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The Impact of the Termination Rule in Cooperation Experiments

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Abstract

This paper analyzes the impact of three termination rules for repeated-game experiments. We compare treatments with a known finite end, an unknown end and two variants with a random termination rule. The termination rules do not significantly effect cooperation rates.

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1 Introduction

The game theoretic predictions for repeated games crucially depend on whether a game is finitely or infinitely repeated. In particular, cooperation can usually be sustained only if the game has an infinitely repeated horizon. While many experiments have shown that stable cooperation can nevertheless occur with finitely many repetitions, a central question is how to address the theoretical dichotomy between finitely and infinitely repeated games in the design of cooperation experiments. This paper analyzes three termination rules commonly used in experiments and compares their impact on cooperation rates.

The first termination rule is simply to repeat the stage game of the experiment a finite number of times and to inform participants about the number of repetitions in the instructions. This method is transparent as subjects have common knowledge about the length of the experiment just as they have about all other aspects of the game. However, game-theoretic predictions from infinitely repeated games do not apply with this termination rule. A further disadvantage is that end-game effects may occur.

The second method is to refrain from informing participants about the actual length of the experiment. This termination rule may help avoiding end-game effects. The main disadvantage of this termination rule is that it is difficult to control for subjects' beliefs regarding the number of periods. Holt (1985) dismisses this method since he prefers to fully inform subjects about the things to come in an experiment.

The third termination rule is to impose a random stopping rule to terminate the experiment. The termination mechanism (e.g., the throw of a die) and the termination probability are common knowledge. This method attempts to make repeated game arguments relevant. The termination probability implies a discount factor which allows predictions based on the infinitely repeated game to be made. However, Selten, Mitzkewitz and Uhlich (1997) argue that infinitely repeated games cannot be approximated in the laboratory. Subjects know for sure that the experiment is of some finite duration and that the experimenter simply cannot continue "forever". Therefore, backward induction arguments and the logic of a finitely repeated game apply. On the positive side, a random end might also help avoiding end-game effects.

This paper compares the three termination rules using a prisoner's dilemma as the stage game. To our knowledge, we are the first to compare the termination rules in a unified frame though a few papers have analyzed some of the issues we address (see the conclusion).

2 Theory and Experimental Design

The stage game underlying our cooperation experiments is the simple prisoner's dilemma in Table 1. This is a standard two-player prisoner's dilemma with $S_i = \{defect,\ cooperate\},\ i = 1, 2,$ as strategy sets (in the experiment, neutral labelling for the strategies was used). The static Nash equilibrium of the game in Table 1 is $\{defect,\ defect\}$.

	defect	*cooperate*
defect	350, 350	1000, 50
cooperate	50, 1000	800, 800

Table 1: The stage game

Our four treatments reflect the above discussion of termination rules. In treatment Known, the end of the experiment was given to the participants simply by saying that the experiment would last for 22 periods. In treatment Unknown, the length of the experiment (28 periods) was not mentioned to the participants and the instructions merely said that the experiment would last at least 22 periods. In RandomLow, the instructions said that the experiment would last at least 22 periods and then the experiment would continue with a probability of 1/6. In treatment RandomHigh, there were at least 22 periods and then the experiment would continue with a probability of 5/6.[1]

The subgame perfect Nash equilibrium predictions for the treatments are as follows. The static Nash equilibrium, {*defect, defect*}, is also the unique prediction of the finitely repeated game in treatment Known. In Unknown, we cannot control for subjects' prior on the termination of the experiment. The static Nash equilibrium may apply but possibly repeated game arguments have bite as well. If we ignore Selten, Mitzkewitz and Uhlich's (1997) argument, we can make predictions based on infinitely repeated games for the treatments with a random end. From Stahl (1991), {*cooperate, cooperate*} is a subgame perfect Nash equilibrium outcome of the infinitely repeated game if and only if the discount factor is larger than $4/13 \approx 0.31$. Cooperation may thus only emerge in RandomHigh. In RandomLow, the unique subgame perfect Nash equilibrium is {*defect, defect*}.

The experiments were conducted in the experimental laboratory at Royal Holloway, University of London. Ten pairs of subjects participated in each treatment, so, in total, 80 students participated. Average payments were £7.20. Sessions lasted about 45 minutes including time for reading the instructions.

3 Experimental Results

We start by looking at cooperation rates in the four treatments. In order to take possible dependence of observations into account, we report the number of *cooperate* choices per pair; see Table 2. This is also the unit of observation of the statistical tests below. We refer to the first 22 periods, so the maximum is 44 *cooperate* choices.[2]

[1]We control for the minimum number of periods (rather than the expected number of periods) across treatments because an analysis of the impact of termination rules requires that subjects play the same number of periods before the termination rule is triggered.

[2]In three out of the four sessions with a random end, play stopped after period 22. The remaining session (RandomHigh) had 26 periods.

Treatment	*cooperate* choices per pair										rate
KNOWN	44	43	42	22	11	9	6	3	3	1	41.8%
UNKNOWN	43	43	34	24	21	16	13	11	11	9	51.1%
RANDOMLOW	43	43	43	37	30	19	16	13	12	8	60.0%
RANDOMHIGH	44	44	43	33	32	31	17	13	7	6	61.3%

Table 2: Results by (ordered) pairs

Comparing treatments across the ten ranked pairs, there are three to six pairs in each treatment who have a cooperation rate of 66% or more, and there are also three to six pairs in each treatment who cooperate at a rate of less than 33%. It seems remarkable that there are virtually no differences between RANDOMLOW and RANDOMHIGH. In the KNOWN treatment, there are three pairs who virtually do not cooperate at all. Looking at the sum of *cooperate* choices across all ten pairs, cooperation rates differ between treatments and the treatments with random end seem to achieve better cooperations rates. However, these differences are not significant.[3] We conclude

Result 1. *The termination rule does not have a significant effect on cooperation rates.*

Next, we turn to end-game effects. Comparing the average cooperation rate in periods 1 to $(t-1)$ to the rate in period t with a related-sample Wilcoxon test and separately for all treatments, we find significantly lower prices in periods 20, 21 and 22 in treatment KNOWN (Wilcoxon related-sample test, $p < 0.05$). To check for an end-game effect is important because to consider the sum of *cooperate* choices across all periods is biased when an end-game effect occurs in some treatments but not in others. Accordingly, excluding periods 20 to 22 implies slightly more even cooperation rates of 44.2%, 48.7%, 61.8% and 62.4%

[3]The p-values of the according Mann-Whitney U tests range between 0.19 (KNOWN vs RANDOMLOW) and 0.85 (RANDOMLOW vs RANDOMHIGH).

in Known, Unknown, RandomLow and RandomHigh respectively.

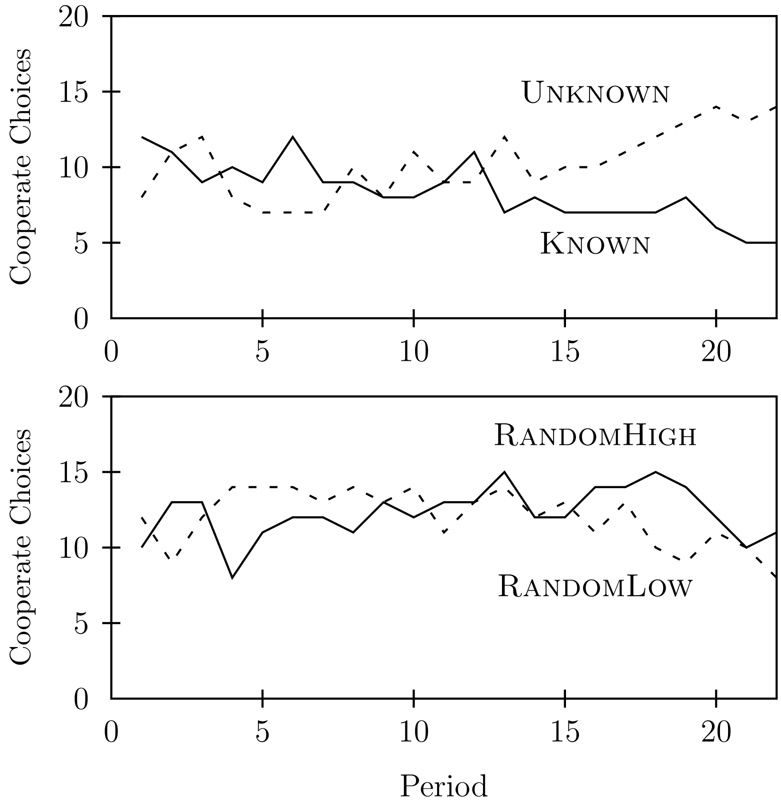

Figure 1: Cooperation over time

Figure 1 shows the time path of *cooperate* choices in the experiments. The time paths of the four treatments often overlap, so we show the data in two separate figures. All treatments start at a level of around ten *cooperate* choices. Known and Unknown stay at this level; after period 15 the number of *cooperate* choices stays constant in Known but it increases in Unknown. Both RandomLow and RandomHigh average at a higher level than the other treatments between period five and period 15 (though this is not significant). Then cooperation declines towards period 22 (as mentioned, again not significant).

Result 2. *A known finite horizon leads to a significant end-game effect in the last three periods. The other termination rules do not cause a comparable drop in cooperation.*

Finally, we summarize the results regarding RandomLow and RandomHigh. We do not observe different cooperation rates though cooperation is predicted to occur only in RandomHigh. Moreover, one might expect that the continuation probability affects behavior towards period 22, but, again, we do not observe such any impact. We therefore conclude:

Result 3. *In treatments with a random termination rule, the termination probability does not significantly affect behavior.*

4 Conclusion

In this paper, we analyze three termination rules for repeated game experiments. In our data, we find that the termination rule does not have a significant effect on cooperation rates though treatments with random end seem to achieve better cooperations rates. When a random termination rule is implemented, the termination probability does not significantly affect behavior as results are virtually identical in these treatments—in clear contrast to the prediction based on the theory of infinitely repeated game. A known finite horizon leads to a significant end-game effect while the other termination rules do not.

The results suggest that the choice of the termination rule for cooperation experiments should be more determined by practical matters than by efforts to match the requirements of infinitely repeated games. Practicality and transparency presumably favor the commonly known finite horizon. The end-game effects which may occur are often not troublesome; most researchers using this termination rule simply test for them, and, if significant end-game effects occur, they discard these periods from the analysis.

Our results are consistent with Engle-Warnick and Slonim (2003). They ran trust game sessions with a known horizon of five periods and sessions with a random stopping rule with a continuation probability of 0.8. With inexperienced players, they find that the level of trust does not vary in the two treatments even though the *repeated* game was played twenty times. Roth and Murnighan (1978) found that a higher continuation probability does lead to more cooperation in the prisoner's dilemma. However, in the modified setup analyzed in Murnighan and Roth (1983), this could not be confirmed.[4]

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[4]The experimental design in both papers deviates from standard prisoner's dilemma experiments (like ours). See the discussion in Roth (1995).