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An Experimental Analysis of Two-Person Reciprocity Games*

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Abstract

Experimental evidence is presented documenting a subject's behavior when faced with simple games that require turn taking for efficiency. Both symmetric and asymmetric games as well as games with explicit punishment actions are studied and compared. The length of the game is a treatment variable; experiments simulating one-shot, finite and infinite repetition games are conducted. Group outcomes are sorted by the player's average payoffs and the importance of focal solution concepts like group welfare, equality, and symmetry are inferred. Individual strategies used in the experiments are also sorted and compared enabling a discussion of endgame effects and conflict within the games.

1 Reciprocity Games

As described in Ostrom (1990), the farmers near the city of Valencia, Spain take turns directing water from canals onto their fields. When one farmer has taken all the water he needs, the next farmer, who has been waiting, gets to take all the water he needs. There is obvious temptation for the waiting farmers to try to take water out of turn; Valencia is hot and dry and the crops are in constant danger, especially in drought years. Remarkably enough these turn-taking schemes have survived for centuries.

The purpose of the turn-taking scheme is to insure an efficient, or at least near efficient, use of the water supply. Without the agreement to rotate, the farmers would waste valuable resources fighting amongst themselves over the scarce water. It is possible that farmers closer to the canals, or further upstream, would have an advantage in an unfettered contest for the water. The advantaged farmers might even be better off with free competition than with the turn-taking scheme. However, the disadvantaged farmers might be forced out of business without the turn-taking scheme, and the total amount of crops produced might go down. By following the turn-taking scheme, the farmers avoid these potential problems.

There are other situations in which turn-taking schemes can enable groups of people to exploit a resource to their collective advantage. Two firms, for example, can alternatively offer monopoly price bids in a series of contract auctions. Without the turn-taking scheme, the firms would be forced to offer competitive price bids; the earnings of the auction's winner would be drastically reduced. Similarly, two opposed politicians can alternatively vote against their immediate best interests so that a string of bills, some of which please their constituents, will be assured of passage. If the politicians did not agree on a turn-taking scheme, their votes would cancel out and perhaps no bills would pass.

All these situations can be classified under the rubric of Reciprocity Games. A Reciprocity Game, then, is any noncooperative situation in which some efficient outcomes can only be realized by utilizing nontrivial correlated strategies, or turn-taking. Repeated versions of classical games like the Battle of the Sexes and Chicken are Reciprocity Games, pure coordination games like The Repeated Prisoner's Dilemma are not.

As an example of a Reciprocity Game, consider the repeated, finite action, two player game implied by the stage-game payoff matrix G_1, where

$$G_1 = \begin{bmatrix} (3,3) & (3,7) \\ (7,3) & (4,4) \end{bmatrix}.$$

Label the actions A and B. Let the top and bottom rows represent the payoffs if the row player chooses action A or B, respectively. Let the left and right-hand columns represent the payoffs if the column player chooses action A or

B, respectively.

Assuming that both players are rational, or expected utility maximizers, that they are non-altruistic, and that they have complete information about the payoffs and the rationality of the other player, noncooperative game theory offers certain predictions about the player's behavior. The clarity of these predictions depends upon the number of times that the stage-game is repeated.

If the stage-game is not repeated, each player has a dominate strategy, which is to choose action B. Play of this action at every stage is also the unique subgame perfect equilibrium of any finite repetition game. In equilibrium, each player receives a payoff of four in each stage. The equilibrium is efficient only in the non-repeated or one-shot game; in the repeated game, all the efficient outcomes involve alternating between the stage-game payoffs of $(3, 7)$ and $(7, 3)$. To gain these payoffs, both players must choose their dominated action, and furthermore, the players must coordinate so that they do not choose the dominated action at the same time. Given an even number of stages, the simple alternation scheme of having the players take turns choosing actions A and B leads to an outcome in which each player gets an average stage payoff of five.

If the stage game is repeated an infinite number of times, the folk theorem implies that there are an infinite number of subgame perfect equilibria. Any outcome that has payoffs greater than or equal to four is subgame perfect.

In fact, there are an infinite number of efficient subgame perfect equilibria, each one involving some pattern of alternation between $(3,7)$ and $(7,3)$. The multiplicity of equilibria is in itself a problem for the players – which equilibrium should they coordinate on? Axiomatical concepts like symmetry, group welfare, or equality can be used to determine focal points, yet, even with these concepts there need not be a unique equilibrium. The efficient payoffs do share a common trait, however. In the efficient outcomes, the players must resort to a pattern of alternation between the stage-game payoffs of $(3,7)$ and $(7,3)$.

The purpose of this paper, then, is to examine the ability of people to enter into alternation schemes and achieve efficient outcomes to reciprocity games. The games will be studied under three different repetition conditions: one-shot, finite repetition, and infinite repetition. Comparisons will be made between a game that has symmetric payoffs and a game that has asymmetric payoffs. The effects of adding a third action, one intended to be a clear punishment, will also be considered.

2 Related Research

The previously mentioned book by Ostrom (1990) is concerned with examining the ability of people to efficiently exploit common pool resources. She reviews several case histories in which groups of people are able to introduce rotation schemes and successfully exploit the resource. Some of her examples have been in place for centuries.

Ostrom *et al.* (1991) have abstracted from these real life examples in an experimental study of the use of a common pool resource. In their study, rotation schemes offer an efficient way to exploit the resource, and, in fact, some of the eight-person groups try to institute these schemes. Ostrom *et al.* find that these schemes fail do to mistrust, mistakes or cheating. The authors find that the efficiency of the use of the resource increases if individuals are allowed to impose fines on one another; however, resource use never reaches optimal levels.

Murninghan *et al.* (1987) studied modified Prisoner's Dilemmas that were in fact Reciprocity Games. They found that in infinite repetition treatments and with the ability to communicate, subjects often resorted to alternation schemes, some sacrificing potential payoffs to do so. Some subjects also attempted *complex alternation* schemes in an effort to generate more equal payoffs.[1] Their treatments are similar to the infinite repetition, symmetric treatment considered here. The main differences between the treatments are that Murninghan *et al.* allow communication, and also the asymmetries in their payoff structure occur on the main diagonal.

Palfrey and Rosenthal (1991a; 1991b) and Cooper *et al.* (1990; 1989; 1987) have studied various public goods and coordination games that with repetition become Reciprocity Games. Cooper *et al.* (1990; 1987) also examined the addition of an action deemed to be a punishment. They found that the availability of the extra action did effect the players choice of strategies.

Selten and Stoecker (1986), in their work on finitely repeated Prisoner's Dilemmas, developed a system of outcome classification that is similar to the strategy classification system used here.[2]

3 The Experimental Design

Each of four different payoff treatments will be examined under three different repetition conditions. The four different payoff treatments are: symmetric (G_1), asymmetric (G_2), symmetric with punishment (G_3), and asymmetric with punishment (G_4). Each of these treatments is represented by a payoff matrix in Table 1. The different repetition conditions are: one-shot, finite repetition, and infinite repetition.

3.1 Equilibria

The equilibria for G_1 have been discussed already, but for completeness, they will also be examined here along with the equilibria in the other three games.

First, in the one-shot conditions of both G_1 and G_2 there is either a unique dominate strategy or dominate solvable Nash equilibria. In G_1 the unique equilibrium is for both players to choose action B, it gives each of them a payoff of four. The outcome will be denoted by the pair $\{B, B\}$ so that each player's move is reflected. In G_2 the unique equilibrium, $\{A, B\}$, is for the row player to choose action A and get a payoff of three, and for the column player to choose action B and get a payoff of seven.

Recall that the games G_3 and G_4 are identical to the games G_1 and G_2, respectively, except that G_3 and G_4 have an additional action available to the players. The action is clearly not a desirable action; if it is played, both players get much worse payoffs. However, the availability of the action means that both G_3 and G_4 have three equilibria instead of only one. They share the equilibria of their counterparts, namely $\{B, B\}$ and $\{A, B\}$, respectively, plus they each have two additional equilibria.

In G_3 the additional equilibria are: $\{(\frac{1}{4}B, \frac{3}{4}C), (\frac{1}{4}B, \frac{3}{4}C)\}$, the fractions representing the weights in a mixed strategy, and $\{C, C\}$. In G_4 the additional equilibria are: $\{(\frac{1}{3}A, \frac{2}{3}C), (\frac{1}{7}A, \frac{6}{7}C)\}$ and $\{C, C\}$. These additional equilibria are dominated, in the sense that both players get higher payoffs, by the $\{B, B\}$ equilibrium in G_3 and the $\{A, B\}$ equilibrium in G_4.

Finite repetition creates no additional equilibria in either G_1 or in G_2. However, in G_3 and in G_4 finite repetition creates many additional equilibria. In fact, due to a finite game folk theorem, any minimax-dominating outcome can be approximated by a subgame perfect equilibrium if the number of stages is large enough.[3] The folk theorem result causes a problem that is very similar to the problem encountered in the infinite repetition games, how do players coordinate on a particular equilibrium when the set of equilibria is very large?

Infinite repetition, in all four games, leads to sets of equilibria that are very large indeed – they are infinite. In fact, the infinite repetition folk theorem says that if the discount rate is low enough, any outcome to a game which results in average stage-game payoffs which are greater than the minimax payoffs is supportable as a subgame perfect equilibrium. [4] Note that the minimax payoffs for G_1 through G_4 are: $(4,4), (3,7), (1\frac{3}{4}, 1\frac{3}{4})$, and $(1\frac{2}{3}, 1\frac{3}{4})$. Again, the question is: How do players coordinate on a particular equilibrium when the set of equilibria is very large?

It is possible to pare the sets of equilibrium outcomes down to the manageable level of three or less by applying the axiomatic refinements of Equality, Symmetry, and Welfare Maximization, along with Pareto Optimality. The Equality refinement requires each player to receive the same payoff; the Symmetry refinement requires each player to choose their dominated action the same number of times; and the Welfare Maximization refinement requires the sum of the player's payoffs to be maximized. Pareto Optimality, of course, means that each outcome must be efficient. The equilibria that pass these refinements will be called focal solutions.

Specifically, in G_1 and G_3, the *one to one* alternation scheme leads to average stage payoffs of $(5, 5)$ and satisfies all four of these refinements. For the symmetric games, the imposition of the refinements means that the number of focal solutions is the same in the one-shot, finite, and infinite repetition conditions. In each case, there is a unique focal solution.

On the other hand, in G_2 and G_4, a *one to one* alternation scheme satisfies only the Symmetric refinement and leads to average stage payoffs of $(4, 5)$. To satisfy the Equality refinement requires a *one to two* alternation scheme. In this scheme the row player chooses action A half as often as the column player chooses action B and players end up with average stage payoffs of $(4\frac{1}{3}, 4\frac{1}{3})$. Furthermore, to satisfy the Welfare Maximizing refinement leads to play of the $\{A, B\}$ stage game equilibrium and average stage payoffs of $(3, 7)$. For the asymmetric games, the imposition of the refinements means that the number of focal solutions is three in the infinite repetition condition and in the finite repetition condition of G_4. The one-shot condition and the finite repetition condition of G_2 have unique focal solutions.

The behavior in the one-shot games should be considered as a calibrating device. The outcomes achieved are worst case outcomes in the sense that there is no chance for the players to use an efficient rotation scheme. Theory predicts that behavior will conform to the Nash Solution, which will be defined as Hypothesis 1.

Although not equilibria in all cases, the following hypotheses will be considered for both the finite and infinite repetition treatments (notice that they do not specify behavior in the earliest stages of the game; they allow a period of time for the players to coordinate):

Hypothesis 1 (Nash Solution) *After a certain period, each player chooses the action which leads to the highest Pareto-Ranked, subgame perfect equilibrium.*

Hypothesis 2 (Alternating Solution) *After a certain period, the outcome to the game will have players alternating between action A and action B such that the realized play will be* $\{\ldots, \{A, B\}, \{B, A\}, \{A, B\}, \ldots\}$.

Hypothesis 3 (Welfare Solution) *After a certain period, the outcome to the game will be such that the sum of the players payoffs is maximized.*

Hypothesis 4 (Equality Solution) *After a certain period, the outcome to the game will maximize the sum of the players payoffs subject to having each player receive the same payoff.*

Hypothesis 1 embodies the predicted outcome in the finite repetition games. The Nash Solution is also an equilibrium in any of the infinite repetition games, although it is not an efficient equilibria in the symmetric cases. Hypothesis

2 embodies the axiomatic refinement of Symmetry, it requires the players to adopt a one to one rotation scheme; Hypothesis 3 embodies the axiomatic refinement of Welfare Maximization; and Hypothesis 4 embodies the axiomatic refinement of Equality. Although not always equilibria, these three solutions are efficient outcomes to the finite repetition games.

4 The Experiments

All the experiments were performed in a laboratory at the California Institute of Technology. The experiments were run on a set of computers linked together in a network. The subject pool consisted of students, most of whom were recruited from introductory economics and political science courses. There were nine experimental sessions: one session for each finite and infinite repetition treatment of G_1, G_2, G_3, and G_4; and one session for all the one-shot treatments. The number of subjects in each session varied from ten to fourteen because some recruited subjects did not show up for some experiments.

The following outline describes the order of events that took place in a typical experimental session:

1. Each subject entered the laboratory and sat at the terminal of their choice.

2. The subjects were read a set of directions detailing the rules of the ses-

sion. The subjects were not shown a payoff matrix, instead each action and payoff was explained to them independently. The subjects were led through two practice periods and then quizzed.[5]

3. In a period, each subject chose either A or B (or C) and was then informed of their payoff and partner's choice. This was repeated under the following conditions:

   (a) In the one-shot treatments, each subject was randomly matched with another at the beginning of each period. The game ended after 15 periods.

   (b) In the finite repetition treatments, each subject played the same person each period. The game ended after 15 periods.

   (c) In the infinite repetition treatments, each subject played the same person every period. After the 15th period, a ten-sided die was rolled so that the subjects could see the result. If a 9 was rolled then the game ended, otherwise the game continued another period after which there was another die roll. The game did not end until a 9 was rolled.

4. At the end of the game, the subjects were randomly matched with a person whom they had not played and another game was started.

5. Each subject in a session played 4 games and was then paid cash for

each *point* they earned in the experiment. In the one shot treatments, the order of games was: G_1, G_3, G_2, and G_4. In the finite and infinite repetition treatments, the subjects played the same game four times.

6. The experimental session ended.

In the symmetric treatments, every player faced the same payoffs, so there was no difference between a row and a column player. Hence, in the symmetric treatments, all subjects were treated identically.

On the other hand, in the asymmetric treatments, the labels row and column had meaning, the player unlucky enough to be a row player was at a disadvantage. In order to prevent row players from gambling that they would become column players later in the session, at the beginning of each asymmetric treatment half of the subjects were informed that they would be row players for all four games in the session. In the one-shot session, this division took place before the third game, after all the symmetric games had been played.

Table 2 reports the number of subjects and the number of observations, respectively, in each treatment.[6] An observation consists of the outcome of one complete game and two sequences of actions, one for each player involved. The table also shows the dates of each session, the length, the exchange rate, and the order of the one-shot treatments.

5 The Results

5.1 The One-Shot Treatment

The first step is to examine the players' behavior in the one-shot treatments. The Table 3 describes the number of times each possible outcome pair was observed.[7]

In order to determine whether or not an individual's actions changed as s/he gained experience with the game, the data was split into the first eight periods and the last seven periods and then compared using a standard χ^2 test.[8] In no case was there a significant difference between the distribution of actions at the beginning and the distribution of actions at the end. The χ^2s were: 0.3370 for G_1, 0.2983 for G_2 row players, 1.2301 for G_2 column players, 1.6290 for G_3, and 2.5813 for G_4 column players. The column players in G_4 chose action B in every case.

In G_1, fourteen of the 150 observations, or 9.3 percent, assigned payoffs below the minimax to at least one of the players. In G_2, sixteen of the seventy-five row player observations and six of the seventy-five column player observations, 21.3 percent and 8 percent respectively, assigned payoffs below minimax payoffs. Assuming that the true frequency of below individually rational payoffs is the lower end of a 95 percent confidence interval around these observed frequencies would lead to the following percentages: 5.4, 13.4, and 2.8, respectively.

Obviously, there is a substantial minority of players who play non-equilibrium strategies. In an ideal environment, Hypothesis 1, that each player chooses the subgame perfect equilibrium strategy, would be rejected on the basis of even one non-equilibrium play. However, the criteria adopted for this experimental environment allows their rejection only if the upper bound of the 95 percent confidence interval around the observed proportion of plays is less than 0.95. These bounds are displayed in the Table 4. Hypothesis 1 must be rejected for G_1, and for the row players in both asymmetric treatments. The fact that not all people always play the unique, subgame perfect equilibrium strategy in one-shot games has been observed many times.[9]

Notice the significant change in the behavior of the column players when comparing G_2 to G_4. In G_2, 8 percent of the actions chosen by the column players violate the Nash Solution, in G_4 no actions chosen violate the Nash Solution. This is an anomaly because behavior does not change for the row player, neither does it change between G_1 and G_3. One explanation for the data is that, because G_2 and G_4 were played in succession by the same players, the column players learned how to play according to Hypothesis 1. Oddly enough, the row players did not share in the revelation.

5.2 The Finite and Infinite Repetition Treatments: Average Payoffs

The outcomes to the finite and infinite repetition treatments are represented by the average payoffs of both players. To allow a period of time for the players to coordinate on a specific outcome, the first four periods are ignored. Also, so that the infinite repetition treatments remain comparable to the finite repetition treatments, the averaging ends with the fifteenth period (the finite repetition treatments were fifteen periods long).

Referring to Figure 1, the set of possible outcomes to G_1 if it were infinitely repeated is represented by the triangular figure in both the top and bottom diagrams. Given that a ten period average is used, the possible outcomes are a subset of the triangular set. Actual outcomes to the games are shown by a letter representing one or more observations. The letter is located at the coordinates determined by the average payoffs of the players.

For an outcome to be Pareto Optimal, it must be located on the hypotenuse of the triangular set. The 45° line highlights the outcomes in which the players receive equal payoffs. Every outcome located northeast of the dotted lines payoff dominates the minimax. These minimax dominating outcomes, given a small enough discount rate, are subgame perfect equilibria if the game is infinitely repeated.

In Figure 1, the top diagram represents the outcomes of the finite repetition treatment of G_1. The bottom diagram represents the outcomes of the infinite repetition treatment of G_1. Similar figures are constructed for the two treatments of G_2, G_3, and G_4.

Note that in G_1 and G_3 there is no difference between a row and a column player. In order to avoid drawing conclusions from arbitrarily scattered outcomes, all the outcomes are located on or below the 45° line. In G_2 and G_4, there is a difference between a row and a column player.

Again referring to Figure 1, specifically to the top diagram which shows the outcomes of the finite repetition treatment, notice that the outcomes occur in two clusters. One cluster is located around the unique one-shot equilibrium or Nash Solution, point $(4,4)$. The other is located around the focal solution, the outcome that embodies the Alternating Solution, the Equality Solution and the Welfare Maximizing Solution, point $(5,5)$. The observations are divided roughly between the two clusters. Although the Nash Solution was the most observed with five, fourteen groups were able to improve upon it using some pattern of reciprocation, three actually implemented the focal solution. One player out of the twenty pairs received below minimax payoffs.

The bottom diagram, which shows the outcomes of the infinitely repeated treatment, is in sharp contrast to the top one. Here, twenty-one of twenty-four observations are located at the focal solution. Of the three remaining outcomes, two are located near the Nash Solution, and the last is located at an outcome better than the Nash Solution but not as good as the focal solution. The extension of the time-horizon from finite to infinite draws many outcomes away from the Nash Solution and to the focal solution. People appear to have few problems implementing a rotation scheme and achieving efficient payoffs, approximately 90 percent succeed, if G_1 is infinitely repeated.

Figure 2 shows the outcomes of the finite and infinite repetition treatments of G_3. Recall that G_3 is identical to G_1 except that an additional action, a punishment, was added to the action space. Despite the additional strategy, Figure 2 closely resembles Figure 1. In the top diagram, the finite repetition treatment, thirteen of the twenty outcomes are close to the focal solution. In the bottom diagram, the infinite repetition treatment, nineteen of the twenty-four outcomes are at the focal solution.

The top diagram in Figure 3 shows the outcomes of the finite repetition treatments of G_2, the first of the asymmetric games. Seven outcomes were at the Nash and Welfare Maximizing Solutions, point $(7,3)$. One outcome was at the Alternating Solution, point $(5,4)$. No outcomes were at or even near the Equality Solution, point $(4\frac{1}{3},4\frac{1}{3})$.[10] More than half of the outcomes, eleven of twenty, have the row player receiving less than minimax payoffs.

The bottom diagram shows the outcomes to the infinite repetition treatment of G_2. Unlike in the symmetric games, there is no improvement in the efficiency of the outcomes as the time horizon gets longer. Roughly the same proportion of outcomes are at the Nash Solution, the Alternating Solution, and the Equality Solution (eight, two, and zero observations out of twenty-four, respectively) as in the finite repetition treatment. Again, half of the outcomes have the row player receiving less than minimax payoffs. If anything, the payoffs in the infinite repetition treatment are worse than the payoffs in the finite repetition treatment.

Figure 4 shows the outcomes to G_4. Recall that G_4 is identical to G_2 except that a punishment action is added. Unlike in the symmetric case, here the presence of the punishment action changes behavior. In the top diagram, the most observed outcome is the Alternating Solution, point $(5, 4)$. This is in contrast to the most observed outcome in the finite repetition treatment of G_2 which was the Nash or Welfare Solution, point $(7, 3)$. However, a substantial number of outcomes are still inefficient outcomes. The bottom diagram has these same features: the most observed point is the Alternating Solution, and many observations are at inefficient outcomes. Again, drawing on the similarity between the top and bottom diagram, infinite repetition did not greatly improve the chances of coordinating on an efficient outcome.

Table 5 shows the distribution of outcomes over the focal point solutions. It is clear that infinite repetition makes a difference in the symmetric treatments – it results in a higher percentage of efficient Alternating Solution outcomes.

In the asymmetric case, infinite repetition does not seem to make a difference, the distribution over the focal solutions remains similar. However, the addition of a punishment action causes a shift from the Welfare Maximizing Solution to the Alternating Solution. In every asymmetric treatment, a substantial number of outcomes are not efficient.

5.3 Comparing Average Payoffs

Table 6 shows the average payoffs in the one-shot treatments and in rounds 5 to 15 of the finite and infinite repetition treatments. In the symmetric treatments, the average payoffs rise as the time horizon lengthens. In the one-shot treatment, the average is near the payoff associated with the Nash Solution, which assigns each player four. In the infinite repetition treatments, the average is near the payoff associated with the Alternating Solution, which assigns each player five. There seems to be little lost or gained from the addition of the punishment action.

The asymmetric treatments are much different than the symmetric ones, the longer horizons do not imply more efficient group payoffs. In fact, from the point of view of the column player, the longer time horizon is disastrous – especially when the punishment action is present. The average column player's payoff drops more than 20 percent when moving from the one-shot treatment to either the finite or infinite repetition treatment of G_4. From the group's perspective, this drop in the column player's payoff is not made up for by the small increase in the payoffs of the row player. The average row player only gets around 10 percent more when moving from the one-shot to either repeated treatment of G_4. The finite repetition treatment of G_2 is the only treatment where the players improve upon the payoffs of the one-shot treatment.

5.4 The Finite and Infinite Repetition Treatments: The Strategy Space

The following definitions divide the strategy sets associated with each repetition treatment into three disjoint parts:

Definition 1 (Alternating Strategy) *An individual's sequence of play is an Alternating Strategy if, for every period in the sequence, the group's play in the previous period was* $\{A, B\}$ *or* $\{B, A\}$*, then individual's play in this period is B if last period it was A and A if last period it was B.*

Definition 2 (Nash Strategy) *An individual's sequence of play is a Nash Strategy if for every period in the sequence, the individual's play corresponds to the action taken in the highest Pareto ranked, one-shot, subgame perfect equilibrium.*

Definition 3 (Other Strategy) *An individual's sequence of play is an Other Strategy if it is not an Alternating Strategy or a Nash Strategy.*

It is possible to sort every individual's complete sequence of actions into one of the three previous categories. The Alternating Strategy category includes all strategies that try to alternate – dire punishment strategies as well as completely forgiving strategies. The Nash Strategy category includes only the one strategy.[11] The Other Strategy category is a catchall and could contain many things, completely random behavior being one example.

Table 7 shows the distribution of strategies for each game's finite repetition treatment. Notice that in the symmetric games G_1 and G_2, the Alternation Strategy is picked most often. Also there is not a significant difference between the distributions, so the punishment action makes little difference.

In the asymmetric games G_2 and G_4, there is a significant difference between the distribution of strategies with and without the presence of the punishment action. The difference exists for both the row and the column players. The presence of Other Strategies on the part of the row players in G_2 shows that there were attempts at alternation – they do not just play the Nash Strategy. Most of the column players, however, play the Nash Strategy. So, the row players tend to either give up and play the Nash Strategy themselves or they punish their partners with the minimax. Most of them start playing the Nash Strategy.

The proportion of players that play an Alternating Strategy in G_4 is much higher for both types when the the punishment action is present. Note that the players never have to use this action, its presence is enough to cause the shift. A substantial number of players, both row and column, still pick an Other Strategy.

In fact, in each of the finite repetition games, a large number of Other Strategies are chosen. Possible explanations for this is that there is conflict between the players, or that they miscoordinate in the early rounds. In any case, there is uncertainty during the game about which equilibrium strategy, the Alternating Strategy or the Nash Strategy, each player is supposed to use.

Another explanation is that there are end-game effects present. With end-game effects, players who had been choosing their action according to the Alternating Strategy would change to the Nash Strategy before the last period. Unlike in G_1 and G_2, in G_3 and G_4 end-game effects would be consistent with many subgame perfect equilibria.

Table 8 reproduces each strategy distribution when the last two periods of play are ignored.[12] There is, in fact, a dramatic end-game effect in both symmetric games; 17.5 percent of the subjects switched from Alternating Strategy to Other Strategy in the last two periods of G_1, 20 percent switched in G_3. The data from the asymmetric games, on the other hand, show positively no evidence of an end-game effect. One must conclude, then, that the Other Strategies present in G_2 and G_4 are due to conflict or miscoordination.

Table 9 shows the distribution of strategies for each game's infinite repetition treatment. Notice that in the symmetric games G_1 and G_2, the Alternation Strategy is again picked most often. Also there is not a significant difference between the distributions, so the punishment action makes little difference.

The presence of the punishment action also makes little difference in the asymmetric games, although there is some shift away from the Nash Strategy for the column players. The high number of Other Strategies shows that the conflict and miscoordination present in the finite repetition treatments is still there in the infinite repetition treatments.

The strong difference between the symmetric finite and infinite repetition treatments is not surprising considering the presence of the end-game effects. What is surprising is the strong difference between the finite and infinite repetition treatments of G_2. There was no end-game effect present in the finite treatment of G_2.

6 Conclusions

After considering the evidence presented here, it is not unreasonable to predict that some groups of people, like the aforementioned Valencian farmers, will be able to enter into stable alternation schemes if they are faced with situations similar to Reciprocity Games. The farmers are in a symmetric situation, 80 percent of the farms are less than 1 hectare. The farmers are involved in an infinite repetition conflict, the farms have been there for centuries. Like most of the participants in infinite repetition treatments of G_1 and G_3, the farmers have been able to institute an efficient rotation scheme.

In these experiments, it has been shown that people faced with symmetric Reciprocity Games enact solutions which are progressively more efficient as the time horizon increases from one-shot to finite repetition to infinite repetition. End-game effects have been found in the finite repetition treatments. In symmetric situations, punishment options play very little role.

The ability of groups of people to obtain efficient outcomes if there are large asymmetries between them is much more doubtful. As has been seen, there can be a conflict or miscoordination if the turn-taking and welfare maximizing solutions are different. Although some succeed in instituting one of these two efficient focal outcomes, of those who fail, many get non-individually rational payoffs. Not a single group successfully instituted a *one to two*, or equal payoff, rotation scheme.

Unlike the symmetric games, efficiency in the asymmetric games does not tend to increase as the time horizon lengthens. In fact, due to prolonged conflict or miscoordination, average payoffs in the infinite repetition treatments are below the average payoffs in the one-shot treatments. With finite repetitions, the presence of the punishment action causes an increase in the number of alternation schemes that are successfully implemented or tried, although the number of efficient outcomes does not increase significantly and the average payoffs fall.

Certainly the results of the examination of the asymmetric games highlights problems from a policy standpoint. Common welfare criteria, like the Utilitarian criterion (maximize the sum of the payoffs), the Rawlsian criterion (maximize the minimum payoff), Pareto Optimality, or even simple rationality are not always achievable without intervention. In fact, clearly bad outcomes occur frequently.

And what type of intervention will work? If you care about the sum of the payoffs you may choose to shorten the length of the game. Shortening the length of the game will certainly benefit the group, but the disadvantaged will suffer for it. If you care about equality you may choose to endow people with the ability to punish, or tax, or fine the other participants. Among the efficient outcomes, there will be more egalitarian behavior, but the combined benefits of the group will likely fall on average.

On the other hand, the results of the symmetric games are very encouraging from a policy standpoint. Punishments, taxes or fines are not necessary. Simply increase the time horizon and efficiency rises.

Notes

1 Murninghan *et al.*, p. 17.

2 In Selton and Stoecker (1986) either a Cooperative outcome or End-Effect Play occurs if the cooperative alternative in the one-shot game is chosen consecutively for $m > 4$ periods during the supergame. Unlike Selten and Stoecker, this paper examines the sequence of play at the individual level and makes inferences about the types of strategies that each individual plays, either Alternating, or Nash (or Other).

3 For example, for G_1 repeated $T >= 3$ times,

$$[\{B, A\}_1, \{A, B\}_2, \{B, A\}_3, \ldots, \{A, B\}_{T-1}, \{B, B\}_T]$$

with the threat of playing $\{C, C\}$ for each subsequent stage if there is a defection is subgame perfect. To be more specific, in repeated versions of one-shot games that have multiple Nash equilibria, for any individually rational and feasible outcome u there exists a length T and a subgame perfect equilibrium such that if U is the average stage payoff in the equilibrium,

$$||U - u|| < \varepsilon$$

for any $\varepsilon > 0$. The result holds for two-person games and for n-person games if the dimensionality of the payoff space is equal to the number of players. For details see Benoit and Krishna (1985); p. 919; refer to Theorem 3.7.

4 The equilibrium payoffs must be such that the following equation holds:

$$\frac{1}{1-\delta}v_i \geq \bar{v}_i + \frac{\delta}{1-\delta}v_i^*$$

$$\frac{1}{1-\delta}v_i^* = \frac{1}{1-\delta}((1-\delta^t)v_{i,min} + \delta^t v_i)$$

where v_i is the average payoff of the equilibrium strategy given no defection, $\bar{v}_i$ is the maximum payoff a player can get by deviating, vi^* is the average payoff of the chosen punishment strategy, and δ is the discount rate. Equation 1 says that the total payoff for playing the equilibrium must be greater than the total payoff for deviating once and then getting the punishment payoff for the rest of the game. For details see Fudenberg and Maskin (1986); pp. 533 - 554; refer to Theorem 1. In the infinite repetition treatments, the discount rate was ten percent.

5 A copy of the directions and quiz used in the one-shot treatment of G_4 is included in the appendix.

6 There were 93 subjects total. An effort was made not to have experienced players, however 7 did participate in two sessions. Two participated in 4/20/90 and 5/17/90, one participated in 5/17/90 and 5/18/90, and four participated in 5/11/90 and 5/18/90. These people were never matched with

the same person more than once, even across sessions.

7 In G_1, half of the subjects played A at least once. In G_4, one subject was responsible for all the plays of action C.

8 χ_i^2, here and elsewhere, is the standard test statistic using Yate's continuity correction. It has a χ^2 distribution with i degrees of freedom. For a complete explanation of this test, see Everitt (1977) pp. 12 - 14.

9 See Ledyard (1992), Dawes (1980) and Cooper *et al.* (1987; 1990).

10 The Equality Solution requires a *one to two* rotation scheme, *i.e.* row plays A once for each two times that column plays A. This rotation scheme has a three move cycle. What is exhibited in the figures is a ten move average payoff. Even if a *one to two* rotation scheme was implemented, the ten move average would not give equal payoffs. However, any *one to two* rotation scheme would result in payoffs located on the Pareto Frontier and the averaging system used would locate the outcome within 0.2 payoff points of the Equality Solution. No outcomes were within these tolerances.

11 It is possible to have a sequence of plays defined as both an Alternating and a Nash Strategy. In the symmetric treatments, if both players choose action B in every round, each player's strategy will be put into both categories. Fortunately, no pair of players chooses action B in each round, so the problem does not surface.

12 Two was chosen because it is the minimum number of periods that allows both players a chance to defect from the Alternate strategy.

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Appendix A: Instructions

The following is a copy of the instructions given in the one-shot treatments of G_4.

INSTRUCTIONS FOR A DECISION-MAKING EXPERIMENT

This is an experiment in decision making. You will be paid *in cash* at the end of the experiment. The amount of money you earn will depend upon the decisions you make and on the decisions other people make. We request that you do not talk at all or otherwise attempt to communicate with the other subjects except according to the specific rules of the experiment. If you have a question, feel free to raise your hand. One of us will come over to where you are sitting and answer your question in private.

This experiment has 15 separate rounds and then it will end. During each round of the experiment you will be randomly paired with another subject. You will **never** be paired with the same subject for two rounds in a row.

Each round you will be given a token which will be worth either 4 or 2. It will always be worth the same amount. Each round you will be able to use the token in one of three ways: option A, or option B, or option C.

PAYOFFS

The amount of money you earn in a round depends upon which option you pick as well as which option your partner picks. **WHAT HAPPENS IN YOUR GROUP HAS NO EFFECT ON THE PAYOFFS TO MEMBERS OF THE OTHER GROUPS AND VICE VERSA.** In each round, you have nine possible earnings. These are shown in the following table:

EARNINGS TABLE

Your Choice	His/Her Choice	Your Earnings
A	A	3 points
A	B	3 points
A	C	1 point
B	A	Your Token Value + 3 points
B	B	Your Token Value
B	C	1 point
C	A	1 point
C	B	1 point
C	C	2 points

To summarize the table:

1 **ROWS 1 to 3:** If you choose option A you will get 3 points if your partner picks either option A or option B. If you choose option A and your partner chooses option C, you will get 1 point.

2 **ROWS 4 to 6:** If you choose option B you will get your token value +

3 points if your partner picks option A, you will get your token value if your partner picks option B, or you will get 1 point if your partner picks option C.

3 **ROWS 7 to 9:** If you choose option C you will get 1 point if your partner picks either option A or option B. If you choose option C and your partner chooses option C, you will get 2 points.

SPECIFIC INSTRUCTIONS:

At the end of the experiment you will be paid 5 cents for every point you have accumulated.

Appendix B: Quiz

The following is a copy of the quiz given in the one-shot treatments of G_4.

QUIZ

id #. ______________________________

1. If my token is worth 4 points, the other player in my group will have a token value equal to:

   i. 4 points.

   ii. 2 points.

   iii. Either 4 or 2 points.

   iv. None of the above.

2. If someone was in my group on round 5 of an experiment, it will be **certain, very likely, impossible** that he or she will be in my group on round 6.

3. If my token value is 2 and I choose option B and my partner chooses option A, how many points will I earn?

4. If I choose option A and my partner chooses option C, how many points will I earn?

5. If at the end of a round I have 2 points, how much am I paid for that round?

Table 1: The payoff tables for the four different payoff treatments: symmetric (G_1), asymmetric (G_2), symmetric with punishment (G_3), and asymmetric with punishment (G_4).

The Payoff Tables

$$G_1 = \begin{bmatrix} (3,3) & (3,7) \\ (7,3) & (4,4) \end{bmatrix} \qquad G_2 = \begin{bmatrix} (3,3) & (3,7) \\ (5,3) & (2,4) \end{bmatrix}$$

$$G_3 = \begin{bmatrix} (3,3) & (3,7) & (1,1) \\ (7,3) & (4,4) & (1,1) \\ (1,1) & (1,1) & (2,2) \end{bmatrix} \qquad G_4 = \begin{bmatrix} (3,3) & (3,7) & (1,1) \\ (5,3) & (2,4) & (1,1) \\ (1,1) & (1,1) & (2,2) \end{bmatrix}$$

Table 2: The date of each experiment along with the number of subjects, the number of observations, the number of periods, the exchange rate, and, if there were different treatments in one session, the order of treatments. O, F, and I stand for one-shot, finite repetition, and infinite repetition, respectively.

Experiments							
game	trtmnt	date	subj.	obs.	length	$\frac{penny}{point}$	order
G_1	O	2/4/91	10	75	1	5	1
	F	1/31/91	10	20	15	4	-
	I	5/18/90	12	24	{61, 37, 17, 29}	4	-
G_3	O	2/4/91	10	75	1	5	2
	F	1/14/91	10	20	15	4	-
	I	5/17/90	12	24	{20, 41, 26, 25}	4	-
G_2	O	2/4/91	10	75	1	5	3
	F	2/1/91	10	20	15	4	-
	I	5/11/90	12	24	{28, 19, 16, 20}	4	-
G_4	O	2/4/91	10	75	1	5	4
	F	2/1/91	14	28	15	4	-
	I	4/20/90	12	24	{16, 29, 21, 24}	4	-

Table 3: The distribution of outcomes in the one-shot treatments. The entries in each table represent the number of times each outcome was observed in that treatment. The outcomes that satisfy Hypothesis 4, the Nash Solution, have been underlined. Notice that there are no entries below the diagonal in the symmetric games G_1 and G_3; the symmetric outcomes are classified together. In the asymmetric games, all outcomes are classified separately.

The Distribution of Outcomes
One-Shot Treatments

$$G_1 = \begin{bmatrix} 1 & 12 \\ & \underline{62} \end{bmatrix} \qquad G_2 = \begin{bmatrix} 6 & \underline{53} \\ 0 & 16 \end{bmatrix}$$

$$G_3 = \begin{bmatrix} 1 & 9 & 0 \\ & \underline{63} & 2 \\ & & 0 \end{bmatrix} \qquad G_4 = \begin{bmatrix} 0 & \underline{58} & 0 \\ 0 & 13 & 0 \\ 0 & 4 & 0 \end{bmatrix}$$

Table 4: For each **One-Shot** treatment, the breakdown of individual strategy choices between successes and others for the Nash hypothesis is shown. Also shown is the frequency of success and the upper bound of its 95 percent confidence interval. Finally, the distribution of observations under the hypothesis when there is no punishment strategy is compared to the distribution of observations when there is a punishment strategy; a χ^2 statistic is reported.

One-Shot Contingency Table

Hyp. 1 Nash Solution

			Row		Column	
	G_1	G_3	G_2	G_4	G_2	G_4
successes	136	137	59	58	69	75
other	14	13	16	17	6	0
freq.	0.9066	0.9133	0.7866	0.7733	0.9200	1.000
high	0.9460	0.9514†	0.8657	0.8541	0.9723†	1.000†
χ_1^2	0.0000		0.0000		4.3403*	

† - significant at $\alpha = 0.05$

* - significant by adopted criteria

high is the upper bound of the 95% c. interval around freq.

Table 5: For each finite (F) and infinite (I) repetition treatment, the distribution of outcomes over each focal point solution is shown.

Distribution of Outcomes Over
Focal Point Solution Concepts:

	G_1		G_3		G_2		G_4	
	F	I	F	I	F	I	F	I
Hyp. 2 Alternating	3	21	5	19	1	2	8	7
Hyp. 3 Welfare	*	*	*	*	7	8	3	5
Hyp. 4 Equality	*	*	*	*	0	0	0	0
Hyp. 1 Nash	5	0	1	0	**	**	**	**
Other	12	3	14	5	12	14	17	12

* - Hyp. is the same as Alternating
** - Hyp. is the same as Welfare

Table 6: The average payoffs in the one-shot treatment and in rounds 5 – 15 of the finite and infinite repetition treatments.

Average Payoffs						
	One-Shot		Finite		Infinite	
	G_1	G_3	G_1	G_3	G_1	G_3
player	4.147	4.027	4.535	4.585	4.908	4.850
group	8.294	8.054	9.070	9.170	9.816	9.700
	One-Shot		Finite		Infinite	
	G_2	G_4	G_2	G_4	G_2	G_4
row	2.785	2.725	2.955	3.021	2.896	3.029
col	6.040	6.160	6.175	4.757	5.638	4.821
group	8.825	8.885	9.130	7.778	8.534	7.850

Table 7: In each **Finite Repetition** treatment, the distribution of strategy choices is shown. The distribution of strategies when there is no punishment strategy is compared to the distribution of strategies when there is a punishment strategy; a χ^2 statistic is reported.

Finite Repetition Contingency Table

			ROW		COL	
	G_1	G_3	G_2	G_4	G_2	G_4
Alt.	21	23	0	11	4	10
Nash	6	4	2	2	15	4
Other	13	13	18	15	1	14
χ^2_2	0.4909		10.2234*		19.4124*	

* - significant at $\alpha = 0.05$

Table 8: The different strategy distributions over the focal solutions obtained when all periods are taken into account and also when all but the last two periods are taken into account are displayed for each finite repetition treatment.

Finite Repetition,
Strategy Distributions,
All Periods and All But the Last 2 Periods:

	G_1		G_3	
	all periods	all periods - 2	all periods	all periods - 2
Alt.	21	28	23	30
Nash	6	6	4	5
Other	13	6	13	5

Row Players

	G_2		G_4	
	all periods	all periods - 2	all periods	all periods - 2
Alt.	0	0	11	11
Nash	2	2	2	2
Other	18	18	15	15

Column Players

	G_2		G_4	
	all periods	all periods - 2	all periods	all periods - 2
Alt.	4	4	10	10
Nash	15	15	4	5
Other	1	1	14	13

Table 9: In each **Infinite Repetition** treatment, the distribution of strategy choices is shown. The distribution of strategies when there is no punishment strategy is compared to the distribution of strategies when there is a punishment strategy; a χ^2 statistic is reported.

Infinite Repetition Contingency Table						
			ROW		COL	
	G_1	G_3	G_2	G_4	G_2	G_4
Alt.	42	40	6	6	2	7
Nash	2	1	6	4	12	6
Other	4	7	12	14	10	11
χ^2_2	1.2003		0.5538		4.8254	

* - significant at $\alpha = 0.05$

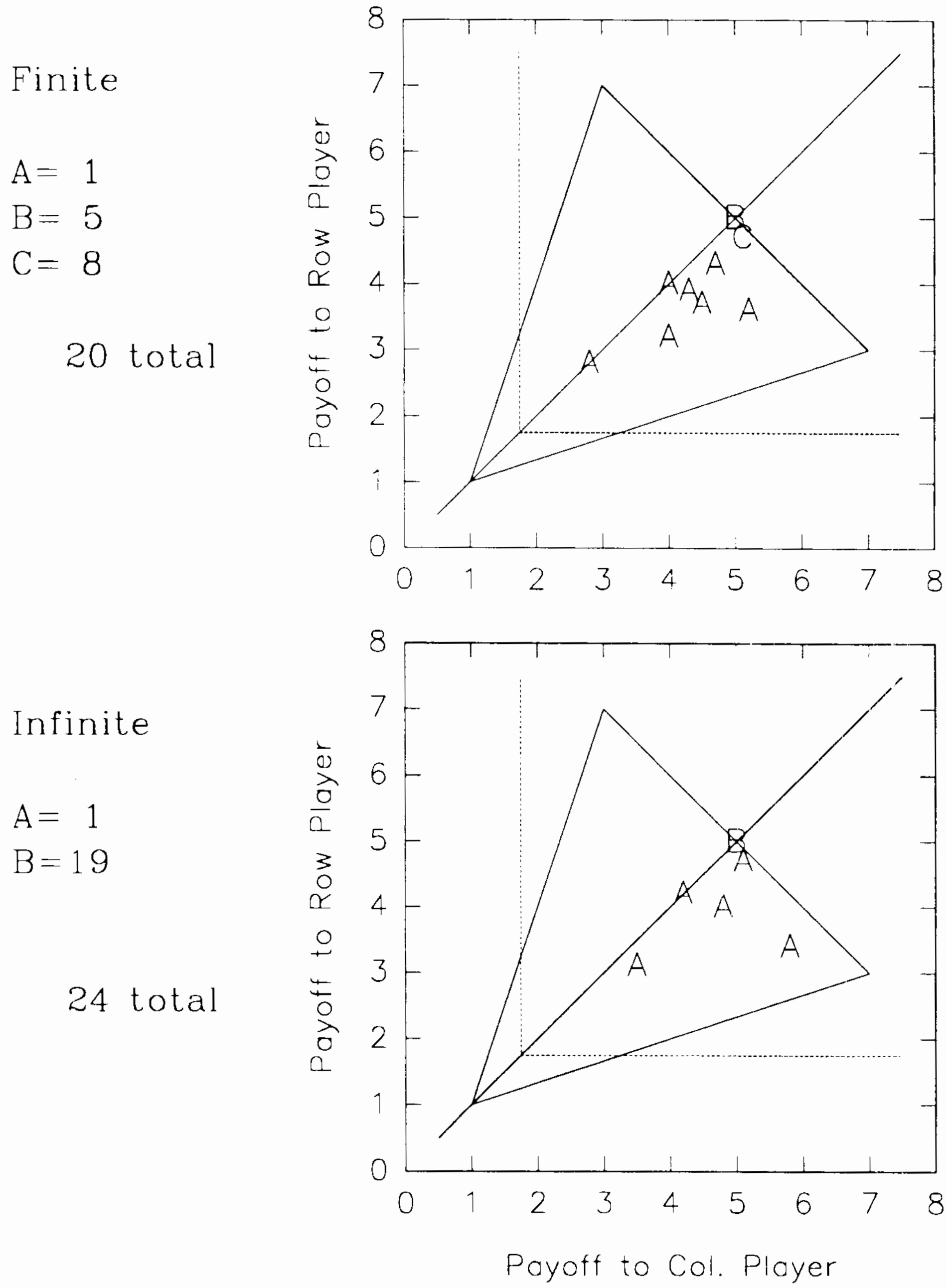

Figure 2: The outcomes to the repeated treatments of G_3. The top diagram shows the finite repetition treatment, the bottom diagram shows the infinite repetition treatment. Each letter represents one or more outcomes. The dots show the payoffs to the stage game. Every outcome on or to the northeast of the dotted line dominates each players minimax payoff. The 45° line represents equal payoffs.

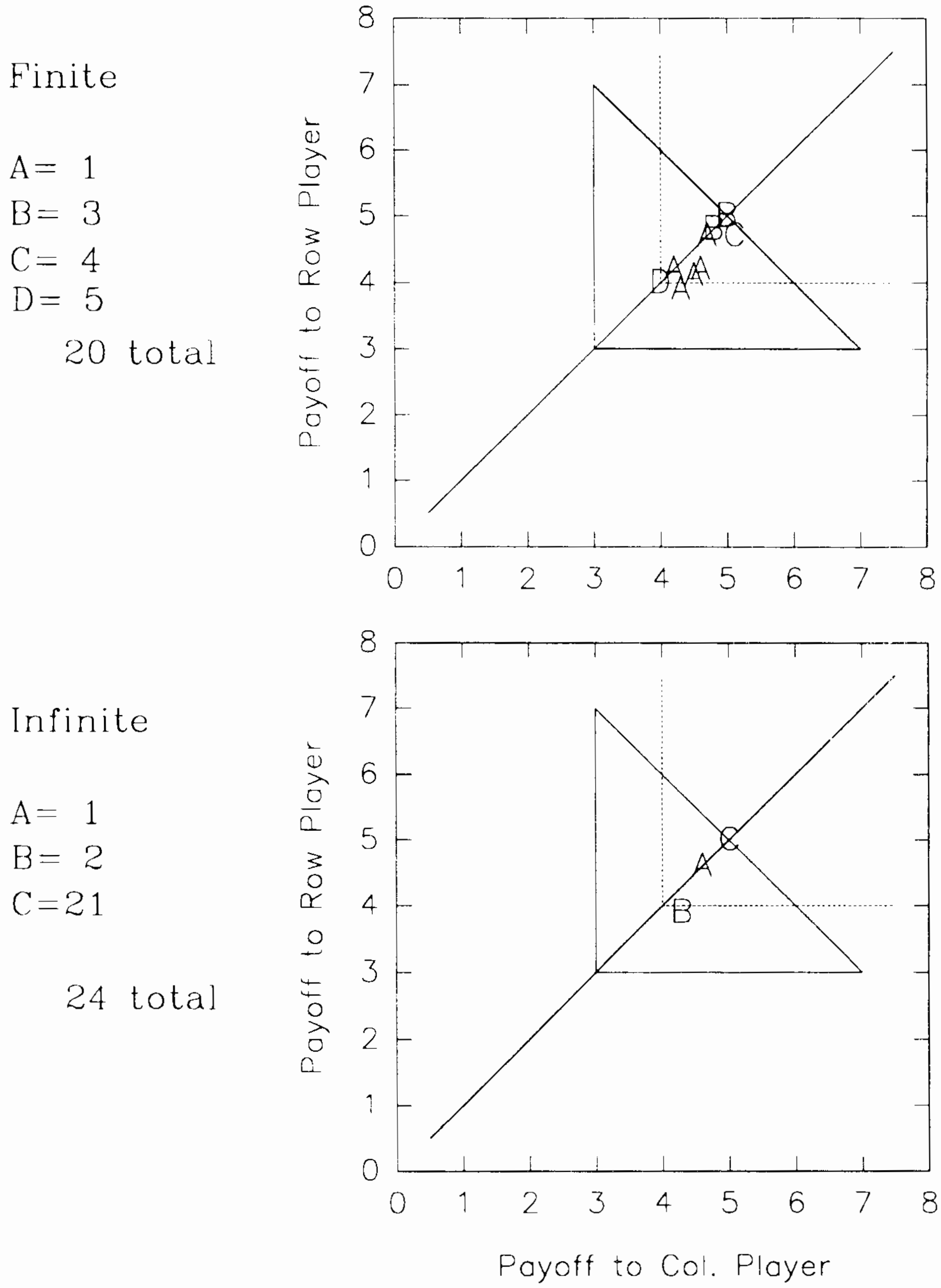

Figure 1: The outcomes to the repeated treatments of G_1. The top diagram shows the finite repetition treatment, the bottom diagram shows the infinite repetition treatment. Each letter represents one or more outcomes. The dots show the payoffs to the stage game. Every outcome on or to the northeast of the dotted line dominates each players minimax payoff. The 45° line represents equal payoffs.

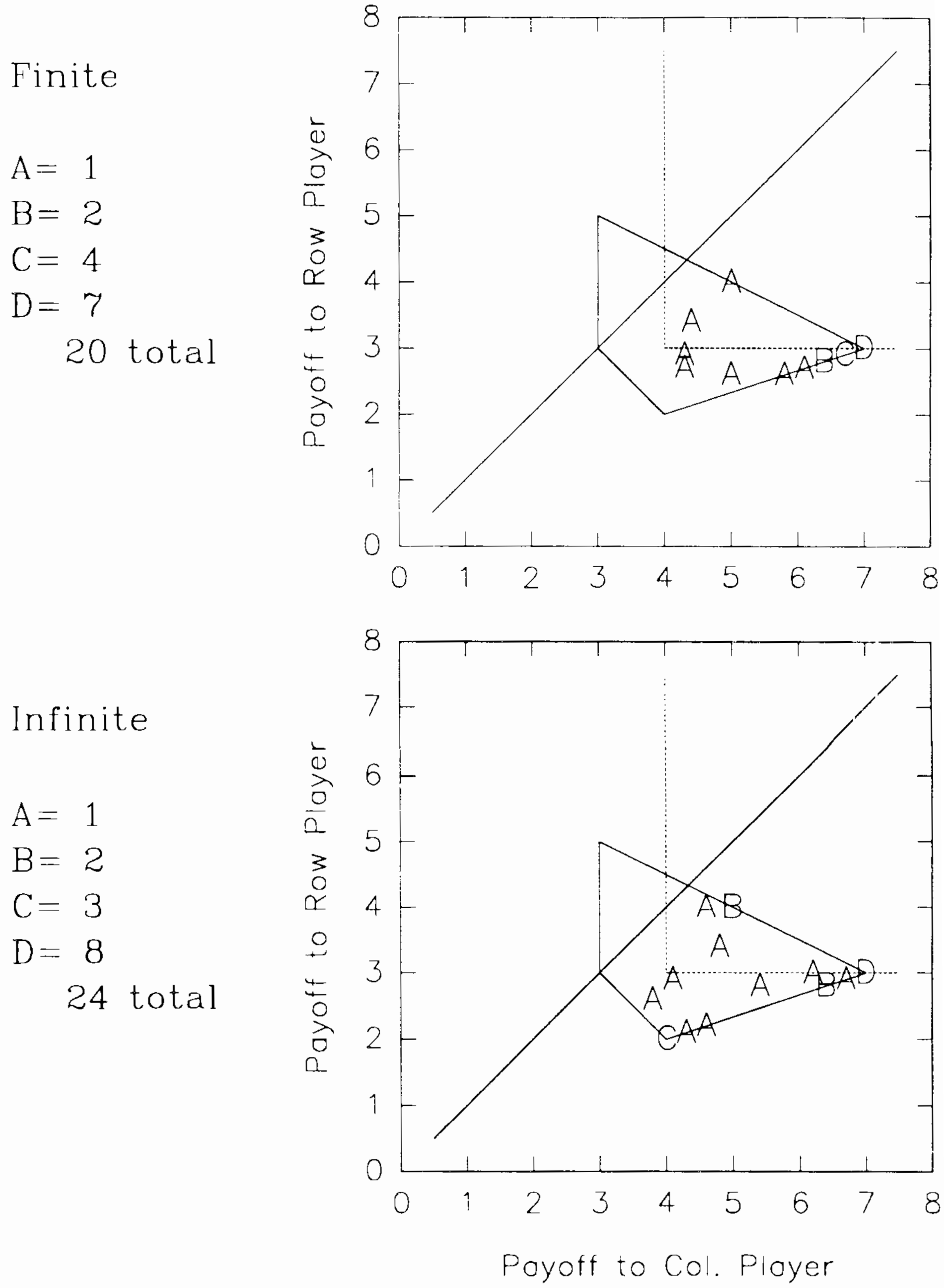

Figure 3: The outcomes to the repeated treatments of G_2. The top diagram shows the finite repetition treatment, the bottom diagram shows the infinite repetition treatment. Each letter represents one or more outcomes. The dots show the payoffs to the stage game. Every outcome on or to the northeast of the dotted line dominates each players minimax payoff. The 45° line represents equal payoffs.

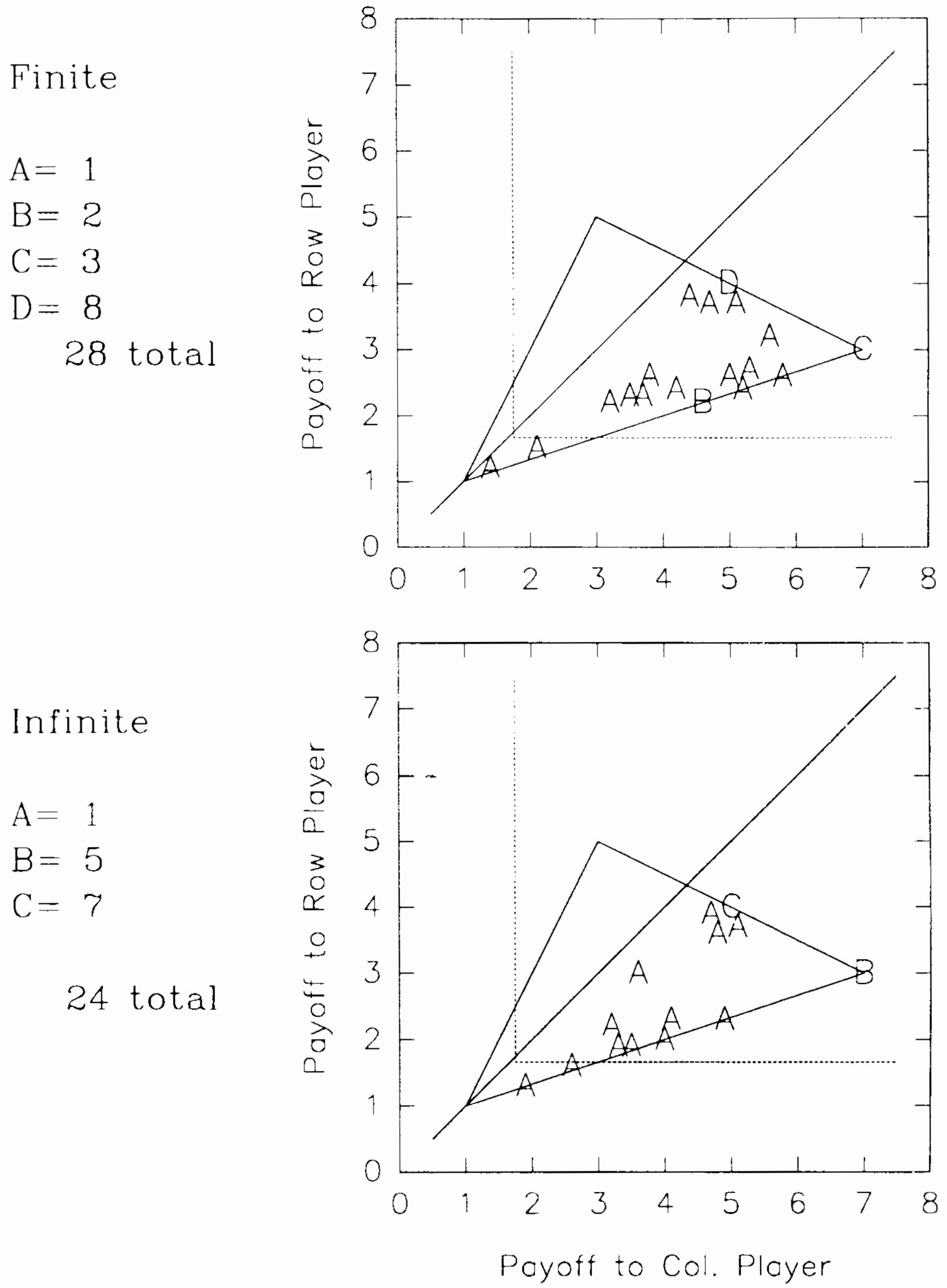

Figure 4: The outcomes to the repeated treatments of G_4. The top diagram shows the finite repetition treatment, the bottom diagram shows the infinite repetition treatment. Each letter represents one or more outcomes. The dots show the payoffs to the stage game. Every outcome on or to the northeast of the dotted line dominates each players minimax payoff. The 45° line represents equal payoffs.

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