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# Testing static game theory with dynamic experiments: A case study of public goods

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ABSTRACT

Game theory provides predictions of behavior in many one-shot games. On the other hand, most experimenters usually play repeated games with subjects, to provide experience. To avoid subjects rationally employing strategies that are appropriate for the repeated game, experimenters typically employ a "random strangers" design in which subjects are randomly paired with others in the session. There is some chance that subjects will meet in multiple rounds, but it is claimed that this chance is so small that subjects will behave as if they are in a one-shot environment. We present evidence from public goods experiments that this claim is not always true.



Game theory provides predictions of behavior in many one-shot games. On the other hand, when testing one-shot games many experimenters conduct dynamic sequences of multiple games with subjects, to provide experience and to collect a larger set of observations. We consider the difficulty of drawing inferences about static game theory using repeated game experiments. Theoretically, the restrictions under which the predictions of a repeated game are identical to its one-shot version are very strong, involving common knowledge of the rationality of the other player as well as the absence of psychological valuations affecting the subjective payoffs. Behaviorally, both of these assumptions are likely violated in many experimental situations designed to test the theory.

To avoid subjects rationally employing strategies that are appropriate for the repeated game, and inappropriate for the one-shot game, experimenters often employ techniques that minimize or eliminate the probability that subjects meet more than once. In a "Random Strangers" design subjects are randomly paired with others in the session. There is some chance that subjects will meet multiple times, but it is believed that this chance is so small that subjects will behave as if they are in a one-shot environment. In fact, this belief is so strong that it has been referred to as a "repeated single-shot" design (Andreoni and Croson, 2008). In a "Perfect Strangers" design a matching algorithm is used that guarantees that subjects meet only once. The polar opposite is a "Partners" design where the same subjects are pitted against each other for each

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round in a repeated game. We examine whether subjects perceive a Random Strangers experiment the same way that they perceive a Perfect Strangers experiment, such that the former can be used to reliably implement static games in the laboratory.

Comparisons of Partners and Random Strangers designs have been common since Andreoni (1988) reported the counter-intuitive result that the latter generates a greater amount of cooperation than the former. Most of the replications and variations of this experiment have found no significant difference in behavior, and a few even report the opposite, more intuitive, pattern. All of these studies assume that the Random Strangers design is a good proxy to a Perfect Strangers design. Nevertheless, to date there has been no systematic test of Random Strangers versus Perfect Strangers, which is surprising given the popularity of the former. We provide evidence from public goods experiments that shows that *the assumption that Random Strangers is the same as Perfect Strangers should be treated with considerable caution*. We find that the fraction of subjects that play the game strictly by the non-cooperative Nash Equilibrium prediction is significantly higher in Perfect Strangers. The difference is 13 to 30 percentage points depending on the group size.

The Random Strangers design is by far the most popular operational counterpart of a one-shot environment in experiments. $N$ subjects are recruited into a session in which subjects are paired into groups of $K < N$ in each round. We assume without loss of generality that $N$ is an integer multiple of $K$. In the Random Strangers design the $K$ subjects in each group are picked at random from the $N$ subjects. This random selection is repeated in each period, and there is some chance, varying in $N$ and $K$, that any one subject will see the same partner in a later period providing that the subjects are not in the last round. This chance gets small very quickly as $N$ increases in relation to $K$, and on the basis of this arithmetic it is usually assumed to be an adequate procedure that ensures that subjects behave as if the chance is actually zero. Occasionally, subjects are told that these chances are very small.

The Perfect Strangers design, on the other hand, picks pairings in a way that ensures that no subject will *ever* be paired with the same person in later rounds. The only problem with the Perfect Strangers design is that it is "subject hungry." For $K > 2$, and $N$ around 20 or so, it becomes difficult to run sessions with more than a few rounds. But the Perfect Strangers design is the one that literally matches the one-shot notion that underlies the theories being tested in the lab.

Experimenters know all of this, and yet it is surprising to find virtually no studies that systematically compare behavior in Perfect Strangers and Random Strangers settings. The applications in which the Random Strangers has been employed are important ones, involving public goods and auctions. The implications of the ability of the Random Strangers to implement a controlled one-shot environment may therefore be quite significant. If the design does not sufficiently implement the required one-shot environment, inferences drawn based on experimental tests may be inappropriate.

We test the assumption that Random Strangers implement a one-shot environment, in the sense of Perfect Strangers, using the classic public goods voluntary contribution game. We find that *the assumption that subjects treat Random Strangers designs as if they were one-shot experiments is false.* Our subjects behave in a systematically different manner in the Perfect Strangers design. In fact, we can show that the Perfect Strangers design is associated with more subjects adopting a strict free riding behavior consistent with the one-shot theory, rather than with subjects simply providing smaller contributions conditional on making some contribution. The quantitative magnitude of this effect does depend on the size of the cohort used, and is smaller when we use cohort sizes closer to the received literature. Thus the use of the Perfect Strangers design seems to *encourage a qualitative change in the way subjects view the game*, with more of them thinking the game through in the strategic manner assumed by game theory. We also re-analyze data from two of the previous experiments that have examined Partners and Random Strangers, and show that their results are consistent with these conclusions.

## 1. Partners, Random Strangers, and Perfect Strangers

### *1.1. Theoretical issues*

Why do we worry about Strangers designs at all, let alone whether they are Random Strangers or Perfect Strangers? If the game has a finite and known number of repetitions, if the stage game in any single round has only one Nash Equilibrium (NE), and if it is common knowledge that all players can backward induct for the horizon of the game,[1] then the NE of the repeated game for rational players is just a "degenerate" succession of NE of the stage games and reputation plays no role. Nevertheless, if one relaxes any of these three conditions, then there may be many NE of the repeated game that differ from degenerate, successive plays of the NE of the stage game.[2] Additionally, even in finitely repeated games with unique equilibria reputation effects can be generated by relaxing the common knowledge assumption of rationality, as shown by Kreps et al. (1982).

The public good games considered in the experimental literature are virtually identical in form to the prisoners' dilemma games considered in repeated game theory. In the standard form of both games there is invariably a single NE of the stage

[1] Chess reminds us that backward induction is not an "all or nothing" thing behaviorally.

[2] For textbook expositions, see Fudenberg and Tirole (1991, ch. 4,5) or Binmore (1992, ch. 8). Obviously repeated games are interesting in their own right. Our concern is with the difficulty of drawing inferences about static game theory using repeated game experiments. The task of drawing inferences about repeated game strategy choices from observed actions in repeated game experiments is actually a delicate one: see Engle-Warnick and Slonim (2006) for a discussion of the issues and a proposed methodology.