

The Evolution of Revolution: Is Splintering Inevitable?

Atin Basuchoudhary
Virginia Military Institute
Lexington, VA 24450
Email: basuchoudharya@vmi.edu

Laura Razzolini
Virginia Commonwealth University
Richmond, VA 23284
Email: lrazzolini@vcu.edu

Abstract: *We use an evolutionary model to study splintering in rebels' groups. We assume that rebels possess cultural traits that encourage cooperation, defection (splintering) or some sort of trigger behavior like Tit-For-Tat. We characterize the dynamic process through which the rebels' discount rate determines whether splintering will occur in the population, even when cooperation is efficient. Contrary to the usual Folk Theorem prediction, we show that, even when rebels are extremely patient, cooperation may not evolve if the initial distribution of cultures in the population is not favorable. Thus, political actions by the states or governments that make rebels impatient may cause splintering to be almost inevitable. Our paper closes a gap in the literature by providing a theory for why rebel groups may coalesce or no. Policies that affect the patience of rebels and change the distribution of cultures have great influence on the likelihood of rebels' groups' splintering.*

JEL Codes: D74, C73

Key Words: Evolutionary Game Theory, Rebels, Splintering, Violence, Counterinsurgency.

1. Introduction

We study theoretically the process that drives splintering or cooperation among rebel groups. Analysis of conflict often suggests that rebels do not always cooperate. For instance, conflict in Africa is driven by splintering rebel movements, as rebel groups that start off cooperating often end up splintering in violently warring factions. The Mapping Militant Organizations website (Crenshaw, 2012a) dramatically illustrates this effect for countries like Iraq, Pakistan, and Somalia. On the other hand, it is also evident that groups like Al-Qaeda in Iraq did coordinate their rebellious activities in adaptive response to U.S. anti-insurgency operations (Cigar, 2011). In this paper, we analyze the process that drives cooperation among rebels. We assume that rebels either cooperate, defect, or use a trigger strategy and that this behavior is cultural. The rebels' goal is to produce political acts of rebellion that generate a private benefit for the non-rebel population in the country (U.S. Dept. of the Army, 2007, pp. 1-19). These political acts of rebellion, however, are socially disruptive in the sense that they reduce productive acts. The non-rebel population is assumed to have convex preferences over productive acts and political acts; that is, the marginal benefit from political acts falls as the number of political acts increases. When rebels cooperate, the number of political acts produced is controlled and restricted, thus leaving space for productive activity (Tullock, 1974 and Collier and Hoeffler, 1998 and 2002). However, if rebels splinter, competitive pressure increases the number of political acts produced at the expense of productive acts (Bloom 2005, Cunningham 2011, Cunningham et. al. 2012, Lilja 2012 and Pearlman 2008/2009). Moreover, rents gained through the provision of political acts also decrease since the marginal benefit of political acts fall as the number of political acts increase. Thus, from the perspective of productive activity, cooperative rebels are better than splintered or defecting rebels. Further, from the rebels' perspective, cooperation is better than splintering, since cooperation maximizes rents. The question, then, becomes why don't rebels cooperate always? Our paper builds a theoretical model that seeks to explain the fundamental conditions under which either cooperation or splintering may evolve.

We use a standard evolutionary model to study the evolution of cooperation among rebels. Rebels belong to a culture of cooperation, defection, or a trigger culture. Rebels are boundedly rational in the sense that they do not strategize about whether to cooperate or not.

Replicator dynamics guide their behavior. If cooperation guarantees greater benefits than defection, the proportion of rebels in the population who follow a culture of cooperation will be larger than the proportion of rebels with a culture of defection. This modeling approach, therefore, focuses on what sort of behavior is more likely to be successful in a population, rather than on optimum individual strategies.

The Folk theorem predicts that with sufficient levels of patience or incentives to build a reputation, cooperation among individuals is possible, if not inevitable (Kandori, 1992). In an evolutionary setting, trigger strategies like Tit-For-Tat or Win-Stay-Lose-Shift can ensure cooperation (see Nowak and Sigmund, 1990). In the same spirit, we argue that cooperation can emerge when trigger strategies are played by randomly matched and boundedly rational players. However, we note that when players can belong to different cultures of cooperation, defection, or a trigger culture, whether cooperation actually emerges or not depends on both the *initial* distribution of cultures in the population and on how patient individuals are. In fact, we find that the initial distribution of the population matters to the point where even extremely patient people may end up not cooperating. Thus, this paper provides a counter example to the generally accepted prediction of the Folk Theorem according to which boundedly rational players cooperate always, as they become very patient (Fudenberg and Maskin, 1990).

A policy implication from our model is that counter-insurgency (COIN) interventions aimed at increasing rebels' patience are more likely to promote rebels' groups' cohesion, while interventions that can change the proportions of different rebel cultures through attrition, coercion, or persuasion will have an inevitable negative impact on rebels' groups' cohesion. For instance, a militaristic policy may actually encourage splintering if it changes the distribution of cultures among rebels, by selectively killing all those belonging to a certain culture, or if it changes the rebels' time horizon (see Crenshaw, 2012b). Our modeling approach can also be used to predict whether militant groups in Benghazi, Libya will coordinate or not their actions against the national government in Tripoli, as the interim Libyan leadership cracks down on different terroristic groups in the country.

2. Literature Review

This paper is qualitatively different from most of the common approaches to conflict present in the literature. The literature has focused on civil strife (Goldstone et al., 2010) and has analyzed the possible motivations of rebel leaders, the choice of targets and the effect of deterrence (see, among the others, Collier and Hoeffler 2004, Gurr, 1968, Tellis, Szayna, and Winnefield 1997, Fearon and Laitin, 2003, Hegre et al., 2001, Mousseau, 2001, Herbst, 2004, Basuchoudhary, Hentz and Razzolini 2011, Basuchoudhary and Shughart, 2010, and Frey, 2004).

Another strand in the literature has focused on the organization of rebel groups and, analytically, is the closest to our paper. Rebels are modeled as entrepreneurs who maximize current or future profits (respectively, considering rebellion as a business or as an investment) (see Grossman, 1991, Collier et al., 2003, and Anderton and Carter, 2009). Our paper models rebels as choosing between producing political change and acts of rebellion. Rebels belong to one of three cultures -- cooperate, defect, or trigger (specifically TFT). We use a simple prisoner dilemma model in an evolutionary framework to capture both the stability and the evolutionary dynamics of rebels' interactions. We specifically study within group dynamics and provide a methodology for analyzing how rebel groups splinter. Thus, unlike Gates (2002), we keep our focus on whether rebel groups break up or not, irrespective of their motivation.

A general theory that could explain the process through which rebels cooperate or splinter is missing. A number of case studies have empirically explored possible causes for splintering. Several studies have found that competition among rebels, particularly when competing for the "affection" of a particular ethnic group, may encourage outbidding in extremism and in the level of violence (Bloom 2005, Pearlman 2008/2009, Cunningham 2011, Cunningham, Bakke and Seymour. 2012, and Lilja 2012). Generational changes in leadership may fracture rebel groups (Lawrence, 2010) and government policies may exacerbate this process when killing top leaders (Girardet, 2011). Bueno de Mesquita (2008) theorizes that extremism increases as rebels splinter, while Kydd and Walter (2002) suggest that peace negotiations between the state and rebel groups are responsible for increased splintering and concomitant violence. Existing divisions in society may also encourage splintering (see Christia, 2008, Kalyvas, 2006), while cohesive social bonds seem to discourage splintering (Staniland,

2012). Rebels are found to splinter out of disagreements over a strategy or a tactic (Zirakzadeh, 2002, Moghadam and Fishman, 2010). Finally, Bapat and Bond (2012) suggest that government pressures may break up rebel groups because of commitment problems. However, there is no single model that captures the dynamic process that can predict whether a group will break up or not.

Our model provides predictions that show how rebels' incentive to cooperate evolves over time as a function of exogenous factors, such as the proportion of the population that happens to cooperate and the population's level of patience. In other words, we answer the following question: What are the dynamic conditions under which rebels' groups coalesce? Recently, duffy (2009) and Dal Bo and Frechette's (2011) have experimentally studied cooperation and defection in the laboratory. Their experimental results support our result that even extremely patient rebels may not cooperate, even though their methodology does not explicitly study the evolution and path of cooperation over time. We use a standard evolutionary model to understand rebels' behavior and shed light on rebels' group dynamics. Vasin (2006) has suggested that in finite settings when an external manipulator can arbitrarily reward or penalize players according to the manipulator's interest, cooperation may not evolve. We generalize this result to the case when repetition is infinite and there are no external manipulators to the game. Our model provides a methodology for determining whether certain policies are more likely to increase or decrease social disruption from rebellion.

We introduce the payoffs pertaining to rebels in each culture in Section 3. These payoffs determine how "fit" each culture is in relation to each other. In Section 4 we derive the conditions that determine whether a culture will succeed or not. In Section 5, we derive phase diagrams to investigate the dynamics of how rebel cultures may develop. We discuss some policy implications of our model and conclude in Section 6.

3. Payoffs to Rebels

Let n be the number of rebels in a country. As in Anderton and Carter's model (2009, p. 115-118), rebels produce rebellion or political acts, e , that generate a private benefit for the non-rebel population. These acts are appropriative in nature. The non-rebel population also receives benefits from productive acts. Since productive and political acts compete with each other in the

use of scarce resources, it is reasonable to argue that an increase in the number of political acts, e , reduces productivity in the country. In other words, non-rebels have convex preferences over appropriative political acts and productive acts. Even though the variable e is discrete, for simplicity we will treat it as continuous. Rebels in a cooperative culture choose e by coordinating their actions, while rebels in a defecting culture choose e through individualistic behavior. We will show that cooperative behavior restricts the number of political acts, while defection increases the number of political acts produced. Supplying political acts is costly. We assume a linear cost function of the form $C = ze$, where z is the constant marginal cost of producing political acts, e .

All members of society, both rebels and non-rebels, derive some *private* benefit from the production of political acts, of the form: $B = f(e)$, where the function $f(e)$ is decreasing in e . In what follows, we will use $B = d - e$, where d is a basic level of benefit achieved with no rebellion. A negatively sloped benefit function from e suggests that the population places higher value on rebellion obtained with fewer political acts and is a consequence of the population's assumed convex preferences over political and productive acts. Intuitively, as more political acts are provided, their value falls because of the disruption they cause.

Fewer political acts also generate greater private benefits for the rebels. Since the rebels' clients place a higher value on fewer political acts, this allows the rebels to extract higher rents when fewer acts are produced. Intuitively, rebel groups that can appropriate large resources with fewer political acts have greater rents to extract. These rents may include "income from natural resources, voluntary or coerced material support from the surrounding population, and financial support from foreign government, criminal syndicates, or diaspora." (Anderton and Carter, 2009, page 115-116).

We use an evolutionary game theoretic model to study the interaction among members of a rebel group, as each member determines how many political acts and ultimately political change to produce. As it is customary in evolutionary games, individuals' interaction is observed over time and individuals are assumed to be programmed to play a certain strategy, which corresponds to some underlying genotype or culture and environment. Endowed with a strategy, individuals or rebel groups in the country interact with each other in pairs and this interaction

determines the level of political acts that is produced, and the payoffs or fitness of each particular culture. Whenever a pair meets, the level of political acts produced is the sum of the individual productions. Each rebel determines his/her own level by either maximizing the pair's joint benefits or by selfishly maximizing his/her own individual benefit.

3.1 Payoffs from cooperative behavior

If two rebels or two rebels groups jointly decide the level of political acts to produce, they maximize common benefits and rents as:

$$\max_e B_{coop} = (d - e)e - ze, \quad (1)$$

where B_{coop} are the joint benefits and may include prestige and power obtained as a result of political change. The cooperative optimal level of e and the maximum joint benefit from political acts, respectively, are

$$e_{coop}^* = \frac{d - z}{2} \quad \text{and} \quad B_{coop}^* = \left(\frac{d - z}{2}\right)^2. \quad (2)$$

Assuming that the rebels divide the benefits from political acts equally,¹ each rebels i 's benefits from cooperation are

$$B_{i,coop}^* = \frac{B_{coop}^*}{2} = \frac{(d - z)^2}{8}. \quad (3)$$

3.2 Payoffs from individualist behavior

If each rebel, or group of rebels, i maximize personal benefit from political acts, given the expectation that others are doing the same, i 's objective function is

$$\max_{e_i} B_{i,nc} = (d - e_i - e_j)e_i - ze_i, \quad (4)$$

¹ Note that in this case each rebel produces $\frac{d - z}{4}$ amount of political events, or $1/n$ of the optimum output.

where political change is the sum of acts produced by i and j , and $B_{i,nc}$ is the benefit from political acts under non-cooperative behavior. Maximizing the above objective function and assuming symmetry, we get:

$$e_{i,nc}^* = \frac{d-z}{3}. \quad (5)$$

The total amount of political acts produced in this case is $e_{nc} = \frac{2(d-z)}{3}$ and benefits from political acts are $B = d - \frac{2(d-z)}{3}$, which can also be written as $B = z + \frac{d-z}{3}$. The payoff to each rebel i , $B_{i,nc}^*$ is

$$B_{i,nc}^* = \frac{(d-z)^2}{9}. \quad (6)$$

3.3 Payoffs when one rebel defects and the other cooperates

Consider, finally, the case in which a rebel or a group, j , maximizes joint benefits, while i maximizes individual benefits when determining the production level of political acts. That is, i is individually choosing production assuming that rebel j is choosing the cooperative level of political acts, $e_{j,coop} = \frac{d-z}{4}$. In this case, i 's objective function is

$$Max_{e_i} B_{i,in} = B(e)e_i - ze_i = \left(d - \frac{d-z}{4} - e_i \right) e_i - ze_i, \quad (7)$$

where $B_{i,in}$ is rebel i 's payoff when that the other rebel j maximizes joint benefits and the subscript in tracks individualistic behavior.²

² Consider, as an example, a deal struck between rebels' groups. However, some group may have been at the same time secretly wooing foreign powers to support the group takeover of the country at the expense of the others. One can even presume that a certain level of deviousness marks the interaction among individual rebels' commanders as well.

The optimal amount of political acts produced by the individualist rebel, obtained by maximizing the above objective function, is

$$e_{i,in}^* = \frac{3(d-z)}{8}. \quad (8)$$

Thus, total output in this case is $e_{in} = \frac{5(d-z)}{8}$, the benefit from political acts are

$B(e_{in}) = z + \left(\frac{3(d-z)}{8}\right)$ and the payoffs to the individualist rebel i , and the cooperative rebel j are, respectively

$$B_{i,in} = \left(\frac{9(d-z)^2}{64}\right) \quad \text{and} \quad B_{j,in} = \left(\frac{3(d-z)^2}{32}\right). \quad (9)$$

4. The evolutionary game

Repeated individualistic or joint production choice of political acts will determine over time the type of strategy or culture of each rebel or group. While it is possible for the rebels to use many different strategies over time, we will focus on three particular strategies or cultures. Dal Bo and Frechette (2011) have identified, in the context of a Prisoners Dilemma game, the strategies that are used most commonly by players when repeatedly interacting over time. One strategy or culture is to always choose to produce the cooperative level of political acts from period to period. A second culture or strategy is to always choose the individualistic level of political acts, or to always defect. Finally, the third strategy that is most commonly used is the Tit-For-Tat strategy (TFT), in which case behavior depends on what has happened in the previous period. A rebel playing the TFT strategy will choose the cooperative level of production at the beginning of the interaction and then, in any subsequent period, will select the production level that has been chosen by the player with whom he/she was matched in the previous period.³

³ Another strategy, commonly used and strategically equivalent to TFT, is the Grim strategy, according to which a rebel will choose the cooperative level in the first period and in any future period as long as the other player also chooses it. If the other player chooses the individualistic level of production, then the rebel will defect forever. This strategy is equivalent to the TFT strategy, when played against the always cooperate or always defect strategy.

We will use our derivations from the previous section to represent payoffs from pair-wise interactions between rebels or groups of rebels in the population. The payoffs are represented in Table 1 below. Each cell in Table 1 reports the payoffs for two groups or two individuals i and j from a population of n rebels. The payoffs for the cases in which both rebels choose cooperation or both choose defection are as calculated and discussed in the previous section, and are now discounted by the term $(1 - \delta)$ to account for the repetition over time of the interaction. The discount rate δ measures the rebels' level of patience; δ close to 1 indicates high willingness to wait for later rewards, while a low level of δ is a sign of impatience and inability to wait for future rewards.

If a defector meets a cooperator, then in every period the defector will earn a payoff of $\frac{9(d-z)^2}{64(1-\delta)}$, while the cooperator will earn a payoff of $\frac{3(d-z)^2}{32(1-\delta)}$. When one of the two rebels plays the TFT strategy, if he/she meets a cooperator, they will both choose to cooperate in the first period and in every subsequent period, as the cooperator will keep choosing to cooperate and so will the TFT player, responding accordingly to the previous choice of his/her opponent.

Both players will earn a payoff of $\frac{(d-z)^2}{8(1-\delta)}$. The same outcome occurs if the TFT

	Always Cooperate	Always Defect	TFT
Always Cooperate	$\frac{(d-z)^2}{8(1-\delta)}$, $\frac{(d-z)^2}{8(1-\delta)}$	$\frac{3(d-z)^2}{32(1-\delta)}$, $\frac{9(d-z)^2}{64(1-\delta)}$	$\frac{(d-z)^2}{8(1-\delta)}$, $\frac{(d-z)^2}{8(1-\delta)}$
Always Defect	$\frac{9(d-z)^2}{64(1-\delta)}$, $\frac{3(d-z)^2}{32(1-\delta)}$	$\frac{(d-z)^2}{9(1-\delta)}$, $\frac{(d-z)^2}{9(1-\delta)}$	$\frac{9(d-z)^2}{64} + \frac{\delta(d-z)^2}{9(1-\delta)}$, $\frac{3(d-z)^2}{32} + \frac{\delta(d-z)^2}{9(1-\delta)}$

TFT	$\frac{(d-z)^2}{8(1-\delta)}$,	$\frac{3(d-z)^2}{32} + \frac{\delta(d-z)^2}{9(1-\delta)}$,	$\frac{(d-z)^2}{8(1-\delta)}$,
	$\frac{(d-z)^2}{8(1-\delta)}$	$\frac{9(d-z)^2}{64} + \frac{\delta(d-z)^2}{9(1-\delta)}$	$\frac{(d-z)^2}{8(1-\delta)}$

Table 1 – Fitness from each strategy

rebel interacts with another TFT player. On the other hand, if the TFT player meets a defector, in the first period the TFT rebel will cooperate, while the other player will choose to defect. In every future period, both rebels will choose to defect, so that the TFT rebel will earn

$$\frac{3(d-z)^2}{32} + \frac{\delta(d-z)^2}{9(1-\delta)}, \text{ while the defector will earn } \frac{9(d-z)^2}{64} + \frac{\delta(d-z)^2}{9(1-\delta)}.$$

Notice that the second term in both expressions corresponds to the payoff from defecting forever while interacting with a defector; the first term for the TFT player is the payoff from cooperating while interacting with a defector, and the first term for the defecting player is the payoff from defecting while interacting with a cooperator.

Table 1 represents an evolutionary stage game and we will use the replicator dynamics to check the evolutionary stability of each strategy. Let x denote the initial proportion of cooperators and y the initial proportion of TFT rebels in the population. As a consequence, the initial proportion of defectors is $1-x-y$. The expected fitness of each of the three strategies is calculated below.

The expected fitness for a cooperator is

$$x \left(\frac{(d-z)^2}{8(1-\delta)} \right) + (1-x-y) \frac{3(d-z)^2}{32(1-\delta)} + y \frac{(d-z)^2}{8(1-\delta)} = - \frac{(d-z)^2}{32(1-\delta)} (3+x+y). \quad (10)$$

The expected fitness for a TFT player is

$$x \left(\frac{(d-z)^2}{8(1-\delta)} \right) + (1-x-y) \left(\frac{3(d-z)^2}{32} + \frac{\delta(d-z)^2}{9(1-\delta)} \right) + y \left(\frac{(d-z)^2}{8(1-\delta)} \right) = - \frac{(d-z)^2}{288(1-\delta)} (9x+9y+5\delta-5x\delta-5y\delta+27). \quad (11)$$

Finally, the expected fitness for a defector is

$$x \left(\frac{9(d-z)^2}{64(1-\delta)} \right) + (1-x-y) \left(\frac{(d-z)^2}{9(1-\delta)} \right) + y \left(64 + \frac{\delta(d-z)^2}{9(1-\delta)} \right) = -\frac{(d-z)^2}{576(\delta-1)}(17x+17y-17y\delta+64). \quad (12)$$

The population of rebels has a certain initial distribution of cooperators, defectors, and TFT-ers. Given this initial distribution, some strategies will be fitter than others. Below we do pair-wise comparisons of average fitness of each strategy.

To compare the average fitness of the TFT strategy with the average fitness of the always cooperate strategy, consider equations (11) and (10). TFT is fitter than always cooperate when

$$-\frac{(d-z)^2}{288(1-\delta)}(9x+9y+5\delta-5x\delta-5y\delta+27) > -(d-z)^2 \frac{3+x+y}{32(\delta-1)},$$

which simplifies to

$$x + y < 1. \quad (13)$$

The inequality in (13) is represented in Figure 1. In the shaded region in Figure 1, the proportions of players in the three cultures are such that TFT is a fitter strategy than always cooperate. The boundary that demarcates the zone in \mathbb{R}^+ where TFT is fitter than cooperation is negatively sloped and independent of δ . Moreover, the x and y intercept are always at 1. Since proportions of players choosing a particular strategy cannot exceed 1, constraint (13) will always bind. In other words, the TFT strategy will always be fitter than the always cooperate strategy in this evolutionary setting.

Result 1. *The fitness of the TFT strategy always exceeds the fitness of the always cooperate strategy, for all $x, y \in (0,1)$ and is independent of δ .*

Result 1 follows from equation (13) which is independent of δ . Since x , and y are limited to the unit interval, $x, y \in (0,1)$, for all relevant distributions of the population among TFT and cooperative rebels, TFT will always be a fitter strategy than always cooperate.

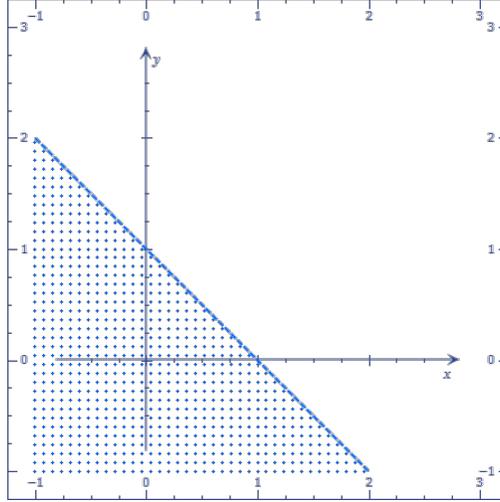


Figure 1 – TFT Fitter than Cooperate

To compare the average fitness of TFT and always defect, consider equations (11) and (12). TFT is fitter than always defect if

$$-\frac{(d-z)^2}{288(1-\delta)}(9x+9y+5\delta-5x\delta-5y\delta+27) > -\frac{(d-z)^2}{576(\delta-1)}(17x+17y-17y\delta+64),$$

which simplifies to

$$y > -\left(\frac{1}{7\delta+1}\right)(x+10\delta-10x\delta-10). \quad (14)$$

Inequality (14) is represented in Figure 2, for three possible values of δ , respectively $\delta=0$, $\delta=0.1$, and $\delta=1$. In each shaded region, for all values of x and y , the TFT strategy is fitter than the always defect strategy. The slope of the boundary of expression (14) is $(1/(7\delta+1))(10\delta-1)$. As δ rises, the boundary that demarcates the shaded area in \mathbb{R}^+ where TFT is fitter than defect shifts down in the x, y space, though it remains positively sloped, as long as $\delta \in [0.1, 1]$. For any $\delta < 0.1$, the slope of the boundary is negative. Further, for any $\delta < 1$ the origin, the point at which the entire population uses the always defect strategy, lies in the zone in which defect is preferred over TFT. Lastly, the boundary of expression (14) passes through the origin when $\delta = 1$.

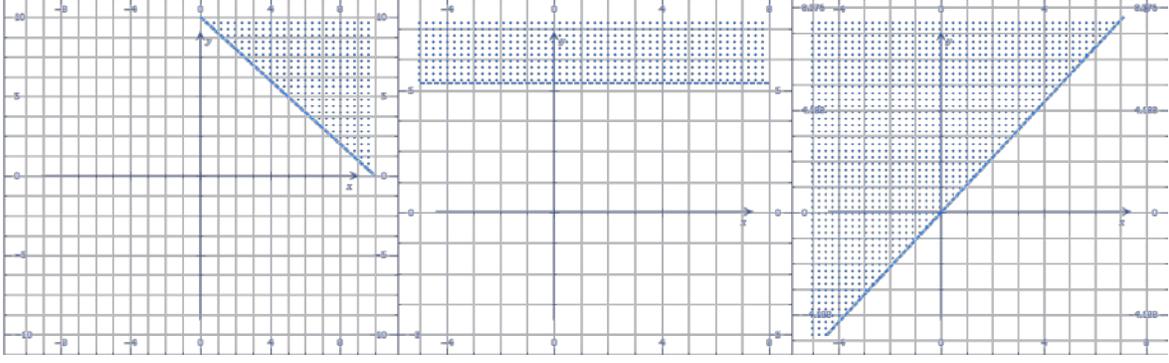


Figure 2. TFT Fitter than Defect for $\delta=0$, $\delta=0.1$, $\delta=1$

Result 2. For any $\delta < \frac{9}{17} = 0.529$, the strategy always defect is fitter than TFT, for all $x, y \in (0,1)$.

Setting $x = 0$ and $y = 1$ in equation (14) yields $\delta < \frac{9}{17} = 0.529$. Equation (14) is positively sloped (slope is approximately 0.911) when $\delta = \frac{9}{17}$. As δ falls, equation (14) becomes less positively sloped and the y intercept rises beyond 1. Thus, for any $\delta < \frac{9}{17}$, the shaded region above equation 14 where TFT is fitter than defect can never include any positive x, y . Thus, for all $x, y \in (0,1)$, always defect is fitter than TFT.

Finally, to compare the average fitness of the always defect and always cooperate strategies, consider equations (10) and (12). Always defect is fitter than always cooperate when

$$-\frac{(d-z)^2}{576(\delta-1)}(17x+17y-17y\delta+64) > -(d-z)^2 \frac{3+x+y}{32(\delta-1)},$$

which simplifies to

$$y < -\left(\frac{1}{17\delta+1}\right)(x-10). \quad (15)$$

Inequality (16) is graphed in Figure 3, respectively for $\delta = 1$ and $\delta = 0$. The shaded areas represent the values of x and y for which the always defect strategy is fitter than always cooperate. As δ rises, the boundary given by equation (15) that demarcates the zone in \mathbb{R}^+ where

defect is fitter than cooperate becomes flatter and slides down the vertical axis. Moreover, this equation is negatively sloped for all $\delta \in (0,1)$.

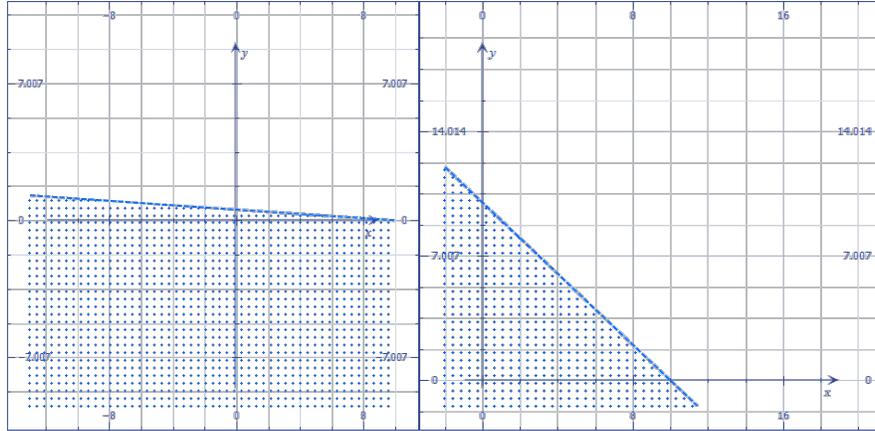


Figure 3. Defect is Fitter than Cooperate for $\delta=1$, $\delta=0$

Result 3. For any $\delta < \frac{9}{17} = 0.529$, the strategy always defect is fitter than always cooperate for all $x, y \in (0,1)$.

Setting $x = 0$ and $y = 1$ in equation (15) yields $\delta < \frac{9}{17} = 0.529$. Note that the y intercept rises beyond 1 as δ rises beyond $9/17$. Further, the slope of equation (15) becomes steeper as δ falls.⁴ Thus, for any $\delta < \frac{9}{17}$, the space in \mathbb{R}^+ where defect is fitter than cooperate includes all $x, y \in (0,1)$. In other words, for any $\delta < 9/17$, defect will be fitter than cooperate for any possible distribution of cooperators, TFT, and defectors in the population.

5. Phase diagrams

In this section we develop phase diagrams to focus on the dynamics of behavior change for different levels of patience δ . Recall that the population of rebels is distributed in the space $x, y \in (0,1)$. However, depending on the initial distribution of the strategy cultures among the population, one of the three strategies will be the fittest. Then, the proportion of rebels who adopt

⁴ Equation (15) can be rewritten as $y = (-x/(1+17\delta)) + (10/(1+17\delta))$. The slope ranges from -1 when $\delta=0$ to $-(1/18)$ when $\delta=1$.

that fittest strategy will increase and change the underlying distribution of strategy cultures in the population. This change in distribution has important repercussions for whether a rebel group will follow a path of defection and eventually splinter or not. We find that for high enough levels of patience, TFT may be evolutionarily stable. This, in turn, may lead to cohesive rebel groups. However, defection may also be an evolutionary stable strategy, even when rebels have an extraordinarily high level of patience. In other words, the dynamics of the changes in the distribution of the strategy cultures depends on *both* the initial distribution of these cultures and the patience of rebels. This has implications for policy that are discussed in Section 6 below.

We noted in the previous section that the relative fitness of the three strategies depends on δ . Proposition 1 below shows how the regions bounded by equations (13), (14) and (15) change as δ changes. We, then, run two simulations to illustrate the impact of a varying δ on the dynamics of changes in the proportion of rebels who will follow a particular strategic culture.

We do this for $\delta < \frac{9}{17}$, and then we repeat it for $\delta > \frac{9}{17}$. Note that when $\delta = \frac{9}{17}$, equations (13), (14) and (15) intersect at $x = 0, y = 1$.⁵

Proposition 1. *Equation (13) is the locus of the point of intersection between equations (14) and (15).*

Proof. Solving for x and y in equations (14) and (15), gives us

$$x = 1 - \left(\frac{9}{17\delta} \right) \quad \text{and} \quad y = \left(\frac{9}{17\delta} \right).$$

Thus for any δ , $x + y = 1$. This proves Proposition 1.

Proposition 1 shows that as δ rises the locus of the points of intersection between equations (14) and (15) effectively slides down equation (13). As a consequence, the $x, y \in (0,1)$ space is split into as many as three distinct regions. In each of these regions one of the three strategy cultures will dominate. Thus, the proportion of rebels who adopt, over time and

⁵ Setting $x=0$, and $y=1$, in each (13), (14), and (15), yields $\delta=9/17 = 0.529$ in each of the three equations.

generations, a particular strategy culture changes in each of these regions. Figure 4 below show the three regions A, B and C for two particular values of δ (1 and 0.6, respectively).

The boundaries defined in (13), (14), and (15) are shown in the two diagrams in Figure 4. Since the proportions of the population who are either TFT-ers (x) or defectors (y) can at most add up to 1, equation (13) constrains the area we consider to the three zones. Proposition 1 predicts that as δ becomes smaller, the regions A and B become smaller, while C becomes larger, as can be seen in Figure 4 for $\delta=1$ and $\delta=0.6$. Further, based on our derivations in Section 4, in both regions A and B, the TFT strategy is fitter than either always cooperation or always defect. In region C the always defect strategy is fitter than either TFT or always cooperate. Thus, as δ rises, it becomes harder to cooperate.

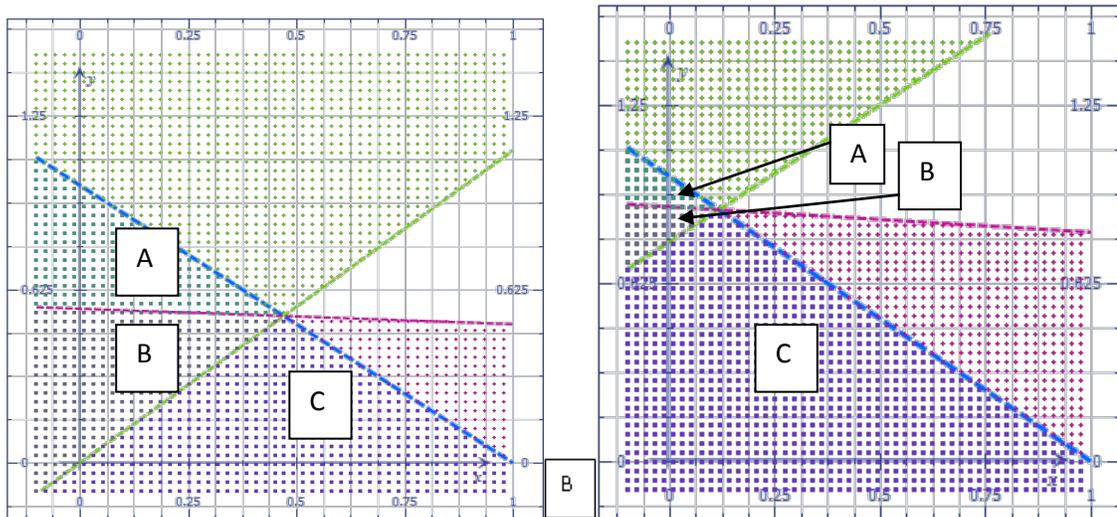


Figure 4. The three zones for $\delta=1$ and $\delta=0.6$

To see this, consider respectively the case when $\delta < \frac{9}{17}$ and $\delta > \frac{9}{17}$. In the first case, rebels are quite impatient. In figure 5 below we show the boundaries defined by (13), (14), and (15) when $\delta = \frac{9}{17}$. Notice that the regions A and B disappear. Recall that defect is always fitter than either TFT or always cooperate in region C, while in regions A and B, TFT is always fitter than either always cooperate or always defect. Thus, when rebels are impatient, specifically when $\delta \leq \frac{9}{17}$, always defect is the fittest strategy. That is, the entire population of rebels will

learn to defect. In other words, whatever the initial distribution of the population is among the always cooperate or TFT cultures, these proportions will move toward the origin over time and generations, as individuals will learn to be defectors.

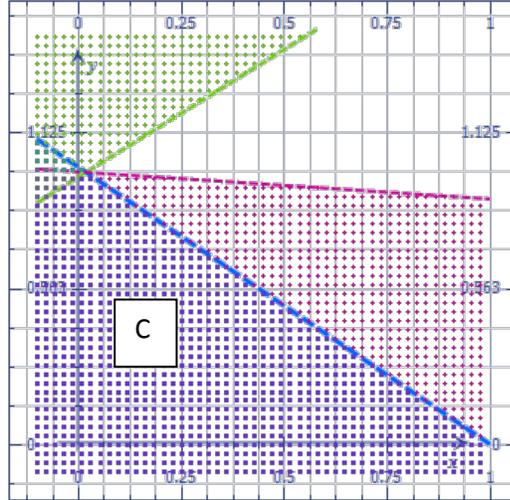


Figure 5. The three zones for $\delta = \frac{9}{17}$

This will in effect splinter rebel movements. Note that we have assumed that patience is an exogenous variable. Thus, any intervention by the government of the state that would reduce the time horizon and the patience level of the rebels is likely to cause or aggravate splintering.

Consider next the other case when $\delta > \frac{9}{17}$, that is, rebels are patient. In this case cooperation among rebels is possible but not certain. Once again, the population space is divided into three regions, A, B, and C (Figure 6 below shows the three regions drawn for $\delta = 0.9$). In region A, delineated by relations (13) and (15), TFT is fitter than either always cooperate or always defect. Thus, given the possibility of future reciprocal punishments, cooperation reigns thanks to the TFT strategy and not because of the always cooperate strategy. Idealist rebels with a steely eyed determination to create a united front against state power will die out of the population, only to be replaced by pragmatists who only cooperate through fear of future retaliation.

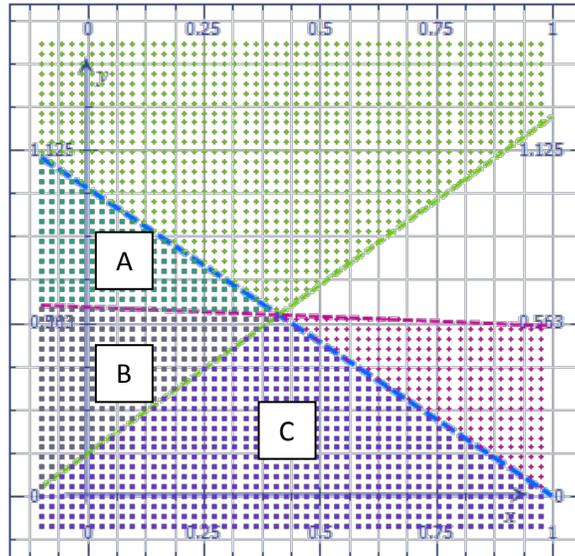


Figure 6. The three zones for $\delta=0.9$

In region C, though, defect is still the fittest strategy. Again, if the initial distribution of the population among the three strategies starts in this region, society will veer towards defection and the rebel groups will splinter.

As δ rises, the size of the regions A and B increases. It becomes more likely to find initial distributions of the population that fall in the A and B regions. This, in turn, suggests that cooperation is more likely to prevail as people become more patient. Notice that there is always the possibility that if the initial distribution of strategies/culture realizes in region C, even with patience levels close to 1, rebels will never cooperate. In fact, defection is possible even with perfectly patient rebels, i.e. with $\delta = 1$. For example, in Figure 4, when $\delta = 1$, Zone C is not a null set. This is in contrast with the standard Folk Theorem prediction, which establishes that for high enough level of patience, cooperation will succeed. In our evolutionary set up, it is possible for cooperation to fail even with perfect patience. Many experimental laboratory tests of the evolution of cooperative behavior over time have failed to show the emergence of cooperation (see Duffy and Ochs, 2009, Dal Bo and Frechette, 2011). This is not surprising, as the initial distribution of the population among types is as important as the level of patience in determining the evolution of behavior.

6. Discussion and conclusions

Our model suggests that even extremely patient rebels' groups are likely to splinter. This splintering is inevitable when exogenous shocks (like an assault on rebels groups by the state or invasive forces) reduce the rebels' time horizon for decision making, thus lowering the discount rate. From a policy perspective, this generates testable hypotheses. A successful offensive against a rebel group in a civil war is likely to lead to the formation of splinter cells, as long as the demand for appropriative political acts persists. When rebels defect, the quantity of political acts supplied is larger than when they cooperate. However, if rebels are patient enough, *and* the population distribution among cooperator and TFT types lie in regions A or B, then cooperation is a plausible outcome. This result is consistent with Crenshaw (2012b) who provides three case studies, which suggest that "strategic expectations about the future course of a conflict, in particular whether it is escalating or de-escalating" influence rebel groups' cohesion in the directions predicted by our model. Moreover, cooperation is possible when the initial proportion of TFT-ers in the population is high relative to the people who subscribe to the other two cultures. The TFT's ability to enforce cooperation gives its players an advantage over both the always cooperate and always defect strategies. Mere patience is insufficient to allow cooperation to emerge in this population unlike the Folk Theorem suggests. The initial population distribution indeed matters.

Military actions that change the distribution of cultures in a population may explain the success of policies such as the "Anbar Awakening," a policy adopted by the U. S. in Iraq in 2007. During this time, the Iraqi Sunni forces coalesced against the violent depredations of Al Qaeda in Iraq (AQI). The success of American forces against conventional Iraqi forces and the subsequent de-Baathification can be considered a shock to the time horizon of the Sunni Iraqis, who embraced the splintered violence of AQI. However, over time a clear difference appeared in the behavior of the local Iraqi Sunni's compared to the foreign Jihad members of AQI. The firsts had a longer time horizon, as they lived in the country and had families and history in Iraq, while the foreign AQI members most likely had a much shorter time horizon, with no long term stake in Iraq. As the U.S. policy continued, the patient Sunni's became relatively more numerous and, therefore, an integral part of the change in behavior that led to the Anbar Awakening. In a similar fashion, the U. S. could follow this type of policy in Afghanistan by creating a division between the short time horizon of the Pakistan based Taliban and the longer time horizon of the local tribal elders and residents of the Afghan villages.

On the other hand, even when rebels are patient, if not enough TFT types are present in the population, the always defect strategy will reign and rebel groups will splinter. The initial proportion of rebels endowed with the different strategies is a function of the culture present in the country where the rebellion is occurring. In other words, whether rebels will splinter or not might be rooted in prevailing cultural norms. Thus, a purely militaristic approach - even if it is successful in separating patient from impatient rebels, as in the Anbar Awakening - may not be sufficient to prevent the splintering of rebel movements into more violent offshoots. Splintering and violence can only be prevented through the building of political institutions that provide peaceful political change and economic institutions that reduce the need for appropriative political acts. Further, selective policing and targeting of rebel cultures might actually change the distribution of cultures itself. For example, if the initial distribution of rebels realizes in region C of Figure 6, splintering is expected. But if the initial distribution lies in regions A or B, then cooperation enforced through a trigger strategy is still possible. If the state selectively targets established groups who have the means to enforce cohesion through a TFT strategy, this might reduce the proportion of rebels belonging to this culture relative to the defect culture. This sort of state action may also change the dynamics of a rebel movement and splinter a cohesive rebellion. Such splintering would increase policing costs for the state and may lead to state failure (Basuchoudhary, Bang, Shughart, 2012 and Basuchoudhary and Shughart, 2010).

Our paper closes a gap in the literature on conflict by developing a model that captures the dynamic pathways for rebel group cohesion. We argue that rebels' patience and the proportion of rebels who adhere to a culture of cooperative behavior drive rebel group cohesion. In addition, violent suppression of rebellions, insofar as it impacts the patience of rebels, is likely to lead to the splintering of rebel groups, more competition among them and ultimately more violence.

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