\lambda}+\beta V^e(0|1) \tag{A.28}$$

We demonstrated in Lemma 1 that $V^e(1|1,\phi^H) > V^e(0|1,\phi^H)$ for $\gamma_t \sim u[-1,0)$ when $\theta \geqslant \theta^*$. From equations (A.12) and (A.18) respectively in the proof of Lemma 1,

$$V^e(1|0,\phi^H) = \frac{R_t\left(1-\phi^H\right)\left(y_{e,t}(\theta)-P-\mu\right)}{\lambda(1-\beta)}$$
$$V^e(0|0,\phi^H) = \frac{R_t(y_{e,t}(\theta)-T)}{\lambda(1-\beta)} \tag{A.29}$$

As shown in Section A of Lemma 1, $V^e(1|0,\phi^H) > V^e(0|0,\phi^H)$ for $\gamma_t \sim u[-1,0)$ when $\theta \geqslant \theta^*$.

Proof of Proposition 3: From the proofs of Section B in Lemma 1 and Proposition 1, we know that for $\gamma_t \sim u[-1,0)$, if $\theta \geqslant \theta^*$ then $h^c = 1$ and $V^c(h^c|\ h^e,\phi_t)$ is such that $V^c(1|1,\phi^H)$ $> V^c(0|1,\phi^H)$ and $V^c(1|0,\phi^H) > V^c(0|0,\phi^H)$ in the state $\phi_t = \phi^H$. Thus the civilians will opt for and not deviate from $h^c = 1$ in the state $\phi_t = \phi^H$ for $\gamma_t \sim u[-1,0)$ when $\theta \geqslant \theta^*$. From the proofs of Section A in Lemma 1 and Proposition 2, $V^e(h^e|\ h^c,\phi_t)$ is such that $V^e(1|1,\phi^H) >$ $V^e(0|1,\phi^H)$ and $V^e(1|0,\phi^H) > V^e(0|0,\phi^H)$ for $\phi_t = \phi^H$. Thus the ruling elite will choose and not deviate from $h^e = 1$ in response to $h^c = 1$ in the state $\phi_t = \phi^H$ for $\gamma_t \sim u[-1,0)$ when $\theta \geqslant \theta^*$. Further, from the definition of MPE and (background) Claim A stated above, the state stops fluctuating once $K_t\{h^e(h^c = 1,\phi^H) = 1\}$, which means that $\phi_t^H = \phi_{t-1}^H(K_{t-1} = 1)$ and $\phi_{t+1}^H = \phi_t^H(K_t = 1)$. This implies that $K_t = \max\{h^c, h^e\} = 1$ for $\phi_t = \phi^H$ emerges as a *stationary* Markov perfect equilibrium in pure strategies for $\gamma_t \sim u[-1,0)$ when $\theta \geqslant \theta^*$.

Proof of Claim 3: $\frac{y_{c,t}(\theta)}{(1-\lambda)}$ increases in θ, since by construction, $y_{c,t}(\theta)$ (weakly) increases in θ and $(1-\lambda) > 0$. Recall from the text that the civilians' per capita per period payoff if they opt to challenge the elite is $\frac{(1-\pi)(1-R_t)(1-\phi^H)(y_{c,t}(\theta)+P-\delta)}{(1-\lambda)}$ where $\delta = l+\omega$ and $(y_{c,t}(\theta)+P-\delta)$

is their net return from doing so. When $h^c = 1$ for $h^e \in \{0, 1\}$, then $m = 1$. Further, for $h^c = 1$, it is plausible that $P = 1$. This implies that the civilians net return per capita from challenging the elite for $\theta \geqslant \theta^*$ is $\frac{(y_{c,t}(\theta)-l-\omega)}{(1-\lambda)}$. Note that $(y_{c,t}(\theta) - 1 - l) \geqslant 0$ for $\omega = 1$ as $y_{c,t}(\theta)$ (weakly) increases in θ. Further, from the expressions for $V^c(1|1, \phi^H)$ and $V^c(1|0, \phi^H)$ in Lemma 1, we find that $V^c(1|1, \phi^H) > 0$ and $V^c(1|0, \phi^H) > 0$ for $y_{c,t}(\theta)$ (weakly) increasing in θ in the state $\phi_t = \phi^H$ for $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$. This implies that if $\theta \in [\underline{\theta}, \overline{\theta}]$, then $\frac{(y_{c,t}(\overline{\theta})-1-l)}{(1-\lambda)} > \frac{(y_{c,t}(\underline{\theta})-l)}{(1-\lambda)}$ for $\theta \geqslant \theta^*$ in the state $\phi_t = \phi^H$ when $\gamma_t \sim u[-1, 0)$.

Proof of Claim 4: Recall that the civilians per capita per period payoff in the political contest state is $\frac{(1-\pi)(1-R_t)(1-\phi_t)(y_{c,t}(\theta)+P-\delta)}{(1-\lambda)}$ where $\delta = l + m + \omega$. Further, recall that that the authoritarian polity is populated by a continuum of measure one of individuals where $\lambda < 1/2$ is the population share of the elite, while $(1 - \lambda) > 1/2$ is the population share of the civilians; hence by construction, $\lambda + (1 - \lambda) = 1$. Suppose that $\frac{(1-\pi)(1-R_t)(1-\phi_t)(y_{c,t}(\theta)+P-\delta)}{(1-\lambda)} = 1$ given that the authoritarian polity is populated by a continuum of measure one of individuals. From this aforementioned expression, it follows after some algebra that $1 - \frac{1}{(1-\pi)(1-R_t)(1-\phi_t)(y_{c,t}(\theta)+P-l-m-\omega)} = \lambda$. For $h^c(h^e = 1, \phi_t\} = 1$ and thus $K_t = \max\{h^c, h^e\} = 1$ in the state $\phi_t = \phi^H$ (see Proposition 3), it must be the case that $m = 1$ and $\omega = 1$. Further, as shown in the proof of claim 5 below, in the limit, it is plausible that for $K_t = \max\{h^c, h^e\} = 1$ in the state $\phi_t = \phi^H$, $\pi \to 1$ and hence $(1 - \pi) \to 0$. For $m = 1$, $\omega = 1$ and $(1 - \pi) \to 0$, $\lim_{(1-\pi)\to 0} \lambda = 1 - \frac{1}{(1-\pi)(1-R_t)(1-\phi_t)(y_{c,t}(\theta)+P-l-m-\omega)} \to 1$. For $\lim_{(1-\pi)\to 0} \lambda \to 1$, $(1 - \lambda)$ strictly decreases as claimed. Because civilians residing in developed urban areas in the autocratic polity are drawn entirely from $(1 - \lambda)$, a strict decrease in $(1 - \lambda)$ means that a decline in the population share of civilians in developed urban areas when $K_t = \max\{h^c, h^e\} = 1$ in the state $\phi_t = \phi^H$ (which exists as a MPE in a drought if $\theta \geqslant \theta^*$).

Proof of Claim 5: Suppose that $h^e = 0$ in response to $h^c = 1$ for $\gamma_t \sim u[-1, 0)$ when $\theta \geqslant \theta^*$. Then $\pi(h^e = 0, h^c = 1) = 0$ and therefore $(1 - \pi(h^e = 0, h^c = 1)) = 1$. In contrast, suppose that $h^e = 1$ in response to $h^c = 1$. Then it is possible that $\overline{\pi}(h^e = 1, h^c = 1) = 1/2$

or *at the very least* $\underline{\pi}(h^e = 1, h^c = 1) > 0$. Thus, Claim 5 holds as $\overline{\pi}(h^e, h^c) > \pi(h^e, h^c)$ and $\underline{\pi}(h^e, h^c) > \pi(h^e, h^c)$.

Summary Statistics

Table A1: List of Countries Analyzed and Years as Autocracy

Country	Beginning year	End Year	Country	Beginning year	End Year
Cuba	1995	2009	Haiti	2000	2004
Mexico	1995	2000	Guatemala	1995	1995
Venezuela	2006	2009	Peru	1995	2000
Yugoslavia	1995	2000	Russian Federation	1995	2009
Belarus	1995	2009	Armenia	1995	2009
Georgia	1995	2003	Azerbaijan	1995	2009
Guinea-Bissau	1995	2003	Gambia	1995	2009
Senegal	1995	2000	Mauritania	1995	2009
Niger	1997	1999	Cote d'Ivoire	1995	2009
Guinea	1995	2009	Burkina Faso	1995	2009
Liberia	1998	2003	Sierra Leone	1995	1998
Ghana	1995	2000	Togo	1995	2009
Cameroon	1995	2009	Nigeria	1995	1999
Gabon	1995	2009	Central African Republic	2004	2009
Chad	1995	2009	Congo (Brazzaville)	1998	2009
Congo (Kinshasa)	1995	2009	Uganda	1995	2009
Kenya	1995	2002	Tanzania	1995	2009
Burundi	1997	2003	Rwanda	1995	2009
Eritrea	1995	2009	Angola	1995	2009
Mozambique	1995	2009	Zambia	1997	2009
Zimbabwe	1995	2009	Namibia	1995	2009
Botswana	1995	2009	Swaziland	1995	2009
Morocco	1995	2009	Algeria	1995	2009
Tunisia	1995	2009	Libya	1995	2009
Sudan	1995	2009	Iran	1995	2009
Iraq	1995	2003	Egypt	1995	2009
Syrian Arab Republic	1995	2009	Jordan	1995	2009
Saudi Arabia	1995	2009	Kuwait	1995	2009
United Arab Emirates	1995	2009	Oman	1995	2009
Afghanistan	1997	2001	Turkmenistan	1995	2009
Tajikistan	1995	2009	Kyrgyzstan	1995	2009
Uzbekistan	1995	2009	Kazakhstan	1995	2009
China	1995	2009	Taiwan	1995	2000
Korea (North)	1995	2009	Pakistan	2000	2008
Bangladesh	2008	2008	Myanmar	1995	2009
Nepal	2003	2006	Thailand	2007	2007
Cambodia	1995	2009	Laos	1995	2009
Malaysia	1995	2009	Singapore	1995	2009
Indonesia	1995	1999			

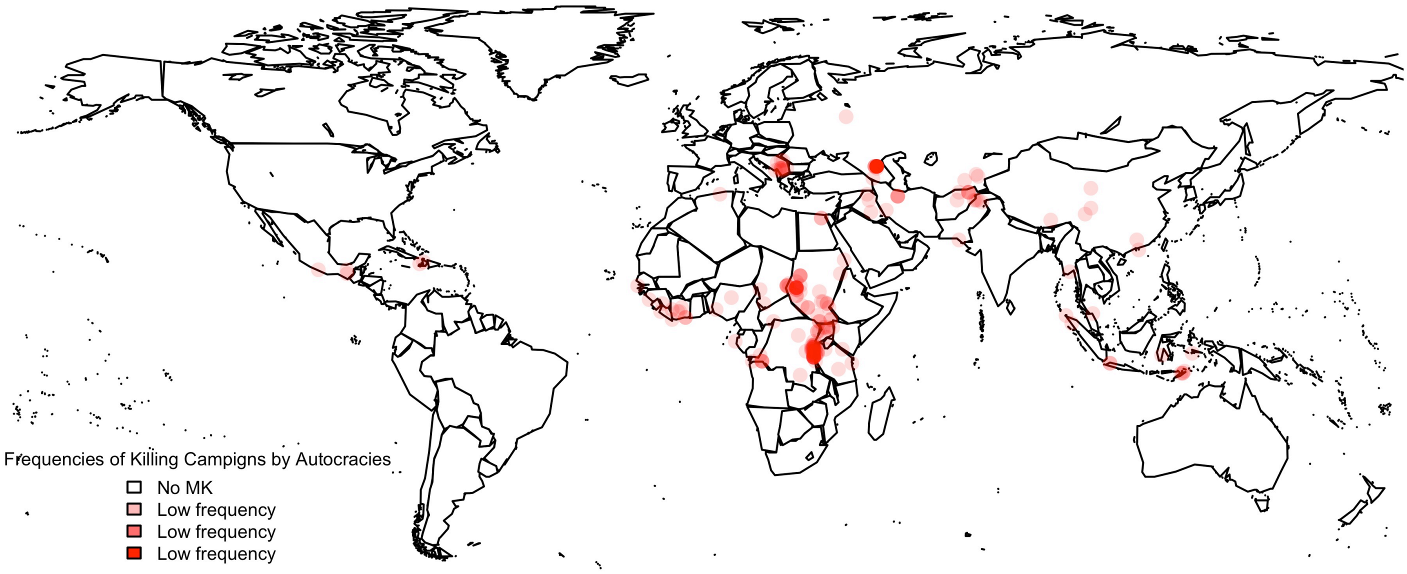
Note: 2009 was the last year observed in the sample.

Table A2: Summary Statistics for Dependent and Independent Variables, 1996-2008

	Median	**Mean**	**Std. Dev.**	**Min**	**Max**
Cell level indicators					
$Killing\ Campaigns_t$	0	0.0004	0.020	0	1
$Killing\ Campaigns_{t-1}$	0	0.0004	0.020	0	1
$Urban\ Development\ PC_t$	0	0.039	0.170	0	4.944
$Urban\ Development\ PC_{t-1}$	0	0.038	0.170	0	4.944
$Drought_t$	0	0.008	0.087	0	1
$GCP_t{}^1$	0.067	0.358	0.634	0	5.995
$GCP_{t-1}{}^1$	0.065	0.352	0.625	0	5.995
$Population_t{}^1$	8.449	8.198	3.042	0	16.519
$Population_{t-1}{}^1$	8.422	8.181	3.035	0	16.519
$Conflict_t$	0	0.063	0.243	0	1
$Conflict_{t-1}$	0	0.062	0.241	0	1
$Party_t$	0	0.299	0.458	0	1
$Personal_t$	1	0.613	0.487	0	1
$Monarch_t$	0	0.041	0.198	0	1
$Intentional\ Deaths_t$	0	0.110	6.854	0	1,262
$Intentional\ Deaths_{t-1}$	0	0.111	7.101	0	1,262
$Mean\ Night\ Light_t$	0	0.749	2.471	0	58.365
B. dist.[1]	5.743	5.595	1.433	0	9.306
T. Time[1]	6.340	6.439	1.110	0	10.310
Cap. Dist.[1]	7.117	7.091	1.106	1.609	8.870
$Drought\ (Alt.)_t$	0	0.021	0.143	0	1
Country level indicators					
$Drought\ (Count.)_t$	0	0.033	0.178	0	1
$Polity2_t$	3	-0.324	5.490	-10	9
$Polity2_{t-1}$	2	-0.380	5.503	-10	9
$GDP\ PC_t{}^1$	8.917	8.566	0.973	5.298	11.084
$GDP\ PC_{t-1}{}^1$	8.917	8.547	0.962	5.298	11.084
$Oil_t{}^1$	19.007	16.612	5.845	0	19.980
$Oil_{t-1}{}^1$	19.007	16.613	5.842	0	19.980
$Gas_t{}^1$	6.103	5.522	3.055	0	8.424
$Violent\ Civil\ Disobedience_t$	0	0.4	0.49	0	1
$Violent\ Civil\ Disobedience_{t-1}$	0	0.429	0.495	0	1

[1] Natural log.

Figure A1: Killing Campaigns By Country for All Autocratic Countries, 1996-2008 (PITF)



Robustness Analysis and Additional Plots

Robustness Models

To verify the robustness of the findings presented in the main paper we replicate our Full model specification from the main paper, accounting for a variety of different specifications, potential confounders, and modeling approaches in Tables A3–A4. First, in Model A.1 we employ an alternative cell level drought indicator that is more sensitive to temporal issues; rather than focusing on the number of months in a given year that experienced drought, we simply dichotomize this variable based on whether the final month of the rainy season in a given grid cell was two or more standard deviations below the mean during year t. Second, because the effect of droughts might "spillover" from different cells, and could even trigger migration from rural to urban areas, we create a new, *country* level indicator of drought in Model A.2. This indicator was also obtained from the PRIO-Grid dataset (Tollefsen et al., 2012), and was dichotomized based on whether *any grid cell within a given country* experienced precipitation levels measured at 1.5 standard deviations or more below the mean for a consecutive streak of five months or more. A value of one was given to all cells within a given country during year t if this was the case, zero otherwise.

Third, to illustrate that the effect *Urban Development* PC_t is not simply driven by the difference between urban and rural areas, but rather by *higher levels* of urban development per capita levels, we reestimate our main models on a subsample consisting solely of cells with some level of urbanization (Bontemps, Defourny and Van Bogaert, 2009) in Model A.3. Using these "urban cells only" sample thus illustrates that the interaction of drought and higher urban development levels per capita, specifically, is associated with killing campaigns by state forces, and not the fact that urban areas are more likely to have a higher number of targets or preexisting organized resistance movements compared with non-urban areas. Fourth, some studies suggest that party-based regimes are less prone to repress their subjects compared with rulers in other "types" of authoritarian regimes (Davenport, 2007*b*). Hence, in Model A.4 we replicate our Full model with the inclusion of dummies denoting whether the autocratic regime was party-based, personalist, or monarchic during year t (with military regimes being the reference category). Fifth, we relax some of the theoretical assumptions used to code *Urban Development* PC_t by using a more generalized indicator of nighttime light levels in a given cell during year t (Tollefsen et al., 2012) in Model A.5.

Sixth, we show that our findings are robust to the decision not to use lagged indicators due to the inferential biases such lagging might generate (Bellemare, Masaki and Pepinsky, 2017) by lagging all our indicators (excluding $Drought_t$) by one year in Model A.6. Seventh, to account for the possibility that the interactive effect of urban development levels per capita and drought is driven by our choice of how to dichotomize our dependent variable, we reestimate our Full specifications in ordinary least squares (OLS) framework and using a continuous dependent variable measuring the total number of civilians killed by government forces in a given cell during a given year (PITF, 2009) in Model A.7. Eight, to address the potential effect of spatial and serial correlations at higher levels of aggregation, we re-estimate the Full model, where standard errors are clustered at the country level, in model A.8. Finally, because killing campaigns are a rare event, with more than 90% zero values on our *Killing* $Campaigns_t$ indicator, we reestimate the empirical specifications presented in our main models using the rare-events logit model, which is better suited to these data (King and Zeng, 2001) in Model A.9.

Finally, while we included fixed effects by country in our models as to allow for both within- and across-cell effects within a given country, this choice might affect our ability to draw causal inference from these models. Alternatively, we could isolate only within-cell variations using fixed effects by grid cell, our cross-sectional unit of analysis. Indeed, the use of unit of analysis fixed effects – i.e., including binary variables for the units of analysis, in this case grid cells, to capture observed and unobserved influences on an outcome of interest (the frequency of conflict in this case) that are constant over time – is a well-established statistical procedure for identifying causal relationships (Angrist and Pischke, 2009). However, the computational requirements of estimating such models within a logit framework prevented us from reestimating the models used in the main paper. Instead, we use a more flexible generalization of the linear model, where all variables are demeaned and the "within-transformation" is applied to multiple factors (Gaure, 2013). It is important to note that relying on such models when the dependent variable is binary can inflate standard errors, thus making it more likely that our hypothesis will be rejected (i.e., a "type II error"). Because the coefficient estimates in such linear probability models remain unbiased estimates of the true parameter values β (see Long, 1997, 34-83), we decided to still rely on these models, but not to cluster standard errors by grid-cell considering that doing so can lead to false inferences under such contexts (King and Roberts, 2014). As Table A5 illustrates, our findings hold when unit-of-analysis fixed effects are used and only within-grid-cell variations are isolated, suggesting that our findings are robust even to these more rigorous empirical standards. Note than in these models the variables *Travel Time* and *Distance to Capital* are dropped from analysis as these indicators do not vary over time and are constant for each grid cell within the sample.

Table A3: **Robustness Analyses**

	A.1 Alt. Drought	A.2 Count. Drought	A.3 Urban Only	A.4 Regime Type	A.5 NTL
Urban Development PC$_t$	1.118* (0.352)	1.102* (0.350)	1.645* (0.387)	0.750* (0.301)	–
Nighttime light$_t$	0.097*	–	–	–	0.095* (0.024)
Drought$_t$	–	–	0.577 (0.917)	0.001 (0.794)	−0.239 (0.807)
Drought (Alt.)$_t$	−0.281 (0.465)	–	–	–	–
Drought (Count.)$_t$	–	−1.559 (1.177)	–	–	–
Drought$_t$ × *Urban Development PC*$_t$	–	–	3.296* (1.034)	3.234* (0.918)	–
Drought (Alt.)$_t$ × *Urban Development PC*$_t$	0.941* (0.458)	–	–	–	–
Drought (Count.)$_t$ × *Urban Development PC*$_t$	–	1.868* (0.735)	–	–	–
Drought$_t$ × *Nighttime light*$_t$	–	–	–	–	0.269* (0.073)
Killing Campaigns$_{t-1}$	2.173* (0.335)	2.161* (0.336)	0.989* (0.527)	2.615* (0.332)	2.125* (0.336)
Violent Civil Disobedience$_{t-1}$	0.062 (0.398)	0.155 (0.406)	−0.457 (0.605)	0.528 (0.272)	0.080 (0.401)
GCP$_t$[1]	−0.346 (0.266)	−0.318 (0.265)	−0.398 (0.335)	−0.215 (0.234)	−0.509 (0.283)
Population$_t$[1]	0.556* (0.117)	0.549* (0.118)	0.352* (0.176)	0.654* (0.105)	0.544* (0.116)
Border Distance[1]	−0.415* (0.075)	−0.415* (0.075)	−0.251 (0.133)	−0.440* (0.066)	−0.416* (0.075)
Travel Time[1]	−0.895* (0.203)	−0.898* (0.203)	−0.824* (0.306)	−0.843* (0.188)	−0.926* (0.200)
Distance to Capital[1]	0.349* (0.135)	0.366* (0.136)	0.272 (0.171)	0.231* (0.101)	0.363* (0.136)
Conflict$_t$	2.186* (0.254)	2.178* (0.253)	2.536* (0.383)	2.223* (0.231)	2.257* (0.258)
Polity2$_t$	0.155* (0.058)	0.155* (0.058)	0.098 (0.073)	0.026 (0.027)	0.150* (0.060)
GDP PC$_t$[1]	0.818 (0.884)	0.889 (0.886)	−0.165 (1.226)	0.040 (0.169)	0.794 (0.892)
Oil$_t$[1]	0.163 (0.132)	0.164 (0.133)	0.600 (0.353)	0.030 (0.019)	0.162 (0.134)
Gas$_t$[1]	−0.121 (0.352)	−0.096 (0.353)	0.194 (0.459)	−0.273* (0.084)	−0.130 (0.358)
Party$_t$	–	–	–	−0.009 (0.425)	–
Personal$_t$	–	–	–	0.179 (0.343)	–
Monarch$_t$	–	–	–	−14.117 (291.937)	–
Constant	−6.409 (6.949)	−7.054 (6.970)	−11.853 (36,217.990)	−8.591* (2.716)	−6.062 (6.990)
Observations	347,816	347,816	63,058	347,816	349,101
Log Likelihood	−757.075	−755.984	−348.575	−817.877	−749.015
Akaike Inf. Crit.	1,700.149	1,697.967	879.149	1,699.755	1,684.030

Note: * indicates $p < 0.05$.
Values in parentheses are robust standard errors clustered by cell-id.
All models include year and country fixed effects, excluding the Regime Type model.
[1] In natural log form.

Table A4: **Robustness Analyses - Continued**

	A.6 Lagged	A.7 N. Deaths	A.8 CSEs	A.9 RE Logit
Urban Development PC_{t-1}	–	0.895* (0.359)	–	–
Urban Development PC_t	–	0.501* (0.077)	1.112* (0.357)	1.134* (0.354)
$Drought_t$	−0.074 (0.785)	−0.221 (0.122)	−0.176 (0.819)	0.129 (0.816)
$Drought_t$ × *Urban Development* PC_{t-1}	3.225* (0.840)	–	–	–
$Drought_t$ × *Urban Development* PC_t	–	9.693* (1.009)	3.755* (0.923)	3.540* (0.956)
Killing $Campaigns_{t-1}$	2.247* (0.340)	–	2.201* (0.333)	2.125* (0.335)
Violent Civil $Disobedience_{t-1}$	0.488 (0.391)	−0.098* (0.050)	0.076 (0.399)	0.107 (0.400)
State $Deaths_{t-1}$	–	0.268* (0.002)	–	–
${GCP_{t-1}}^1$	−0.282 (0.267)	–	–	–
${GCP_t}^1$	–	−0.005 (0.030)	−0.279 (0.266)	-0.304 (0.267)
${Population_{t-1}}^1$	0.585* (0.115)	–	–	–
${Population_t}^1$	–	0.016 (0.010)	0.540* (0.115)	0.515* (0.117)
Border Distance[1]	−0.378* (0.074)	−0.025* (0.011)	−0.433* (0.075)	-0.426* (0.075)
Travel Time[1]	−0.904* (0.202)	−0.010 (0.018)	−0.921* (0.203)	-0.928* (0.202)
Distance to Capital[1]	0.349* (0.135)	0.067* (0.020)	0.398* (0.133)	0.352* (0.136)
$Conflict_{t-1}$	0.949* (0.246)	–	–	
$Conflict_t$	–	0.820* (0.055)	2.240* (0.259)	2.187* (0.256)
$Polity2_{t-1}$	0.176* (0.084)	–	–	–
$Polity2_t$	–	0.039* (0.008)	0.145* (0.059)	0.139* (0.060)
$GDP\ {PC_{t-1}}^1$	1.593 (0.873)	–	–	–
$GDP\ {PC_t}^1$	–	0.010 (0.106)	0.741 (0.888)	0.828 (0.888)
${Oil_{t-1}}^1$	0.147 (0.111)	–	–	–
${Oil_t}^1$	–	0.005 (0.010)	0.147 (0.130)	0.109 (0.133)
${Gas_{t-1}}^1$	0.274 (0.351)	–	–	–
${Gas_t}^1$	–	0.013 (0.037)	−0.098 (0.359)	-0.183 (0.360)
Constant	−10.922 (6.995)	5.833* (1.115)	−11.317 (6.457)	-5.756 (6.977)
Observations	348,582	347,816	347,816	347,816
R^2	–	0.076	–	–
Adjusted R^2	–	0.076	–	–
Log Likelihood	−788.553	–	−754.382	–
Akaike Inf. Crit.	1,763.106	–	1,692.764	1,690.20

Note: * indicates $p < 0.05$.
Values in parentheses are robust standard errors clustered by cell-id, excluding Model A.8, where standard errors were clustered at the country level.
All models include year and country fixed effects.
[1] In natural log form.

Table A5: **Killing Campaigns by Government Forces, 1996-2008 – Grid Cell Fixed Effects**

	A.10 Baseline	**A.11 Medium**	**A.12 Full**
Urban Development PC_t	0.001	0.003*	0.003*
	(0.001)	(0.001)	(0.001)
$Drought_t$	−0.001	−0.0004	−0.0003
	(0.0004)	(0.0004)	(0.0004)
$Drought_t$ × *Urban Development* PC_t	0.055*	0.062*	0.062*
	(0.003)	(0.003)	(0.003)
Killing $Campaigns_{t-1}$	−0.052*	−0.040*	−0.041*
	(0.002)	(0.002)	(0.002)
Violent Civil $Disobedience_{t-1}$	–	0.0003	−0.0001
		(0.0001)	(0.0002)
GCP_t[1]	–	−0.001	−0.001*
		(0.001)	(0.001)
$Population_t$[1]	–	0.0003	0.001*
		(0.0003)	(0.0004)
Border Distance[1]	–	0.0001	0.00002
		(0.002)	(0.002)
$Conflict_t$	–	–	0.003*
			(0.0002)
$Polity2_t$	–	–	0.0001*
			(0.00002)
GDP PC_t[1]	–	–	0.001
			(0.0003)
Oil_t[1]	–	–	0.00003
			(0.00003)
Gas_t[1]	–	–	0.0001
			(0.0001)
Observations	371,183	347,849	347,816
R^2	0.187	0.178	0.178
Adjusted R^2	0.108	0.095	0.096

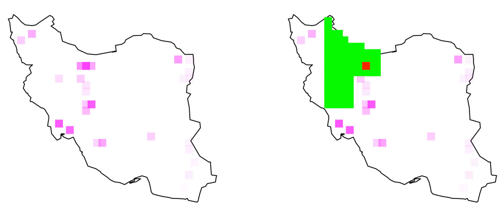
Note: * indicates $p < 0.05$.
Coefficient values are reported with standard errors in parentheses.
All models include year and grid-cell fixed effects.
[1] In natural log form.

Visual Evaluation of Effects by Grid Cell

To further illustrate our analysis' substantive effect and provide a more contextualized evaluation of our results, we report below the by-0.5-degree-cell maps for three separate states, representing three different world regions, for the years 1998 and 1999 (to provide an opportunity to evaluate within-case variations in addition to variations across cases). For each case, urban development per capita (UDPC) levels are reported over the period (in purple), as well as the number of grid cells affected by drought (green) if any, and whether a killing campaign (KC) occurred (red). The title of each map also includes the maximum level of urban development in said country of the 1998-1999 period.

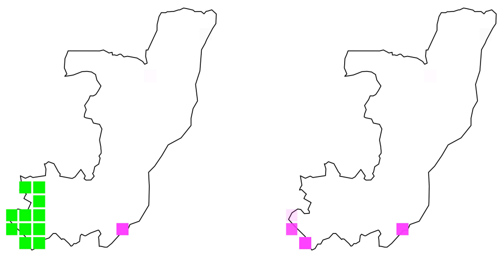
The first case, 1998-1999 Iran, is reported in Figure A2 to further explore the effect of severe drought in authoritarian countries with high urban development per capita levels. As this figure illustrates, Iran has a rather high levels of urban development per capita, with a maximum for the period of 2.67. In 1998 the country experienced no drought and no killing campaign, despite its high urban development levels. In 1999, however, a severe drought occurs, and a killing campaign is perpetrated in the capital, Tehran.

Figure A2: Iran (max UDPC=2.67): (left) 1998 – high UDPC, no drought, no KC; (right) 1999 – high UDPC, drought, a KC;



The second case, 1998-1999 Republic of Congo, is reported in Figure A3 to illustrate a scenario where, even though drought occurs, urban development per capita levels within the autocratic state are low, and a killing campaign is not reported. The maximum level of UDPC in Congo over the 1998-1999 period is a low 0.75, mostly concentrated in the southern part of the state, around Point Noir and Dolisie (southwest) and the capital Brazzaville (southeast). As Figure A3 illustrates, while the urbanized area of the state experienced a severe drought in 1998 no killing campaign occurred. Violence did not occur in 1999, when there no severe drought was reported.

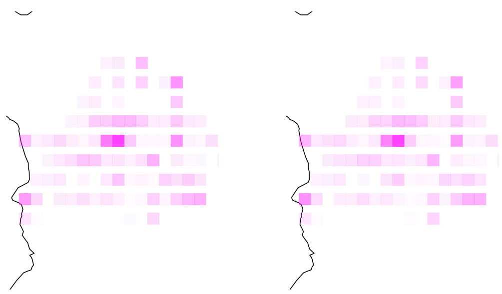
Figure A3: Congo (max UDPC=0.75): (left) 1998 – low UDPC, no drought, no KC; (right) 1999 – low UDPC, drought, no KC;



The second case, 1998-1999 Belarus, is reported in Figure A4 to illustrate a scenario where, even though urban development per capita levels within the autocratic state are relatively high, no drought had occurred, and a killing campaign was not reported.[5] The maximum level of UDPC in Belarus over the 1998-1999 period is a medium-to-high 1.32. As Figure A4 illustrates, even though most of the state's area is urbanized to some extent, it experienced no drought and no killing campaigns over the 1998-1999 period.

[5]Note that state borders are not delineated in this figure as the "maps" package in R used to compile them reports only a USSR map. Nevertheless, the state's borders are reflected in the distribution of urbanization within its territory.

Figure A4: Belarus (max UDPC=1.32): (left) 1998 – high UDPC, no drought, no KC; (right) 1999 – high UDPC, no drought, no KC;



Overall, then, Figures A2-A4 provide an way of "looking inside the data" to illustrate where the associations reported in the main article come from, and point to some cases that follow our research hypothesis. These figures hence land support to the associations between high urban development, economic/climatic shocks, and state violence as developed in the main article.

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