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Constructing strategies in the indefinitely repeated prisoner's dilemma game[☆]

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ABSTRACT

We propose a new approach for running lab experiments on indefinitely repeated games with high continuation probability. This approach has two main advantages. First, it allows us to run multiple long repeated games per session. Second, it allows us to incorporate the strategy method with minimal restrictions on the set of pure strategies that can be implemented. This gives us insight into what happens in long repeated games and into the types of strategies that subjects construct. We report results obtained from the indefinitely repeated prisoner's dilemma with a continuation probability of $\delta = .95$. We find that during such long repeated prisoner's dilemma games, cooperation drops from the first period of a supergame to the last period of a supergame. When analyzing strategies, we find that subjects rely on strategies similar to those found in the literature on shorter repeated games—specifically Tit-For-Tat, Grim Trigger, and Always Defect. However, we also identify features of strategies that depend on more than just the previous period that are responsible for the drop in cooperation within supergames, but that may be overlooked when using the common strategy frequency estimation approach.

1. Introduction

The repeated prisoner's dilemma has been used as a stylized setting to model a wide variety of situations across many disciplines (e.g., Cournot competition, advertising, public good provision, arms races, evolution of organisms, etc.). Because of this breadth, the repeated prisoner's dilemma is one of the most commonly studied games in all of game theory, as researchers try to gain a better understanding of how and when cooperation emerges. In this paper, we run experiments on the indefinitely repeated prisoner's dilemma game using an innovative experimental interface that allows subjects to directly construct their strategies in an intuitive manner and to participate in "long" indefinitely repeated prisoner's dilemmas (continuation probability $\delta = 0.95$). We use this environment to gain a unique perspective on the strategies that subjects construct in the indefinitely repeated prisoner's dilemma and on the factors that make subjects cooperate.

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Our experimental interface implements the strategy method (Selten, 1967) and allows subjects to construct strategies in an intuitive manner. A player constructs a strategy by developing a set of rules. Each rule is an "if this, then that" statement, which contains an input and an output. The input to a rule is a list of $n \geq 0$ action profiles, while the output of a rule is the action that will be played after the input has occurred. Our design ensures that in any period of a repeated game, the set of rules for a player prescribes a unique action to be played in that period. In contrast to standard indefinitely repeated games experiments, in which players directly choose an action in each period, our approach allows players' actions to be chosen automatically using the rules in the rule set.

Following Dal Bó and Fréchette (2017), the experiment is divided into three stages: the direct-response stage, the non-binding stage, and the locked-response stage. In the direct-response stage, players play the repeated game directly. In this way, players are able to learn the nature of the game and the trade-offs involved in such indefinitely repeated interactions. In the non-binding stage, players create strategies which select actions for them, though players are not required to play the action prescribed by the strategy. This stage allows players to gain experience with how constructed strategies make choices and allows them to construct a strategy that matches their desired behavior. In the locked-response stage, players cannot make any changes to their strategies, and their strategies play for them automatically. This stage provides incentives for strategy construction.

This experimental design offers several benefits over standard indefinitely repeated games experiments. First, we can directly view players' strategies. A growing body of literature aims to better understand the strategies played in repeated prisoner's dilemma games. The literature takes three approaches to identifying the strategies that subjects play. In the first approach, actions directly chosen by players are then used to make inferences about these players' actual strategies (Bigoni et al., 2015; Camera et al., 2012; Dal Bó and Fréchette, 2011; Fudenberg et al., 2012; Stahl, 2013). This inference requires the researcher to specify a predefined set of strategies to be used in the estimation. While commonly studied strategies work well in shorter repeated games, it is not clear if this same set of strategies is appropriate for longer repeated games. In the second approach, players select from a set of strategies (Cason and Mui, 2017; Dal Bó and Fréchette, 2017). This approach also requires researchers to specify a set of strategies to begin with. Although the strategies are now directly observable, subjects' behavior may be influenced by the strategies presented in the set. In the third approach, which we take, players construct strategies from scratch (Bruttel and Kamecke, 2012; Dal Bó and Fréchette, 2017; Embrey et al., 2016; Romero and Rosokha, 2016). An advantage of our interface is that there are minimal restrictions on the types and lengths of pure strategies.[1] We then can determine the extent to which the typically assumed sets of strategies are appropriate for long repeated prisoner's dilemma games and provide a foundation for using a particular set of strategies.

In addition to being able to observe subjects' strategies, our experimental interface allows us to run long indefinitely repeated games. Indefinitely repeated games are implemented in the lab by imposing a termination probability at the end of each period (Roth and Murnighan, 1978). One difficulty with this standard approach is that a single repeated game can last a very long time. Therefore, indefinitely repeated games in the laboratory have typically focused on situations with relatively low continuation probabilities. Since subjects are constructing complete strategies with our interface, choices can be semi-automated (i.e., actions played by the strategy are confirmed by the subject) or fully automated (i.e., actions are played by the strategy automatically) for a large part of the experiment. This feature is useful for running long repeated games experiments in the lab. Long repeated games may reveal important aspects of behavior that are not evident in shorter repeated games. Furthermore, long repeated games are important for a broad class of macroeconomics experiments in which the underlying models rely on sufficiently high discount factors (Duffy, 2008).

Our design allows us to test whether our interface impacts subjects' behavior. In our experiment, subjects' ability to construct strategies did not significantly impact levels of cooperation, and these levels were similar to those found in previous studies that used similar experimental parameters. These findings suggest that our experimental interface does not affect subjects' behavior. Using this interface, we ran indefinitely repeated prisoner's dilemma experiments with continuation probability $\delta = 0.95$ and find three main results. First, in long repeated games, levels of cooperation decrease from the beginning of the supergame to the end of the supergame (*Result 1*). Second, by directly viewing strategies that subjects created using our interface, we find strong evidence that subjects construct strategies longer than memory-1 (*Result 2*). Finally, using a clustering algorithm that allows endogenously determining groups of similar strategies, we find that subjects use strategies that behave similarly to memory-1 strategies such as Tit-for-Tat, Grim Trigger, and Always Defect (*Result 3*).

Though many of the subjects played strategies that behave similarly to memory-1 strategies, a significant proportion of the strategies had a common feature that differentiated them from memory-1 strategies. This common feature, which we refer to as a *CsToD* rule, causes a strategy to defect after a sequence of multiple periods of mutual cooperation. These *CsToD* rules provide an explanation for *Result 1* and the seemingly contradictory *Result 2* and *Result 3*. Specifically, even though subjects may be playing according to a memory-1 strategy after most histories, they may have more complex components to their strategies, such as the *CsToD* rules. These complex components are played rarely, but could cause cooperation to break down from the beginning to the end of the supergame. Using simulations, we show that the *CsToD* rules impact cooperation rates but may not affect strategy estimates when standard maximum likelihood procedures are used.

[1] A shortcoming of this interface is that it doesn't allow subjects to play mixed strategies, which may play a role in the indefinitely repeated prisoner's dilemma (e.g., Breitmoser, 2015).