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Group size and cooperation among strangers☆

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ABSTRACT

We study how group size affects cooperation in an infinitely repeated n-player Prisoner's Dilemma (PD) game. In each repetition of the game, groups of size $n \leq M$ are randomly and anonymously matched from a fixed population of size M to play the n-player PD stage game. We provide conditions for which the contagious strategy (Kandori, 1992) sustains a social norm of cooperation among all M players. Our main finding is that if agents are sufficiently patient, a social norm of society-wide cooperation becomes easier to sustain under the contagious strategy as n increases toward M. In an experiment where the population size M is fixed and conditions identified by our theoretical analysis hold, we find strong evidence that cooperation rates are higher with larger group sizes than with smaller group sizes in treatments where each subject interacts with $M-1$ robot players who follow the contagious strategy. When the number of human subjects increases in the population, the cooperation rates decrease significantly, indicating that it is the strategic uncertainty among the human subjects that hinders cooperation.

1. Introduction

What choice of group size maximizes (or minimizes) the possibility of achieving a social norm of cooperation in a finite population of self-interested strangers? This question would seem to be of some importance for the design of ad hoc committees, juries and teams. It is also of interest to experimentalists interested in understanding how the extent of pro-social behavior might depend on the matching group size of subject participants. In this paper we offer an answer to this question. Specifically, we consider a population of players of fixed size M. In every period, $t = 1, 2, \ldots, \infty$, players in this population are

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randomly and anonymously matched to form groups of size n and then play an n-person Prisoner's Dilemma game with all the members of their group. The total number of groups, M/n, is assumed to be an integer (i.e., M is a multiple of n).

The $n = 2$ person version of this environment has been previously studied by Kandori (1992), who shows that a social norm of cooperation among anonymous, randomly matched players is sustainable under certain conditions on the game. Kandori further shows that a social norm of cooperation among strangers in the $n = 2$ case becomes more difficult to sustain as M gets large and the possibility vanishes in the limit as $M \to \infty$. By contrast, in this paper we fix M and ask: for what value(s) of $n > 2$ is a social norm of cooperation among strangers easiest to achieve? In other words, is there an optimal group size for maximizing the likelihood of cooperative outcomes?

Our answer is that under certain conditions – specifically if agents are sufficiently patient – a social norm of cooperation among strangers, which is sustained by universal play of a "contagious" trigger strategy, becomes steadily easier to achieve as n gets larger, and becomes easiest to achieve when $n = M$. That is, we find that cooperation can be easiest to sustain when the group size is as large as possible. This seemingly counterintuitive finding readily follows from the rational-choice logic of the contagious trigger strategy that is used to support cooperation among randomly matched, non-communicative and anonymous "strangers." Intuitively, if agents are sufficiently patient, then the costs of igniting a contagion toward mutual defection are greatest when the matching group size, n, equals the population size, M. On the other hand, once a defection has started in the community, the benefits to slowing down the contagious process are also minimized in this same case where $n = M$. Therefore, the players' incentives to follow the contagious strategy are easiest to satisfy when the group size is as large as possible.

Our main finding is consistent with Kandori's (1992) result. While we fix M and show that a social norm of cooperation is easier to achieve as n increases toward M, Kandori's result can be viewed as showing that for the case where n is fixed at 2, cooperation is easier to sustain for a smaller M. Still, our findings serve to generalize Kandori's (1992) extension of the folk theorem for repeated games with random, anonymous matchings to the multiple-player ($n > 2$) Prisoner's Dilemma game. The n-player version of the Prisoner's Dilemma game is widely used to model a variety of *social* dilemmas including, e.g., the tragedy of the commons (Hardin, 1968). In addition, we show that our monotonicity result holds in an n-player binary public good game.

We also provide an empirical test of our main theoretical results by designing and implementing an experiment. In this experiment, we fix the population size, M, and the discount factor, δ, and study play of an indefinitely repeated game in which players from the population are randomly and anonymously matched in each repetition to play an n-player version of the Prisoner's Dilemma stage game. Within the population of size M, some fraction of players are robot players programmed to play according to the contagious strategy while the remaining fraction of players are human subjects and this ratio is public knowledge. In this setting we find strong evidence that, consistent with our theoretical predictions, cooperation rates are higher with larger matching groups, e.g., of size $n = 6$ as compared with smaller matching groups, e.g., of size $n = 2$ as subjects learn, with experience, the more immediate consequences of triggering an infectious wave of defection when the group size is larger. We show further how differences in cooperation rates between different group sizes vary in ways that reflect the predictions of our theory as we vary the payoff incentives of the game as well. Finally we show how our theoretical results find the strongest support when we eliminate strategic uncertainty by having subjects interact only with robot players.

Our paper contributes to the theoretical and experimental literature on sustaining cooperation among anonymous, randomly matched players. While this is an admittedly stark environment, it is an important benchmark case in both the theoretical and experimental literature and one that naturally characterizes many types of socio-economic interactions.[1] In addition to the original seminal paper by Kandori (1992), Ellison (1994) and Dal Bó (2007) provide further generalizations of how a social norm of cooperation may be sustained among anonymous, randomly matched players in 2-player Prisoner's Dilemma games. Xie and Lee (2012) extend Kandori's result to 2-player "trust" games under anonymous random matchings. Camera and Gioffre (2014) offers a tractable analysis of the contagious equilibria by characterizing a key statistic of contagious punishment processes and deriving closed-form expressions for continuation payoffs off the equilibrium path. Experimentally, Duffy and Ochs (2009) report on an experiment that examines play in an indefinitely repeated, two-player Prisoner's Dilemma game and find that a cooperative norm does not emerge in the treatments with anonymous random matching but does emerge under fixed pairings as players gain more experience. Camera and Casari (2009) examine cooperation under random matching by focusing on the role of private or public monitoring of the anonymous (or non-anonymous) players' choices. They find that such monitoring can lead to a significant increase in the frequency of cooperation relative to the case of no monitoring. Duffy et al. (2013) test the contagious equilibrium in the lab using trust games and find that information on past play significantly increases the level of trust and reciprocity under random matchings. Camera et al. (2012) report wide heterogeneity in strategies employed at the individual level in an experiment in which anonymous randomly matched subjects play the Prisoner's Dilemma game in sequences of indefinite duration. Compared with this previous literature, our paper is the first to theoretically and experimentally extend the analysis of the contagious equilibrium from a 2-player stage game to an n-player stage game. Our main theoretical finding, that a cooperative social norm is easier to sustain with a larger rather than a smaller group size, is new to the literature but finds support both in our own experiment

[1] There is also an experimental literature that studies cooperation in repeated Prisoner's Dilemma games of indefinite duration among fixed pairs of players (partners) e.g., Dal Bó (2005, 2007), Aoyagi and Fréchette (2009), Dal Bó and Fréchette (2011), Fudenberg et al. (2012). Engle-Warnick and Slonim (2006) examines a trust game of indefinite duration with fixed pairs.