Peer effects in public contributions: theory and experimental evidence*

Coralio Ballester
Universidad de Alicante

Pablo Brañas–Garza
Universidad de Granada

María Paz Espinosa
Universidad del País Vasco

June 27, 2008

Abstract

This paper analyzes the impact of social integration on cooperative behavior. We show that if the social network shows assortative mixing

*We acknowledge comments and suggestions from Christoph Hauert, Konstantin Klemm and participants at the SYDN-Berlin 2008. María Paz Espinosa acknowledges financial aid from MEC (SEJ2006-06309/ECON) and Gobierno Vasco, DEUI (IT-313-07); Pablo Brañas-Garza from DGCYT (SEJ2007-62081/ECON).

then conditional cooperation is an equilibrium strategy for altruistic subjects with a high degree of social integration.We provide experimental evidence on the relationship between individuals' position in a social network and their contributions in a public good game.

Keywords: public good game, social networks, conditional cooperation

JEL Class.: C91, D64, C72, H41.

1 Motivation

The experimental literature on linear Public Good Games (PGG hereafter) has documented several regularities: *i*) on average subjects contribute positive amounts even though Nash equilibrium contributions are zero, *ii*) contributions decline over time, and *iii*) there is heterogeneity between subjects in their contribution levels. This pattern of behavior has been systematically observed (see Davis and Holt, 1993 and Ledyard, 1995).[1]

The initial willingness to contribute can be due to conditional cooperation –subjects who cooperate as long as others cooperate too, strategic

[1] Zelmer (2003) analyzes the effect on contributions of marginal per capita returns, communication, positive framing, heterogeneous endowments, experienced participants and other variables.

signalling or, simply, to individuals' social preferences. Learning effects, the frustration of players' attempts to sustain cooperation and backward induction arguments (endgame effects) are commonly used to explain the decline of contributions over time. Heterogeneity of behavior has been attributed to subjects' different types (conditional cooperators, free-riders,...).[2]

In this paper we analyze the impact of social integration on the level of contributions in a PGG and provide experimental evidence on this relationship. To capture an individual's social type we use two measures of integration within his/her (university class)[3] social network:[4] *in–degree* (the number of subjects who call him a friend) and *betweenness* (a measure of centrality/importance of the subject within the network). Both variables are obtained through a coordination game (step 1) that reveals the existing social network.

Then, we explore whether a subject's network attributes are related to his cooperative behavior in a context where private incentives would indicate not

[2]See Anderson et al (1998), Andreoni (1988, 1995), Brandts and Schram (2001), Goeree et al (2002), Houser and Kurzban (2002), Palfrey and Prisbey (1996, 1997), Levati (2002) and Keser and van Winden (2000), among others.

[3]We intentionally chose an existing social network. For this purpose, we did the recruitment process in a university classroom. A standard recruitment procedure would not provide us with the necessary density of network connections.

[4]An excellent textbook to introduce social network measures is Jackson (2008).

.

to do so. In particular, we check the relationship between social integration and behavior in a linear public good game (step 2). We find a strong positive relation between subjects' contributions and social connections.

We propose a theoretical framework to interpret these results. In our model individual differences in contributions observed in the initial period of the PGG are related to the subjects' position in a social network, together with the fact that this network shows assortative mixing. Subjects have social preferences but each subject values the payoff of other player only if they are socially connected. In a separating perfect Bayesian equilibrium players may contribute differently depending on their social preferences and their position in the network. Moreover, their behavior is also determined by the observed signals, which implies a decline in contributions over time.

The conditions for the separating equilibrium in our game exclude strategic signalling, that is contributing in the initial periods of the game just to induce others to cooperate and then obtain a higher payoff; in our model conditional cooperation is an equilibrium strategy only for altruistic subjects with a high degree of social integration.[5] This theoretical framework is consistent with previous experimental evidence showing heterogeneity in

[5] However, in a pooling equilibrium we might observe a decline in contributions due to strategic signalling behavior.

the behavior of subjects playing PGG and relates these differences to the subjects' different levels of social integration.[6] Our analysis emphasizes the importance of peer effects in the underlying social network.

In the heart of our model, we take as given that all subjects are socially concerned. More specifically, we consider that individuals care about their linked mates. The fact that some agents are more socially skilled (have more links) than others is determinant in their attitude towards cooperation. In particular, we model players as being uninformed about their opponents' identity. Socially skilled players interpret observed behavior as a signal of their rivals' type: after a cooperative signal they assume that the other player is socially skilled like them. This is a consequence of a positive degree correlation in the social network: agents with the same social skills tend to be connected among them.[7]

Conditional cooperation has been considered as a result of preferences for fairness, like inequity aversion or reciprocity (Fischbacher, Gachter and Fehr, 2000).[8] We show that even if subjects did not have any preference for

[6] González, González-Farías and Levatti (2005) find that 55% of the subjects playing PGG can be regarded as conditional cooperators.

[7] Thus cooperative behavior from social agents is not only the result of having a friend as a rival with higher probability, but it is due to the fact that socially similar agents tend to behave homogeneously.

[8] See also Sugden (1984) Andreoni (1995), Palfrey and Prisbrey (1997) Anderson, Go-

fairness, in equilibrium we could observe a conditional cooperation behavior. Here our subjects are not concerned about strangers but about their actual partners.

Ours is a very speficic model which fits in the recent literature in network games.[9] In this literature some papers have restrictedd their attention to games with complete information where each player's payoff is determined by the actions accurred in the neighborhood (for instance, see Calvó-Armengol and Zenou 2004, Ballester *et al.* 2006, 2008, Bramoullé and Kranton 2007 or Ballester and Calvó-Armengol 2008). Our paper is closer to the novel approach developed in Galeoti *et al.* (2007). They analyze general network games in an incomplete information setting, where each player's utility is determined by his neighbor's (and his own) actions. In our model, each player's payoff is also dependent on the actions of his opponent, whether he is a friend or not. The fact that the rival is his neighbor alters (increases) his payoff.

The paper is organized as follows. Section 2 presents our theoretical framework, to illustrate the idea that social preferences and the position in

---

eree and Holt (1998) Fehr and Schmidt (1999) and Bolton and Ockenfels (2000).

[9] For a thorough analysis of networks in economics, see Jackson (2008).

.

the network affect the equilibrium strategies and imply a declining pattern of contributions over time in a perfect Bayesian equilibrium. In Section 3 we describe the experimental design and procedures. Section 4 contains the empirical results and our interpretation based on the model. Section 5 concludes.

2 The model

Agents in the set $N = \{1, \ldots, n\}$ are embedded in a network g, where $g_{ij} = 1$ if agents i and j are friends and $g_{ij} = 0$ otherwise. We assume that g is symmetric, that is, $g_{ij} = g_{ji}$ for all i and j.[10] Let

$$N_i = \{j \in N \backslash \{i\} : g_{ij} = 1\}$$

be the set of agents that are neighbors of i in g, and $k_i = |N_i|$.

We model a situation with incomplete information in which the information privately available to each agent i is his set of neighbors N_i. Two agents are randomly selected to play a game Γ (that we describe below) and none

[10] This is without loss of generality. We assume this property for simplicity and because actual friendship networks, like those that we deal with in this paper, are highly symmetric.

of them knows the identity of the other. Given $\overline{k} \in \{0, \ldots n-1\}$, let $G\left(\overline{k}\right)$ be the probability that a random opponent j of i has at least $\overline{k}$ neighbors, conditioned on i's information:

$$G\left(\overline{k}\right) = \Pr\left[|N_j| \geq \overline{k}; N_i\right].$$

We are implicitly assuming that this probability is independent of the identity of i and his neighborhood N_i. Nevertheless, this does *not* imply that this independence holds if we condition on the opponent being an actual friend in the network ($g_{ij} = 1$). For this reason, let $r\left(k_i, \overline{k}\right)$ be the probability that player i with k_i neighbors is randomly matched to a friend j (i.e., $g_{ij} = 1$) to play game Γ, given that j has at least $\overline{k}$ neighbors:

$$r\left(k_i, \overline{k}\right) = \Pr\left[g_{ij} = 1; |N_i| = k_i, |N_j| \geq \overline{k}\right],$$

and

$$q\left(k_i, \overline{k}\right) = \Pr\left[g_{ij} = 1; |N_i| = k_i, |N_j| < \overline{k}\right]$$

be the probability that player i with k_i neighbors is matched to a friend j with less than $\overline{k}$ neighbors. From now on, we will refer to agents with at least

$\overline{k}$ neighbors as "socially skilled", while the rest will form the set of "socially unskilled" agents.

Once the two agents have been randomly matched, they are called upon to play the following two-stage game, Γ, where at each stage both players (labeled 1 and 2) choose simultaneously whether to cooperate or defect: $a_1^t, a_2^t \in \{C, D\}$ for $t = 1, 2$.[11]

Following Fehr and Schmidt (1999) we will assume that subjects are endowed with *other-regarding preferences*, that is, they care about others' welfare.[12] Each player $i = 1, 2$ receives a monetary payoff $P_i^t\left(a_1^t, a_2^t\right)$ at stage t. The utility of player i in game Γ is then given by

$$u_i\left(a_1^1, a_2^1, a_1^2, a_2^2\right) = P_i^1\left(a_1^1, a_2^1\right) + P_i^2\left(a_1^2, a_2^2\right) + \alpha g_{ij}\left[P_j^1\left(a_1^1, a_2^1\right) + P_j^2\left(a_1^2, a_2^2\right)\right],$$

where $\alpha \geq 0$ is a scalar, assumed to be common to all agents,[13] that measures the degree of concern of i towards his friends (kindness).

[11] We may also interpret this situation as follows. Several pairs of agents are selected randomly from a large population and each pair has to play a $2-$player game. If this population is large, we obtain strategic independence across games.

[12] We do not deal with the motivations behind social preferences. We just assume individuals are *socially–concerned.*

[13] In our framework we assume that all agents are equally socially concerned. It is the fact that an agent is more social (has more connections) that will determine his higher concern about efficient outcomes.

We assume the following tables of utilities.[14]

	C	D
C	$2+2\alpha, 2+2\alpha$	$3\alpha, 3$
D	$3, 3\alpha$	$1+\alpha, 1+\alpha$

if $g_{ij} = 1$

	C	D
C	$2, 2$	$0, 3$
D	$3, 0$	$1, 1$

otherwise

Γ is a Bayesian game where player i's type is given by N_i. We restrict ourselves to strategies where each player's strategy depends on the *size* of his neighborhood k_i. Then, player i's (pure) strategy is defined by the following mappings at stages 1 and 2:

$$\begin{aligned} a_i^1 &: \{0, \ldots, n-1\} \rightarrow \{C, D\} \\ a_i^2 &: \{0, \ldots, n-1\} \times \{C, D\}^2 \rightarrow \{C, D\}. \end{aligned}$$

Now, we characterize a *separating equilibrium* where agents' strategies only depend on the size of their neighborhood and on the observed first stage action by the other player.

Proposition 1 *If there exists* $\overline{k} \in \{1, \ldots, n-1\}$ *such that for all* i

[14] This is a particular Bayesian version of the prisoner's dilemma, which has the same structure as a public good game with two players.

1. for all $k_i < \overline{k}$

$$\alpha r\left(k_i, \overline{k}\right) \leq 1/2 \tag{1}$$

$$\alpha q\left(k_i, \overline{k}\right) \leq \frac{G\left(\overline{k}\right)}{2\left(1 - G\left(\overline{k}\right)\right)}\left[1/G\left(\overline{k}\right) - 2 - \alpha r\left(k_i, \overline{k}\right)\right] \tag{2}$$

2. for all $k_i \geq \overline{k}$

$$\alpha r\left(k_i, \overline{k}\right) \geq 1/2 \tag{3}$$

$$\alpha q\left(k_i, \overline{k}\right) \in \left[\frac{G\left(\overline{k}\right)}{2\left(1 - G\left(\overline{k}\right)\right)}\left[1/G\left(\overline{k}\right) - 2 - \alpha r\left(k_i, \overline{k}\right)\right], \frac{1}{2}\right] \tag{4}$$

then there exists an equilibrium where

$$a_i^1\left(k_i\right) = \begin{cases} C & \text{if} \quad k_i \geq \overline{k} \\ D & \text{if} \quad k_i < \overline{k} \end{cases}$$

$$a_i^2\left(k_i, a_1^1, a_2^1\right) = \begin{cases} C & \text{if} \quad k_i \geq \overline{k} \text{ and } a_j^1 = C \\ D & \quad \text{otherwise} \end{cases}$$

Proof. See Appendix 2.

Proposition 1 shows that in a separating equilibrium the socially skilled agents follow a conditional cooperation strategy (continue cooperating until the opponent defects), while the socially unskilled players behave as free-riders. The experimental literature on the PGG has found evidence of this heterogeneous behavior of players.[15] Proposition 1 rationalizes the observed behavior in terms of the social types of players and the peer effects in game Γ.

The conditions for a separating equilibrium can be interpreted as follows:

1. Condition (1) ensures that a socially unskilled agent will defect in the second period after observing C, through a lower probability of partnership with a friend. Condition (3) affects the behavior of a socially skilled agent in the second stage after observing C.

2. Expression (2) determines the incentives for the unskilled to defect in the first round. This condition implies, first, that $\overline{k}$ should be above the median of the degree distribution.[16] This is reasonable: the class of socially skilled agents cannot be too large, otherwise the unskilled would be willing to cooperate in the first round, with a high probability of finding a cooperator to cheat on in the next round. Our equilibrium condition excludes this type of strategic behavior by the socially un-

[15] See for instance González et al (2005).

[16] This is shown in lemma 2 in Appendix 2.

skilled players.

Second, condition (2) implies that $\alpha q\left(k_i, \overline{k}\right) \leq 1/2$ for $k_i < \overline{k}$: unskilled agents should not be too connected among them; otherwise they would cooperate in the second round.

It turns out that the restrictions on r and q for the unskilled agents become more demanding as $\overline{k}$ decreases and gets closer to the median (as the socially skilled class grows). In this case, the two social classes have a considerable size. The incentives of unskilled agents must be such that they have a small probability of social matching so that the overall chance of meeting a friend will be small and defection will follow in the first round.

3. The implications of (4) are similar. As in the case of unskilled agents, the probability q of being matched to a socially unskilled should not be very large: $\alpha q\left(k_i, \overline{k}\right) \leq 1/2$. On the other hand, in order to ensure cooperation of the skilled in the first round, there must be a minimum probability $q\left(k_i, \overline{k}\right)$ of being a friend of an unskilled partner.

   As opposed to socially unskilled agents, condition (4) becomes more stringent as $\overline{k}$ grows. If the socially unskilled group grows very large, the only way to induce cooperation of the few skilled is to be socially linked to a relatively high number of unsocial friends.

4. The set of conditions (1) to (4) is related to the existence of some correlation in the degrees of the nodes. In words, positive assortativity is reflected in the fact that socially skilled agents should be more likely to be linked to socially skilled agents than to the unskilled. This is clearly implied by the equilibrium conditions in proposition 1.

5. Our equilibrium requires a kindness parameter $\alpha \geq 1/2$. This makes it a dominant strategy to cooperate if a player is certain about being matched to a friend in game Γ. Although this may seem a strong requirement, note that in a more general model the presence of more than two players should relax the one-to-one kindness requirements at equilibrium.

Our simple result goes along the same lines as the general findings in Galeotti *et al.* (2007) - non-decreasing Bayesian equilibria in games where there is degree complementarity. Here, we focus on equilibrium perfection of a simple two-stage game, where the payoff of each player depends on the actions of the opponent, event if he is a not a friend.

In game Γ we have assumed a particular payoff structure and two players. This framework may not fit all the situations but it illustrates the idea that peer effects could be important for experimental research. The position in a social network may affect a player's behavior when he interacts (anonymously) with other players. This setup is often found in laboratory experiments. Even though the experimenter may want to test something apparently unrelated to the underlying social network, he should be concerned by the social links between subjects and their heterogeneity in this respect.

An implication of our results is that the recruitment process should not ignore the existing social networks. It is not unlikely that subjects (for example, university students) are heterogeneous in their network position and potentially this will affect their decisions in the laboratory. This heterogeneity is probably being controlled for in many experiments but it is probably a better strategy to recognize explicitly the potential effect of the networks and tailor the recruitment process accordingly (see also footnote 3).

To highlight the idea that their position in social networks may affect the behavior of players even when they are randomly matched, we have considered that the driving force for cooperation is just kindness to friends. Of course, there are other important factors like inequality aversion that have been extensively explored in the literature.[17]

Although simple, our model allows us to contribute important elements to the discussion of the experimental evidence in PGG.

- First, agents are aware of their pattern of relationships before the game starts and do not know the identity of their actual opponents in the game. This has strategic implications on their behavior regarding the chance of meeting a friend behind the computer. These implications become more apparent as the network displays higher degree correlation.

- Second, we show a simple argument of why socially skilled agents can behave in a more altruistic way in the game. The reason is that, even though every agent is assumed to have social preferences and the same concern for his friends, a player with more friends feels more willing to cooperate because of the higher likelihood of facing a friend as a partner in the lab. Moreover, the equilibrium has the property of declining contributions of the socially unskilled and of betrayed social players.[18]

[17] See Fischbacher, Gachter and Fehr (2000).

[18] Andreoni (1995) relates the decline in contributions to the frustrated attempts to sustain cooperation.

- Third, we show that the structure of the network may allow for certain kind of equilibria where each agent's behavior is shaped by the number of neighbors he has, allowing him to signal his type to his opponent. In particular, networks that display a higher degree of assortativity seem more likely to allow agents to adopt this separating behavior at equilibrium.

Finally, our results require certain conditions which may or may not hold in laboratory experiments. In particular, we required some assortative mixing in the social network. To check whether our results have some empirical relevance we run a PGG with anonymous partners (not necessarily neighbors in the network). We test whether the underlying network has an influence on the behavior of subjects.

3 Experimental design & preliminaries

The experiment was conducted in two stages: a network elicitation phase and a PGG.

Step 1: Network elicitation

71 first year undergraduate students in Business Administration at the

Universidad de Granada –with no previous exposure to Game Theory– participated in a network elicitation experiment in a single session[19] held on April 27^{th}, 2007. Subjects were invited to reveal their class friends' names, together with an index of friendship "strength" (from acquaintance to good friend). According to the mechanism, subjects were rewarded with a fixed prize of 5 euros as follows *a)* if a randomly selected (bidirectional) link was corresponded and the revealed strengths sufficiently close or *b)* when they did not name anybody.[20]

In contrast to Leider et al. (2007) –a powerful experimental device to elicit the maximum number of existing links (and even distant neighbors) within a given social network[21]– our approach captures close relationships. It does not give incentives to name many friends but only close friends. If the subject decides not to name anybody, then his friends (those who named him) will lose the prize. Hence, a subject will name a friend when he is pretty sure his friend is going to name him and he values his relationship enough (since he can always get the prize by not naming anyone).

[19] In order to maximize the number of links we run the experiment within a regular class after students finished their teaching (see footnote 3). At the same time we run the experiment in two classes: A and B. This experiment uses data from class B.

[20] See Brañas-Garza et al. (2007) for details on the properties of this elicitacion mechanism. See also Appendix 1.

[21] Goeree et al (2006) provides a different approach, based on a survey, which also yields good results.

On average, subjects sent 2.25 links (st. dev. 1.84) and received 2.26 links (st. dev. 1.82); 70% of the elicited links were bidirectional (corresponded).[22] Moreover, 17% of the subjects did not receive any link and 18% did not send any link. Betweenness centrality is, on average, 4.50 (st. dev. 3.44). Main data are available in Appendix 5.3 (Table A1).

Women received, on average, 2.71 links (st. dev. 2.01) while men received 1.87 links (st. dev. 1.60). Mann Whitney test supports this gender bias ($Z_{MW} = -1.78; p = 0.07$). Differences among females and males are even stronger for centrality; betweenness was 5.34 (st. dev. 3.38) for women and 3.82 (st. dev. 3.37) for men ($Z_{MW} = -1.98; p = 0.04$).

Figure 1 shows the histogram for in-degree.[23] 16% of the subjects did not receive any link, around 20% of them received 1, 2 or 3 links and less than 20% were named by 4 or more players.

If we define as 'very popular' those members of the network named by five or more people, we see that there are few very popular individuals. This is the *first* important feature of our social network: A small fraction of the members of the network are very popular.

[22] This is what we assumed in our model. See also footnote 10.

[23] We used in-degree instead of out-degree because –taking into account how the network is elicited– the subject cannot influence it.

Figure 1: Degree distribution

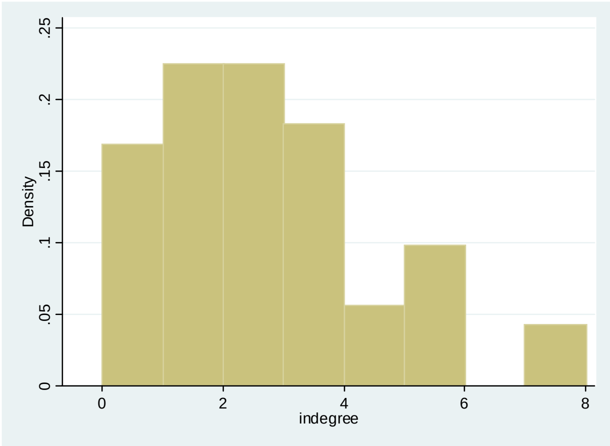


Figure 2 shows the network's graph. Note that the network is formed by a number of clusters weakly connected.

A salient characteristic of our network is *assortativity*, that is, a preference to attach to others who are similar (the nodes in the network that have many connections tend to be connected to other nodes with many connections). In social networks we would expect that highly connected individuals tend to be connected to other high degree members[24] and indeed this assortative mixing is observed for our network participants. We focus on *in–degree* and check whether those who are named by a lot of friends are connected with individuals with larger in–degree.

[24]Newman (2002) provides evidence that social networks are often assortatively mixed, while technological and biological networks tend to be disassortative.

Figure 2: The elicited Network

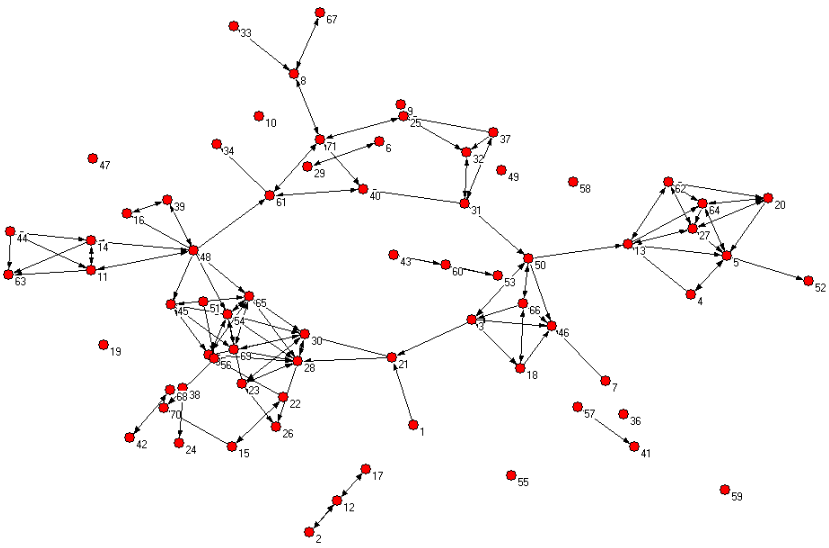
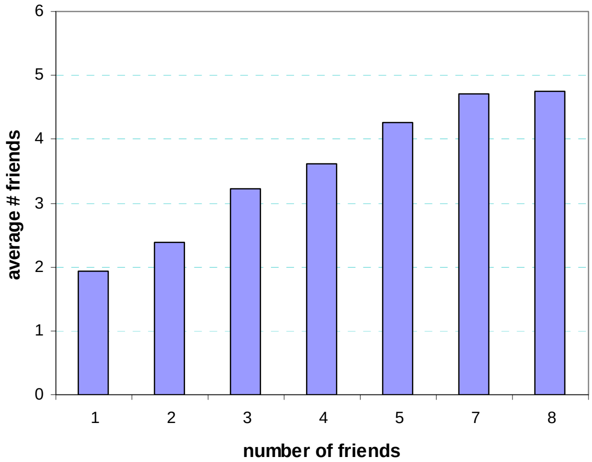


Figure 3 shows this assortative mixing. The X-axis shows the subjects sorted by the number of friends who named them (*in-degree* $= 0, 1, ..., 8$) whereas the Y-axis counts the average in-degree of their respective friends: clearly, popular individuals are linked with popular individuals. This is the *second* important feature of our social network: it shows assortative mixing.

In sum, the network obtained with our elicitation mechanism has two features that we want to highlight:

- A small fraction of the subjects is highly connected.
- The social network shows assortative mixing.

Figure 3: ASSORTATIVITY



Step 2. PGG

On May 31^{th}, 2007, 48 of the "network members" participated in a PGG.[25] They played a 4-person linear public good game (anonymous *partners*) for five periods (12 groups). Each period subjects were given an endowment of 100 coins of 2 euro cents each. They were asked to make a decision on how much to allocate to a private account and how much to allocate to a public account.[26] After each round subjects were informed about their profit

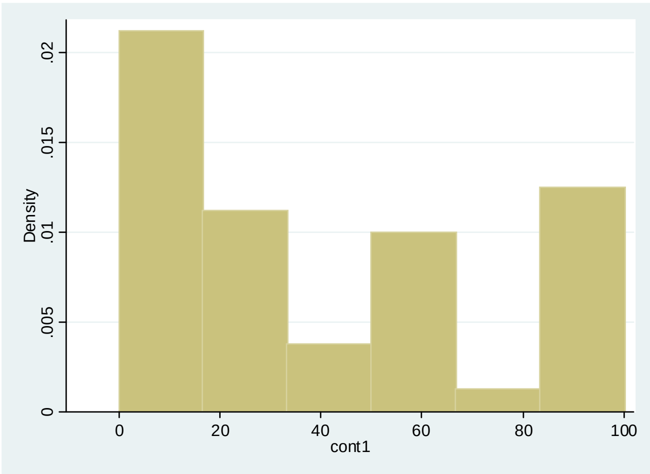
[25] This second session was run one month after the network elicitation session and only 50 subjects (out of the 71 attending the first session) showed up. Two of them could not participate since we needed groups of 4 people for the PGG, so that finally we were left with 48 subjects.

[26] Contributions were expressed in number of coins, thus, they were integer numbers between 0 and 100, $c_{it} \in [0, 100]$. Participants were informed that any money allocated to the private account they could keep for themselves, and this independently of other subjects' actions, while all the money allocated to the public account (the sum of the

(private + public accounts earnings). Each participant earned the sum of payoffs obtained in the five periods (11.3 euros on average).

On average, subjects contributed 39.29 (st. dev. 36.53)[27] with a minimum (maximum) contribution of 0 (100) coins. Figure 4 shows contributions in round 1. Contributions decline over time and there is heterogeneity in the subjects contribution levels. Main data are available in Appendix 5.3 (Table A1).

Figure 4: OBSERVED CONTRIBUTIONS



money allocated by the four members of the group) would be multiplied by 1.5 and then it would be divided equally among the four members. For details see Brañas–Garza & Espinosa (2008).

[27] This is not very different from the average contribution in other PGG experiments.

4 Results

In this section we use the experimental data obtained through the network elicitation device to establish the "social type" of each player. Each player is characterized by in-degree and betweenness. I*n-degree* captures the number of links each subject receives, therefore it is reflecting the individual “stock” of social capital. *Betweenness* measures the centrality of each subject, that is how relevant is each individual within the complete network. Given that this measure is a combination of in–degree and out–degree, the individual might affect this variable through the number of links that he declares.

Columns [1] and [2] in Table 1 explore the role of *in–degree* on PGG first round contributions. We also used *in-degree*^{2} to capture possible nonlinear effects. We have included a dummy to control for gender effects (those unrelated to women’s social type). The result is that those who receive more links -those who have more friends- are more prone to contribute. The effect is even more significant in regression [2], when the variable in-degree is squared. Therefore, we may conclude that those subjects who receive more links contribute more in the first round.

Table 1: Contributions Round 1

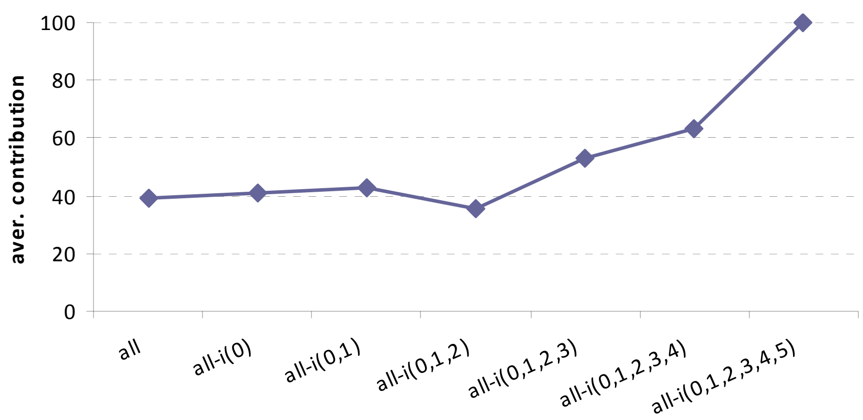
	In-degree		*Betweenness*	
in-degree	6.42			
	(0.02)			
in-degree^2		1.04		
		(0.00)		
betweenness			3.36	
			(0.03)	
betweenness^2				0.33
				(0.00)
female	-16.09	-17.36	-15.54	-16.30
	(0.11)	(0.09)	(0.13)	(0.10)
constant	30.26	29.82	37.12	35.26
	(0.00)	(0.00)	(0.00)	(0.00)
R^2	0.12	0.11	0.17	0.16

(*) N=48; p-values between brackets.

Similarly, columns [3] and [4] explore the effect of centrality. We use *betweenness* and *betweenness^2*. Results are identical to those reported for in–degree: more central subjects contribute significantly more.

Hence, both measures of social integration capture the same effect: social subjects are more prone to contribute in the first round of a PGG. Figure 5, shows the average contribution for the whole sample ("*all*" on the left, $n = 48$) and the average contributions for subsequent re-samplings according to the level of socialization:[28] $all - i(0, .., j-1)$ denotes the set of subjects with an in-degree of at least j.

Figure 5: Average Contributions



This figure confirms the result showed in the previous regression analysis. When those subjects with smaller number of friends are progressively

[28] Note that "*all - i(0)*" includes the whole sample with the exception of those who did not receive any link ($n = 44$); "*all - i(0,1)*" when the sample contains those subjects with at least 2 received links ($n = 35$); "*all - i(0,1,2)*" for subjects receiving at least 3 links ($n = 21$); "*all - i(0,1,2,3)*" for subjects receiving at least 4 links ($n = 10$); "*all - i(0,1,2,3,4)*" for subjects receiving at least 5 links ($n = 8$) and, finally, "*all - i(0,1,2,3,4,5)*" includes only those who received 6 links ($n = 3$).

removed from the population, then the (average) first round contribution in the PGG increases substantially: more social subjects are willing to contribute more in the PGG.

We may interpret the above result using the theoretical framework developed in the previous section. Social subjects are more optimistic about the probability of interacting with players they care about and who (since social networks show assortativity) would be also optimistic in this respect. This optimism is rational and leads to cooperation in equilibrium. Thus, the levels of socialization may be at the heart of the observed players' attitudes concerning cooperation in games.

The literature has also documented that contributions decay over time. Then, given that social subjects are more prone to start contributing, the key question is whether this sort of "wishful thinking" would survive to experience: when the individual has received some feedback about other players' contributions.

Columns [1] to [4] in Table 2 present the regression analysis (Table 1) but now for second round contributions.

Table 2: CONTRIBUTIONS ROUND 2

	In-degree		*Betweenness*	
in-degree	-1.33			
	(0.63)			
in-degree^2		-0.03		
		(0.93)		
betweenness			-1.84	
			(0.22)	
betweenness^2				-0.10
				(0.38)
female	14.64	13.69	16.40	15.48
	(0.11)	(0.15)	(0.08)	(0.10)
$contribution_{t-1}$	0.45	0.42	0.50	0.47
	(0.00)	(0.00)	(0.00)	(0.00)
$feedback_{t-1}$	0.11	0.10	0.13	0.10
	(0.08)	(0.08)	(0.03)	(0.06)
R^2	0.56	0.59	0.61	0.60

(*) N=48; p-values between brackets.

As independent variables we use individual's past contribution ($t-1$) and the profit earned in the previous stage (private + public earnings).[29] In addition, we control for gender effects. The four reported regressions give the same message: once past contributions and feedback are controlled for, the individual level of socialization loses any predictive power.

We see that the effect of in-degree and betweenness completely vanish in the second round, once subjects have updated their beliefs.

This is consistent with the prediction of our model. In a separating equilibrium, the social type is revealed and even social subjects stop contributing in the second stage if they have observed a bad signal.

There are two policy implications from there results:

1) The level of social integration among the participants may help the promotion of public projects.

2) But, the success of these projects crucially depends on the interaction between socially skilled and unskilled agents.

[29] Observe that the constant becomes not significant when we introduce $contribution_{t-1}$.

5 Discussion

Our main result is that the position in a social network may affect a player's behavior when he interacts (anonymously) with other players and that the structural properties of friendship networks affect cooperative behavior.

It is commonly believed that a random matching of subjects in the laboratory would eliminate any peer effects. However, we have shown that the fact that the game is played anonymously, i.e. subjects ignore the identity of the partners, and that the game is not played in the network, do not cancel the peer effects (see footnote 3).

We develop a theoretical framework which allow us to interpret the experimental results as the outcome of a separating Perfect Bayesian equilibrium. We also provide experimental evidence relating the level of social integration (betweenness, in-degree) to the level of contributions. The strong positive association between contributions and social integration supports our interpretation. Our approach may be useful to explain cooperation in other contexts.

We use a two-step experimental design: first, using a coordination game we elicit the latent social network; second, subjects play an anonymous repeated PGG. Using the data of both experiments we check if individual social integration is correlated to contributions in the PGG.

Our experimental analysis provides two central results: more social subjects contribute more in the first round; this effect disappears in the second round. This observation is consistent with our model's prediction that socially skilled players would follow a conditional cooperation strategy and after a negative feedback they would stop contributing.

References

[1] Anderson, S. P., Goeree, J. and C. A. Holt (1998). A Theoretical Analysis of Altruism and Decision Error in Public Goods Games. *Journal of Public Economics* **70**(2): 297-323.

[2] Andreoni, J. 1995. Cooperation in public-goods experiments: kindness or confusion?. *The American Economic Review* **85**(4): 891-904.

[3] Andreoni, J. 1988. Why Free Ride? Strategies and Learning in Public Goods Experiments. *Journal of Public Economics* **37**(3): 291-304.

[4] Ballester, C., Calvó-Armengol, A., and Y. Zenou. 2006. "Who's Who in Networks. Wanted: The Key Player," *Econometrica* 74, 1403-1417.

[5] Ballester, C., Calvó-Armengol, A., and Y. Zenou. 2008. "Delinquent Networks," mimeo.

[6] Ballester, C. and A. Calvó-Armengol. 2008. "Moderate Interactions in Games with Induced Complementarities," mimeo.

[7] Bramoullé, Y. and R. Kranton. 2007. "Public goods in networks," *Journal of Economic Theory* 135(1), 478-494.

[8] Brandts, J. and A. Schram. 2001. "Cooperation or Noise in Public Goods Experiments: Applying the Contribution Function Approach," *Journal of Public Economics* **79**: 399-427.

[9] Brañas-Garza, P. and M. P. Espinosa. 2008. "Unraveling Public Good Games: the Role of Priors," *Universidad de Granada mimeo.*

[10] Brañas-Garza, P., Cobo-Reyes, R., Jiménez, N. and G. Ponti. 2007. "Psychological games and social networks: a "privacy–respectful" device bases on guilty aversion," *ThE Papers* 05/19 *Universidad de Granada.*

[11] Calvó-Armengol, A. and Y. Zenou. 2004. "Social Networks and Crime Decisions: The Role of Social Structure in Facilitating Delinquent Behavior," *International Economic Review* 45, 935-954.

[12] Chaudhuri, A. and T. Paichayontvijit. 2006. "Conditional cooperation and voluntary contributions to a public good," *Economics Bulletin* **3**(8): 1-14.

[13] Croson, R. Forthcoming. "Theories of Commitment, Altruism and Reciprocity: Evidence from Linear Public Goods Games," *Economic Inquiry.*

[14] Davis, D. and C. A. Holt. 1993. Chapter 6. Experimental Economics, Princeton: *Princeton University Press.*

[15] Fehr, E. and K. Schmidt. 1999. "A Theory of Fairness, Competition and Cooperation," *Quarterly Journal of Economics* **114**: 817-868.

[16] Fischbacher, U., Gachter, S. and E. Fehr. 2001. "Are people conditionally cooperative? Evidence from a public goods experiment," *Economics Letters* **71**(3): 397-404.

[17] Galeotti A., Goyal, S. Jackson, M. O., Vega-Redondo, F. and L. Yariv. 2007. Network games. *mimeo.*

[18] González, L. G., González-Farías, G. and M. V. Levati. 2005. "Logit estimation of conditional cooperation in a repeated public goods experi-

ment," Discussion Papers on Strategic Interaction 2005-05, Max Planck Institute of Economics.

[19] Goeree, J. K., McConnell, M., Mitchell, T., Tromp, T. and L. Yariv. 2006. "A Simple 1/d Law of Giving," *Caltech mimeo*.

[20] Houser, D. and R. Kurzban. 2002. "Revisiting kindness and confusion in public goods experiments," *The American Economic Review* **92**(4):1062-1069.

[21] Keser, C. and F. van Winden. 2000. "Conditional Cooperation and Voluntary Contributions to Public Goods," *Scandinavian Journal of Economics* **102**(1): 23-39.

[22] Jackson M.O. 2008. Social and Economic Networks. Princeton: *Princeton University Press*.

[23] Ledyard, J. O. 1995. Public Good: a Survey of Experimental Research. In: The Handbook of Experimental Economics (eds. J. H. Kagel and A. E. Roth), Princeton: *Princeton University Press*.

[24] Leider, S., Mobius, M., Rosenblat, T. and D. Quoc-Anh. 2007. "How Much is A Friend Worth? Directed Altruism and Enforced Reciprocity in Social Networks," Harvard University *mimeo*.

[25] Levati, M. V. 2002. "Explaining Private Provision of Public Goods by Conditional Cooperation An Evolutionary Approach," mimeo.

[26] Newman, M. E. J. 2002. "Assortative Mixing in Networks," *Physical Review Letters* 89(20): 208701.

[27] Zelmer, J. 2003. "Linear Public Goods Experiments: A Meta-Analysis," *Experimental Economics* **6**:299-310.

5.1 Appendix 1. Brañas-Garza et al. (2007) mechanism

The elicitation protocol is as follows. Students are asked to reveal the names (and surnames) of their friends within their undergraduate class and, using a scale from 1 to 4, the strength of each relationship.[30]

Let s_{ij} define the strength given by i to the ij relationship; the stregth is framed in the experimental instructions as follows:

$s_{ij} = 1$: j is an *acquaintance* of i;

$s_{ij} = 2$: j is a *close acquaintance* of i;

$s_{ij} = 3$: j is a *friend* of i;

$s_{ij} = 4$: j is a *close friend* of i.

Finally, if subject i does not name subject j, we set $s_{ij} = 0$.

As for the outcome function of the mechanism, subjects would receive a prize under these two CASES:

- CASE 1: if they did not name anybody, or
- CASE 2: if they named at least one subject, and the following two conditions hold:

[30] Note that in Spain individuals have always two surnames (instead of only one as is usual in other countries).

Condition 1 For each subject i one out of the elicited links would be selected at random (with equal probability). Let $\hat{\jmath}$ denote the subject named in the randomly selected link. For subject i to receive the prize it is necessary that $\hat{\jmath}$ has also named her (i.e. that $s_{\hat{\jmath}i} \neq 0$);

Condition 2 To obtain the prize, the friendship strength should also be *accurate* in that the difference in strength should not be higher than 1: $D_{i\hat{\jmath}} = |s_{i\hat{\jmath}} - s_{\hat{\jmath}i}| \leq 1$.

CASE 1 corresponds to a "privacy-respectful" clause (subjects may not reveal the names of their friends and still get the prize); CASE 2 corresponds to the coordination protocol, similar to that of MRQ.

5.2 Appendix 2.

Lemma 2 *Condition (2) implies that* $G\left(\overline{k}\right) \leq 1/2$ *and* $\alpha q\left(k_i, \overline{k}\right) \leq 1/2$ *for all* i *such with* $k_i < \overline{k}$.

Proof. The bound in the right-hand side of (2) must be positive, that is, that $1/G\left(\overline{k}\right) - 2 - \alpha r\left(k_i, \overline{k}\right)$ which implies that $G\left(\overline{k}\right) \leq 1/2$. On the other hand, this bound is decreasing in $G\left(\overline{k}\right)$, so that it attains its maximum value $1/2$ at $G\left(\overline{k}\right) = 0$. ∎

Proof of Proposition 1. We start with optimal actions at the second stage for player 1 (for player 2, the same results apply by changing the labels).

1. $k_1 < \overline{k}$.

   (a) Case $(a_1^1, a_2^1) = (C, C)$. Then, $k_2 \geq \overline{k}$ and $a_2^2 = C$. Expected utilities of player 1 at period 2 are:

   $$\begin{aligned} U_{1,D}^2 &= 3 \\ U_{1,C}^2 &= 2 + 2\alpha r\left(k_1, \overline{k}\right). \end{aligned}$$

   Then $U_{1,D}^2 \geq U_{1,C}^2$ holds if and only if (1) is satisfied.

   (b) Case $(a_1^1, a_2^1) = (D, C)$. Then, $k_2 \geq \overline{k}$ and $a_2^2 = D$. Expected utilities of player 1 at period 2 are:

$$\begin{aligned} U_{1,D}^{2} &= 1+\alpha r\left(k_{1},\overline{k}\right) \\ U_{1,C}^{2} &= 0+3\alpha r\left(k_{1},\overline{k}\right). \end{aligned}$$

Then $U_{1,D}^{2} \geq U_{1,C}^{2}$ holds under (1).

(c) Case $(a_1^1, a_2^1) \in \{(C,D), (D,D)\}$. Then, $k_2 < \overline{k}$ and $a_2^2 = D$. Expected utilities of player 1 at period 2 are:

$$\begin{aligned} U_{1,D}^{2} &= q\left(k_{1},\overline{k}\right)(1+\alpha)+\left(1-q\left(k_{1},\overline{k}\right)\right)1 \\ U_{1,C}^{2} &= q\left(k_{1},\overline{k}\right)(3\alpha)+\left(1-q\left(k_{1},\overline{k}\right)\right)0. \end{aligned}$$

Then $U_{1,C}^{2} \geq U_{1,D}^{2}$ holds if and only if $\alpha q\left(k_{1},\overline{k}\right) \leq 1/2$, which is results from lemma 2.

2. $k_i \geq \overline{k}$.

(a) Case $(a_1^1, a_2^1) = (C,C)$. Then, $k_2 \geq \overline{k}$ and $a_2^2 = C$. The expected utility at period 2 from cooperation is

$$\begin{aligned} U_{1,C}^2 &= r\left(k_1, \overline{k}\right)(2+2\alpha) + \left(1 - r\left(k_1, \overline{k}\right)\right) 2 \\ &= 2 + 2r\left(k_1, \overline{k}\right)\alpha, \end{aligned}$$

while if he chooses $a_1^2 = D$, then he gets at period 2

$$\begin{aligned} U_{1,D}^2 &= r\left(k_1, \overline{k}\right) 3 + \left(1 - r\left(k_1, \overline{k}\right)\right) 3 \\ &= 3. \end{aligned}$$

Then $U_{1,C}^2 \geq U_{1,D}^2$ which holds under condition (3).

(b) Case $(a_1^1, a_2^1) \in \{(C, D), (D, D)\}$. Then, $k_2 < \overline{k}$ and $a_2^2 = D$. Expected utilities of player 1 at period 2 are:

$$\begin{aligned} U_{1,D}^2 &= 1 + q\left(k_1, \overline{k}\right)\alpha \\ U_{1,C}^2 &= 0 + 3q\left(k_1, \overline{k}\right)\alpha. \end{aligned}$$

Then $U_{1,D}^2 \geq U_{1,C}^2$ if and only if $\alpha q\left(k_1, \overline{k}\right) \leq 1/2$ in (4).

(c) Case $(a_1^1, a_2^1) = (D, C)$. Then, $k_2 \geq \overline{k}$ and $a_2^2 = D$. Expected utilities of player 1 at period 2 are:

$$
\begin{aligned}
U_{1,C}^{2} &= r\left(k_1, \overline{k}\right)(3\alpha) + \left(1 - r\left(k_1, \overline{k}\right)\right) 0 \\
U_{1,D}^{2} &= r\left(k_1, \overline{k}\right)(1+\alpha) + \left(1 - r\left(k_1, \overline{k}\right)\right) 1.
\end{aligned}
$$

Then $U_{1,C}^{2} \geq U_{1,D}^{2}$ holds under condition (3).

At the first stage, we consider the following scenarios for player 1:

1. $k_1 < \overline{k}$. Then,

$$
\begin{aligned}
U_{1,D}^{1} &= G\left(\overline{k}\right)\left[3 + 1 + r\left(k_1, \overline{k}\right)\alpha\right] \\
&\quad + \left(1 - G\left(\overline{k}\right)\right)\left[2q\left(k_1, \overline{k}\right)(1+\alpha) + 2\left(1 - q\left(k_1, \overline{k}\right)\right) 1\right] \\
U_{1,C}^{1} &= G\left(\overline{k}\right)\left[2 + r\left(k_1, \overline{k}\right) 2\alpha + 3\right] \\
&\quad + \left(1 - G\left(\overline{k}\right)\right)\left[q\left(k_1, \overline{k}\right)(3\alpha + 1 + \alpha) + \left(1 - q\left(k_1, \overline{k}\right)\right)(0+1)\right].
\end{aligned}
$$

Then, $U_{1,D}^{1} \geq U_{1,C}^{1}$ is equivalent to (2).

2. $k_1 \geq \overline{k}$. In this case,

$$\begin{aligned}
U^1_{1,C} &= G\left(\overline{k}\right)\left[2r\left(k_1,\overline{k}\right)(2+2\alpha)+\left(1-r\left(k_1,\overline{k}\right)\right)2\left(1\right)\right] \\
&\quad +\left(1-G\left(\overline{k}\right)\right)\left[0+q\left(k_1,\overline{k}\right)3\alpha+1+q\left(k_1,\overline{k}\right)\alpha\right] \\
&= 1+3G\left(\overline{k}\right)+4r\left(k_1,\overline{k}\right)\alpha G\left(\overline{k}\right)-4q\left(k_1,\overline{k}\right)\alpha G\left(\overline{k}\right)+4q\left(k_1,\overline{k}\right)\alpha,
\end{aligned}$$

and

$$\begin{aligned}
U^1_{1,D} &= G\left(\overline{k}\right)\left[r\left(k_1,\overline{k}\right)(3+3\alpha)+\left(1-r\left(k_1,\overline{k}\right)\right)(3+0)\right] \\
&\quad +\left(1-G\left(\overline{k}\right)\right)\left[1+q\left(k_1,\overline{k}\right)\alpha+1+q\left(k_1,\overline{k}\right)\alpha\right] \\
&= 2+G\left(\overline{k}\right)+3r\left(k_1,\overline{k}\right)\alpha G\left(\overline{k}\right)-2q\left(k_1,\overline{k}\right)\alpha G\left(\overline{k}\right)+q\left(k_1,\overline{k}\right)\alpha.
\end{aligned}$$

Then, $U^1_{1,C} \geq U^1_{1,D}$ holds if (4) holds. ∎

5.3 Appendix 3: main data

Table A1: MAIN DATA

ident	*cont*	*out*	*in*	*ident*	*cont*	*out*	*in*
1	10	1	0	37		3	1
2	80	2	2	38	35	1	1
3		4	4	39		2	2
4	30	2	1	40	20	2	3
5		5	5	41		1	1
6	20	1	1	42	10	1	1
7		1	0	43	0	2	2
8	50	3	3	44	20	3	2
9	0	0	0	45	0	4	5
10		0	0	46	8	1	5
11	0	4	3	47		0	0
12	25	2	2	48		8	3
13	0	4	5	49		0	0
14	25	4	3	50	15	4	3
15		2	1	51		1	0
16	50	1	2	52		0	1
17	45	2	2	53	100	2	2
18	35	3	2	54	100	6	8
19	50	0	0	55		0	0
20	50	4	3	56	100	1	2
21	0	2	2	57		1	1
22		2	1	58		0	0
23	25	4	3	59		0	0
24	18	1	1	60	50	2	2
25	0	2	3	61	10	3	3
26	50	1	2	62		4	4
27		4	5	63	0	0	3
28	100	5	7	64	25	4	4
29	0	1	1	65	100	6	5
30	100	4	7	66	100	4	2
31		4	2	67	50	1	1
32		2	3	68	100	1	1
33	50	1	1	69	100	5	5
34		0	1	70	100	0	2
35	15	5	3	71	0	4	4
36	15	0	0				