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Political Competition, Resource Availability, and Conflict: A Simulation

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Abstract: This paper explores the dynamics of political competition, resource availability, and conflict through a simulation-based approach. Utilizing agent-based models (ABMs) within an evolutionary game theoretical framework, we investigate how individual behaviors and motivations influence collective outcomes in civil conflicts. Our study builds on the theoretical model developed by Basuchoudhary et al. (2023), which integrates factors such as resource availability, state capacity, and political entrepreneurship to explain the evolution of civil conflict. By simulating boundedly rational agents, we demonstrate how changes in resource availability can alter the nature of civil conflict, leading to different equilibrium outcomes. The findings highlight the importance of understanding individual motivations and adaptive behaviors in predicting the stability and resolution of conflicts. This research contributes to the growing body of literature on the use of agent-based models in evolutionary game theory and provides valuable insights into the complex interactions that drive civil violence.

Keywords: rents; civil war; evolutionary modeling; agent based modeling; resources

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1. Introduction

Civil war is characterized by organized and sustained violence between factions within the same country, typically involving many participants and resulting in substantial casualties [1]. Due to their internal nature and the fact that the opposing parties often continue to exist within the same national borders post-conflict, civil wars are distinct from other forms of conflict, such as interstate wars. This internal dynamic creates unique challenges and consequences not typically present in international conflicts.

Studies on insurgencies often explore why conflicts start, escalate, or end (see, among others [2–4]). Institutional weakness is frequently cited as a cause, with repressive states being prone to civil war [5]. However, the type of democratic institutions in ethnically diverse societies also factors into civil war risk; power-sharing institutions reduce risk while majoritarian systems and presidential regimes increase it [6]. Resource-rich states with weak institutions are likely to experience civil war, while those with strong state capacity are less susceptible [7]. Personalist and neo-patrimonial regimes within otherwise weak states are especially vulnerable due to centralized power lacking institutional checks [8]. Strong political and legal institutions help prevent civil wars by constraining elites and reducing the need for militias. This suggests that civil wars involve struggles for political control and reform [9]. Key questions arise about how institutions, resources, and state capacity

influence political competition, how violence alters political behavior, and how culture affects these processes. To address these questions, we propose agent-based modeling techniques within a theoretical framework for evolutionary games.

Studies on insurgencies often focus on the reasons behind the start, escalation, or cessation of conflicts [2–4]. There are competing explanations for rebel motivation, such as the well-known greed versus grievance debate [10]. In contrast, other explanations revolve around resource availability, the opportunity costs of civil conflict, state capacity, and political entrepreneurship. All these factors can be combined to model a dynamic theory where changes in resource availability alter the nature of civil conflict [11]. However, the intricate interactions between these factors make empirical confirmation challenging. Moreover, even an analytical solution becomes complicated.

EGT, or Evolutionary Game Theory, models how individuals adapt their strategies based on interactions with others, which can be applied to social dynamics where cultural or learned behaviors are predominant. For instance, individuals may imitate successful strategies or explore new ones, akin to cultural evolution rather than genetic mutation [12]. These models can illustrate how the environment and past interactions influence future social dynamics; they are predictive and, therefore, very well suited for policy analysis. For example, EGT models how cooperation can evolve in social dilemmas by altering the games played based on previous outcomes, thus supporting prosocial behaviors in changing environments [13]. Moreover, in real-world scenarios, individuals often engage in multiple interactions simultaneously. EGT provides tools to analyze these complex dynamics by considering multiple games and their combined effects on social behavior, which can lead to diverse and sometimes unexpected outcomes [14]. Thus, EGT models are particularly suited for studying civil conflict because creating policy to deter such conflicts requires complex dynamic analyses [15]. Agent-based models, or ABMs, are highly beneficial when the link between individual behaviors and collective outcomes is poorly understood or when real-world data collection is impractical or risky. ABMs can handle complex interactions among agents, such as those involving finite populations, stochastic decisions, and spatial interactions, often intractable with purely mathematical models [16]. Moreover, they allow for modeling heterogeneous populations where each agent can have unique strategies and characteristics, providing a more realistic representation of biological and social systems [16,17]. In scenarios where mathematical solutions are difficult or impossible to derive, such as non-weak selection or high mutation rates, ABMs can simulate outcomes and provide insights that are otherwise inaccessible [17]. Indeed, mathematical models are crucial for validation. However, ABMs enable the exploration of broader parameter ranges and more complex scenarios, offering a complementary approach to traditional methods [17]. Consequently, ABMs help facilitate the study of emergent behaviors in multi-agent systems, allowing researchers to observe how collective behaviors evolve from individual interactions under various conditions [18]. Indeed, by incorporating learning algorithms, ABMs can model how agents adapt and optimize their strategies over time, reflecting the dynamic nature of evolutionary games [19].

This is especially pertinent when examining civil conflict. Considering individual motivations within a group is crucial when analyzing group dynamics. For example, when studying a rebel group, one must consider the personal motivations that may influence group behavior. Modeling these motivations is challenging, as people rationalize decisions in various ways, even when responding to surveys. ABMs can approximate these behavioral explanations and determine analytical outcomes that are computationally difficult. In summary, ABMs offer a simple yet powerful framework for explaining the dynamics of civil violence, making it easier to comprehend and simulate different social conflicts. Additionally, a computer-assisted approach can simplify complex scenarios, for instance,

by reducing an ABM to a stochastic model with two coarse-grained degrees of freedom, capturing the dynamics of civil violence while significantly reducing computation time.

We use boundedly rational agents to simulate an evolutionary game-theoretic (EGT) framework. These agents can evaluate the costs and benefits of their actions and learn how to make better choices. Agent-based methods are precious in evolutionary game theory for modeling complex interactions that are challenging to capture with purely mathematical approaches. These methods allow each agent to be individually modeled, with their own strategies and evolving. This approach is advantageous for studying finite populations, non-vanishing mutation rates, stochastic decisions, and spatial interactions. For example, agent-based simulations can predict evolutionary outcomes in scenarios where traditional mathematical models fall short, such as the weak selection-strong mutation limit [16]. Therefore, we contribute to a small but growing body of literature using agent-based models by modeling boundedly rational rebel and state actors to demonstrate how the outcome of a civil conflict can evolve toward different results depending on the availability of resources.

This paper, building on the theoretical framework proposed by Basuchoudhary et al. [11], presents a unique model that attempts to simulate the evolution of conflict in different power and rent contexts.

2. Basuchoudhary et al. (2023)—Describing the Theory [11]

This paper models rebels with distinct objectives: Warlord rebels, who directly appropriate rents, and Reform rebels, who are motivated by grievances that can be assuaged by capturing state machinery. Both types of rebels redistribute rents to overcome collective action problems. The common drive to capture or challenge the state's authority to control rents serves as a unifying force among rebels. If they gain political power, rebel leaders may redistribute state resources to their in-group. The state, in response to insurgency, can either aggressively defend its rent monopoly or negotiate to share rents in the disputed region, depending on the proportion of state elites that support a particular response.

Reform insurgents seek to address the unequal allocation of resources by striving to gain political power. In many African countries, this entails challenging the neo-patrimonial regime and the patron-client networks controlled by the political elite. This often requires a conventional war and a more centralized command to capture a state [20]. In addition, scholars have explored the inherent challenges in coordination in such rebellions. Rebel leaders can only redistribute resources to their clients if they successfully attain political power [11].

2.1. The Formal Model [11]

This paper models a neo-patrimonial setting where rebels and state elites battle over the distribution of rents. In Nigeria's fiscal federalism system, controlling resource rents or profits in the South differs from the North due to the presence of directly appropriable resources such as oil. Rebels in the South can either steal resources to control rents or demand a greater share. In contrast, insurgents in the resource-poor North can only increase rents by replacing elites through violence or negotiation. The model captures various causes of civil conflict and motivations for controlling rents.

The model is based on the assumption of an ongoing regional conflict between state elites and rebel groups. The rebels are categorized into two types: Warlord (W) with a probability x and Reform (R) with a probability of $1 - x$. In the population, this means that a proportion x of the rebel population is of the Warlord type. This structure emphasizes two conflicting causal theories of rebel behavior—one where the population rebels to secure a direct share of the profits and the other where rebels aim to gain control of the state to capture those profits. There are two types of state elite populations: Aggressive (A) with probability y and Conciliatory (C) with probability $1 - y$. Aggressive elites are more likely to continue to fight rebellion, while conciliatory elites are more likely to bargain with rebels even when either type of elite begins by fighting rebels.

In this model, individuals adapt their behavior to maximize personal benefits. These adaptive behaviors affect stability outcomes and the possibility of achieving stability, particularly in response to contextual changes. Thus, Warlord rebels can learn to become Reformists or vice versa, just as state elites can learn to become Aggressive even if they start as Conciliatory or vice versa. This contextual "learning" changes the nature of conflict in the model and is a standard feature of evolutionary game-theoretic modeling. The disputed region generates rents V in any period. Neo-patrimonial leaders exclusively seek rents for redistribution; thus, state elites and rebels focus on acquiring V. (Rent-seeking is not just a neopatrimonial vice [21]. To that extent, our model may be generalized to other settings where rent-seeking is a key feature.)

Warlord rebels are only interested in obtaining a share of the rents αV where $\alpha \in (0, 1)$ without necessarily needing to control the state. To achieve this, they may resort to theft, such as stealing oil directly from underwater pumps. They may also be open to a peaceful arrangement where they can still retain a share of the profits without engaging in conflict, although they are not opposed to war if it means securing their share. In regions without directly appropriable resources, capturing the state machinery may be the only way to gain rents. Reformist rebels aim to capture the state to obtain and distribute rents in a neo-patrimonial world.

Capturing state machinery can be costly. In a neo-patrimonial system, the state redistributes a fraction of rents V, using $1 - L$ to run itself and provide public goods. For instance, redistributing rents in Nigeria through the federal structure may incur losses, with L representing "leakage" toward neo-patrimonial redistribution. Essentially, neopatrimonialism involves the state redistributing rents under a "big man." Thus, controlling the state offers a net benefit LV. We assume that L is a constant share of rents for simplicity. If warlords capture V, they face lower organizational costs, as they do not need to maintain ministries or public goods, normalizing their administrative costs to zero.

State elites control the state machinery and stand to lose it if defeated by rebels or if they negotiate peace. For insurgents, gaining this machinery is a benefit if they win since they did not possess it initially. Hence, it is a positive LV in the rebels' function when victorious. Conversely, LV represents a loss for state elites if they are defeated by Reform insurgents or granted autonomy. War costs are denoted as C_r for rebels and C_g for state elites, with probability p indicating the probability that state elites will win, affecting their expected gains.

Aggressive state elites engage both kinds of rebels in a win-lose scenario. In contrast, conciliatory state elites negotiate with Warlord rebels and share resources. These conciliatory elites might also relinquish control over state apparatus and the associated benefits in a region. Consequently, this results in four potential strategic interactions between rebels and state elites, as depicted in the evolutionary stage game illustrated in Table 1.

Table 1. Payoff matrix for rebels and state elites.

	State Elites	
	Aggressive (y)	**Conciliatory (1−y)**
Rebels		
Warlord (x)	$(1-p)(V-C_r)-pC_r$; $p(V-C_g)-(1-p)C_g$	$\alpha V; (1-\alpha)V$
Reform (1−x)	$(1-p)(LV-C_r)-pC_r$; $p(LV-C_g)-(1-p)(C_g+LV)$	$LV; -LV$

2.2. The Replicator Dynamic

The general replicator dynamic equation is a differential equation that models the evolution of the proportion of individuals adopting a specific strategy based on their relative fitness (payment) [22,23].

2.2.1. Expected Payoffs

The expected payoff to the rebels are

$$\text{Total Expected Payoff}_{\text{Warlord}} = y \cdot ((1-p) \cdot (V - C_r) - pC_r) + (1-y) \cdot (\alpha V)$$

and

$$\text{Total Expected Payoff}_{\text{Reform}} = y \cdot ((1-p) \cdot (LV - C_r) - pC_r) + (1-y) \cdot LV$$

The expected payoffs to the state elites are

$$\text{Total Expected Payoff}_{\text{Conciliatory}} = x \cdot (1-\alpha)V - (1-x) \cdot LV$$

and

$$\text{Total Expected Payoff}_{\text{Aggressive}} = x \cdot \big(p(V - C_g) - (1-p)C_g\big) + (1-x) \cdot \big(p(LV - C_g) - (1-p)(C_g + LV)\big)$$

2.2.2. The Replicator Dynamic

To derive the replicator dynamics, we will use the expected payoffs calculated previously for each population. Replicator dynamics in this context measure how the proportions of each type of behavior (Warlord vs. Reform for rebels; Aggressive vs. Conciliatory for state elites) change over time based on the relative success (payoffs) of each behavior.

The replicator dynamic equation for a given type i in a population is given by

$$\dot{x}_i = x_i(\pi_i - \bar{\pi})$$

where x_i is the proportion of the population choosing strategy i, π_i is the expected payoff for strategy i, and $\bar{\pi}$ is the average payoff across all strategies in the population.

Recall that x represents the proportion of Warlord rebels, so $1 - x$ is the proportion of Reform rebels. We use the expected payoffs for each rebel type derived earlier to calculate the average payoff for Rebels as

$$\bar{\pi}_{\text{Rebels}} = x \cdot \pi_{\text{Warlord}} + (1-x) \cdot \pi_{\text{Reform}}$$

The replicator dynamic for the proportion of Warlord rebels x is

$$\dot{x} = x(\pi_{\text{Warlord}} - \bar{\pi}_{\text{Rebels}})$$

This equation describes the change in the proportion of Warlord rebels over time. If $\pi_{\text{Warlord}} > \bar{\pi}_{\text{Rebels}}$, the proportion of Warlord rebels will increase; otherwise, it will decrease.

Recall that y represents the proportion of Aggressive state elites. Using the expected payoffs calculated for each type of state elite, the average payoff for State Elites is

$$\bar{\pi}_{\text{State}} = y \cdot \pi_{\text{Aggressive}} + (1 - y) \cdot \pi_{\text{Conciliatory}}$$

The replicator dynamic for the proportion of Aggressive State Elites y is

$$\dot{y} = y(\pi_{\text{Aggressive}} - \bar{\pi}_{\text{State}})$$

This equation describes the change in the proportion of Aggressive state elites over time. If $\pi_{\text{Aggressive}} > \bar{\pi}_{\text{State}}$, the proportion of Aggressive elites will increase; otherwise, it will decrease.

These replicator dynamic equations generate the evolutionary stability of the behaviors for both rebels and state elites based on their respective payoffs. Over time, the system may converge to a stable equilibrium if one strategy in each group dominates, or it may oscillate if the payoffs favor shifts between strategies depending on population proportions.

2.2.3. Stability Conditions

To determine the stability of the equilibrium points in the replicator dynamics system, we need to analyze the fixed points where $\dot{x} = 0$ and $\dot{y} = 0$. These fixed points represent stable or unstable population distributions for Warlord and Reform rebels (x) and Aggressive and Conciliatory state elites (y). Stability analysis involves finding conditions under which these points are stable.

The replicator dynamic equations for each group are as follows:

1. For rebels:

$$\dot{x} = x(\pi_{\text{Warlord}} - \bar{\pi}_{\text{Rebels}}) = 0$$

2. For state elites:

$$\dot{y} = y(\pi_{\text{Aggressive}} - \bar{\pi}_{\text{State}}) = 0$$

For these equations to hold, we either have $x = 0$, $x = 1$, $y = 0$, $y = 1$ (pure strategies), or the difference in payoffs between strategies equals zero at interior points.

The fixed points at the boundaries (Pure Strategies) are as follows:

- $x = 0$: Entire population adopts the Reform strategy for rebels.
- $x = 1$: Entire population adopts the Warlord strategy for rebels.
- $y = 0$: Entire population adopts the Conciliatory strategy for state elites.
- $y = 1$: Entire population adopts the Aggressive strategy for state elites.

For interior fixed points (Mixed Strategies), i.e., ($0 < x < 1$ and $0 < y < 1$), we require the following:

- $\pi_{\text{Warlord}} = \pi_{\text{Reform}}$ for rebels.
- $\pi_{\text{Aggressive}} = \pi_{\text{Conciliatory}}$ for state elites.

Stability requires that we describe the Jacobian matrix of partial derivatives for the system at these equilibria to determine stability. For the system

$$\begin{cases} \dot{x} = x(\pi_{\text{Warlord}} - \bar{\pi}_{\text{Rebels}}) \\ \dot{y} = y(\pi_{\text{Aggressive}} - \bar{\pi}_{\text{State}}) \end{cases}$$

the Jacobian matrix J is

$$J = \begin{pmatrix} \frac{\partial \dot{x}}{\partial x} & \frac{\partial \dot{x}}{\partial y} \\ \frac{\partial \dot{y}}{\partial x} & \frac{\partial \dot{y}}{\partial y} \end{pmatrix}$$

Evaluating J at each equilibrium point and analyzing the sign of its eigenvalues will determine whether each fixed point is stable (negative eigenvalues) or unstable (positive eigenvalues). The calculations require substituting the values of π_{Warlord}, π_{Reform}, $\pi_{\text{Aggressive}}$, and $\pi_{\text{Conciliatory}}$ as per the previously derived formulas.

2.2.4. Solution Process

Bargaining failures are a key cause of conflict. Therefore, we will investigate solutions given the relative sizes of our two bargaining variables, α and L.

To find the conditions for an interior equilibrium, we need to set the payoffs for each pair of strategies equal to each other.

For Warlords, set $\pi_{\text{Warlord}} = \pi_{\text{Reform}}$:

$$y \cdot ((1-p)(V - C_r) - pC_r) + (1-y) \cdot (\alpha V) = y \cdot ((1-p)(LV - C_r) - pC_r) + (1-y) \cdot LV$$

Expanding and grouping terms with y on one side and $(1-y)$ terms on the other leads to

$$y \cdot ((1-p)(V - C_r - LV) + C_r p) = (1-y) \cdot (L - \alpha)V$$

Dividing both sides by V and isolating y gives us

$$y^* = \frac{(L-\alpha)}{(1-p)(V - C_r - LV) + C_r p}$$

This proportion y^* represents the interior equilibrium condition for the state elites when both Warlord and Reform behaviors are balanced.

For State Elites' set $\pi_{\text{Aggressive}} = \pi_{\text{Conciliatory}}$,

$$x \cdot (p(V - C_g) - (1-p)C_g) + (1-x) \cdot \big(p(LV - C_g) - (1-p)(C_g + LV)\big)$$

$$= x \cdot (1-\alpha)V + (1-x) \cdot LV$$

Expanding and simplifying this equation yields an expression for the interior equilibrium proportion x based on the parameters. Solving for x here gives

$$x^* = \frac{L}{p(V - C_g) + (1-p)(C_g - LV)}$$

This equilibrium x^* represents the balance point for the proportion of Warlord rebels.

For pure strategies, we analyze conditions where x and y are either 0 or 1, signifying that one strategy becomes dominant for either the rebels or state elites.

1. For $x = 1$ (all Warlord rebels) stability requires $\pi_{\text{Warlord}} > \pi_{\text{Reform}}$ for all y. This occurs if

$$(1-p)(V - C_r) - pC_r > (1-p)(LV - C_r) - pC_r \Rightarrow V > LV$$

This simplifies to $L < 1$, which typically holds, so $x = 1$ is a feasible equilibrium for dominant Warlord behavior.

2. For $x = 0$ (all Reform rebels) Stability requires that $\pi_{\text{Reform}} > \pi_{\text{Warlord}}$ for all y. This holds if

$$LV > \alpha V$$

which gives the condition $L > \alpha$, favoring Reform behavior over Warlord.

3. For $y = 1$ (all Aggressive state elites) Stability requires $\pi_{\text{Aggressive}} > \pi_{\text{Conciliatory}}$ for all x.This leads to a condition comparing

$$p(V - C_g) - (1 - p)C_g > LV$$

4. For $y = 0$ (all Conciliatory state elites) stability requires $\pi_{\text{Conciliatory}} > \pi_{\text{Aggressive}}$. For this to hold, $(1 - \alpha)V > L$.

2.2.5. Phase Diagrams

This section represents the phase diagrams given the following parameters. This illustrates a particular outcome replicated using the simulations in the following section. Say we are given the following parameters:

- Total rents, $V = 5$
- Probability of state victory, $p = 0.6$
- Conflict cost for rebels, $C_r = 1$
- Conflict cost for state elites, $C_g = 1$

Say further, we have initial population proportions of $x_{\text{init}} = 0.25$ and $y_{\text{init}} = 0.75$.

In the left diagram of Figure 1 ($L = 0.5, \alpha = 0.25$), starting from the initial conditions, the system moves toward a stable equilibrium with a higher proportion of Reform rebels and Conciliatory state elites. However, in the right diagram of Figure 1 ($L = 0.25, \alpha = 0.5$), beginning with the same initial proportions, the system converges towards an equilibrium with Warlord rebels and Aggressive state elites as dominant strategies.

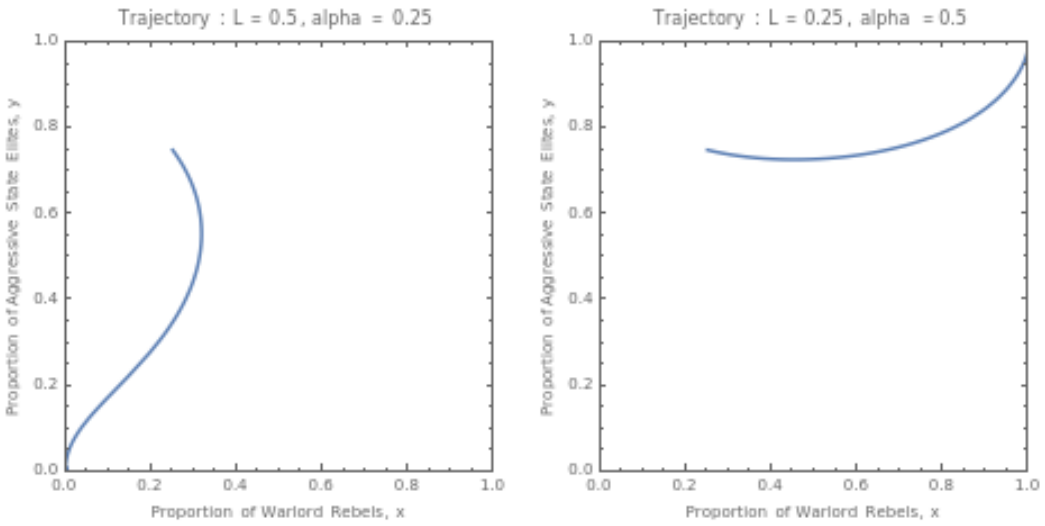


Figure 1. Hardwired initial conditions.

These trajectories show how the system evolves from the specified initial conditions in each scenario, ultimately converging to a stable configuration based on the relative values of L and α.

One can find examples of such behaviors. For instance, warlords have colluded with the Taliban to organize attacks against US forces (who could be reasonably described as

aggressive) to justify expenditures. Security groups contracted for protection frequently killed civilians, making it look as though U.S. forces were complicit in corruption and abuse of power [24]. Alternatively, rebels and the Congolese state collaborate when the state can offer plum administrative positions with opportunities to gather rents, thus bringing rebels into the government when it is more efficient to generate rents by controlling the government [25]. Moreover, this entire section is based on a case study of Nigeria where the share of rents versus the ability of the government to transfer resources has led to two very different conflicts in the northern and southern parts of the same country—Nigeria [11]

Of course, this entire system is driven by the analytical solution methods noted here. Moreover, anecdotes are not generalizable. Can our results here [11] be replicated without these mathematical guardrails? If so, it may be a first step toward finding a generalizable justification for this model. We turn to this, the innovation in this paper, next.

3. Simulation

For obvious reasons, we cannot do randomized control trials to test any hypotheses generated by the analytical solutions described above. The paucity of localized data also means an observational causal study is unlikely. Therefore, our "empirical" approach is to simulate a system in which electronic agents with minimal learning capabilities are let loose in a cyber sandbox to play the game we have demonstrated above. Are the results reminiscent of our analytical results? Of course, we must model these agents carefully since agents who behave the way we tell them to may behave exactly the way we expect! Our cyber agents must have some degree of "free will." In this instance, it means that they are allowed to make mistakes. Thus, we should expect some anomalous results.

The Rebels are divided into Warlords (W) and Reform (R) types with proportions x and $1-x$, respectively, and the State Elites group is divided into Aggressive (A) and Conciliatory (C) types with proportions y and $1-y$, respectively. In our algorithm, we have the following key parameters: the total number of rebels, the total number of state elites, the number of generations, and the number of interactions per generation. In specific runs mentioned here, we used 500 total Rebels and 500 total State Elites.

In the first generation, a pair of one Rebel and one Elite is chosen randomly according to the distributions determined by x and y. These two people interact, and the payouts are determined according to the payout matrix. This process of choosing pairs and allotting payouts is repeated a certain number of times, say 10 times. The payouts from all 10 interactions are added to the population counts of the four groups (W,R,A,C), and the populations of Rebels and State Elites are then rescaled back to 500 each, now with different proportions x and y. For example, in one trial with initial values of $x_{init} = 0.25$ and $y_{init} = 0.75$, we may have

$$(W, R, A, C) = (125, 375, 375, 125)$$

at the start and after one generation $x = 0.288$ and $y = 0.802$, so the population levels are

$$(W, R, A, C) = (144, 356, 401, 99)$$

This process is repeated over a set number of generations. In the following pictures, the typical number of generations is 150, with 10 interactions per generation unless explicitly stated otherwise. If any values W, R, A, or C ever hit zero, that group has "died out", and we stop the process at that generation. This is quite possible if the payouts are much more favorable to one (more) group. This could also happen even if the payout structures are better for a group, but the interactions swing towards another group due to randomness.

That is, this is not deterministic. At each generation, we keep track of the values x and y to produce plots to show the evolution of population types over time.

We completed this experiment multiple times, keeping the values C_g and C_r fixed while varying the values of p, V, α, L to see how the behavior of the system changes. We look at two cases where, in each of these scenarios, we change the values of p and V to predict the outcomes as individuals learn from the behavior of others in the population.

4. Discussion

In this section, we highlight some observed regularities in our simulations. The main results are presented as simulated evolutionary phase diagrams. The phase diagrams are unit boxes since x and y are the proportions of the population of rebel warlords and aggressive state elites, ranging from 0 to 1. We ignore population proportions of less than 0 or bigger than 1 in these diagrams since they are meaningless in any realistic setting. The point x^* represents the proportion of warlord rebels where the average pay-off or fitness from being aggressive state elites equals the average fitness for being conciliatory. Similarly, y^* represents the proportion of aggressive state elites for which the fitness of the warlord culture equals that of the reform culture among rebels. Thus, x^* and y^* are potential attractors or could be tipping points for behavioral cascades. Without an analytical solution, we will let our simulations reveal the outcomes of learning given a particular initial population distribution.

Bargaining failure over rents is a well-known cause of conflict [26,27]. Thus, the share of rents obtained via controlling the state L and the share received by direct bargaining between the insurgents and the state, α, play essential roles. If state control allows a larger share of rents than a directly bargained approach, the incentive to control the state would presumably be higher. The role of state power in controlling insurgencies is also well-known [26]. The phase diagrams below show how the availability of rents V, the relative share of rents, α and L, and the state capacity expressed as the ex-ante likelihood that the state will win the war, p, determine that the type of rebels and state elites—and therefore the nature of conflict—are likely to evolve.

We notice that, when the population of insurgents has a higher proportion of Warlords than x^*, then Conciliation is fitter than Aggression, thereby increasing y. Similarly, when $y > y^*$, x increases. Our simulations, though, provide a more granular link between individuals' learning behaviors in a population and their resource and political context.

Scenario 1. $L > \alpha$

$L = 0.5, \alpha = 0.25, Cg = 1, Cr = 1, x_{init=0.25}, y_{init} = 0.75.$

We vary p where p takes the values $p = [0.2, 0.4, 0.6, 0.8]$ while keeping V fixed, and we then again vary V where $V = [5, 10, 25, 40, 60]$ while keeping p fixed. Figures 2–6 represent these dynamics. The darker line represents an average of the dynamics.

Controlling state power should be advantageous in this case and advantage Reform insurgency. However, the very fact that the state can control resources has an impact on state power itself. Notice that, as V rises, the phase diagrams appear to negate the possibility of an attractor—that is, the system does seem likely to reach an equilibrium. Thus, the availability of rents reduces the likelihood of a bargained outcome characterized as one where the conciliatory state culture is part of a stable attractor. Notice further that the system reaches $y = 1$ only at the very highest level of p—i.e., the state is powerful enough to ensure a victory over the rebels. Thus, the state is likely to be conciliatory only if it is likely to win. This lends credence to the idea that powerful states are more likely to facilitate a compromise. The interesting twist is that the Warlord insurgency is more likely to succeed; notice that, when p = 0.8, x appears to creep toward 1. Thus, reform insurgencies are less

likely to survive when states are powerful—though Warlord insurgencies can. In short, state power seems to drive more of the explanatory power for which type of insurgency is likely to succeed than the availability of rents.

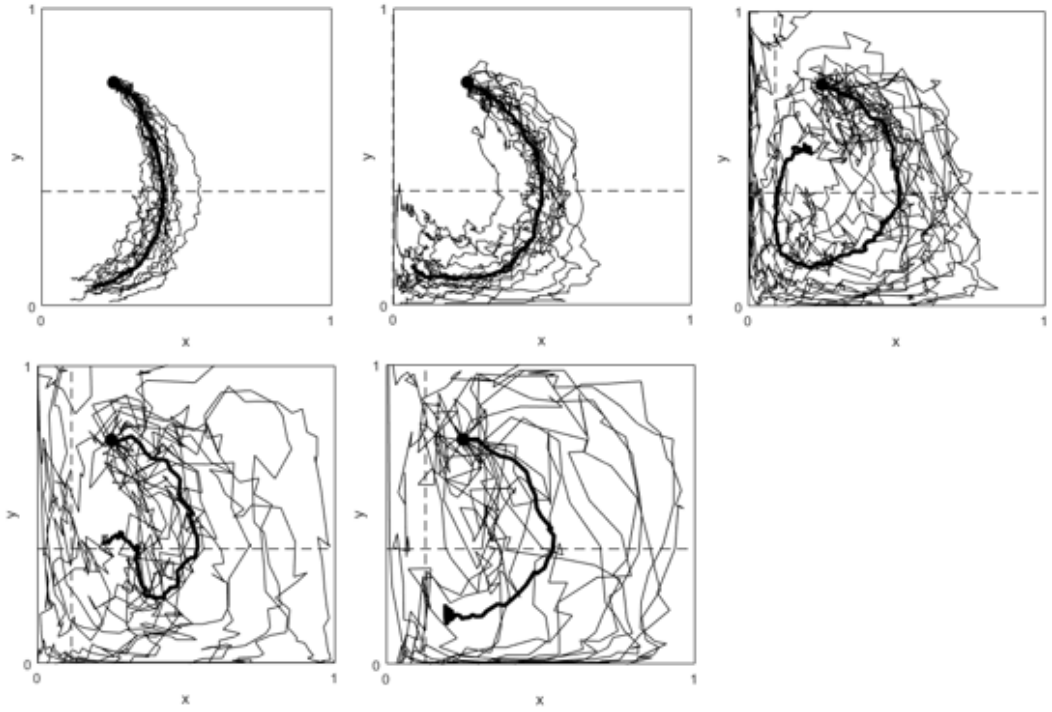


Figure 2. Case p = 0.2, V ranging [5 10 25 40 60]. Here y* = 0.385 and x* ranging [−0.154, 0, 0.092, 0.115, 0.128].

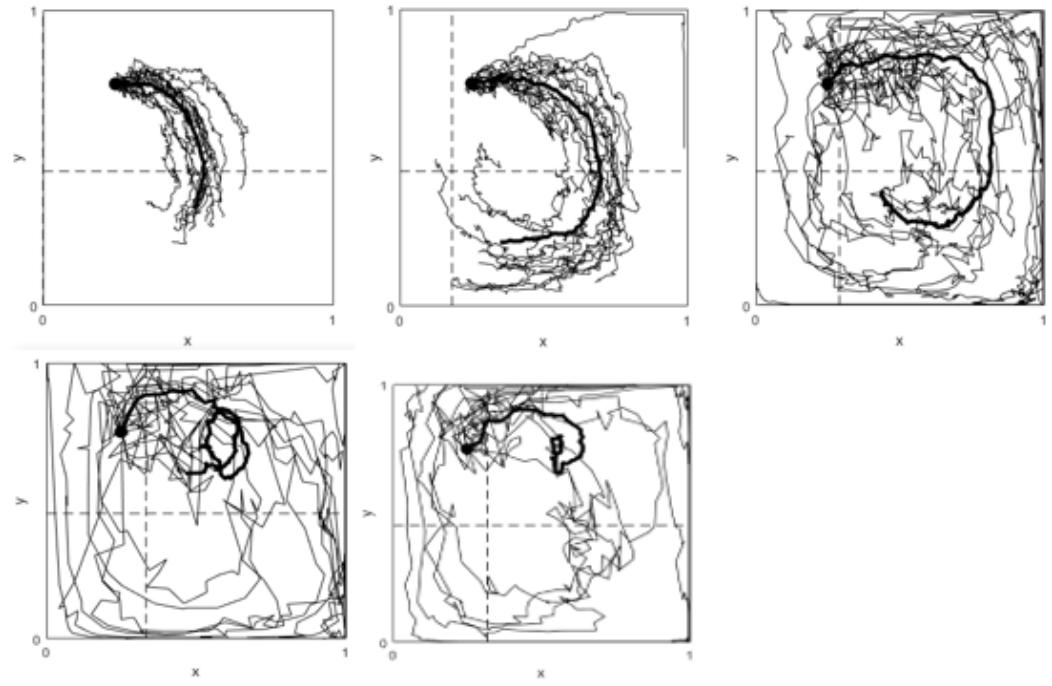


Figure 3. Case p = 0.4, V ranging [5 10 25 40 60]. Here y* = 0.454 and x* ranging [0, 0.18, 0.29, 0.318, 0.33].

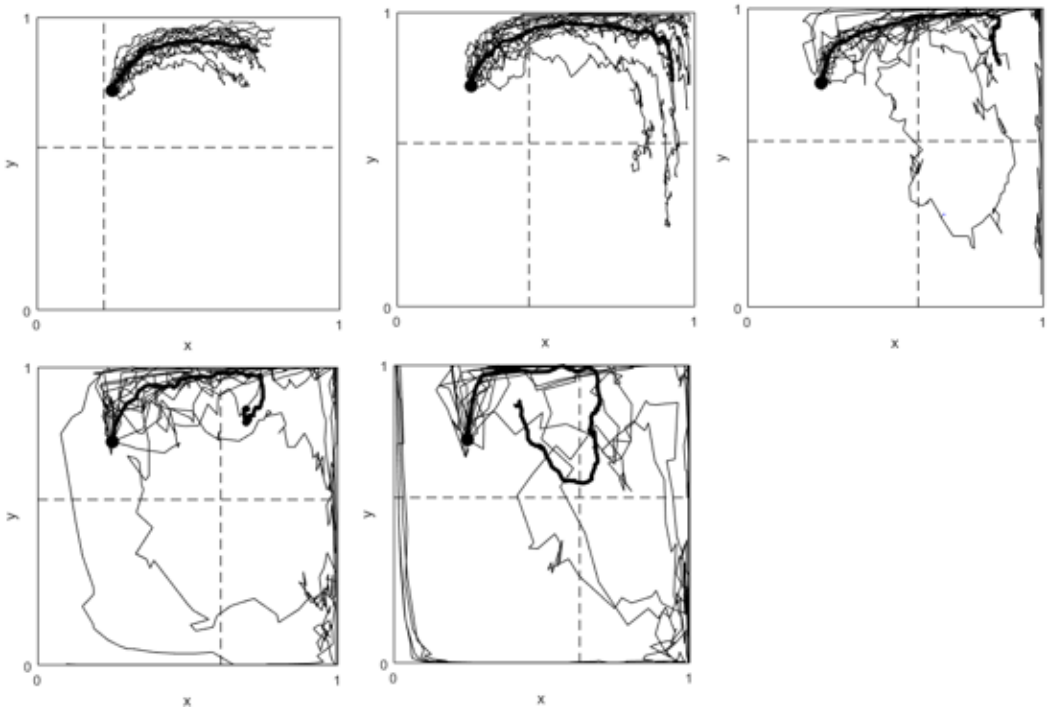


Figure 4. Case p = 0.6, V ranging [5 10 25 40 60]. Here y* = 0.556 and x* ranging [0.22, 0.44, 0.58, 0.61, 0.63].

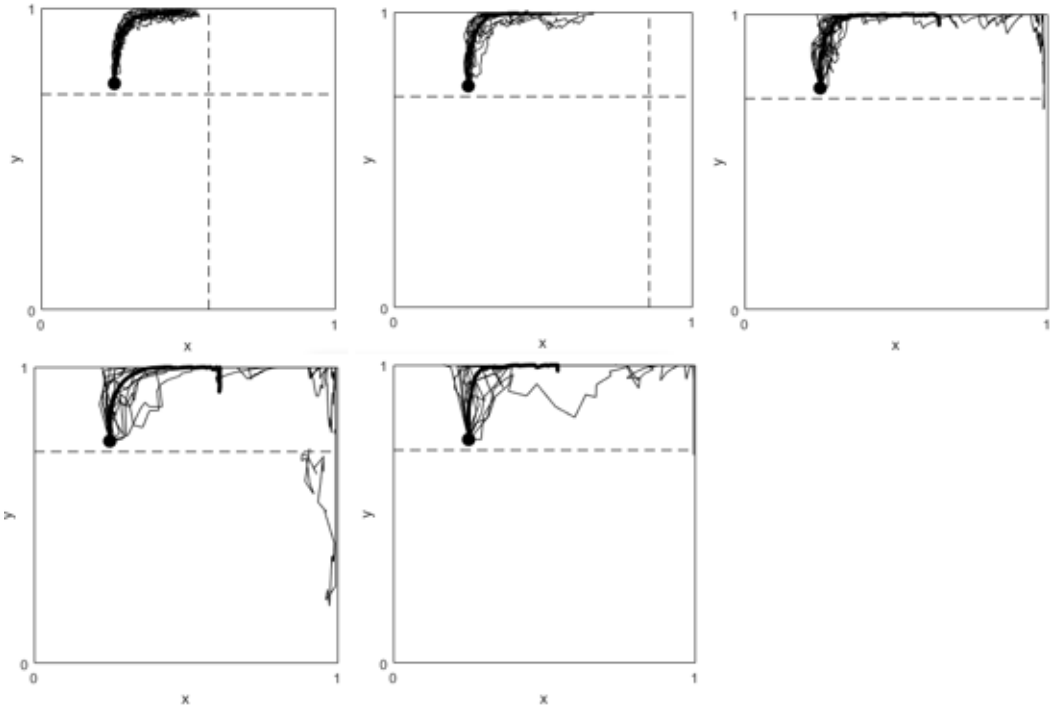


Figure 5. Case p = 0.8, V ranging [5 10 25 40 60]. Here y* = 0.71 and x* ranging [0.57, 0.86, 1.03, 1.07, 1.09].

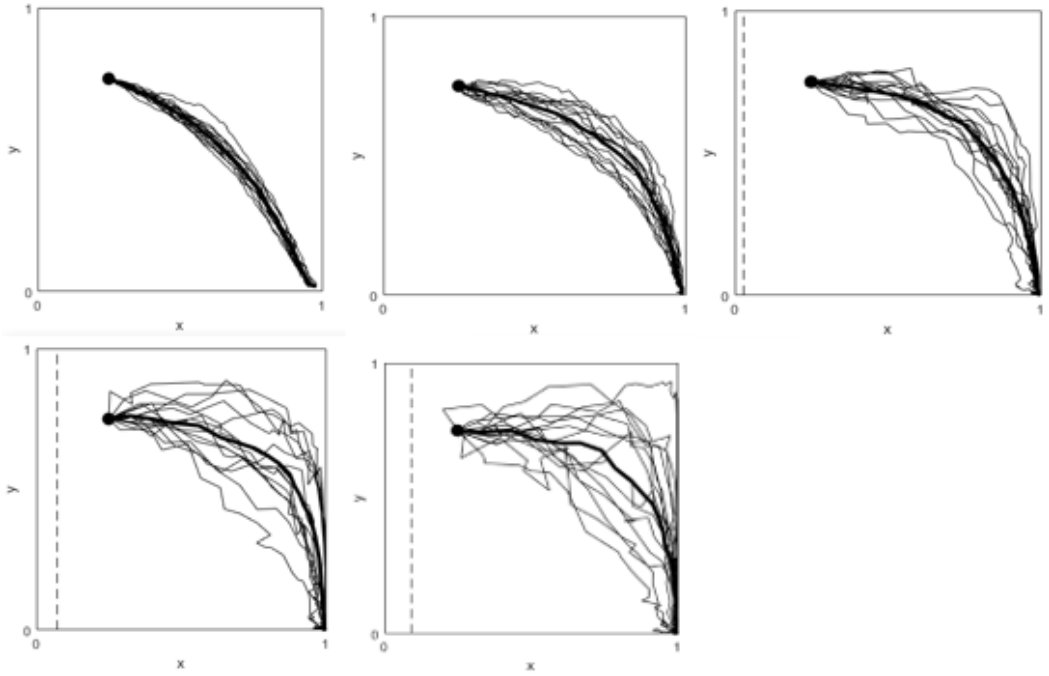


Figure 6. Case p = 0.2, V ranging [5 10 25 40 60]. Here y* = −0.71 and x* ranging [−0.43, −0.14, 0.03, 0.07, 0.09].

Scenario 2. $L < \alpha$

$L = 0.25, \alpha = 0.5, C_g = 1, C_r = 1, x_{init} = 0.25, y_{init} = 0.75.$

Again, we vary p where p takes the values $p = [0.2, 0.4, 0.6, 0.8]$ while keeping V fixed, and we then again vary V where $V = [5, 10, 25, 40, 60]$ while maintaining p fixed. Figures 7–9 represent these dynamics. Once again, the darker line represents an average of the dynamics.

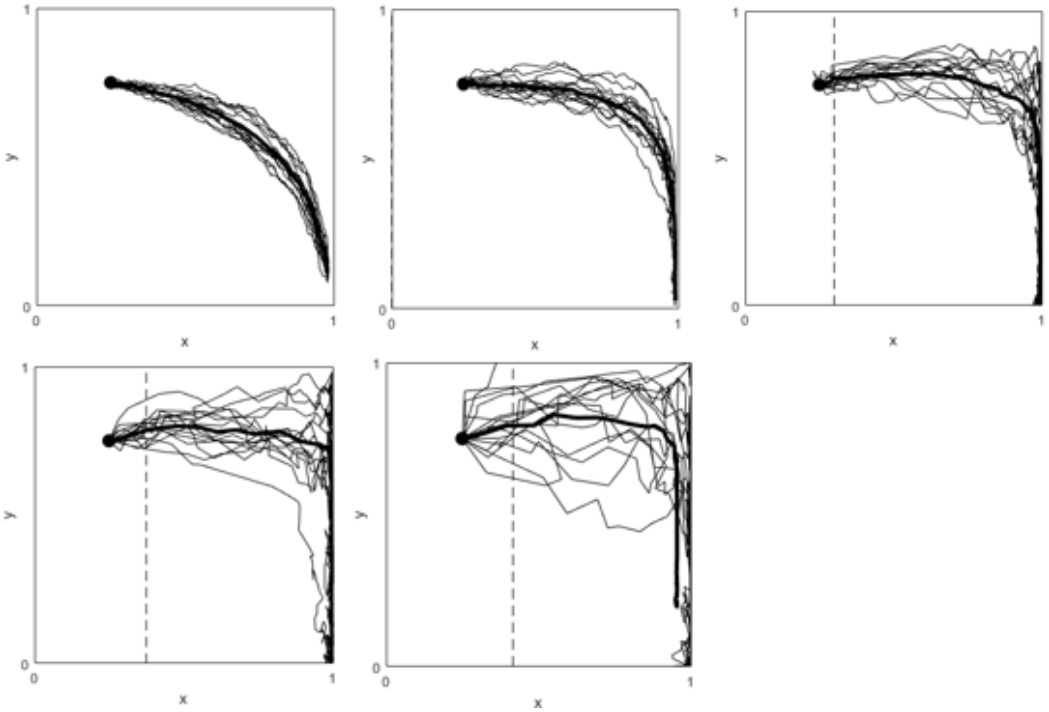


Figure 7. Case p = 0.4, V ranging [5 10 25 40 60]. Here y* = −1.25 and x* ranging [−0.2, 0, 0.3, 0.38, 0.42].

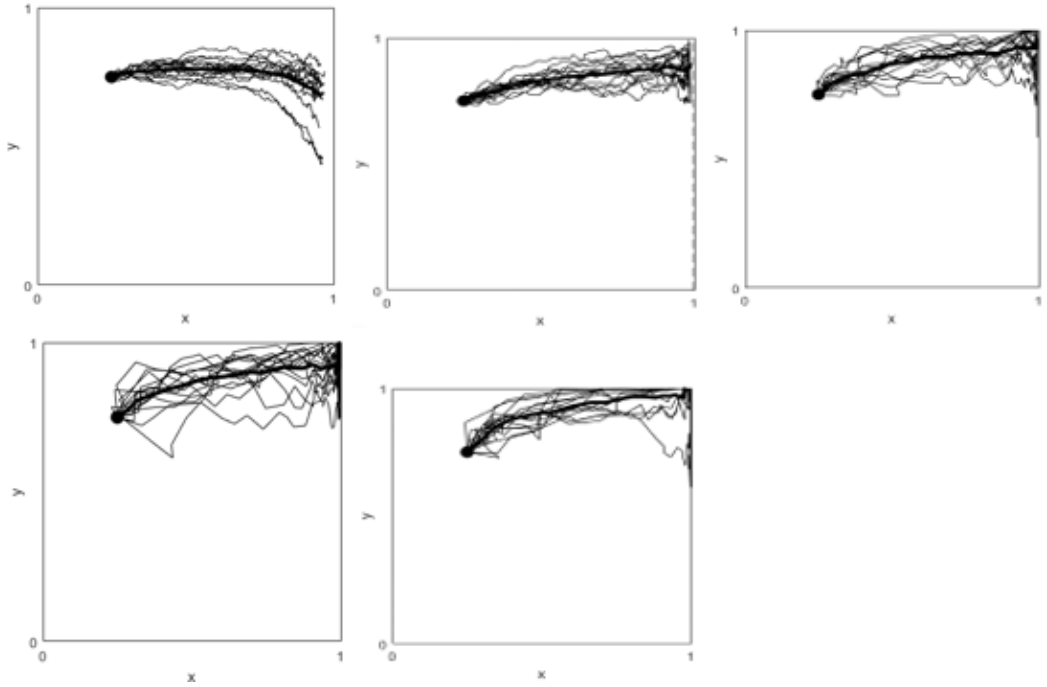


Figure 8. Case p = 0.6, V ranging [5 10 25 40 60]. Here y* = −5 and x* ranging [−1, 1, 2.2, 2.5, 2.67].

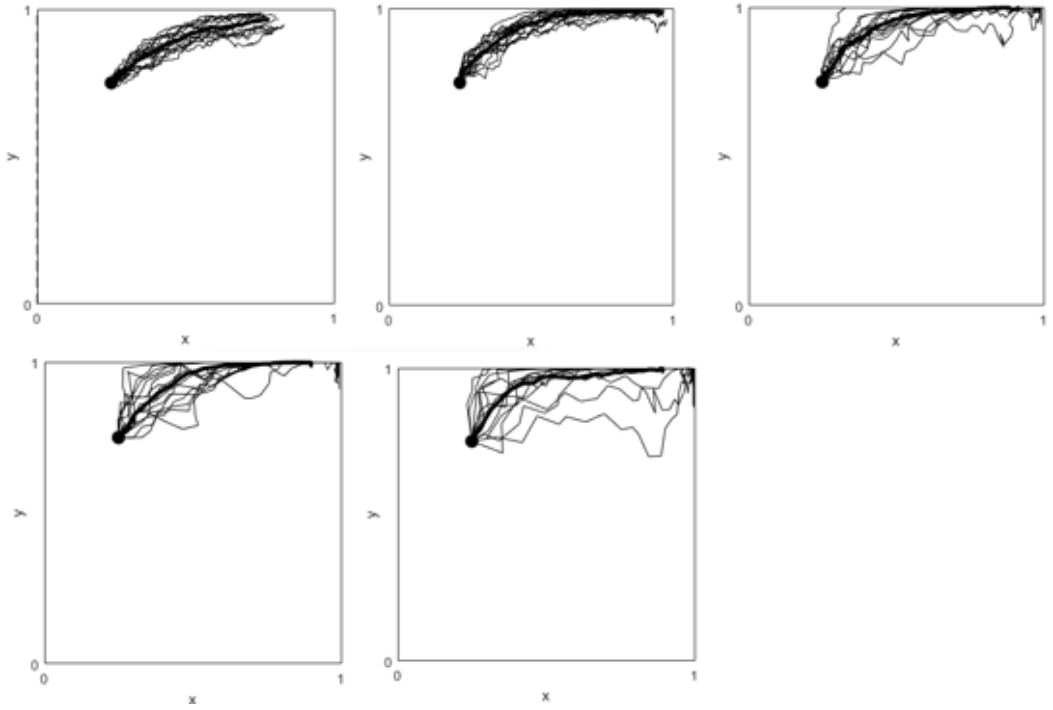


Figure 9. Case p = 0.8, V ranging [5 10 25 40 60]. Here y* = 2.5 and x* ranging [0, −1.2, −1.6, −1.75, −1.83].

This scenario suggests that bargained outcomes should lead to some stable détente with rebels, perhaps even co-opting them into the state. There appears to be an attractor, depending on our proxy of state capacity p. When the state capacity is low, the system seems to be attracted toward $x = 1$ and $y = 0$. That is, the system favors warlord rebels and Conciliatory state elites. However, as p increases and the state capacity improves, the system changes to $x = 1$ and $y = 1$. That is, irrespective of the availability of rents, state capacity seems to determine the likely outcome of the conflict.

Last, the reader will note that the simulations for when p = 0.6 and V = 5 somewhat match the predicted outcomes from the analytical solutions with the same parameters shown in Figure 2. The analytical solution was not hard coded into the simulations; i.e., the simulated agents had "free will" to choose better outcomes. Nevertheless, our simulated "empirical" approach does approximate the predictions of the analytical approach.

5. Conclusions

Our paper models the evolutionary dynamics of state capacity, resource availability, and conflict through a simulation-based approach. We have shown how individual behaviors and motivations can significantly influence collective outcomes in civil conflicts using agent-based models within an evolutionary game theoretical framework. Our findings underscore the importance of understanding the adaptive behaviors of both rebels and state elites in predicting the stability and resolution of conflicts. The simulations reveal that state capacity plays a more crucial role than resource availability in determining the nature of insurgencies and that powerful states are more likely to facilitate a bargained solution. Furthermore, the study highlights that reform insurgencies are less successful than warlord insurgencies. Last, our paper suggests that how resources are shared does matter—that is, if the state has a higher capacity for distributing rents than the nature of conflict, whether the state is likely to be conciliatory or aggressive, and whether rebels are likely to be of the warlord type or reform, differs. These insights suggest that agent-based models in evolutionary game theory can lead to clear, testable hypotheses and provide valuable perspectives on the complex interactions that drive civil conflict. Future work will involve changing parameters in this framework to derive further information about how contextual changes—for example, differences in the cost of war because of infusions of foreign aid—can lead to differences in outcome. Nevertheless, we urge caution in interpreting the results of our modeling approach as the sole determinant of policy. Mathematics is no substitute for human judgment.

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