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Free riders and strong reciprocators coexist in public goods experiments: evolutionary foundations

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Abstract:

Experimental evidence indicates that free riders and strongly reciprocal papers coexist in the public goods game framework. By means of an evolutionary analysis, we provide an endogenization of this behavioral regularity.

Keywords: Free Riding; Cooperation; Strong Reciprocity; Public Goods Game; Evolutionary Game Theory.

JEL Classification: B41; C73; D74; Z13.

1 Introduction

In the last decades, experimental research on private provision of public goods has been successfully conducted within the well-known Public Goods Game (PGG) framework, where a low number of subjects are given an identical endowment and allowed to either invest (possibly part of) it in a public account or keep it in a private account. Lab evidence on both unrepeated PGGs and first rounds of repeated PGGs indicates that economic theory overestimates the relevance of free riding, as in the aggregate subjects contribute *significantly more* than the canonical model of *Homo Oeconomicus* alone predicts. However, experiments reveal that the observed rate of cooperation is associated with a significant degree of behavioral heterogeneity, as some players ride free on others' generosity, while other individuals contribute to the public account. In our paper, we provide this experimental fact with evolutionary foundations as we show, to our knowledge for the first time, that *stable coexistence* between free riders and so called strong reciprocators is possible, within a PGG setting.

2 The model

Let us consider a (very large) community of individuals continuously interacting over time and enjoying the benefits of a given collective good. Randomly occurring encounters involve four players at a time, with a material PGG to be played[1]. Each single player has to make a binary, 'all-or-nothing' choice: he may either contribute to the public good (by giving a certain amount of money) or free ride. Therefore, material consequences for the players depend on their choosing between contribute (or 'cooperate', C) and free ride (or 'defect', D) only. Further, we assume the good to be provided is a *threshold* public good: actual provision occurs only insofar as a sufficiently large proportion of individuals do contribute to it (Cadsby and Maynes 1999). In particular, we suppose that if n_C is the number of players cooperating in each matching, $n_C = 2$ is the 'critical threshold' of cooperators needed for the public good to be privately provided[2]. Hence, the material consequences of each 4-player interaction (for the row player) are captured by the following payoff matrix:

	DDD	DDC	DCC	CCC
D	a	a	b	c
C	d	e	f	g

(1)

Table 1 *4-player PGG payoff matrix*

where:
$c > b > e > a > d$

[1]Well-known 4-player PGG experiments include Fehr and Gächter (2000), Fischbacher et al. (2001), Masclet et al. (2003), Kurzban and Houser (2005) and Noussair and Soo (2008).

[2]Like in our model, most threshold PGG experiments assume that players can either decide not to contribute or to contribute by a given amount.

$c > f$
$g > f > e$ [3] .

Let us suppose that two player types exist: *Egoists* and *Strongly Reciprocal players*. We define an *Egoist* or *Selfish* player (SEL) as a *Homo Oeconomicus* who always plays D. By contrast, a *Strong Reciprocator* (SR) is willing to both (conditionally) cooperate and incur costs in order to punish defectors[4]. As Fehr and Fischbacher (2005) point out, available empirical evidence shows that strong reciprocity is thus far the quantitatively most important type of social preference. Further, experiments suggest that the presence of explicit, targeted punishment opportunities crucially affects the final aggregate outcomes (see Fehr and Gächter 2000 and Ones and Putterman 2007).

As Ok and Vega-Redondo (2001) highlight, the answer to the question concerning how the material payoffs of the individualistic and non-individualistic agents compare in equilibrium at various population compositions crucially depends inter alia on the extent of *information* agents have on their opponent's type. In this regard, though it has been argued that players tend to subconsciously signal their type via facial expressions and other emotional factors (Frank 1988), economists have been skeptical towards the assumption that individuals can correctly identify their opponents' 'type'. In this light, we suppose that SRs do *not* recognize their opponents' type *ex ante* and that they bravely play C in each matching[5]. However, we also assume that, after cooperating, they can recognize their opponents' type (ex post recognition assumption) and that if SRs see that their opponent is a SEL, they are willing to incur material costs in order to punish her, by displaying 'altruistic punishment'. More specifically, we assume that the level of punishment costs critically depends on the number of SELs and SRs involved in the 4-player matching. As a consequence, each matching will lead to one of the (material) outcomes captured by the matrix below:

$$\begin{array}{ccccc} & SEL, SEL, SEL & SEL, SEL, SR & SEL, SR, SR & SR, SR, SR \\ SEL & a & a - \frac{\varepsilon}{3} & b - \varepsilon & c - 3\varepsilon \\ SR & d - \lambda & e - \lambda & f - \lambda & g \end{array} \qquad (2)$$

Table 2 *4-player matchings in a SEL-SR population*

[3]By assuming that $g > f > e$, we are supposing that the threshold public good under study also possesses the following feature. Once a specific *provision-point* (the 'threshold') is met (Isaac et al. 1989), the amount of the public good may further increase, provided that the aggregate level of contributions increases. This is equivalent to assuming that contributions beyond the threshold levels, far from being wasted, result in further benefits to the group. In our model, this is captured by the assumption that the individual payoff from playing C when the other three players also cooperate (that is, g) is greater than the individual payoff from playing C when only two out of three opponents cooperate (that is,f), which in turn is greater than the individual payoff from playing C when only one of the three opponents cooperates (that is, e).

[4]Kocher et al. (2008) run PGG experiments on three continents and show that both free riding and conditional cooperation are ubiquitous, though the distribution of types differs across countries.

[5]This attitude resembles Sugden's (1986) notion of 'brave reciprocity'.

where $\lambda > 0$ indicates the *cost of punishing* and $\varepsilon > 0$ indicates the *cost of being punished*. Expected payoffs can be calculated by using conditional probabilities. By indicating with x and $1-x$ the proportions of individuals of the types SEL and SR, respectively, we have:

$$\Pi_{SEL}(x) = ax^3 + (a - \frac{\varepsilon}{3})x^2(1-x) + (b-\varepsilon)x(1-x)^2 + (c-3\varepsilon)(1-x)^3$$

$$\Pi_{SR}(x) = (d-\lambda)x^3 + (e-\lambda)x^2(1-x) + (f-\lambda)x(1-x)^2 + g(1-x)^3$$

The growth rates of the proportions are given by the well-known replicator equations (Taylor and Jonker 1978). Replicator dynamics are a widely adopted model of social (as well as natural) selection dynamics characterized by payoff monotonicity, where the most rewarding strategies spread over at the expense of less rewarding ones (Weibull 1995). In this 2-type population, we analyze the following replicator dynamics:

$$\dot{x} = x(1-x)\left(\Pi_{SEL} - \Pi_{SR}\right) \tag{3}$$

where $\dot{x}$ represents the time derivative of x. We suppose that social evolution is driven by *material* payoffs *only*: players imitate the individuals who achieve the best performances in purely material terms. As Ok and Vega-Redondo (2001) observe: "it is possible that non-individualistic preferences are materially more rewarding than individualistic preferences in certain strategic environments" (p. 233).

3 Results

The payoff difference in (3) can be written as:

$$\Pi_{SEL} - \Pi_{SR} = \alpha x^3 + \beta x^2 + \gamma x + \delta \tag{4}$$

where:

$\alpha := -f + b + \lambda + \frac{7}{3}\varepsilon + e - d + g - c$

$\beta := -2b + 2f - \lambda - \frac{22}{3}\varepsilon - e + a - 3g + 3c$

$\gamma := -f + b + \lambda + 8\varepsilon + 3g - 3c$

$\delta := -g + c - 3\varepsilon$

We can state the following results.

Proposition 1 *Dynamics (3) are characterized by the following features:*

1) Equation (3) always admits the stationary states $x = 0$ and $x = 1$.

2) At most three stationary states with $x \in (0,1)$ can exist.

3) The stationary state $x = 1$ (where all players are SELs) is always locally attracting.

4) The stationary state $x = 0$ (where all players are SRs) is locally attracting if $\varepsilon > \frac{c-g}{3}$ and repelling if $\varepsilon < \frac{c-g}{3}$.

5) At most one stationary state with $x \in (0, 1)$ can be attracting.

In **Figure 1**, by a numerical example, we show the complete taxonomy of dynamic regimes that can be observed. Full (open) dots represent attracting (repelling) stationary states.

Proposition 2 *The basin of attraction of the fixed point $x = 1$ (where all players are SELs) shrinks if (ceteris paribus) the cost of being punished ε increases or if the cost of punishing λ decreases.*

4 Conclusion

Almost two decades ago, in concluding their pioneering theoretical work on the dynamics of free riding in PGG experiments, Miller and Andreoni (1991) pointed out: "our understanding of the private provision of public goods may be improved by more careful research into evolutionary game theory, and by theory and experiments that examine the motives, decision processes, and dynamics of public goods games" (p 14). By using the evolutionary methodology, we proceeded along these lines and succeeded in 'mapping' some robust findings emerging from last years' growing experimental research on PGGs. On the whole, with regard to a SEL-SR population where a 4-player PGG is continuously played, we found that the equilibrium critically depends on both information and behavioral assumptions concerning SRs. In particular, it is the case that, under ex post recognition, coexistence of SELs and SRs may occur. Our major result is that we are able to evolutionarily account for experimental evidence by showing that the equilibrium population, far from being monomorphic, is a *mixture* of selfish and non-selfish types[6]. To our knowledge, this is the first work where such mixed equilibrium emerges within a PGG setting[7]. Finally, in line with experimental evidence, we shed light on the crucial role played by both the costs of punishment.

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[6] Here we are able to reach this conclusion with reference to a PGG framework where 4-player matchings continuously occur within a 2-type population, whereas Antoci and Zarri (2008) show that this does not occur with *pairwise* random matchings (so that the material PD, rather than the PGG, is played) and several 3-type populations (composed of Altruists, Egoists and various forms of Strong Reciprocators).

[7] Under some conditions, Guttman (2000) finds stable coexistence of selfish and unselfish players by studying a 2-type population made of opportunists and reciprocators. However, he does not focus on a PGG framework. Further, in his model, all the players are expected payoff maximizers and reciprocators are not allowed to explicitly sanction defectors.

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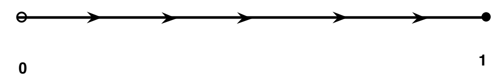
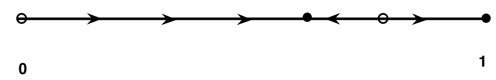
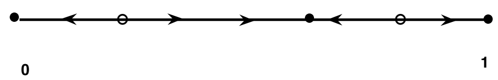


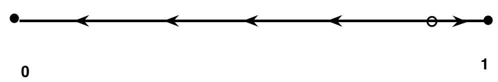
(a) $\epsilon = 3.8$



(b) $\epsilon = 3.82$



(c) $\epsilon = 3.9$



(d) $\epsilon = 4.2$

Figure 1: Dynamic regimes of (3). The parameters' values are: $a = 0.3$, $b = 6$, $c = 13.5$, $d = 0.1$, $e = 0.4$, $f = 1$, $g = 2$, $\lambda = 0.1$.