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Butter, Guns, and Ice Cream under Climate Shocks: Scarcity Pricing, Predation, and Price Stabilization

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Butter, Guns, and Ice Cream under Climate Shocks: Scarcity Pricing, Predation, and Price Stabilization*

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Abstract

This preliminary note aims to provide a theoretical model to accommodate the apparent contradictions emerging in the literature on the climate change–violent conflict nexus. In particular it builds on the butter–guns–ice-cream framework of Caruso (2010) to study how climate shocks can influence the emergence of violence between groups when agriculture is the main economic activity. Two groups allocate a fixed endowment between contested agricultural production ("butter") and coercion ("guns"). The safe activity ("ice cream") yields diminishing marginal returns and is determined residually by the budget constraint once butter and guns are chosen. A common climate shock shifts agricultural productivity. Allowing exposure to differ across groups generates realized asymmetries in the contested production. In a further extension, the relative price of the contested good responds endogenously to effective scarcity. In fact, the model nests two mechanisms within a unified structure. The first is an opportunity-cost margin, operating through the returns to peaceful activity. The second is a rapacity (prize-value) margin, operating through the value of contested production. We allow conflict to be inconclusive by modeling stalemate in the contest success function. In addition, we introduce endogenous destructiveness, decreasing in aggregate coercion. We also incorporate an institutional-capacity parameter that moderates violence by dampening scarcity-driven price spikes. The analysis proceeds from a benchmark to a sequence of extensions. The benchmark delivers a tractable equilibrium characterization and transparent sufficient conditions for the main comparative statics. The extensions show how endogenous destruction, scarcity pricing, and price stabilization attenuate incentives and generate empirically relevant nonlinearities, without overturning the core sign predictions.

Keywords: climate shocks; conflict models; butter and guns; opportunity cost; rapacity; institutions; food prices.

JEL codes: D74, O13, Q54, Q18.

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1 Introduction

A large empirical literature documents that weather and climate shocks are strongly related to agricultural outcomes, yet their relationship to violence is heterogeneous across settings and specifications. Canonical contributions emphasize income and opportunity-cost channels whereby adverse shocks reduce earnings and lower the cost of recruitment into violence (Koubi, 2019; Blattman and Miguel, 2010). Other work highlights prize-value and rapacity channels, especially when scarcity triggers relative price spikes that increase the value of appropriable resources (McGuirk and Nunn, 2025; Dube and Vargas, 2013). At the same time, the climate–conflict relationship remains contested and context-dependent, with mixed evidence across data sets, periods, and institutional environments (Buhaug et al., 2023; Helman et al., 2020; Von Uexkull et al., 2016; Buhaug, 2010; Hsiang et al., 2013).

This paper develops a theoretical framework designed to accommodate this heterogeneity rather than rule it out by assumption. The key idea is that climate shocks can affect conflict incentives through two conceptually distinct margins that need not move in lockstep: the *opportunity cost* of coercion (via changes in returns to peaceful activity) and the *value of the prize* over which groups fight (via changes in the quantity and, when prices adjust, the value of contested resources). By embedding both margins in a single contest environment with a contested agricultural sector and a safe sector, the model yields transparent conditions under which adverse shocks dampen or fuel violence, and why sign patterns can differ across contexts.

We start from the "butter–guns–ice cream" model of Caruso (2010), which studies resource allocation between a contested sector and a safe activity in a contest setting. We then introduce three ingredients motivated by the microeconomics of communal violence in developing contexts. First, climate shocks hit the contested agricultural technology and can do so asymmetrically due to heterogeneous exposure, generating realized asymmetries in the prize even among ex ante similar groups. Second, the contest admits stalemate, capturing inconclusive or deterrence-driven outcomes that are empirically relevant in communal settings. Third, coercion is endogenously destructive: higher aggregate arming reduces the fraction of the contested resource that survives, creating a "burn-the-prize" wedge that tempers incentives to escalate.

Finally, we model institutional capacity (λ) as a moderator operating through *price stabilization*. When the butter price responds endogenously to effective scarcity, scarcity can amplify rapacity incentives by raising the monetary value of control. Stronger institutions dampen this scarcity–price feedback by partially anchoring prices to a target level, thereby weakening the rapacity channel. This resonates with the broader view that state capacity shapes conflict incentives and the ability to absorb shocks (Besley and Persson, 2008, 2011).

Methodologically, the analysis proceeds from a baseline model to a sequence of extensions. The baseline delivers a tractable equilibrium characterization and a clean sufficient condition for interior comparative statics. The extensions incorporate heterogeneous exposure, endogenous destructiveness, endogenous pricing, and institutional price stabilization to show how the opportunity-cost and rapacity forces interact, generating empirically plausible nonlinearities and state-contingent responses without requiring knife-edge assumptions.

The framework delivers three main theoretical takeaways. First, it provides a unified mapping from climate states into equilibrium allocations across production (butter), coercion (guns), and safe activity (ice cream), clarifying when shocks operate primarily through opportunity costs versus prize valuation. Second, it explains why empirical estimates of climate–violence links can be unstable: heterogeneity in exposure, the possibility of stalemate, and endogenous destruction jointly generate state-contingent and non-monotone responses of coercion. Third, it formalizes institutions as a moderator of the rapacity channel: by dampening scarcity-driven price spikes, higher λ weakens incentives for predation precisely in the low-supply states in which the prize-value mechanism would otherwise be strongest.

2 Background

This paper draws insights from and contributes to two different strands of the literature: one theoretical and the other largely empirical. First this paper builds on the long tradition that models conflict as a technology of appropriation in which agents allocate scarce resources between productive and coercive activities. Canonical contributions formalize this logic through contest success functions and the endogenous choice of conflict effort, (see Tullock (1980), Hirshleifer (1988)Grossman and Kim (1995); Grossman (1991), and Skaperdas (1992), as well as the broader synthesis in Chowdhury (2021); Garfinkel and Skaperdas (2007)). A central insight in this literature is that the economic environment—through technologies, returns, and the value of appropriable resources—maps into equilibrium coercion and welfare. In this spirit, several papers Hafer (2006); Hausken (2005); Baker (2003); Anderton (2000, 1999); Hirshleifer (1995, 1991b) focus on conflict, anarchy, and appropriation in order to analyse the resulting allocation of resources between production and conflict. Our model draws from the contested-versus-safe sector approach in Caruso and Echevarria-Coco (2023); Caruso (2010), which separates an appropriable sector from an activity immune to appropriation and studies how changes in returns shift equilibrium allocations.

Another strand of literature studies how climatic conditions and economic shocks relate to violence. Empirically, a prominent mechanism is the opportunity-cost channel: adverse shocks reduce incomes and raise the relative attractiveness of violence, as documented in influential work such as Miguel et al. (2004) and surveyed in Blattman and Miguel (2010). A second mechanism stresses rapacity and prize-value incentives: when scarcity or commodity-price shocks increase the value of appropriable resources, the expected returns to predation and coercion rise (Dube and Vargas, 2013; Bazzi and Blattman, 2014; Bellemare, 2015). At the same time, evidence on climate–conflict links is sensitive to measurement, sample composition, and context, with results often varying across settings and specifications (Burke et al., 2009; Buhaug, 2010; Hsiang et al., 2013; Dell et al., 2014). These patterns motivate a theoretical framework that can accommodate non-monotone responses and transparent conditions under which different channels dominate.

The model developed in this paper contributes precisely along this dimension. Climate shocks affect the contested agricultural sector directly through productivity, shifting the feasible quantities of appropriable output. When prices are exogenous, this maps naturally into opportunity-cost forces through changes in the relative attractiveness of the safe activity versus contested production and coercion. When prices are allowed to respond endogenously to effective scarcity, the same shock can also operate through a rapacity channel: lower effective supply raises the relative price of the contested good, increasing the monetary value of control and predation. Hence, the framework nests both opportunity-cost and rapacity mechanisms within a single contest model with a contested agricultural sector, a safe sector, and the possibility of stalemate.

Finally, we link these incentives to institutional capacity by allowing institutions to moderate the rapacity channel through price stabilization. In many developing settings, market integration, storage capacity, import capacity, and enforcement against hoarding can dampen scarcity-driven price spikes; conversely, weak institutions may amplify them. This idea is consistent with the broader view that state capacity shapes the economic consequences of conflict and shocks (Besley and Persson, 2008, 2011). In our model, institutions enter parsimoniously by attenuating the sensitivity of prices to effective scarcity, thereby reducing the prize-value amplification that can otherwise translate climate-induced agricultural scarcity into heightened incentives for predation and coercion.

3 Model

3.1 Benchmark model

We build on the butter–guns–ice-cream framework of **?** and tailor it to settings of communal violence in which agricultural resources are the main economic activity. The analysis is within period. Each period can be interpreted as a one-shot game embedded in a repeated environment with state variation; accordingly, we suppress time subscripts.

Timing, climate shock, and common exposure. At the beginning of the period a climate shock $s \in [-1, 1]$ is realized and observed by both groups. Negative values ($s < 0$) represent adverse shocks and positive values ($s > 0$) represent favorable shocks. We introduce a common exposure parameter $e \in [0, 1]$, interpreted as the extent to which the realized shock translates into agricultural productivity. In the benchmark, exposure is *symmetric*: both groups share the same e. Given (s, e), groups choose allocations simultaneously; then conflict resolves (possibly with stalemate) and payoffs are realized.

Groups and allocation. There are two groups $i \in \{1, 2\}$, ex ante symmetric, each endowed with one unit of resources. Each group allocates its endowment between contested agricultural activity ("butter"), coercive effort ("guns"), and a safe activity ("ice cream"):

$$b_i \geq 0, \quad g_i \geq 0, \quad y_i \geq 0, \qquad b_i + g_i + y_i = 1. \tag{1}$$

Since the environment is meant to capture contexts in which agriculture is the primary economic activity and the strategic margins concern production and coercion, we treat (b_i, g_i) as choice variables, with the safe allocation determined residually:

$$y_i = 1 - b_i - g_i. \tag{2}$$

Safe sector (uncontested). Ice-cream output exhibits diminishing marginal returns, as in **?**:

$$Y(y_i) = \chi\, y_i^{\beta}, \qquad \chi > 0,\ \beta \in (0, 1). \tag{3}$$

Contested sector (agriculture) and symmetric climate impact. Agricultural productivity is state-contingent and common across groups:

$$A(s, e) > 0, \qquad \frac{\partial A(s, e)}{\partial s} > 0. \tag{4}$$

To capture the idea that exposure amplifies the realized shock, we assume

$$\frac{\partial A(s, e)}{\partial e} \begin{cases} < 0 & \text{if } s < 0, \\ = 0 & \text{if } s = 0, \\ > 0 & \text{if } s > 0. \end{cases} \tag{5}$$

Butter production displays decreasing returns:

$$B_i(s, e) = A(s, e)\, b_i^{\alpha}, \qquad \alpha \in (0, 1), \tag{6}$$

and total contested output is $B(s, e) \equiv B_1(s, e) + B_2(s, e)$.

Contest with stalemate. We employ the Contest success function in its ratio form axiomatized by Clark and Riis (1998); Skaperdas (1996). A plausible assumption when analysing low-income countries is that no party has a clear-cut technological advantage over the other in fighting activities; therefore, violent conflicts can be expected to be inconclusive. Following Blavatskyy (2010); Caruso (2007) let $\eta > 0$ capture the possibility that conflict is inconclusive. Given coercive efforts (g_i, g_j), the probability that group i prevails is

$$\pi_i(g_i, g_j) = \frac{g_i}{g_i + g_j + \eta}, \tag{7}$$

and the probability of stalemate is

$$\pi_0(g_i, g_j) = \frac{\eta}{g_i + g_j + \eta}, \tag{8}$$

so that $\pi_i + \pi_j + \pi_0 = 1$.

Predation (raid) prize. We model communal violence as predation on the opponent's contested output. Let $\varphi \in (0, 1]$ denote the lootable fraction. In physical butter units, the amount effectively controlled by group i is

$$\widetilde{B}_i(s,e) = \begin{cases} B_i(s,e) + \varphi B_j(s,e) & \text{if } i \text{ wins,} \\ (1-\varphi) B_i(s,e) & \text{if } j \text{ wins,} \\ B_i(s,e) & \text{if stalemate,} \end{cases} \qquad j \neq i. \tag{9}$$

Price and destructiveness (exogenous). In the benchmark, the relative price of butter $p > 0$ is exogenous, and conflict has an exogenous survivability parameter $\theta \in (0, 1)$: only a fraction θ of contested output is effectively usable.

Payoffs. Preferences are quasi-linear: utility coincides with within-period real wealth. Group i's payoff, conditional on (s, e), is

$$U_i(s,e) = Y(1 - b_i - g_i) \; + \; p\,\theta\,\mathbb{E}\Big[\widetilde{B}_i(s,e)\Big], \tag{10}$$

where the expectation is taken over contest outcomes induced by (7)–(8) and the raid rule (9). A (pure-strategy) Nash equilibrium conditional on (s, e) is a profile $(b_1^*, g_1^*, b_2^*, g_2^*)$ such that each pair (b_i^*, g_i^*) maximizes (10) given the opponent's choice.

Symmetric equilibrium and characterization. We focus on symmetric equilibria conditional on (s, e):

$$b_1^*(s,e) = b_2^*(s,e) \equiv b^*(s,e), \qquad g_1^*(s,e) = g_2^*(s,e) \equiv g^*(s,e), \qquad y^*(s,e) = 1 - b^*(s,e) - g^*(s,e).$$

Whenever an interior solution exists, the symmetric equilibrium is characterized by the first-order conditions. Letting $y_i = 1 - b_i - g_i$, the marginal conditions are

$$Y'(y_i) = p\,\theta\,\frac{\partial}{\partial b_i}\mathbb{E}\Big[\widetilde{B}_i(s,e)\Big], \tag{11}$$

$$Y'(y_i) = p\,\theta\,\frac{\partial}{\partial g_i}\mathbb{E}\Big[\widetilde{B}_i(s,e)\Big], \tag{12}$$

together with feasibility (1). Since $B_i(s,e) = A(s,e)b_i^{\alpha}$ and $\pi_i = g_i/(g_i + g_j + \eta)$, the derivatives in (11)–(12) are explicit; for completeness, we report them in Appendix A.1 and provide the symmetric system in $(b^*(s,e), g^*(s,e))$.

Remark (comparative statics). The equilibrium is characterized by the first-order conditions. Following the butter–guns–ice-cream tradition, we adopt a monotonicity condition ensuring that, in the relevant region, the symmetric equilibrium responds in the natural direction to changes in agricultural productivity (see Appendix A.1).

Table 1: Benchmark model: qualitative comparative statics in the symmetric equilibrium

Parameter (increase)	$g^*(s,e)$	$b^*(s,e)$	$y^*(s,e)$	Economic mechanism (intuition)
Climate state s (via $A(s,e)$)	$+$ (Assump. 1)	$+$ (Assump. 1)	$-$ (Assump. 1)	A higher s raises agricultural productivity symmetrically. Under a standard monotonicity condition, a larger contested pie increases incentives to both produce butter and invest in coercion to appropriate it.
Common exposure e (via $A(s,e)$)	$-$ if $s<0$ $+$ if $s>0$ (Assump. 1)	$-$ if $s<0$ $+$ if $s>0$ (Assump. 1)	$+$ if $s<0$ $-$ if $s>0$ (Assump. 1)	Exposure amplifies the realized shock. For adverse shocks ($s<0$), higher exposure lowers productivity and shifts resources toward the safe activity; for favorable shocks ($s>0$), higher exposure increases productivity and strengthens incentives toward butter and guns.
Butter price p	$+$	$+$	$-$	A higher relative value of contested resources raises both the incentive to produce butter and the return to contesting it; the safe sector becomes relatively less attractive.
Survivability θ	$+$	$+$	$-$	When a larger fraction of the contested output survives conflict, the expected value of the prize increases, strengthening incentives to allocate resources to butter and guns rather than to the safe sector.
Lootability φ	$+$	amb.	amb.	Higher φ increases the marginal value of winning (raiding the opponent), hence more guns. The effect on butter and the safe sector is not sign-robust because butter becomes simultaneously more valuable and more exposed to predation risk.
Stalemate η	$-$	amb.	$+$	A larger stalemate mass reduces the decisiveness of guns and thus the marginal return to coercion, shifting resources toward the safe sector. The effect on butter is generally ambiguous because stalemate partially protects own production while reducing the gain from full appropriation.
Butter curvature α	amb.	$+$	$-$	Higher α increases the marginal productivity of butter for given b, strengthening agricultural incentives. The induced effect on guns is in general ambiguous and depends on how a larger prize translates into contest incentives under stalemate.
Safe curvature β	tends to $-$	tends to $-$	tends to $+$	A higher β increases concavity in the safe activity; for relevant allocations this tends to raise the marginal return to y, increasing the opportunity cost of both butter and guns.
Safe scale χ	$-$	$-$	$+$	A higher productivity of the safe sector increases the opportunity cost of investing in contested activity and coercion, shifting resources into y.

Notes. "amb." denotes effects that are not sign-robust without additional restrictions. "tends" indicates directions that obtain for relevant regions of the interior equilibrium but may not be globally sign-robust without additional curvature restrictions.

3.2 Extension 1: Heterogeneous exposure to the climate shock

The benchmark assumes a common exposure parameter e and thus a common agricultural productivity shifter $A(s, e)$ for both groups. This symmetry is what allows us to focus on a symmetric equilibrium conditional on the realized climate state. We now relax this restriction by allowing groups to differ in exposure, which generates *realized* asymmetry even though groups remain ex ante symmetric.

Heterogeneous exposure and productivity. Let $e_i \in [0, 1]$ denote group i's exposure to the climate shock. Agricultural productivity is

$$A_i(s) \equiv A(s, e_i), \qquad A(s, e) > 0, \qquad \frac{\partial A(s, e)}{\partial s} > 0. \tag{13}$$

To capture the idea that exposure amplifies the realized shock, we impose the following sign restriction:

$$\frac{\partial A(s, e)}{\partial e} \begin{cases} < 0 & \text{if } s < 0, \\ = 0 & \text{if } s = 0, \\ > 0 & \text{if } s > 0. \end{cases} \tag{14}$$

Condition (14) is a sign restriction stated pointwise in s. It formalizes that greater exposure amplifies the realized shock—it worsens productivity under adverse shocks and improves it under favorable shocks—and we do not require global smoothness at $s = 0$ for the arguments that follow. Hence, conditional on (s, e_1, e_2), groups can face different productivities $A_1(s) \neq A_2(s)$ whenever $e_1 \neq e_2$.

Technology, contest, and prize (unchanged). All other ingredients are as in the benchmark. Each group $i \in \{1, 2\}$ has endowment one and chooses (b_i, g_i) subject to $b_i \geq 0$, $g_i \geq 0$, and $b_i + g_i \leq 1$, with the residual safe allocation $y_i = 1 - b_i - g_i$. The safe activity yields $Y(y_i) = \chi y_i^\beta$ with $\beta \in (0, 1)$. Contested (agricultural) output is

$$B_i(s, e_i) = A(s, e_i)\, b_i^\alpha \equiv A_i(s)\, b_i^\alpha, \qquad \alpha \in (0, 1), \tag{15}$$

where, for brevity, we write $A_i(s) \equiv A(s, e_i)$. Conflict is governed by the stalemate CSF (7)–(8), and communal violence is modeled as predation on the opponent's contested output under the same raid rule (9). The butter price $p > 0$ and the (exogenous) survivability parameter $\theta \in (0, 1)$ remain unchanged.

Payoffs and equilibrium concept. Conditional on (s, e_1, e_2), group i's payoff is

$$U_i(s; e_1, e_2) = \chi(1 - b_i - g_i)^\beta \; + \; p\theta\, \mathbb{E}\left[\widetilde{B}_i(s; e_1, e_2)\right], \tag{16}$$

where the expectation is taken over contest outcomes induced by (7)–(8) together with the raid rule (9). A (pure-strategy) Nash equilibrium conditional on (s, e_1, e_2) is a profile

$$(b_1^*(s; e_1, e_2), g_1^*(s; e_1, e_2), b_2^*(s; e_1, e_2), g_2^*(s; e_1, e_2))$$

such that each pair (b_i^*, g_i^*) maximizes (16) given the opponent's choice.

Realized asymmetry and characterization. Unlike the benchmark, we can no longer restrict attention to symmetric allocations. When $e_1 \neq e_2$ and thus $A_1(s) \neq A_2(s)$, the equilibrium is in general *asymmetric*:

$$b_1^*(s; e_1, e_2) \neq b_2^*(s; e_1, e_2), \qquad g_1^*(s; e_1, e_2) \neq g_2^*(s; e_1, e_2), \qquad y_1^*(s; e_1, e_2) \neq y_2^*(s; e_1, e_2).$$

Whenever an interior solution exists, equilibrium allocations are characterized by the first-order conditions. Letting $y_i = 1 - b_i - g_i$, the marginal conditions for group i are

$$\chi\beta\, y_i^{\beta-1} = p\theta \frac{\partial}{\partial b_i}\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big], \tag{17}$$

$$\chi\beta\, y_i^{\beta-1} = p\theta \frac{\partial}{\partial g_i}\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big], \tag{18}$$

together with feasibility. Because the contest probabilities depend only on guns and $B_i(s, e_i) = A(s, e_i) b_i^{\alpha}$, the derivatives in (17)–(18) are explicit and reported in Appendix A.2. In particular, exposure heterogeneity enters the best responses through the productivity shifters $\big(A_i(s), A_j(s)\big) = \big(A(s, e_i), A(s, e_j)\big)$, which scale the two contested outputs $\big(B_i(s, e_i), B_j(s, e_j)\big)$ and hence the expected raid prize under predation.

Interpretation. The extension isolates the role of differential exposure in shaping incentives for production and coercion. Holding fixed the common climate state s, a higher exposure e_i decreases $A_i(s)$ when $s < 0$ (adverse shocks) and increases $A_i(s)$ when $s > 0$ (favorable shocks). This generates state-contingent heterogeneity in contested output and, through the raid technology, modifies both the opportunity-cost and prize components of violence incentives. We develop the formal comparative statics with respect to (e_1, e_2) in the subsequent extensions when additional structure is imposed.

Table 2: Extension 1: qualitative comparative statics (group i, conditional on (s, e_i, e_j))

Parameter (increase)	g_i^*	b_i^*	y_i^*	Economic mechanism (intuition)
Climate state s (via $A(s, e_i)$ and $A(s, e_j)$)	$+$ (Assump. 1)	$+$ (Assump. 1)	$-$ (Assump. 1)	A higher s raises agricultural productivity for both groups, scaling the contested pie. Under monotonicity, the higher expected value of contested resources increases incentives to both produce butter and invest in coercion.
Own exposure e_i (via $A(s, e_i)$)	$-$ if $s < 0$ $+$ if $s > 0$ (Assump. 1)	$-$ if $s < 0$ $+$ if $s > 0$ (Assump. 1)	$+$ if $s < 0$ $-$ if $s > 0$ (Assump. 1)	Exposure amplifies the realized shock for group i. Under adverse shocks ($s < 0$), higher exposure reduces $A(s, e_i)$ and shifts resources toward the safe activity; under favorable shocks ($s > 0$), it increases $A(s, e_i)$ and strengthens incentives toward butter and guns.

Continued on next page.

Table 2 continued.

Parameter (increase)	g_i^*	b_i^*	y_i^*	Economic mechanism (intuition)
Opponent exposure e_j (via $A(s, e_j)$)	$-$ if $s < 0$ $+$ if $s > 0$ (Assump. 1)	amb.	amb.	Changing e_j alters the opponent's contested output and hence the *lootable* component of the prize. If $s < 0$, higher exposure lowers $A(s, e_j)$ and reduces the value of raiding the opponent, lowering g_i^*; if $s > 0$, higher exposure raises the opponent's output and strengthens raiding incentives. The induced effects on b_i^* and y_i^* are not sign-robust without additional structure.
Butter price p	$+$	$+$	$-$	A higher relative value of contested resources raises both the incentive to produce butter and the return to contesting it; the safe sector becomes relatively less attractive.
Survivability θ	$+$	$+$	$-$	When a larger fraction of contested output survives conflict, the expected value of the prize increases, strengthening incentives to allocate resources to butter and guns rather than to the safe sector.
Lootability φ	$+$	amb.	amb.	Higher φ increases the marginal value of winning (raiding the opponent), hence more guns. The effect on production and the safe sector is not sign-robust because butter becomes simultaneously more valuable and more exposed to predation.
Stalemate η	$-$	amb.	$+$	A larger stalemate mass reduces the decisiveness of guns and thus the marginal return to coercion, shifting resources toward the safe sector. The effect on butter is generally ambiguous because stalemate partially protects own production while reducing the gain from full appropriation.
Butter curvature α	amb.	$+$	$-$	Higher α increases the marginal productivity of butter for given b_i, strengthening agricultural incentives. The induced effect on guns is in general ambiguous and depends on how a larger prize translates into contest incentives under stalemate.
Safe curvature β	tends to $-$	tends to $-$	tends to $+$	A higher β increases concavity in the safe activity; for relevant allocations this tends to raise the marginal return to y_i, increasing the opportunity cost of both butter and guns.
Safe scale χ	$-$	$-$	$+$	A higher productivity of the safe sector increases the opportunity cost of investing in contested activity and coercion, shifting resources into y_i.

Notes. The table reports qualitative directions for group i's equilibrium allocations in the (generically asymmetric) Nash equilibrium of Extension 3.2. Results that rely on the benchmark monotonicity condition are flagged by Assumption 1. "amb." denotes effects that are not sign-robust without additional restrictions. "tends" indicates directions that hold for relevant regions of an interior equilibrium but may fail globally without stronger curvature conditions. Effects for group j follow by swapping indices i and j.

3.3 Extension 2: Endogenous destructiveness

This extension endogenizes conflict destructiveness while maintaining the heterogeneous exposure structure introduced in Section 3.2. All other primitives remain unchanged: butter and the safe activity feature diminishing marginal returns, conflict follows a CSF with stalemate, the prize is predation (raid) on the opponent's agricultural output, and the butter price p is exogenous.

Environment (as in Section 3.2). At the beginning of the period a common climate shock $s \in [-1, 1]$ is realized and observed. Groups differ in exposure $e_i \in [0, 1]$, implying group-specific agricultural productivity

$$A_i(s) \equiv A(s, e_i),$$

and contested output

$$B_i(s, e_i) = A(s, e_i)\, b_i^{\alpha}, \qquad \alpha \in (0, 1). \tag{19}$$

The safe activity is $Y(y_i) = \chi y_i^{\beta}$ with $\beta \in (0, 1)$ and the resource constraint is

$$b_i + g_i + y_i = 1, \qquad y_i = 1 - b_i - g_i.$$

Conflict is governed by the stalemate CSF (7)–(8), and the raid prize is defined as in (9) with lootability $\varphi \in (0, 1]$. For completeness, Appendix A.2 reports the expected raid prize $\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)]$ and its derivatives with respect to (b_i, g_i) under heterogenous exposure.

Endogenous survivability. Let $G \equiv g_1 + g_2$ denote total coercive effort. We replace the exogenous survivability parameter θ with a survivability function

$$\theta(G) \in (0, 1), \qquad \theta'(G) < 0. \tag{20}$$

This captures the idea that more intense violence destroys a larger fraction of the contested resource (e.g. burning, spoilage, or disruption), reducing the value that either side can ultimately appropriate. A convenient parametric example is

$$\theta(G) = \frac{\bar{\theta}}{1 + dG}, \qquad \bar{\theta} \in (0, 1),\ d > 0, \tag{21}$$

though the equilibrium characterization below only requires (20).

Payoffs. Conditional on (s, e_1, e_2), group i's payoff becomes

$$U_i(s; e_1, e_2) = \chi(1 - b_i - g_i)^{\beta} + p\,\theta(g_1 + g_2)\,\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big], \tag{22}$$

where $\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)]$ is the expected controlled butter under predation and stalemate (Appendix A.2).

Equilibrium characterization. A Nash equilibrium conditional on (s, e_1, e_2) is defined as in Section 3.2. Whenever an interior solution exists, equilibrium allocations are characterized by first-order conditions. Relative to Extension 3.2, guns now affect payoffs through two channels: by shifting contest probabilities and by reducing survivability via $\theta'(G) < 0$. Letting $y_i = 1 - b_i - g_i$, the FOCs can be written as

$$\chi\beta\, y_i^{\beta-1} = p\,\theta(G)\,\frac{\partial}{\partial b_i}\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big], \tag{23}$$

$$\chi\beta\, y_i^{\beta-1} = p\left[\theta(G)\,\frac{\partial}{\partial g_i}\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big] + \theta'(G)\,\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big]\right], \tag{24}$$

together with feasibility $b_i \geq 0$, $g_i \geq 0$, $b_i + g_i \leq 1$. Under interior allocations ($b_i > 0$) we have $B_i(s, e_i) > 0$. Moreover, with $\eta > 0$ the stalemate CSF implies $\pi_j < 1$, hence $(1 - \varphi\pi_j) > 0$. Since $B_i(s, e_i) > 0$, $B_j(s, e_j) > 0$, and $\pi_i, \pi_j, \pi_0 \geq 0$, it follows from (46) that $\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)] > 0$. Therefore, because $\theta'(G) < 0$, the additional term $\theta'(G)\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)]$ is strictly negative and captures an endogenous destruction wedge: marginal increases in coercion improve winning chances but simultaneously shrink the usable prize.

Implications. Endogenous destructiveness weakens incentives to invest in guns relative to Extension 3.2. The effect is especially relevant under heterogeneous exposure: the high-productivity group represents a more valuable target, yet increased coercion by either side reduces the fraction of that value that survives conflict. Hence, the "predator–prey" logic induced by $\big(A(s, e_1), A(s, e_2)\big)$ interacts with a countervailing "burn-the-prize" force induced by $\theta'(G) < 0$.

Remark (comparative statics). Table 3 summarizes qualitative comparative statics for total coercion G^* and the distribution of coercion/production across groups.

Table 3: Extension 2: qualitative comparative statics under endogenous destructiveness

Primitive change	G^*	Distribution across groups	y_i^*	Economic mechanism (intuition)
Steeper destruction: higher d in (21) (or more negative $\theta'(G)$)	−	amb. (target effect may be muted)	+	A steeper decline of $\theta(G)$ makes guns less attractive because additional coercion shrinks the prize that can be appropriated. This shifts resources toward the safe outside option. Cross-group allocation may become less "aggressive" toward the high-productivity target because burning losses are larger when escalating G.
Higher baseline survivability $\bar{\theta}$ in (21)	+	amb.	−	A larger fraction of the contested output survives for any given G, raising the expected marginal return to contesting and strengthening incentives for coercion relative to the safe activity.
Higher lootability φ	+	toward the higher-A target (tends)	amb.	A larger lootable fraction increases the marginal value of winning. With heterogeneous exposure, the more productive group becomes a more attractive target, although endogenous destruction attenuates the net gain from escalation.
Higher stalemate mass η	−	amb.	+	Stalemate reduces the decisiveness of guns and lowers the marginal return to coercion. Under endogenous destruction, this effect combines with the burn-the-prize wedge, further discouraging escalation.

Notes. "amb." denotes effects that are not sign-robust without additional restrictions. "target effect" refers to the idea that higher exposure/productivity of one group increases the opponent's incentive to allocate coercion toward predation. The table refers to equilibrium allocations conditional on (s, e_1, e_2).

3.4 Extension 3: Endogenous butter price

This extension closes the model on the "rapacity via prices" channel by allowing the relative price of the contested good (butter) to respond to effective scarcity. The extension builds on Section 3.3: exposure may be heterogeneous and conflict destructiveness is endogenous via $\theta(G)$. All remaining ingredients are unchanged: butter and the safe activity feature diminishing marginal returns, conflict follows a CSF with stalemate, and the prize is predation (raid) on the opponent's agricultural output.

Effective supply and endogenous price. Let physical contested output be

$$B_i(s, e_i) = A(s, e_i)\, b_i^{\alpha}, \qquad \alpha \in (0, 1), \qquad B(s; e_1, e_2) \equiv B_1(s, e_1) + B_2(s, e_2).$$

As in Section 3.3, let $G \equiv g_1 + g_2$ and $\theta(G) \in (0, 1)$ with $\theta'(G) < 0$ capture endogenous survivability. We define effective aggregate supply as

$$B^{\text{eff}}(s; e_1, e_2) \equiv \theta(G)\, B(s; e_1, e_2). \tag{25}$$

The butter price is now endogenous and depends on effective supply:

$$p = p\Big(B^{\text{eff}}\Big), \qquad p'(\cdot) < 0, \qquad 0 < p(0) < \infty. \tag{26}$$

A convenient capped specification is

$$p\Big(B^{\text{eff}}\Big) = \bar{p}\left(B^{\text{eff}} + \bar{B}\right)^{-\varepsilon}, \qquad \bar{p} > 0,\ \bar{B} > 0,\ \varepsilon > 0. \tag{27}$$

Payoffs and interpretation of $\theta(G)$. Conditional on (s, e_1, e_2), group i's payoff becomes

$$U_i(s; e_1, e_2) = \chi(1 - b_i - g_i)^{\beta} + p\Big(B^{\text{eff}}(s; e_1, e_2)\Big)\ \theta(G)\, \mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big]. \tag{28}$$

The survivability term $\theta(G)$ enters *twice* but captures two distinct objects. First, it scales *aggregate effective supply* $B^{\text{eff}} = \theta(G)B$, which governs scarcity and hence the market price $p(\cdot)$. Second, it scales the *individual usable quantity* controlled by group i: even conditional on control (win/lose/stalemate), only a fraction $\theta(G)$ of the controlled butter remains usable. Thus $\theta(G)$ affects both the price of butter and the quantity effectively consumed/appropriated.

Moreover, the expected controlled butter is strictly positive. Under the stalemate CSF with $\eta > 0$, $\pi_0 = \eta/(g_i + g_j + \eta) > 0$ and $\pi_j = g_j/(g_i + g_j + \eta) < 1$, so $(1 - \varphi\pi_j) > 0$. Since $B_i(s, e_i) > 0$ and $B_j(s, e_j) > 0$, the expression

$$\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big] = \Big(1 - \varphi\pi_j\Big)B_i(s, e_i) + \varphi\pi_i B_j(s, e_j)$$

implies $\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)] > 0$.

Equilibrium characterization. A Nash equilibrium conditional on (s, e_1, e_2) is defined as in Sections 3.2–3.3. Relative to Extension 3.3, the endogenous price introduces an additional feedback: each group's choice affects the effective supply B^{eff} and thus the price $p(\cdot)$. Let $y_i = 1 - b_i - g_i$. Under an interior optimum, the first-order conditions are

$$\chi\beta\, y_i^{\beta-1} = p\Big(B^{\text{eff}}\Big)\ \theta(G)\, \frac{\partial}{\partial b_i}\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big] + p'\Big(B^{\text{eff}}\Big)\ \frac{\partial B^{\text{eff}}}{\partial b_i}\ \theta(G)\, \mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big], \tag{29}$$

$$\chi\beta\, y_i^{\beta-1} = p\Big(B^{\text{eff}}\Big)\ \Big[\theta(G)\, \frac{\partial}{\partial g_i}\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big] + \theta'(G)\, \mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big]\Big] + p'\Big(B^{\text{eff}}\Big)\ \frac{\partial B^{\text{eff}}}{\partial g_i}\ \theta(G)\, \mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big], \tag{30}$$

together with feasibility $b_i \geq 0$, $g_i \geq 0$, $b_i + g_i \leq 1$. Appendix A.4 reports the new derivatives $\partial B^{\text{eff}}/\partial b_i$ and $\partial B^{\text{eff}}/\partial g_i$ and collects the terms introduced by $p'(\cdot)$. The derivatives of the expected raid prize $\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)]$ are unchanged and can be found in Appendix A.2.

Implications. Because $p'(B^{\text{eff}}) < 0$, any force that reduces effective supply (lower b or lower survivability $\theta(G)$) raises the butter price and thus the marginal value of controlling butter. This endogenous scarcity-price feedback strengthens the rapacity channel: when butter becomes scarce in effective terms, its price rises and the expected monetary return to predation increases. At the same time, coercion remains subject to an endogenous destruction wedge through $\theta'(G) < 0$ as in Extension 3.3. Hence, equilibrium coercion reflects the interaction between a "scarcity raises prize value" force (via $p'(\cdot)$) and a "burn-the-prize" force (via $\theta'(\cdot)$).

Remark (comparative statics). Table 4 summarizes qualitative comparative statics under endogenous pricing. The table focuses on total coercion G^* and reports qualitative implications for how equilibrium coercion may be distributed across groups (e.g. toward the higher-productivity target) in the presence of exposure heterogeneity.

Table 4: Extension 3: qualitative comparative statics under endogenous butter price

Primitive change	G^*	Distribution across groups	y_i^*	Economic mechanism (intuition)
Stronger scarcity pricing: larger $-p'(B^{\text{eff}})$ (e.g. higher ε in (27))	tends to +	toward higher-$A(\cdot)$ target (tends)	tends to −	When prices respond more strongly to effective scarcity, the monetary value of controlling butter rises in low-B^{eff} states, strengthening the rapacity channel and raising incentives for coercion relative to the safe activity. Under heterogeneous exposure, the more productive group is a more valuable target and may face stronger predatory pressure.
Larger cap parameter $\bar{B}$ in (27) (weaker spikes)	tends to −	amb.	tends to +	A larger $\bar{B}$ dampens price spikes as B^{eff} falls, weakening the scarcity–price feedback and shifting incentives toward the safe activity.
Higher baseline price level $\bar{p}$ in (27)	+	amb.	−	A uniformly higher valuation of the contested good raises the expected return to producing and contesting butter, strengthening incentives for coercion and reducing safe allocations.
More destruction sensitivity: more negative $\theta'(G)$ (for given G)	amb.	amb.	tends to +	A steeper decline of survivability shrinks effective supply B^{eff} (raising prices) but also reduces the usable quantity of controlled butter and increases the endogenous destruction wedge in (30). The net effect on coercion is not sign-robust without additional restrictions.

Notes. "amb." denotes effects that are not sign-robust without additional restrictions. "tends" indicates a direction that obtains in relevant regions of interior equilibria but may fail globally without additional curvature restrictions. The table refers to equilibrium allocations conditional on (s, e_1, e_2).

3.5 Extension 4: Price stabilization as an institutional moderator

This extension introduces institutions as moderators of the "rapacity via prices" channel. Building on Extension 3.4, the butter price is endogenous because it responds to effective scarcity. We now allow institutional capacity to dampen price spikes, holding all other primitives fixed: heterogeneous exposure, endogenous destructiveness, the CSF with stalemate, and predation (raid) as the prize.

Institutional capacity and stabilization rule. Let $\lambda \in [0,1]$ index institutional capacity to stabilize food prices (e.g. market integration, buffer stocks, import capacity, enforcement against hoarding). Let $\mu(\lambda) \in [0,1]$ be increasing in λ:

$$\mu'(\lambda) > 0. \tag{31}$$

Let $p_m(B^{\text{eff}})$ denote the market price from Extension 3.4, with $p_m'(\cdot) < 0$ and $0 < p_m(0) < \infty$ (e.g. the capped specification in (27)). We define the effective price faced by agents as a convex combination of the market price and a target price $\bar{p}_0 > 0$:

$$p^{\text{eff}}\left(B^{\text{eff}};\lambda\right) = \left(1-\mu(\lambda)\right) p_m\left(B^{\text{eff}}\right) + \mu(\lambda)\,\bar{p}_0. \tag{32}$$

The rule captures the idea that stronger institutions dampen scarcity-driven price spikes by partially anchoring prices to a target level.

Dampened scarcity–price feedback. Differentiating (32) with respect to effective supply yields

$$\frac{\partial p^{\text{eff}}}{\partial B^{\text{eff}}} = \left(1-\mu(\lambda)\right) p_m'\left(B^{\text{eff}}\right). \tag{33}$$

Therefore, for interior stabilization $\mu(\lambda) \in (0,1)$ and for states where $p_m'(B^{\text{eff}}) \neq 0$,

$$\frac{\partial}{\partial \lambda}\left|\frac{\partial p^{\text{eff}}}{\partial B^{\text{eff}}}\right| = -\mu'(\lambda)\left|p_m'\left(B^{\text{eff}}\right)\right| < 0.$$

Hence, institutional capacity λ attenuates the sensitivity of prices to effective scarcity, moderating the rapacity channel introduced in Extension 3.4.

Payoffs. Let $B^{\text{eff}}(s;e_1,e_2) = \theta(G)\,B(s;e_1,e_2)$ as in (25). Conditional on (s,e_1,e_2), group i's payoff becomes

$$U_i(s;e_1,e_2;\lambda) = \chi(1-b_i-g_i)^{\beta} + p^{\text{eff}}\left(B^{\text{eff}}(s;e_1,e_2);\lambda\right)\,\theta(G)\,\mathbb{E}\left[\widetilde{B}_i(s;e_1,e_2)\right]. \tag{34}$$

As in Extension 3.4, under $\eta > 0$ and positive outputs we have $\mathbb{E}[\widetilde{B}_i(s;e_1,e_2)] > 0$.

Equilibrium characterization. A Nash equilibrium conditional on (s,e_1,e_2) is defined as in previous sections. Relative to Extension 3.4, the equilibrium conditions are identical in form, with $p_m(\cdot)$ replaced by $p^{\text{eff}}(\cdot;\lambda)$ and the price-feedback term scaled by $(1-\mu(\lambda))$ through (33). Let $y_i = 1-b_i-g_i$. Under an interior optimum, the first-order conditions can be written as

$$\chi\beta\, y_i^{\beta-1} = p^{\text{eff}}\left(B^{\text{eff}};\lambda\right)\,\theta(G)\,\frac{\partial}{\partial b_i}\mathbb{E}\left[\widetilde{B}_i(s;e_1,e_2)\right] + \frac{\partial p^{\text{eff}}}{\partial B^{\text{eff}}}\,\frac{\partial B^{\text{eff}}}{\partial b_i}\,\theta(G)\,\mathbb{E}\left[\widetilde{B}_i(s;e_1,e_2)\right], \tag{35}$$

$$\chi\beta\, y_i^{\beta-1} = p^{\text{eff}}\left(B^{\text{eff}};\lambda\right)\left[\theta(G)\,\frac{\partial}{\partial g_i}\mathbb{E}\left[\widetilde{B}_i(s;e_1,e_2)\right] + \theta'(G)\,\mathbb{E}\left[\widetilde{B}_i(s;e_1,e_2)\right]\right] + \frac{\partial p^{\text{eff}}}{\partial B^{\text{eff}}}\,\frac{\partial B^{\text{eff}}}{\partial g_i}\,\theta(G)\,\mathbb{E}\left[\widetilde{B}_i(s;e_1,e_2)\right], \tag{36}$$

together with feasibility $b_i \geq 0$, $g_i \geq 0$, $b_i + g_i \leq 1$. Appendix A.5 reports the only new objects relative to Extension 3.4. All other derivatives are unchanged and can be found in Appendices A.2 and A.4.

Implications. Institutional stabilization weakens the scarcity–price feedback that magnifies incentives for predation in low-B^{eff} states. By dampening $|\partial p^{\text{eff}}/\partial B^{\text{eff}}|$ via (33), higher λ reduces the strength of the rapacity channel. In equilibrium, this tends to lower total coercion G^* and to reduce the extent to which predatory incentives concentrate on the higher-productivity group when exposure is heterogeneous, while shifting resources toward the safe activity.

Remark (comparative statics). Table 5 summarizes qualitative comparative statics for λ-driven price stabilization.

Table 5: Extension 4: qualitative comparative statics under price stabilization

Primitive change	G^*	Distribution across groups	y_i^*	Economic mechanism (intuition)
Higher institutional capacity λ (thus higher $\mu(\lambda)$)	tends to −	tends to attenuate targeting of high-$A(\cdot)$ group	tends to +	A higher λ increases $\mu(\lambda)$, dampening scarcity-driven price spikes. Since $\partial p^{\text{eff}}/\partial B^{\text{eff}} = (1-\mu(\lambda))p'_m(\cdot)$, the endogenous rapacity channel from Extension 3.4 is weakened, lowering the marginal return to predation and shifting resources toward the safe activity.
Higher $\bar{p}_0$ (more generous target price)	amb.	amb.	amb.	Raising the anchor price increases the level of p^{eff} when the target binds, potentially increasing the valuation of contested resources while still dampening spikes. The net effect on coercion is not sign-robust without further restrictions on where $p_m(B^{\text{eff}})$ lies relative to $\bar{p}_0$.
Stronger stabilization technology: steeper $\mu(\lambda)$ (higher $\mu'(\lambda)$)	tends to −	tends to reduce concentration (tends)	tends to +	A more responsive stabilization function increases the dampening effect of institutions on scarcity-price feedback for given changes in λ, attenuating the rapacity channel more strongly.

Notes. "amb." denotes effects that are not sign-robust without additional restrictions. "tends" indicates directions that obtain for relevant regions of interior equilibria but may fail globally without additional curvature restrictions. The table refers to equilibrium allocations conditional on (s, e_1, e_2) and given λ.

4 Discussion and implications

This paper embeds climate shocks into a standard butter–guns–ice-cream contest environment (Caruso, 2010) tailored to settings of communal violence where agricultural resources are the main contested activity and violence takes the form of predation (raid) on the opponent's agricultural output. Across all specifications, agents allocate a unit endowment between butter production b_i, coercive effort g_i, and a safe activity y_i, with diminishing marginal returns in both butter and the safe sector, a CSF with stalemate, and a prize defined by lootability φ. The benchmark introduces a common climate shock $s \in [-1, 1]$ and a common exposure parameter $e \in [0, 1]$ that jointly determine agricultural productivity $A(s, e)$. Under the standard monotonicity restriction

(Assumption 1), higher productivity (hence higher s) increases both equilibrium butter and guns and reduces the safe allocation (Table 1). Economically, this is the "larger contested pie" effect: when agricultural resources become more productive, agents both produce more in the contested sector and invest more in coercion to appropriate it.

Extension 3.2 relaxes the benchmark's realized symmetry by allowing heterogeneous exposures (e_1, e_2) so that $A_1(s) \neq A_2(s)$ whenever $e_1 \neq e_2$. The equilibrium becomes generically asymmetric. Two forces now coexist in a transparent way: (i) an *opportunity-cost channel* operating through own productivity, because increasing e_i amplifies the realized shock and shifts allocations toward y_i under adverse shocks ($s < 0$) and toward (b_i, g_i) under favorable shocks ($s > 0$); and (ii) a *rapacity/prize channel* operating strategically through the opponent's productivity, because e_j changes the lootable component of the prize and thus affects g_i^* in the same direction as $A(s, e_j)$ (Table 2). Notably, once productivity becomes asymmetric, several cross-effects on (b_i^*, y_i^*) are not sign-robust without additional structure, reflecting that butter is simultaneously valuable and exposed to predation.

Extension 3.3 endogenizes conflict destructiveness via $\theta(G)$ with $\theta'(G) < 0$, introducing a genuine "burn-the-prize" wedge: marginal coercion increases winning chances but reduces the fraction of the prize that survives. As a result, making destruction steeper (higher d or more negative $\theta'(G)$) robustly lowers total coercion G^* and raises safe allocations (Table 3). In heterogeneous-exposure environments, endogenous destruction also tends to mute predatory "targeting" of the high-productivity group, because escalation destroys more of what makes the target valuable.

Extension 3.4 closes the rapacity mechanism through endogenous prices by letting $p = p(B^{\text{eff}})$ with $p'(\cdot) < 0$ and $B^{\text{eff}} = \theta(G)B$. This creates a scarcity–price feedback: when effective supply is low, the price of butter rises, increasing the monetary value of controlling contested resources. Stronger scarcity pricing (larger $-p'$) therefore tends to increase coercion and reduce safe allocations, and under heterogeneous exposure it tends to strengthen predatory pressure against the high-$A(\cdot)$ group (Table 4). Crucially, because adverse shocks can reduce quantities while increasing prices, the net effect of "agricultural output $\rightarrow$ violence" need not be monotone: the opportunity-cost and rapacity channels may move in opposite directions in the same state.

Finally, Extension 3.5 introduces institutions as moderators of the rapacity channel by partially stabilizing prices: higher institutional capacity λ increases $\mu(\lambda)$ and mechanically attenuates the slope $|\partial p^{\text{eff}} / \partial B^{\text{eff}}|$ (equation (33)). This robustly weakens the scarcity–price feedback and thus tends to reduce equilibrium coercion, dampen targeting, and shift resources toward the safe activity (Table 5).

Table 6: Model summary: assumptions relaxed and headline sign predictions across specifications

Specification		Relaxed assumption (relative to previous)	Sym. exposure?	θ exog.?	p exog.?	$A\uparrow$ (via $s\uparrow$) on (G,b,y)	Heterog. exposure: targeting	More destruction ($d\uparrow$) on G^*	Scarcity pricing ($-p'\uparrow$) on G^*
Benchmark (Sec. 3.1)		Baseline: common (s,e); symmetric $A(s,e)$	Yes	Yes	Yes	+,+,− (Assump. 1)	–	–	–
Extension (Sec. 3.2)	1	Allow $e_1 \neq e_2$ so $A_1(s) \neq A_2(s)$	No	Yes	Yes	+,+,− (Assump. 1)	toward high-A (tends)	–	–
Extension (Sec. 3.3)	2	Replace θ by $\theta(G)$ with $\theta'(G) < 0$	No	No	Yes	+,+,− (Assump. 1)	attenuated (tends)	−	–
Extension (Sec. 3.4)	3	Endogenous price $p = p(B^{\text{eff}})$, $p'(\cdot) < 0$	No	No	No	may be non-monotone (tends)	toward high-A (tends)	amb.	tends to +
Extension (Sec. 3.5)	4	Institutions stabilize prices: $p^{\text{eff}} = (1-\mu(\lambda))p_m + \mu(\lambda)\bar{p}_0$	No	No	No	as Ext. 3 (tends)	attenuated (tends)	amb.	attenuated (tends)

Legend. $G^* \equiv g_1^* + g_2^*$; (G,b,y) refer to total coercion, (symmetric) butter, and safe allocations when symmetry applies. "tends" indicates directions that hold in relevant regions of interior equilibria but may fail globally without stronger curvature/parameter restrictions. "amb." denotes effects that are not sign-robust. "Targeting" refers to a tendency for coercion/predation incentives to concentrate on the group with higher realized productivity $A(s,e_i)$ when exposures differ.

Brief summary Some comparative-static directions are structurally robust across specifications: higher stalemate η lowers the marginal return to guns and (weakly) reallocates toward the safe activity; stronger endogenous destruction (steeper $\theta(G)$) lowers G^*; and higher λ attenuates the price response to scarcity. Other effects are inherently non-robust without stronger curvature or parameter restrictions. In particular, lootability φ raises guns robustly but has ambiguous effects on butter and the safe sector, and the introduction of endogenous prices makes the effect of adverse shocks on coercion potentially non-monotone because quantity and price effects operate simultaneously. In short, the framework nests in one tractable structure (i) opportunity-cost forces operating through productivity and the outside option, (ii) rapacity forces operating through the value of the appropriable prize (including via endogenous prices), and (iii) institutions as moderators that weaken the mapping from scarcity to prize value.

5 Conclusions

This note aims to contribute to the scarce theoretical literature on climate change and the emergence of violence. The empirical literature documents that weather and climate shocks are associated with violence, although this relationship is highly heterogeneous across contexts. In this paper, we develop a theoretical model intended, in part, to accommodate such heterogeneity within a unified analytical framework.

The model is a general-equilibrium, Hirshleifer-style model of conflict that also incorporates a safe economic activity, following Caruso (2010). The economy is characterised by two sectors: an uncontested sector and a contested sector. The latter involves conflict over a joint product ("butter") through the use of unproductive outlays ("guns"). Agents' payoffs depend on outcomes in both sectors; consequently, they must decide how to allocate a fixed endowment of resources between the safe economic activity ("ice cream") and conflictual, predatory activity in the contested sector.

The proposed extension introduces an adverse climate shock affecting the contested sector, allowing the authors to analyse its impact on both the probability and intensity of violent conflict, as well as on overall economic activity. A key assumption, consistent with the empirical realities of low-income regions, is the absence of any technological advantage across agents in fighting. This implies a positive probability of stalemate, as in Caruso (2007).

In the baseline symmetric case, the main result is that an adverse shock reduces productivity in the contested sector, thereby shifting resources toward the safe activity in the uncontested sector. When agents experience heterogeneous exposure to the climate shock—as is likely in reality—two productivity-driven mechanisms become particularly relevant: (i) the opportunity-cost mechanism and (ii) the rapacity effect.

Under the opportunity-cost mechanism, an agent experiencing an adverse shock faces lower productivity in the contested sector and therefore reallocates resources toward the uncontested sector. At the same time, the rapacity channel remains active because an agent's outlay on guns responds positively to the opponent's productivity. In the presence of heterogeneous exposure to climate shocks, productivity differentials thus sustain incentives for rapacious behaviour by the less productive agent in the contested sector. This recalls the famous "Paradox of Power" expounded in Durham et al. (1998); Hirshleifer (1991a). As a result, asymmetric exposure to climate shocks may trigger violent conflict, as shown by the theoretical model.

The paper presents several extensions of the baseline model, and the results are clearly reported in tables. Among these extensions, a particularly important one allows output prices to be endogenous. In this case, a negative shock reduces supply and raises prices, thereby strengthening the rapacity effect. As the supply of butter decreases, its price increases, raising the monetary return associated with winning the contested good. However, allocations to guns are mitigated by an endogenous destruction parameter, which reduces the expected return from conflict. This result provides a clear rationale for the role of institutions in moderating the rapacity effect through price mechanisms. Specifically, in the presence of climate shocks, policies aimed at price stabilisation can dampen predatory incentives and promote the reallocation of resources toward safe, uncontested economic activities.

In sum, the heterogeneity observed in the empirical literature can be partly reconciled by the model developed here. The framework highlights how both opportunity-cost and rapacity mechanisms operate depending on the context and shows that the price channel—often neglected in the empirical literature—plays a crucial role in shaping conflict outcomes.

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A Appendix

A.1 Benchmark model: expected prize and first-order conditions

This appendix reports the expected controlled butter under predation and stalemate, its derivatives, and the symmetric first-order conditions for the benchmark model. Throughout, $A(s,e)$ is common across groups (symmetric exposure), and the butter price p and survivability θ are exogenous. For notational convenience, let

$$A \equiv A(s,e).$$

Expected controlled butter. Given the raid rule (9) and the contest probabilities (7)–(8), expected controlled butter (in physical units) can be written as

$$\begin{aligned}\mathbb{E}\Big[\widetilde{B}_i(s,e)\Big] &= \pi_i\big(B_i + \varphi B_j\big) + \pi_j\big((1-\varphi)B_i\big) + \pi_0 B_i \\ &= B_i + \varphi\pi_i B_j - \varphi\pi_j B_i \\ &= \big(1-\varphi\pi_j\big)B_i + \varphi\pi_i B_j, \end{aligned} \tag{37}$$

where $B_i = B_i(s,e) = A\, b_i^{\alpha}$ and $j \neq i$.

Derivatives with respect to butter. Since π_i depends only on guns,

$$\frac{\partial}{\partial b_i}\mathbb{E}\Big[\widetilde{B}_i(s,e)\Big] = \big(1-\varphi\pi_j\big)\frac{\partial B_i}{\partial b_i} = \big(1-\varphi\pi_j\big)A\alpha\, b_i^{\alpha-1}. \tag{38}$$

Derivatives with respect to guns. Let $D \equiv g_i + g_j + \eta$. Then

$$\pi_i = \frac{g_i}{D}, \qquad \frac{\partial \pi_i}{\partial g_i} = \frac{g_j+\eta}{D^2}, \qquad \frac{\partial \pi_j}{\partial g_i} = -\frac{g_j}{D^2}.$$

Using (37), we obtain

$$\begin{aligned}\frac{\partial}{\partial g_i}\mathbb{E}\Big[\widetilde{B}_i(s,e)\Big] &= -\varphi\frac{\partial \pi_j}{\partial g_i}B_i + \varphi\frac{\partial \pi_i}{\partial g_i}B_j \\ &= \frac{\varphi}{D^2}\Big[g_j\, B_i + (g_j+\eta)\, B_j\Big]. \end{aligned} \tag{39}$$

Symmetric first-order conditions. In a symmetric equilibrium conditional on (s,e), let

$$b_1 = b_2 = b, \qquad g_1 = g_2 = g, \qquad y = 1-b-g, \qquad D = 2g+\eta, \qquad \pi = \frac{g}{2g+\eta}.$$

Moreover, $B_1 = B_2 \equiv B = A\, b^{\alpha}$. Using $Y'(y) = \chi\beta y^{\beta-1}$, the two interior FOCs (11)–(12) become

$$\chi\beta\, y^{\beta-1} = p\theta\,\big(1-\varphi\pi\big)\,A\alpha\, b^{\alpha-1}, \tag{40}$$

$$\chi\beta\, y^{\beta-1} = p\theta\,\frac{\varphi}{2g+\eta}\,A\, b^{\alpha}. \tag{41}$$

Reducing the system. Equating the right-hand sides of (40)–(41) yields a convenient relationship between b and g:

$$b = \frac{\alpha}{\varphi}\Big((2-\varphi)g + \eta\Big). \tag{42}$$

Substituting (42) into $y = 1-b-g$ and then into (41) delivers a single implicit equation determining $g^*(s,e)$ (and hence $b^*(s,e)$ and $y^*(s,e)$). This implicit characterization is standard in the butter–guns–ice-cream tradition and is sufficient for comparative statics.

A monotonicity condition. The comparative statics of $g^*(s,e)$ with respect to the productivity shifter A are in general implicit. We impose a standard monotonicity condition ensuring that the marginal return to coercion does not increase with coercion in the relevant region.

Assumption 1 (Monotone returns to coercion). Define, for $g > 0$,

$$\Psi(g) \equiv \frac{b(g)^\alpha}{2g+\eta}, \qquad b(g) \equiv \frac{\alpha}{\varphi}\Big((2-\varphi)g + \eta\Big). \tag{43}$$

In a neighborhood of the interior symmetric equilibrium, $\Psi(g)$ is weakly decreasing in g, i.e. $\Psi'(g) \leq 0$.

Implication (comparative statics with respect to A). Let the reduced-form equation be

$$F\big(g; A\big) \equiv \chi\beta\, y(g)^{\beta-1} - p\theta\, A\,\varphi\,\Psi(g) = 0, \qquad y(g) \equiv 1 - b(g) - g. \tag{44}$$

Since $\beta \in (0,1)$, we have $F_A = -p\theta\,\varphi\,\Psi(g) < 0$. Moreover,

$$F_g = \chi\beta(\beta-1)\,y(g)^{\beta-2}\,y'(g) \;-\; p\theta\,A\,\varphi\,\Psi'(g).$$

Because $y'(g) = -(b'(g)+1) < 0$ and $\beta - 1 < 0$, the first term is strictly positive. Under Assumption 1, $\Psi'(g) \leq 0$, hence the second term is weakly positive. Therefore $F_g > 0$ in a neighborhood of the equilibrium, and the implicit function theorem implies

$$\frac{dg^*}{dA} = -\frac{F_A}{F_g} > 0. \tag{45}$$

Since $b(g)$ is increasing in g by (42), it follows that $db^*/dA > 0$ and $dy^*/dA < 0$.

Feasibility. Interior solutions require $b^*(s,e) > 0$, $g^*(s,e) > 0$, and $y^*(s,e) = 1 - b^*(s,e) - g^*(s,e) > 0$, which impose restrictions on primitives through (42) and (44).

A.2 Extension 1: expected prize and first-order conditions under heterogeneous exposure

This appendix provides expressions for the expected raid prize and the derivatives used to characterize equilibrium in Extension 3.2. Throughout, the contest technology (including stalemate) and the raid rule are unchanged relative to the benchmark, while contested productivity differs across groups through exposure (e_1, e_2).

A.2.1 Expected prize

Conditional on (s, e_1, e_2), contested output is

$$B_i(s, e_i) = A(s, e_i)\, b_i^\alpha \equiv A_i(s)\, b_i^\alpha, \qquad i \in \{1, 2\}.$$

Under the stalemate CSF,

$$\pi_i = \frac{g_i}{g_i + g_j + \eta}, \qquad \pi_0 = \frac{\eta}{g_i + g_j + \eta}, \qquad \pi_i + \pi_j + \pi_0 = 1,$$

and the raid rule (9) implies the expected controlled butter (in physical units)

$$\begin{aligned}\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big] &= \pi_i\left(B_i(s,e_i) + \varphi B_j(s,e_j)\right) + \pi_j\left((1-\varphi)B_i(s,e_i)\right) + \pi_0\, B_i(s,e_i) \\ &= \Big(1 - \varphi\pi_j\Big)B_i(s,e_i) + \varphi\pi_i B_j(s,e_j),\end{aligned} \tag{46}$$

where $j \neq i$.

A.2.2 Derivatives with respect to b_i

Since contest probabilities depend only on guns, $\partial\pi_k/\partial b_i = 0$ for all $k \in \{i, j, 0\}$. Therefore,

$$\frac{\partial}{\partial b_i}\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big] = \Big(1 - \varphi\pi_j\Big)\frac{\partial B_i(s, e_i)}{\partial b_i} = \Big(1 - \varphi\pi_j\Big)A(s, e_i)\alpha\, b_i^{\alpha-1}. \tag{47}$$

A.2.3 Derivatives with respect to g_i

Let $D \equiv g_i + g_j + \eta$. Then

$$\pi_i = \frac{g_i}{D}, \qquad \pi_j = \frac{g_j}{D}.$$

Differentiating,

$$\frac{\partial\pi_i}{\partial g_i} = \frac{g_j + \eta}{D^2}, \qquad \frac{\partial\pi_j}{\partial g_i} = -\frac{g_j}{D^2}. \tag{48}$$

Using (46) and (48), we obtain

$$\begin{aligned}\frac{\partial}{\partial g_i}\mathbb{E}\Big[\widetilde{B}_i(s; e_1, e_2)\Big] &= -\varphi\frac{\partial\pi_j}{\partial g_i}B_i(s, e_i) + \varphi\frac{\partial\pi_i}{\partial g_i}B_j(s, e_j)\\ &= \frac{\varphi}{D^2}\Big[g_j\, B_i(s, e_i) + (g_j + \eta)\, B_j(s, e_j)\Big].\end{aligned} \tag{49}$$

A.2.4 First-order conditions

Let $y_i = 1 - b_i - g_i$. Group i maximizes

$$U_i(s; e_1, e_2) = \chi y_i^\beta + p\theta\,\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)].$$

Under an interior optimum, the FOCs are

$$\chi\beta\, y_i^{\beta-1} = p\theta\,\Big(1 - \varphi\pi_j\Big)A(s, e_i)\alpha\, b_i^{\alpha-1}, \tag{50}$$

$$\chi\beta\, y_i^{\beta-1} = p\theta\,\frac{\varphi}{(g_i + g_j + \eta)^2}\Big[g_j\, B_i(s, e_i) + (g_j + \eta)\, B_j(s, e_j)\Big], \tag{51}$$

together with feasibility $b_i \geq 0$, $g_i \geq 0$, $b_i + g_i \leq 1$. Equations (50)–(51) characterize equilibrium allocations conditional on (s, e_1, e_2).

A.3 Extension 2: first-order conditions under endogenous destructiveness

This appendix records the only modification to the equilibrium characterization relative to Extension 3.2. The expected raid prize $\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)]$ and its derivatives with respect to (b_i, g_i) are unchanged and are reported in Appendix A.2. The novelty is that survivability depends on total coercion $G = g_1 + g_2$ via $\theta(G)$.

A.3.1 Modified guns first-order condition

Let

$$U_i(s; e_1, e_2) = \chi(1 - b_i - g_i)^\beta + p\,\theta(G)\,\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)], \qquad G = g_1 + g_2.$$

Differentiating with respect to g_i and using $\partial G/\partial g_i = 1$ yields

$$\frac{\partial U_i}{\partial g_i} = -\chi\beta(1 - b_i - g_i)^{\beta-1} + p\left[\theta(G)\frac{\partial}{\partial g_i}\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)] + \theta'(G)\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)]\right].$$

Under an interior optimum, $\partial U_i/\partial g_i = 0$, which gives (24) in the main text. Since $B_i(s, e_i) > 0$ and the contest probabilities are nonnegative, $\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)] > 0$ and thus $\theta'(G)\mathbb{E}[\widetilde{B}_i(\cdot)] < 0$ whenever $\theta'(G) < 0$.

A.3.2 Butter first-order condition

Because $\theta(G)$ does not depend on b_i, the butter FOC simply scales the benchmark marginal condition by $\theta(G)$:

$$\chi\beta(1 - b_i - g_i)^{\beta-1} = p\,\theta(G)\,\frac{\partial}{\partial b_i}\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)],$$

which corresponds to (23).

A.4 Extension 3: additional derivatives under endogenous butter price

This appendix records the additional derivatives introduced by endogenizing the butter price in Extension 3.4. The expected raid prize $\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)]$ and its derivatives with respect to (b_i, g_i) are unchanged and are reported in Appendix A.2. The only modification is that the price depends on effective supply $B^{\text{eff}} = \theta(G)\,B$.

A.4.1 Effective supply and marginal effects

Let

$$B(s; e_1, e_2) = B_1(s, e_1) + B_2(s, e_2), \qquad B^{\text{eff}}(s; e_1, e_2) = \theta(G)\,B(s; e_1, e_2), \qquad G = g_1 + g_2.$$

Since $B_i(s, e_i) = A(s, e_i)b_i^{\alpha}$, we have

$$\frac{\partial B}{\partial b_i} = \frac{\partial B_i(s, e_i)}{\partial b_i} = A(s, e_i)\,\alpha\,b_i^{\alpha-1}. \tag{52}$$

Because $\theta(G)$ does not depend on b_i,

$$\frac{\partial B^{\text{eff}}}{\partial b_i} = \theta(G)\,\frac{\partial B}{\partial b_i} = \theta(G)\,A(s, e_i)\,\alpha\,b_i^{\alpha-1}. \tag{53}$$

Moreover, since B does not depend on (g_1, g_2),

$$\frac{\partial B^{\text{eff}}}{\partial g_i} = \theta'(G)\,\frac{\partial G}{\partial g_i}\,B = \theta'(G)\,B(s; e_1, e_2). \tag{54}$$

A.4.2 Price-feedback terms in the first-order conditions

Let

$$U_i = \chi(1 - b_i - g_i)^{\beta} + p(B^{\text{eff}})\,\theta(G)\,\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)].$$

Differentiating with respect to b_i yields the additional price-feedback term

$$p'(B^{\text{eff}})\,\frac{\partial B^{\text{eff}}}{\partial b_i}\,\theta(G)\,\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)], \tag{55}$$

which appears in (29). Differentiating with respect to g_i yields the additional term

$$p'(B^{\text{eff}})\,\frac{\partial B^{\text{eff}}}{\partial g_i}\,\theta(G)\,\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)] = p'(B^{\text{eff}})\,\theta'(G)\,B(s; e_1, e_2)\,\theta(G)\,\mathbb{E}[\widetilde{B}_i(s; e_1, e_2)], \tag{56}$$

which appears in (30). All remaining terms coincide with those in Extensions 3.2–3.3.

A.5 Extension 4: additional derivatives under price stabilization

This appendix records the only additional objects introduced by institutional price stabilization in Extension 3.5. All definitions from Extension 3.4 continue to apply, including effective supply $B^{\text{eff}} = \theta(G)B$ and the derivatives of B^{eff} reported in Appendix A.4. The expected raid prize $\mathbb{E}[\widetilde{B}_i(s;e_1,e_2)]$ and its derivatives are unchanged and reported in Appendix A.2.

A.5.1 Effective price and its derivative

Let $p_m(B^{\text{eff}})$ denote the market price from Extension 3.4. The stabilized effective price is

$$p^{\text{eff}}\left(B^{\text{eff}};\lambda\right) = \left(1-\mu(\lambda)\right) p_m\left(B^{\text{eff}}\right) + \mu(\lambda)\,\bar{p}_0, \qquad \mu'(\lambda) > 0.$$

Differentiating with respect to B^{eff} yields, for interior stabilization $\mu(\lambda) \in (0,1)$,

$$\frac{\partial p^{\text{eff}}}{\partial B^{\text{eff}}} = \left(1-\mu(\lambda)\right) p_m'\left(B^{\text{eff}}\right). \tag{57}$$

In particular, whenever $p_m'(B^{\text{eff}}) \neq 0$, institutional capacity dampens the slope of the price schedule because $\partial|\partial p^{\text{eff}}/\partial B^{\text{eff}}|/\partial\lambda < 0$.

A.5.2 Price-feedback terms in the first-order conditions

Let

$$U_i = \chi(1-b_i-g_i)^{\beta} + p^{\text{eff}}(B^{\text{eff}};\lambda)\,\theta(G)\,\mathbb{E}[\widetilde{B}_i(s;e_1,e_2)].$$

The price-feedback term in the b_i-FOC is

$$\frac{\partial p^{\text{eff}}}{\partial B^{\text{eff}}}\,\frac{\partial B^{\text{eff}}}{\partial b_i}\,\theta(G)\,\mathbb{E}[\widetilde{B}_i(s;e_1,e_2)], \tag{58}$$

and the price-feedback term in the g_i-FOC is

$$\frac{\partial p^{\text{eff}}}{\partial B^{\text{eff}}}\,\frac{\partial B^{\text{eff}}}{\partial g_i}\,\theta(G)\,\mathbb{E}[\widetilde{B}_i(s;e_1,e_2)]. \tag{59}$$

Relative to Extension 3.4, these terms are scaled by $(1-\mu(\lambda))$ through (57); all remaining components of the first-order conditions coincide with those in (35)–(36).