AN EVOLUTIONARY GAME APPROACH TO FUNDAMENTALISM AND CONFLICT

by

Daniel G. Arce M. and Todd Sandler*

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Abstract

This paper investigates the evolutionary equilibria of a clash of cultures game where conflict results from failures to share social power in individual pairings. Members of a general subpopulation are matched with those of a fundamentalist subpopulation, the latter being more cohesive and insistent that their identity traits define the norms for, and outcomes of, social, economic, and political interaction. Simulations of the evolutionary dynamics reveal a tradeoff between the intolerance of fundamentalism and the likelihood of a takeover. This tradeoff is reversed if fundamentalism is falsifiable: affording non-fundamentalists the ability to signal fundamentalist traits produces a bandwagon effect. *JEL Classification*: D74, C73

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1 Introduction

Economists have increasingly turned their attention to the study of conflict since KENNETH BOULDING [1962] published *Conflict and Defense: A General Theory*. Although four decades have now elapsed, BOULDING'S emphasis on equilibrium, strategic interactions, and dynamics continues to characterize modern treatments of conflicts. Conflict can stem from myriad causes that include contests over resources, political identity, social control, or grievances. Despite the end of the Cold War and the superpower confrontation, conflict remains prevalent today as interstate conflict has given way to intrastate conflicts in the form of civil wars (MURDOCH AND SANDLER [2002]) and subnational clashes among rivalry interests.

There are a number of theoretical foundations to the study of conflict. One foundation depends on contests or tournaments in which opposing interests use their resources to vie with one another for a prize (DIXIT [1987], HIRSHLEIFER [2001], SANDLER [2000a]). This literature is closely akin to the theory of rent seeking, which involves an agent or collective expending resources to obtain a return that results in no gain to society – i.e., a directly unproductive activity. For these contests and rent-seeking activities, the conflictual outcome is affected by a contest success function, which defines appropriative outcome based on the relative "inputs" of fighting effort (HIRSHLEIFER [2000]). Another theoretical basis of conflict comes from a general-equilibrium representation, in which a government must allocate resources to stay in power when confronted by an aggrieved subpopulation, whose resources are being appropriated (GROSSMAN [1991]). A third foundation for conflict can come from population dynamics, for which subgroups' traits or (dissimilar) values can lead to conflict (HIRSHLEIFER [1998], SKYRMS [1996]). This third basis of conflict is dependent on evolutionary game theory, which predicts that those displaying the "fittest" strategy choices, as determined by their resulting payoffs, will survive, multiply, and characterize the population.

In this paper, we put forward an evolutionary game approach to analyze fundamentalism and conflict, consistent with the coexistence of both fundamentalist and non-fundamentalist subpopulations in the same society. The analysis relies on the Nash demand game (NASH [1953]), played between pairings of individuals drawn from the society, and SKYRMS' [1996] model of evolutionary justice. In pairwise interactions, individuals must bargain over the extent of social control, for which an equal footing gives each half of the one-unit pie up for negotiations. One player gains a social dominance over another if his or her take exceeds .5. The fundamentalist subpopulation is assumed to be sufficiently dogmatic to never settle for a minority share of social control. We use simulations of the underlying evolutionary dynamics to show that whether fundamentalist mores characterize social interactions depends upon the distribution of demands within each subpopulation, and, surprisingly, is *inversely* related to the level of fundamentalist intolerance or greediness.

The model is then extended to provide an evolutionary game underpinning to KURAN'S [1989] novel and important notion of preference falsification, where individuals present public preferences that may differ from their true private preferences in order to maximize their well-being. Preference falsification is particularly appropriate for dealing with fundamentalists who provide more favorable terms for those (i.e., fundamentalist or otherwise) who display fundamentalist traits (e.g., dress, customs, views). The analysis is also descriptive of any regime – e.g., communist or fascist – where signaling loyalty is rewarded with preferential treatment that allows one to "fit in." A rich set of population dynamics is shown to derive from either the initial demand proportions of the constituent subgroups or the intolerance of fundamentalists to those not signaling fundamentalist characteristics. Under some circumstances, even a relatively small percentage of the general subpopulation abiding by a fundamentalist orientation may be sufficient to lead to a fundamentalist domination over time if intolerance (i.e., greedy demands) is sufficiently high. Furthermore, fundamentalist intolerance of non-abiders is now *complementary* to this process.

Our analysis is in the spirit of recent political science papers where evolutionary game theory is offered as a basis for understanding ethnic conflict (GOETZE AND JAMES [2001], JOHNSON [2001], ROSS [2001], SALTER [2001]). Evolutionary game theory treats conflict as dynamic, so that those in conflict may change over time depending on the efficacy of strategies played. Moreover, our model accounts for rewards to those who signal in-group loyalty, a behavior that is consistent with RUSSELL HARDIN'S [1995] notion of *One for All*, where group identity can promote collective action. Unlike these earlier contributions, we develop an explicit model to capture evolutionary dynamics. In particular, we represent a dynamic analysis where subgroups can change in numbers over time and fundamentalists can differentiate their treatments of others depending on group actions and identity. Finally, our study differs from BRETON AND DALMAZZONE [2002], for which the emergence of political extremism hinges on information control and not on evolutionary dynamics.

The remainder of the paper contains five sections. The basic SKYRMS [1996] model is presented in Section 2 for a single homogeneous population, where conflicts result from incompatible demands leading to zero payoffs. In Section 3, our evolutionary game depiction of the "clash of cultures" extends the Skyrms model to heterogeneous populations consisting of fundamentalists and a more general subpopulation. Section 4 applies replicator dynamics to simulate the evolution of ethnopolitical conflicts under alternative population and intolerance parameters. In Section 5, the analysis permits fundamentalists to make fair demands when matched with others displaying fundamentalist traits or norms. This behavior not only encourages preference falsification by non-fundamentalists, but also gives rise to interesting population dynamics. Concluding remarks are drawn in Section 6.

2 The Basic Model

In social interactions, paired agents compete for superiority or control over his or her counterpart. GIURIATO AND MOLINARI [2002] characterize this control when applied to two rival groups – fundamentalist and the government – as the share of political power, which varies between zero (no power) and one (complete power), over the rival group. GURR [1994] similarly asserts that such rivalries can ultimately lead to conflict over the distribution of access to state power, which we extend to the notion of *social control*. Culturally distinct people in mixed societies are often locked in rivalries over the way that societal norms are consistent with their distinct identity traits. A larger amount of social control means that an agent has more say over norms, income distribution, justice, and other social divisions. Because we focus on population dynamics among heterogeneous groups, the unit of analysis that drives these dynamics is the division of social control among *paired* individuals, drawn from different cultural groups.

If two or more groups disagree about the distribution of social control, then a conflict ensues. Our focus is on dyads, with the goal of displaying the evolution of conflict in pairwise interactions among individuals belonging to two groups with distinct identities. Rather than being a limiting assumption, our concentration on dyadic interactions among members of the general and fundamentalist subpopulations focuses the analysis where the potential for conflict is the greatest. Such dyads result in equilibrium characteristics for the competing subpopulations that are truly the collective result of individual fitness instead of corporate or hierarchically decreed behavior. By correlating fitness with social control, we adapt a longstanding game – the Nash demand game – that SKYRMS [1996] employs to examine issues of social justice. In the Nash demand game, two players must agree on how to divide a 1-unit good. Each player simultaneously proposes a share for himself or herself. In terms of our context, a player's demand is the minimal amount of social control that he or she is willing to accept. If the proposals are jointly feasible (their sum is less than or equal to one), then each gets what he or she demands; otherwise, each receives zero (conflict ensues). Conceptually, this payoff structure allows for "anti-conflicts" where both parties receive less than what is available (jointly feasible, but inefficient demands). This feature gives players a strong incentive to increase their demands as much as possible without losing compatibility (NASH [1953, 131]). The problem of social control therefore becomes one of coordinating demands in an efficient manner. *A priori* there is no assumption of efficiency, but evolutionary pressure will ultimately lead to efficient outcomes. The game captures the dichotomy between mutual identity and individual self-interest because cooperative ethnopolitical interactions occur only if each group receives a degree of social control that meets or exceeds their demand.

SKYRMS [1996] turns the analysis of the Nash game on its head. The usual procedure is to take the demands of the players as given – i.e., more is better – and find the equilibrium split given these demands under varying game forms. Instead, SKYRMS posits various types of demands related to social norms such as fairness and greediness, and analyzes which would survive in the long-run via an evolutionary framework. This is our point of departure. Specifically, SKYRMS indicates the following types of demands:

Modest (M): demand x_M, where $0 \leq x_M < .5$;

Fair (F): demand exactly half, $x_F = .5$; and

Greedy (G): demand more than .5, $1 \geq x_G > .5$.

Definition: $\Pi_i(x_i,x_j)$ defines the *fitness* of an individual making demand x_i in a pairwise encounter with another individual x_j; i, j = M, F, G. In the Skyrms game, this payoff is:

(1) $$\Pi_i(x_i,x_j) = \begin{cases} x_i \text{ if } x_i + x_j \leq 1, \\ 0, \text{ otherwise.} \end{cases}$$

Suppose that there is a large population of individuals and that they are randomly matched in a pairwise fashion to play the Nash demand game. The entries in each cell of Box 1 represent the outcomes of matching between any combination of modest, fair, and greedy types, as dictated by Eq. (1). Reading across the M-row of Box 1, the first entry indicates that M-types earn a fitness or payoff of x_M each in pairwise encounters amongst themselves. As previously discussed, such an inefficient pairing is expected to lead to more competitive future demands and does not bias the efficiency of our results. In the second entry, when paired with an F-type, the M-type's fitness is x_M and the F-type's fitness is .5. In the final entry of this row, an (M,G) matching yields fitness of x_M and x_G for the M- and G-types, respectively. The other six sets of payoffs are computed in a similar manner. If, for example, two F-types are paired, then each receives .5. The pairing of F- and G-types results in conflict with each receiving 0, as is the case when two G-types are paired.

[Box 1 near here]

This game has several important properties. First, it is an example of a *symmetric game*, which has the following two characteristics:

a. Each player has the same strategy set, S.

b. If Π_r and Π_c are the row and column player's fitness/payoff functions, respectively, then $\Pi_r[x,y] = \Pi_c[y,x]$ for all pure strategies x, $y \in S$.

Payoff symmetry implies that an individual who makes demand x against another making demand y earns the same fitness regardless whether he or she is the row or column player.

Second, the concept of a payoff as a measure of fitness indicates that the relative return of one demand when matched with another (or itself) determines the likelihood that a particular demand will characterize the population. The lower the relative payoff, the more likely a demand will eventually be driven out in the evolutionary sense. Over time, the success of a particular demand is also affected by the distribution of demands within the population. For example, when greedy types predominantly demand .6, and fitness is as determined in Eq. (1), we need only consider modest types who demand .4, because this is the demand that earns them the highest possible fitness in pairwise encounters with greedy types. The reverse could also be said ($x_G = 1 - x_M$) for the survival of greedy types in a population where there is only one predominant x_M demand. As in SKYRMS, we therefore assume that $x_M = 1 - x_G$ throughout. To capture this symbiosis in terms of evolutionary dynamics, we make the following set of definitions:

Definition: If ρ_i is the proportion of individuals in the population making demand x_i, and $\rho = (\rho_1, \rho_2, ..., \rho_N)$ is the (finite) distribution of all demands, $\sum_{i=1}^{N} \rho_i = 1$, then the *expected fitness* of type 'i' in the population is: $E[x_i, \rho] = \sum_{j=1}^{N} \Pi_i(x_i, x_j) \bullet \rho_j$.

Definition: The *population mean fitness* of distribution ρ is $E[\rho,\rho] = \sum_{i=1}^{N} \rho_i \bullet E[x_i, \rho]$.

A demand has a higher fitness if it receives a better than average return. The average returns received will be a function of the proportions of the population choosing each of the strategies, so that we are dealing with the possible equilibria of a dynamic process (HIRSHLEIFER [1982, 15]).

Definition: The growth rate, $\dot{\rho}_i$, of demand x_i behaves according to the *evolutionary replicator dynamic* if:

(2) $$\dot{\rho}_i = \rho_i \bullet [E[x_i, \rho] - E[\rho, \rho]].$$

The replicator dynamic states that the growth rate of demand x_i is proportional to the difference between the expected fitness of types x_i relative to the mean population fitness. If i-types (i = F, M, G) do better than the average fitness, then they will grow within the population; otherwise, the process of natural selection will cause them to die out. The replicator dynamic predicts the following growth rate for each type in Box 1:

$$\dot{\rho}_M = \rho_M \bullet [E[x_M, \rho] - E[\rho, \rho]] = \rho_M \bullet [x_M - \{\rho_M \bullet x_M + \rho_F \bullet .5 \bullet (\rho_M + \rho_F) + \rho_G \bullet x_G \bullet \rho_M\}];$$

$$\dot{\rho}_F = \rho_F \bullet [E[x_F, \rho] - E[\rho, \rho]] = \rho_F \bullet [.5 \bullet (\rho_M + \rho_F) - \{\rho_M \bullet x_M + \rho_F \bullet .5 \bullet (\rho_M + \rho_F) + \rho_G \bullet x_G \bullet \rho_M\}];$$

$$\dot{\rho}_G = \rho_G \bullet [E[x_G, \rho] - E[\rho, \rho]] = \rho_G \bullet [x_G \bullet \rho_M - \{\rho_M \bullet x_M + \rho_F \bullet .5 \bullet (\rho_M + \rho_F) + \rho_G \bullet x_G \bullet \rho_M\}].$$

Instead of finding all equilibrium points for this system of differential equations, we are particularly interested in those distributions that are dynamically stable. An equilibrium is *asymptotically stable* if when slightly perturbed – say, by a mutant invasion of the population – the system tends to return back to the equilibrium point of the evolutionary dynamics. To this end, MAYNARD SMITH AND PRICE [1973] made the following definition:

Definition: Distribution $\rho = (\rho_1, \rho_2, ..., \rho_N)$ is *evolutionary stable* for a symmetric game if:

a. It is a population characteristic that $\rho_{row} = \rho_{column} = \rho$.

b. This distribution fends off mutant invasions that are represented by the alternative distribution ρ^m, as specified by the first-order condition (F.O.C) and second-order condition (S.O.C.):

(F.O.C.) $$E[\rho, \rho] \geq E[\rho^m, \rho] \ \forall \ \rho^m.$$

(S.O.C.) $$\text{If } E[\rho, \rho] = E[\rho^m, \rho], \text{ then } E[\rho, \rho^m] > E[\rho^m, \rho^m].$$

In game-theoretic terms, ρ can be interpreted as a mixed strategy that is an *evolutionary stable strategy* (ESS). The condition (a) and the F.O.C. imply that ρ is a symmetric Nash equilibrium. The S.O.C. is an additional stability condition indicating that if ρ^m is an alternative best reply to ρ, then ρ is a better reply to ρ^m than ρ^m is to itself. The S.O.C. implies that ESS is a refinement of Nash equilibrium; indeed, it is a stricter refinement than properness.[1] If $\rho_i = 1$, then we have an ESS in pure strategies. ESS is our equilibrium concept because TAYLOR AND JONKER [1979] establish that it is a sufficient condition for the asymptotic stability of equilibrium points for the replicator dynamic.

Result 1 [SKYRMS, 1996]: The ESSs for the Nash demand game given in Box 1 are $(\hat{\rho}_M, \hat{\rho}_F, \hat{\rho}_G) = (0, 1, 0)$ and $(\rho_M, \rho_F, \rho_G) = (x_M/x_G, 0, (x_G - x_M)/x_G)$.

In biological terms, the first population distribution, (0,1,0), can be interpreted as a *monomorphism*, since every individual in this population exhibits the fairness trait. The second population distribution, $(x_M/x_G, 0, (x_G - x_M)/x_G)$, can be interpreted as a *polymorphism*, with (x_M/x_G) percent of the population making modest demand x_M, and the remainder making greedy demand x_G. If the percentage of M-types exceeds x_M/x_G, then G-types acquire an advantage within the population and $\dot{\rho}_M$ will decrease via the process of natural selection. In equilibrium, neither the M-types nor the G-types earn a higher expected payoff than the other.

Rather than predicting the particular split that will occur in the Nash demand game, SKYRMS' analysis is novel because it identifies the types of demands than can characterize a population. The *strategies* employed by individuals *become the units of selection*, as opposed to the individuals who employ such strategies. This facilitates our analysis of fundamentalism at a population level, where identity traits may define ethnopolitical conflict. For example, even

[1] In contrast to properness, for $n \times n$ symmetric games where $n \geq 3$, there may be no ESS (e.g., rock-paper-scissors).

though Skyrms' game is played amongst a homogeneous population, the polymorphic equilibrium distribution allows for *conflict* – with probability $\rho_G \bullet \rho_G > 0$, a pairwise matching results in conflicting demands. In the following section, we analyze demands when two heterogeneous subpopulations interact in the Nash demand game, where one's demands more closely resemble the identity traits and cohesiveness of a fundamentalist subpopulation.

3 Clash of Cultures

A clash of cultures between fundamentalists and a general subpopulation is coming to characterize parts of the globe today (HUNTINGTON [1996]). In northern Africa, this clash involves Islamic fundamentalists and other population subgroups in Egypt, Algeria, and Sudan (SANDLER [2000b]). This ethnic conflict may spread to Tunisia and other southern Mediterranean countries. Islamic extremism also poses political and social instabilities for Turkey (GIURIATO AND MOLINARI [2002]) and Saudi Arabia. In Israel, Jewish fundamentalists are in conflict with other more moderate groups, and present a barrier to the peace process, as the 1995 assassination of Prime Minster Yitzhak Rabin so clearly demonstrated. Fundamentalists have kept Afghanistan at war for over two decades. Within nearby states, Islamic fundamentalists represent significant political and social challenges in Pakistan, Uzbekistan, and Tajikistan. In India, Sikh and other extremists represent a clash of cultures with the general subpopulation. Fundamentalists also pose threats in the Philippines (Abu Sayyaf Islamic fundamentalists) and Indonesia (Laskar Jihad).

When a fundamentalist subpopulation interacts with a more general subpopulation, the effect is two-fold. First, the fundamentalists are generally more cohesive; there are organizational economies of scale associated with a singleness of purpose. Second, fundamentalists are, by definition, less likely to compromise on societal issues. In this context, we interpret the greedy strategy as a way of asserting sufficient influence to change the way in which culture, religion, politics, language, status, and other traits determine the outcome of a transaction. Another interpretation is that fundamentalism signals one's unwillingness to compromise on these issues.

Our definition of fundamentalism purposely avoids specific reliance on issues such as religion, violence, irrationality and other characterizations that can misrepresent or too narrowly define what is a widespread phenomenon. Instead, we represent fundamentalism in terms of group cohesiveness and an inability to compromise over issues such as morality in private life, corruption in public state life, and deficiencies in the rule of law, all of which translate into demand for social control.[2] The fundamentalist subpopulation consists of both "zealots" and "followers." In fact, many economists have experienced fundamentalism of this type in their academic departments, where some subgroup gains control over the departmental agenda and will never settle for modest demands. Such academic fundamentalists exercise decisions on the rankings of journals, hiring, and acceptable research topics. They often direct the seminar series and determine the prestige afforded to colleagues' accomplishments.

At the very least, fundamentalists do not propose minority status for themselves on the cultural/ethnic issues that define their identity, which implies that fundamentalists eliminate the modest/moderate strategy from their strategy set. We can use the Nash demand game to examine whether this interpretation of fundamentalism affects the coordination of social control. Such a comparative static is an explicit part of evolutionary game theory, where the strategies themselves are the units of selection rather than the players. Peaceful coexistence often characterizes inter-ethnic relations (FEARON AND LAITIN [1996]), so that the F strategy remains relevant for fundamentalists. Fairness implies relatively equal social control irrespective of cultural/ethnic identity. If a more general subpopulation is represented by the row strategies and the fundamentalist subpopulation is represented by the column strategies, then the interaction between these two subpopulations is

[2] We thank GEORG ELWERT for a discussion of these issues at the Wörlitz conference.

displayed in Box 2.

[Box 2 near here]

For this interaction, the Nash demand game is no longer symmetric, so that the replicator dynamics and definition of ESS do not directly apply. The notion of replicator dynamics can, however, be adapted by recognizing that, in pairwise matching between agents from distinct subpopulations, an individual from the row subpopulation only meets individuals from the column subpopulation. That is, an individual does not meet a colleague or mutant from his or her own subpopulation, which implies that the S.O.C. for an ESS is vacuous, so that only the F.O.C. applies. Hence, the asymptotic stability of an incumbent strategy of a subpopulation requires that it must perform *strictly* better against the *other* subpopulation than does any other (mutant) strategy from its own subpopulation. In such a situation, we must specify distinct distributions, ρ and σ for the row and column subpopulations, respectively. The replicator dynamics corresponding to our cross-population discussion of fitness (TAYLOR [1979]) are defined as:[3]

(3) $$\dot{\rho}_i = \rho_i \bullet [E[x_i, \sigma] - E[\rho, \sigma]] \text{ for } x_i \in S_{row} = S_r,$$

(4) $$\dot{\sigma}_j = \sigma_j \bullet [E[y_j, \rho] - E[\sigma, \rho]] \text{ for } y_j \in S_{column} = S_c.$$

Again, a simple static characterization holds for the asymptotic stability for fixed points of these coupled differential equations:

Result 2 [SELTEN, 1980]: (x_i, y_j) is an ESS for an asymmetric game if and only if it is a

[3] Result 2 is a direct function of SELTEN'S requirement that pairwise matchings occur as in a *truly asymmetric contest*; i.e., those in ρ-subpopulation (σ-subpopulation) do not meet others in the ρ-subpopulation (σ-subpopulation) in contests that determine social control. Hence, one need not consider mutants representing alternative best replies within the same subpopulation, thus implying that the F.O.C. must hold with strict inequality. By contrast, WÄRNERYD [1993] considers an evolutionary model (in an unrelated context) where matchings *within* and across subpopulations are possible and the equilibrium occurs in mixed strategies.

strict Nash equilibrium.

Strategy pair (x_i, y_j) is a strict Nash equilibrium when x_i is the unique best reply to y_j, and vice versa. Hence, an ESS cannot occur in mixed strategies, because, by definition, any pure strategy that is played with positive measure receives the same expected payoff. Result 2 is stated in terms of pure strategies with foresight of this consequence.

From the perspective of our analysis of fundamentalism, SELTEN'S result states that the equilibria in clash of cultures can only be monomorphic outcomes. This is entirely the aim of fundamentalist attempts at social control – first, to remove any heterogeneous elements within its own subpopulation (cohesively raising ethnic identity), and second, to impose its doctrine as the cultural norm for interaction throughout society. Application of this result to the clash of cultures game illustrates this point.

Result 3: The ESSs for the game in Box 2 are (F,F) and (M,G).

In contrast to the analysis of the Nash demand game among a single population, now all equilibria are monomorphic. The monomorphism of the fundamentalist subpopulation is not surprising. What is novel is that ESS requires the general subpopulation to be monomorphic as well, which is a direct consequence of SELTEN's [1980] result. Fairness in both subpopulations is a distinct possibility, but if any group is to gain the lion's share, it is the fundamentalist subpopulation – as identified by the (M,G) equilibrium.

4 The Evolution of Ethnopolitical Conflict

One of the most important contributions of evolutionary game theory is that it provides a theory of population dynamics that determines how equilibrium is reached. The *initial* distribution of demands is unlikely to be monomorphic. If, indeed, the fundamentalist subpopulation rules out moderate behavior – as in the clash of cultures game – the degree to which this creates conflict is a likely predictor of whether the (F,F) or (M,G) equilibrium prevails. The replicator dynamic allows us not only to focus on the equilibrium outcome, but also to predict the evolutionary path over generations of pairwise matchings leading to that equilibrium. We are particularly interested in how initial demand distributions – among the general subpopulation and/or fundamentalists – determine which equilibrium results. For this exercise, we use the discrete version of the replicator dynamics (THOMAS [1986]), where for the initial population distribution (ρ^0,σ^0), the distribution at generation k + 1 is given by:

(5) $$\rho_i^{k+1} = \frac{\rho_i^k E[x_i,\sigma^k]}{E[\rho^k,\sigma^k]} = \frac{\text{expected fitness of } x_i \text{ under distribution } \rho^k}{\text{mean fitness of distribution } \rho^k},$$

(6) $$\sigma_j^{k+1} = \frac{\sigma_j^k E[y_j,\rho^k]}{E[\sigma^k,\rho^k]} = \frac{\text{expected fitness of } y_j \text{ under distribution } \sigma^k}{\text{mean fitness of distribution } \sigma^k}.$$

Eq. (5) states that the proportion of players in the non-fundamentalist subpopulation that make demand x_i in the next generation (k + 1) depends *only* on how non-fundamentalists do against the fundamentalists (in generation k), rather than amongst themselves. This is the essence of SELTEN'S [1980] result, and is reflected in the fact that the fitness of demand $x_i \in S_i$ in the general subpopulation is determined only through its matching with demand $y_j \in S_j$ from the fundamentalist subpopulation. Such matchings occur in generation k according to distribution σ^k. The numerator of (5) measures the expected fitness of $x_i \in S_i$ against the fundamentalist subpopulation, σ_j^k, weighted by the proportion of the general subpopulation, ρ_i^k, that makes demand x_i. The denominator measures the average expected fitness of the general subpopulation when distributed according to ρ^k, and each individual is matched with a fundamentalist according to distribution σ^k. If non-fundamentalist demand x_i does better (worse) against the fundamentalists than the mean fitness, this type will increase (decrease) in generation k + 1. Similar intuition holds for (6) – the evolution of fundamentalist demands depends on the success (failure) of their dealings with non-fundamentalists.

The growth and possible convergence of the demands in the fundamentalist and non-fundamentalist subpopulations are, in part, determined by the distribution of demands in the opposing population. Eqs. (5) and (6) reflect a coupled symbiosis – whether or not a subpopulation converges to distribution ρ^* (σ^*) not only depends on the initial distribution of its own demand ρ^0 (σ^0), but also on that of the coupled subpopulation, σ^0 (ρ^0). The asymptotic stability of such a distribution is characterized by SELTEN'S [1980] theorem, stated in result 2.[4]

The implications of fundamentalism and the potential for conflict can be derived through a simulation of the discrete replicator dynamics for the clash of cultures game. This simulation depends on three variables: the greedy demand (x_G), assumed to be the same in either subpopulation;[5] the initial distribution (ρ^0) in the general subpopulation; and the initial distribution over fundamentalist demands (σ^0). The results for each triple can be summarized by the graphical depiction of ρ_F^k in Figures 1 and 2. According to result 3, only (F,F) and (M,G) are asymptotically stable. It follows that if $\rho_F^k = 1$, the system converges to the (F,F) equilibrium; if, however, $\rho_F^k = 0$, the system converges to (M,G).

[Four-panel Figure 1 near here]

In each of the four panels of Figures 1 and 2, the vertical axis depicts the ratio of F-types in the general subpopulation, ρ_F, while the horizontal axis indicates the number of generations. For example, in panel a of Figure 1, a greedy type demands $x_G = .6$ and half of the general subpopulation is initially fair ($\rho_F^0 = .5$). If half of the fundamentalist subpopulation is initially fair ($\sigma_G^0 = .5$), the system converges to the (F,F) equilibrium, as $\rho_F^k \rightarrow 1$. Yet, the conventional

[4] See also TAYLOR [1979].
[5] As x_G is dominated for the general subpopulation in Box 2, it is played with probability zero by the general subpopulation in our simulations.

wisdom is that it is unlikely that the fundamentalist subpopulation will be so compromising, with half of its members making fair demands. If, instead, we allow $\sigma_G^0 = .6$, Figure 1a illustrates that the system converges to the (M,G) equilibrium ($\rho_F^k \rightarrow 0$). For a larger proportion of greedy fundamentalists, the convergence to the (M,G) equilibrium is even faster. What the simulation illustrates is that when the fundamentalists are not overly insistent in their demands ($x_G = .6$), they do not need an initially high level of cohesiveness in order for their identity traits to define social control. The system converges to (M,G) even though initially only 60% of the fundamentalists are greedy.

In sharp contrast, Figure 1d illustrates that if we have $\rho_F^0 = .5$, but the fundamentalist subpopulation is *more obstinate*, demanding $x_G = .9$, the system converges to an (F,F) equilibrium even if 80% of the fundamentalist subpopulation is greedy. The intuition is that, from such a starting point, fair elements of the fundamentalist subpopulation do much better than greedy ones against the non-fundamentalist subpopulation. In order for $x_G = .9$ to lead to the (M,G) outcome, at least 90% of the fundamentalist subpopulation must initially be making this demand ($\sigma_G^0 = .9$). Figures 1a-1d demonstrate that as fundamentalists show less tolerance (increasing x_G), greater proportions of their initial subpopulation distribution must possess this intolerance if (M,G) is to be the equilibrium.

[Four-panel Figure 2 near here]

Figure 2 presents four panels – 2a-2d – where 80% of the general subpopulation is initially fair. Even for a small degree of fundamentalist intolerance, $x_G = .6$, in Figure 2a, 90% of the initial fundamentalist subpopulation must be intolerant for the equilibrium to converge to (M,G). As x_G increases, the speed of convergence to (F,F) increases. In Figure 2d, convergence to (F,F) occurs within eight generations, even when 90% of the fundamentalists possesses greedy demands of $x_G = .9$.

Result 4: For the clash of cultures game, the following holds:

i. Intolerant fundamentalism (increasing x_G) requires initially greater cohesion (a higher σ_G^0) if they are to take social control. This can be seen by consulting panels a-d of Figures 1 and 2. Higher fundamentalist demands, x_G, require a more cohesive fundamentalist subpopulation in order for fundamentalism – (M,G) – with a subservant general subpopulation to prevail.

ii. The success of fundamentalism depends on the existence of moderate behavior in the non-fundamentalist subpopulation. This can be seen through side by side panel comparisons of Figures 1 and 2. As ρ_M^0 decreases (ρ_F^0 increases), implying that the general subpopulation is less willing to acquiesce to fundamentalist demands, the (F,F) outcome prevails.

iii. Dogmatic fundamentalists ($x_G = 1$) die out quickly. This is because modest elements of the general subpopulation would earn a fitness of zero when matched against greedy fundamentalists. If the greedy demand is 1, then the system converges to the (F,F) equilibrium (not illustrated).

iv. We extend FEARON AND LAITIN'S [1996] study of peaceful and cooperative ethnopolitical interactions – based on the Prisoner's Dilemma – to the case of the Nash demand game. The (F,F) equilibrium occurs for a wide array of initial population distributions and greedy demands.

5 Preference Falsification

As there are countless incidents of peaceful inter-ethnic relations (e.g., Jordan and Morocco) despite the presence of fundamentalist groups, the x_F demand remains relevant for the fundamentalist subpopulation. One of the stated goals of fundamentalism is to transform the general subpopulation, so that fundamentalist traits and norms determine access to state power.

An often-observed aspect of fundamentalism is the willingness to make fair demands for pairwise matchings with others who observe fundamentalist behavior. Notice that we are careful not to say that fundamentalists make fair demands only with other fundamentalists. When there are two distinct subpopulations, what is important is the willingness of non-fundamentalists to *behave according* to fundamentalist doctrine. If fundamentalism operates in this vein, then the opportunities are ripe for preference falsification as a means to maximize payoffs and fitness. In Afghanistan, for example, non-Taliban women wore Burqas and men grew beards as a signal of their adherence to Taliban mores. In academic departments, non-fundamentalists may mimic fundamentalist traits so that they are treated better. If, for example, the empiricists are the fundamentalists, then some theorists may co-author papers with empiricists to enhance their position.

Our use of preference falsification provides an evolutionary game foundation to the influential work of TIMUR KURAN [1989, 1991], for which the truthful revelation of preferences depends on threshold choices for participating in a revolution and the size of a revolutionary collective. In our model, preference falsification or truthful expression hinges on population dynamics driven by fitness. As such, the initial demands of non-fundamentalists, as well as the intolerance (greed) of the fundamentalists, determine whether non-fundamentalists falsify their preferences by signaling fundamentalist traits. Thus, the underlying "thresholds" for truthful revelation is dependent on population dynamics and preference parameters. Shocks that change the population proportions – e.g., US bombing of Afghanistan on 7 October 2001 – can either augment non-fundamentalist proportions (i.e., ρ_F) or decrease fundamentalist proportions (i.e., σ_G), so that preference falsification decreases sufficiently, thereby ending an intolerant fundamentalist regime.

Suppose that non-fundamentalists and fundamentalists alike have access to such a strategy, which signals their willingness to adhere to fundamentalist doctrine, thereby avoiding cross-population conflict. That is, fundamentalism affords falsifiable behavior to the general subpopulation such that adherence to this behavior reduces cross-cultural friction. In this scenario, the following definition proves important:

Definition: A falsifiable fundamentalist strategy, $\Im$, is a conditional strategy[6] that is greedy when matched with any strategy other than itself, and fair when matched with others exhibiting the $\Im$-traits. Formally, we have the following strategy:

$$\Im = \begin{cases} \text{Demand .5 when matched with a } \Im \text{ from the other subpopulation, and} \\ \text{demand } x_G \text{ in all other subpopulation matchings.} \end{cases} \tag{7}$$

When falsifiable behavior replaces greediness in the clash of cultures game, the results of pairwise matchings are given in Box 3. The analyses of Boxes 1, 2, and 3 therefore represent a natural progression from a situation where fundamentalists eliminate moderate demands in an attempt to gain social control (Box 1 to Box 2) to one in which they allow for preference falsification ($\Im$) in a further bid for social control (Box 2 to Box 3). The latter eliminates the greedy demand, because it is dominated by $\Im$.

[Box 3 near here]

By allowing the general subpopulation to avoid intolerance only by adhering to fundamentalist's terms, the fundamentalists create a model of behavior – alternative to fairness – that is aligned with their identity traits. Fundamentalists prefer that social power sharing be done on their terms, rather than a general principle of fairness. Iran after the 1979 revolution, which brought Ayatollah Khomeini to power, conforms to this scenario, because individuals who signaled their adherence to the strict Islamic doctrine were integrated into the society. Similar situations

[6] See DAWKINS [1980] for an introductory discussion of conditional strategies.

characterize present-day Algeria, Nazi Germany under Hitler, or any regime where tolerance is solely based on displaying certain identity traits. In contrast to the clash of cultures – where greediness is a dominated strategy for the general subpopulation (in strategy set S_r) – falsification is not a dominated strategy for this subpopulation. Indeed, even if preference falsification comes at some cost, $\Im$ is an undominated strategy, provided that $\Pi_r(\Im,\Im) > x_M$ – i.e., preference falsification is not too costly. In this way, the results presented below are not tied to the requirement that $\Pi_r(\Im,\Im) = .5$. We have similar results for simulations in which falsification is costly, i.e., $.5 > \Pi_r(\Im,\Im) > x_M$.

The game has two ESSs – (F, F) and $(\Im,\Im)$. At first, the $\Im$ strategy may appear as little more than fairness, but an illustrative comparison of two simulations demonstrates that sharing under fundamentalist terms differs substantially from fairness. Consider the case where the fundamentalist subpopulation is not initially cohesive; there is a 60:40 split among $\Im$- and F-types. Further assume that the greedy demand is .6. In our first simulation, the initial general subpopulation distribution is $(\rho_M^0, \rho_F^0, \rho_\Im^0) = (.45, .05, .50)$. This is illustrated in panel a of Figure 3 where, in contrast to Figures 1 and 2, the evolution of all three types in the general subpopulation are depicted for an initial fundamentalist distribution ($\sigma_\Im = .6$). The system then converges to the $(\Im,\Im)$ outcome. As expected, if more of the general subpopulation is inclined toward $\Im$ at the outset (as compared to F), then $(\Im,\Im)$ results.

[Three-panel Figure 3 near here]

The key to the effectiveness of the $\Im$ strategy's impact on the general subpopulation is seen through a second simulation, where the initial $\Im$ and F proportions for the non-fundamentalists are reversed. Suppose that just 5% of the modest types in the general subpopulation are at the outset willing to behave according to $\Im$. That is, given that there are rewards for behaving according to $\Im$, we ask what happens if even a tiny proportion of the modest elements of the general subpopulation opts for $\Im$ instead, as represented under the distribution $(\rho_M^0, \rho_F^0, \rho_\Im^0) = (.45, .50, .05)$. Panel b of Figure 3 illustrates that once such a perturbation occurs, preference falsification occurs in an extreme way, ultimately resulting in the $(\Im,\Im)$ equilibrium. From this initial ρ^0, the replicator dynamics produce a situation where by generation 13 the general subpopulation is almost entirely modest, and 70% of the fundamentalist subpopulation will share with those elements in the general subpopulation who adopt their cultural identity ($\sigma_\Im^{13} = .7$ – not illustrated). Hence, the situation is not stable; $(\rho_M^{13}, \sigma_\Im^{13}) \approx (1, .7)$ is not an ESS and the replicator dynamics bear this out. The general subpopulation further evolves, *completely switching* to the $\Im$ strategy! The convergence to $(\Im,\Im)$ is unexpected and indicates that $\Im$ has a much larger basin of attraction than F, even though each yields .5 payoffs in symmetric matches. The fundamentalist subpopulation increases monotonically in $\Im$ – it is becoming more cohesive – and by generation 46 the overall distribution is $(\rho_\Im^{46}, \sigma_\Im^{46}) = (1, 1)$. This outcome is asymptotically stable, as it is an ESS for the game in Box 3. Allowing for falsification therefore undermines the robustness of the fairness outcome and facilitates the acceptance of fundamentalist terms in the general subpopulation.

Another novel result is that *our prior observation* that increased greediness requires a more cohesive fundamentalist subpopulation *no longer applies* when fundamentalism is falsifiable. Panels b and c of Figure 3 reveal that, when x_G is increased from .6 to .8, the intra-state distribution rapidly converges to $(\Im,\Im)$ even though $\sigma_\Im^0$ is unchanged at 60% (and $\rho_\Im^0$ = .05). This follows because the benefits of modest demands have decreased relative to falsifiable ones. Payoffs for x_M are .4 in Figure 3b and are just .2 in Figure 3c. Without a falsifiable trait, the success of increased greediness hinges on the cohesiveness among the fundamentalist subpopulation (an increase in σ_G^0) (see Figures 1 and 2). For falsifiable traits, more extreme fundamental demands, in sharp contrast, result in rapid convergence to the entire population displaying fundamentalist traits. This bandwagon effect occurs even for small $\rho_{\mathfrak{Z}}^0$. Thus, we have:

Result 5: When the identity traits of fundamentalism are falsifiable and conditionally fair, then :

i. The falsifiable strategy has a larger basin of attraction than fairness.

ii. Extreme demands applied to anyone not adhering to fundamentalist identity traits will not only increase the cohesiveness of the fundamentalist subpopulation, but will also cause the general subpopulation to capitulate rapidly.

As noted by KURAN [1991], the breakdown of preference falsification can result in the rapid elimination of a regime – e.g., the Milosevic regime in Bosnia, the 1989 Velvet Revolution in Czechoslovakia, the Taliban in Afghanistan, and the communist regime in East Germany. With less preference falsification, intolerance is unable to sustain a fundamentalist regime when the proportion of the general subpopulation making fair demands is large, or the cohesiveness of the hardline fundamentalists is reduced. Similarly, when members of an academic department stop falsifying their preferences owing to the departure of a few intolerant colleagues, the overall acceptance of alternative viewpoints may return, rapidly.

6 Concluding Remarks

This paper has put forth an evolutionary game-theoretic basis of conflict between subpopulations making different demands for control. The underlying dynamics of our approach to conflict, where paired individuals cannot agree on a division, is quite different from the (static) rent-seeking conflict models so prevalent in the literature. Both the evolutionary game and the rent-seeking approaches have their relative strengths and weaknesses. The former is particularly suited to displaying population dynamics and convergence to an equilibrium where a single type or trait is in control. Additionally, the evolutionary representation provides a dynamic framework for KURAN'S [1989, 1991] theory of preference falsification, whereby a non-fundamentalist subpopulation can co-exist in equilibrium with a fundamentalist one by taking on the latter's identity traits. In so doing, greater greed by the fundamentalists to those not displaying their traits may bolster the fundamentalist's hold, unlike the case with no preference falsification. This chameleon behavior by non-fundamentalists may be consistent with rapid regime changes in response to either the elimination of preference falsification or changing population distributions brought about by external shocks. Although chameleon behavior can ensure co-existence between fundamentalists and non-fundamentalists, this behavior is apt to eliminate non-chameleons from the general subpopulation who make modest or fair demands, owing to the large basin of attraction for preference falsification. Thus, co-existence through signaling may come at a high price as Afghanistan sadly demonstrated to the world.

A wide variety of conflict relationships can be examined by evolutionary game theory. Games other than the Nash demand game can form the basis for future analyses. Additionally, elements of rent seeking can be introduced into our framework, so that relative efforts by opposing interests can help determine fitness results among paired encounters with and without preference falsification.

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Daniel G. Arce M.
Department of Economics
Rhodes College
2000 N. Parkway
Memphis, TN 38112-1690
USA
E-mail: arce@rhodes.edu

Todd Sandler
School of International Relations
University of Southern California
Von Kleinsmid Center 330
Los Angeles, CA 90089-0043
USA
E-mail: tsandler@usc.edu

Box 1: Skyrms' Game ($x_M = 1 – x_G$)

	M	**F**	**G**
Modest (M)	x_M, x_M	x_M, .5	x_M, x_G
Fair (F)	.5, x_M	.5, .5	0, 0
Greedy (G)	x_G, x_M	0, 0	0, 0

Box 2: Clash of cultures

	F	**G**
Modest (M)	x_M, .5	x_M, x_G
Fair (F)	.5, .5	0, 0
Greedy (G)	0, 0	0, 0

Box 3: Falsifiable Fundamentalism

	F	$\mathfrak{I}$
Modest (M)	x_M, .5	x_M, x_G
Fair (F)	.5, .5	0, 0
Falsifiable ($\mathfrak{I}$)	0, 0	.5, .5

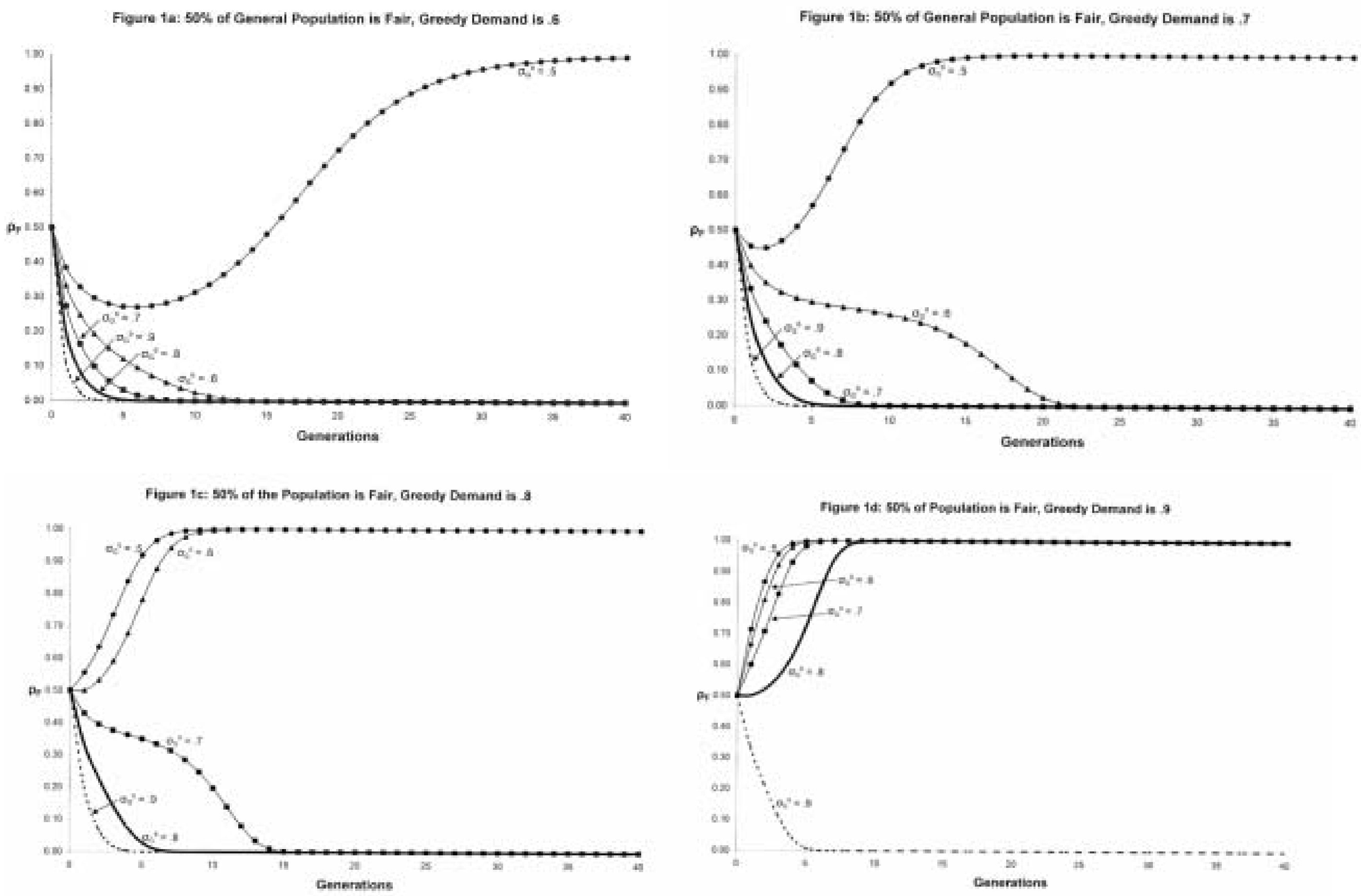
Figure 1a: 50% of General Population is Fair, Greedy Demand is .6
Generations
Figure 1b: 50% of General Population is Fair, Greedy Demand is .7
Generations
Figure 1c: 50% of the Population is Fair, Greedy Demand is .8
Generations
Figure 1d: 50% of Population is Fair, Greedy Demand is .9
Generations

Figure 1

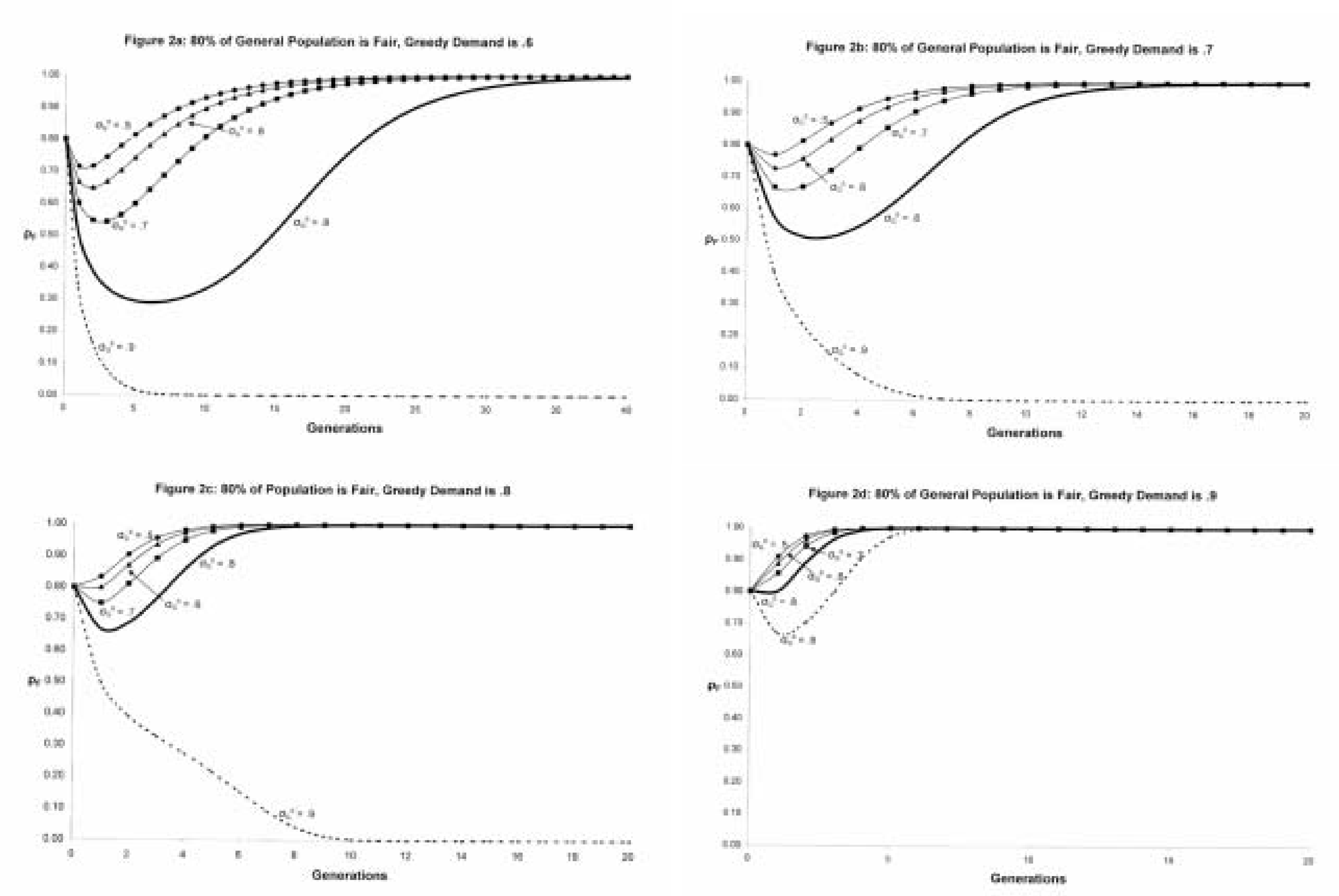
Figure 2a: 80% of General Population is Fair, Greedy Demand is .6
Generations
Figure 2b: 80% of General Population is Fair, Greedy Demand is .7
Generations
Figure 2c: 80% of Population is Fair, Greedy Demand is .8
Generations
Figure 2d: 80% of General Population is Fair, Greedy Demand is .9
Generations

Figure 2

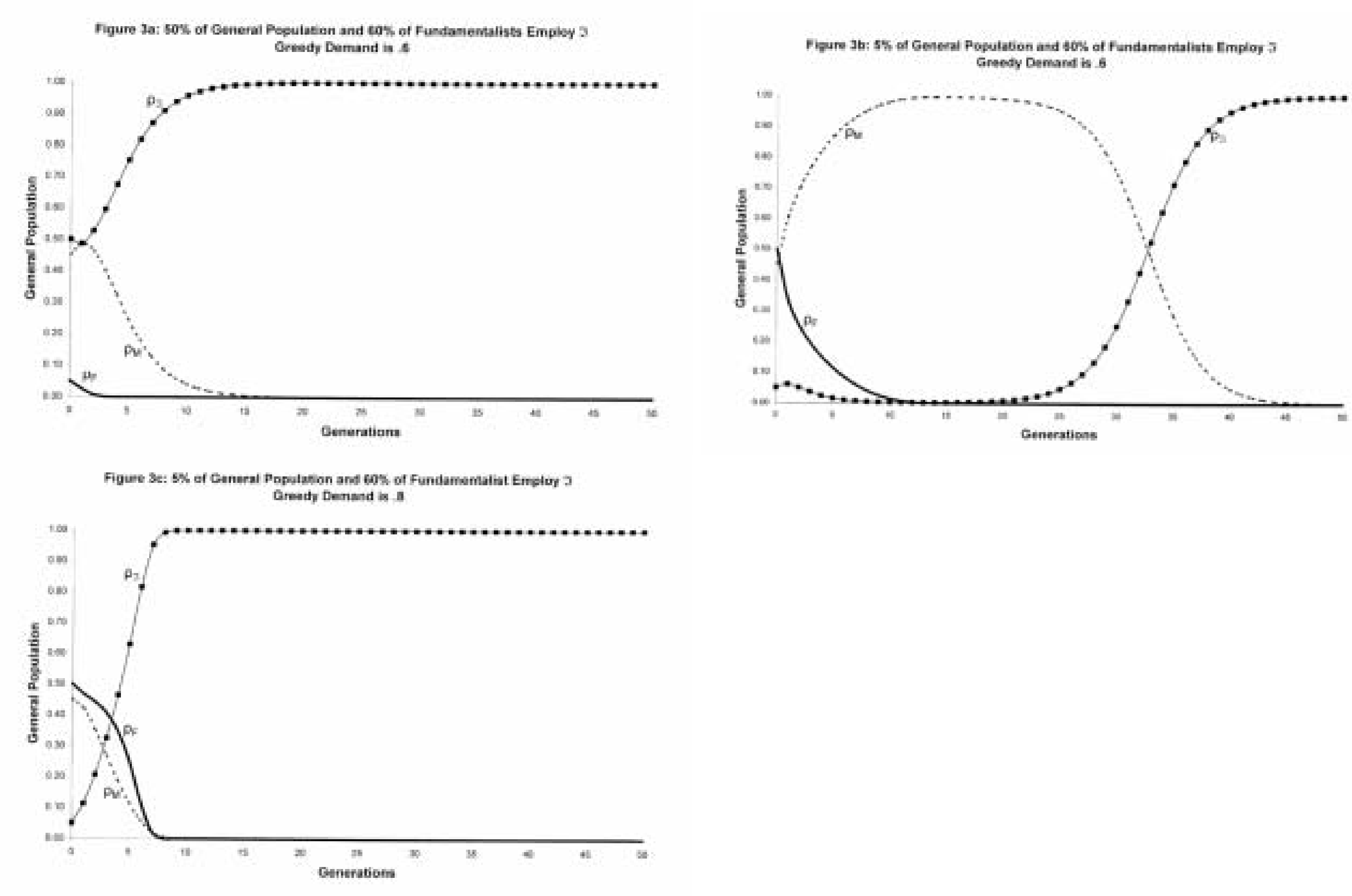

Figure 3a: 50% of General Population and 60% of Fundamentalists Employ
Greedy Demand is .6
Figure 3b: 5% of General Population and 60% of Fundamentalists Employ
Greedy Demand is .6
Figure 3c: 5% of General Population and 60% of Fundamentalist Employ
Greedy Demand is .8
General Population
Generations

Figure 3