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Nudging with heterogeneity in terms of environmental sensitivity : a public goods experiment in networks

Benjamin Ouvrard   Anne Stenger

Abstract

We propose an experiment to test whether the reaction to a nudge implemented in a network depends on the network structure and on the sensitivity of individuals to the environment. After having elicited the sensitivity of subjects to environmental matters, the subjects played a public goods game in a network. The first ten periods served as a baseline. A nudge (announcement of the socially optimal level of investment) was then implemented both under complete information (the content of the nudge takes individuals' position into account) and under incomplete information (the nudge cannot rely on individuals' positions). Nudge implementation induces a higher coordination on the social optimum in the circle network for the most sensitive subjects. In the star network, the targeted nudge induces a decrease in the level of investments for the least sensitive subjects. Thus, nudge implementation should target specific individuals in specific network structures.

Key-Words : environmental sensitivity; inequity aversion; networks; nudge; public goods experiment.

JEL Codes : C72, C91, H41, Q50.

1 Introduction

Whether our network is formal or not (club, association, neighborhood, etc.), our individual decisions are somehow and partly influenced by others' own decisions. The influence of an individual's network has received an increasing attention in the literature, in particular concerning cooperation among individuals to invest in local public goods such as a common garden, water quality of a lake, etc. (Allouch 2015, Bloch and Zenginobuz 2007, Bramoullé and Kranton 2007, Bramoullé *et al.* 2014, Sanditov and Arora 2016).

In this paper we are concerned with local public goods provision and how the influence of an individual's network determines its level. We focus on environmental local public goods because their provision may depend on individuals' interest for such goods. In particular, empirical evidence suggests that an individual's network influences pro-environmental decisions. Welsch and Kühling (2009) studied the determinants for adopting pro-environmental behaviors. Among the different factors (economic, cognitive, consumption in the past), the authors particularly focused on the impact of "reference persons" (peers, neighbors, etc.). They showed that the behavior of reference persons positively influenced individuals' purchases of organic food and green electricity. In another study, Cavalcanti *et al.* (2013) provided evidence that the more that fishermen are integrated into their social network, the more they participate in the development of environmental programs. The intuition is that when fishermen are highly integrated in a network, they do not want to harm their peers. Primmer *et al.* (2014) focused on the determinants of contracting ecosytem services for payment among Finnish forest owners. They showed that the perceived benefits on local members (neighbors, peer forest owners, etc.) increase the probability of contracting these services in the future. In sum, these articles reveal that economic agents are influenced by the behavior of their neighbors, and that this influence may be the result of mimecry or of a strategic response for the purpose of maintaining cooperation.[1]

Notwithstanding, even if agents participate in the provision of local public goods when they belong to a network, they invest less than the socially optimal level (Bramoullé and Kranton 2007, Bramoullé *et al.* 2014). The intuition is that agents do not consider the impact of their investments on the benefit of their neighbors in the network.

During the last decade, non-monetary incentives, and in particular nudges, have

[1]See also Kurz *et al.* (2007), McCallum *et al.* (2007) and Videras *et al.* (2012) for other examples.

been receiving a lot of attention for their potential to steer individuals to adopt pro-environmental behaviors. A nudge presents the advantage of being a simple, costless and non-coercive action with the objective to influence agents' decisions in a given direction (Thaler and Sunstein 2009). Encouraging results have been obtained in this field with nudge implementation, particularly when dealing with environmental concerns: energy savings (Allcott 2011, Costa and Kahn 2013, Ferraro and Price 2013), paper usage (Egebark and Ekström 2016), the adoption of new practices (Kuhfuss *et al.* 2016), etc. For instance, Allcott (2011) found a mean decrease of electricity consumption of around 2% using descriptive messages (the mean electricity consumption of similar neighbors was disclosed), emoticons and providing some advice to reduce electricity consumption. Similar results have been found by Costa and Kahn (2013) and Ferraro and Price (2013).

The objective of this paper was to test whether the efficiency of a nudge implemented to increase the total level of investments for environmental quality with individuals within a network depends: (i) on the sensitivity of individuals to environmental matters; and (ii) on the structure of the network. Point (i) is a direct test of the results obtained in the field by Welsch and Kühling (2009), Cavalcanti *et al.* (2013) and Primmer *et al.* (2014). Point (ii) is less obvious and require some explanation. As emphasized in Bramoullé and Kranton (2007), depending on the structure of the network under consideration, at the social optimum some individuals may contribute more than others. If the regulator has complete information on the position of each individual, then he can nudge them with private messages. However, under incomplete information (the regulator knows the structure of the network, but does not know the position of each individual), then the use of private nudge (as emphasized by Sunstein 2013) is not possible anymore. On the opposite, in some structures (such as the complete and the circle networks), at the social optimum, individuals should all contribute the same. Then, incomplete information is not, *a priori*, a concern for those structures.

Even if the present paper focuses on environmental concerns, we believe that the same framework could be applied to more general questions considering, for instance, individuals' interests in the public good.

We thus proposed a laboratory experiment with similarities to the experiment of Rosenkranz and Weitzel (2012). These authors wanted to test the theoretical predictions obtained by Bramoullé and Kranton (2007) on the Nash equilibria in different networks (complete, circle, star, line). However, differently from these authors, we first elicited the environmental sensitivity of the subjects in order to construct networks with subjects sharing the same sensitivity to environmental matters, to test whether we observe the same results as in the previously quoted papers. In this paper, we define environmental sensitivity as the way individuals take into account the impact of their actions on environmental quality. In addition, contrary to Rosenkranz and Weitzel who focused on the study on Nash equilibria, we allowed the subjects to invest the socially optimal solution.[2] Moreover, our subjects were limited to one structure only (circle or star network) to avoid learning. Finally, our protocol differs from that of Rosenkranz and Weitzel (2012) because our subjects first played a series of ten periods without external incentives, and then another series of ten periods under nudge implementation.

We decided to focus on nudges instead of a tax, for instance, because it appears as an easier tool to implement, cost-wise and logistically speaking. Indeed, in the real word, tax implementation incurs an important cost to society whereas a nudge,while it may be costly as well, may involve less monetary commitments on the part of the regulatory institution as compared to levying a tax.

The rest of the paper is organized as follows. We consider related papers in Section 2. We then briefly state the hypotheses we want to test in Section 3. In Section 4, we detail the protocol of the experiment. The results are presented in Section 5. In Section 6, we focus on the determinants of the probability of coordinating on the Nash equilibrium. Finally, Section 7 contains a discussion and a conclusion.

2 Related literature

In this section, we present the different aspects of research related to the question in this paper. The key ideas mainly rely on the way agents can cooperate within a network, taking the nature of the game, the type of incentive and the form of the network into account. Furthermore, the nature and the implementation of the nudge are important to consider. The way the network is formed can then affect the agent's behavior.

First, our experiment is similar to previous experiments focusing on cooperation in

[2]In Rosenkranz and Weitzel (2012), the subjects' investments could not exceed the Nash equilibrium level.

networks due to the nature of the game we study (voluntary investment in a local public good). Choi *et al.* (2008) proposed an experiment in which individuals form groups of three, and each subject can observe the actions of his/her neighbors at the end of each period (complete network). The authors also considered different values of the public good (high and low). They showed that, for a given time period, the provision rate of the public good is significantly higher when the value of the public good is high compared to the case when it is low. Moreover, the provision rate of the public good is higher in dynamic games[3] than in one-shot games. In another experiment, Choi *et al.* (2011) compared different forms of networks (empty, line, star, one link) with the complete network studied in Choi *et al.* (2008). Moreover, they studied directed and non-directed networks.[4] They showed that the level of cooperation is highly dependent on the form of the network. The lowest rate of cooperation is observed in the empty network, while the highest rate of cooperation is observed in the star network.[5] They also make the distinction between two kinds of behaviors: strategic commitmment and strategic delay.[6] They show that strategic commitment is more likely to be observed in directed networks with uninformed subjects (some can observe the behavior of others, but those who are observed cannot observe the behavior of the observer). Symmetrically, strategic delay is more likely to be observed with informed subjects. Finally, Rosenkranz and Weitzel (2012) provide an experimental test of the theoretical model proposed by Bramoullé *et al.* (2007). In particular, they show that individuals may coordinate on Nash equilibria, but it depends on the shape of the networks. They obtain a higher rate of coordination both in the complete and the star networks. The complete network is characterized by a low centrality (no subject concentrates the number of links) and a high density (each subject has a large number of direct neighbors). The star network is defined by the opposite properties: a high centrality (one individual concentrates the whole neighborhood) and a low density.

[3]In dynamic games, the game was played for three periods.

[4]A network is said to be directed if the links between individuals work in one direction. For instance, individual A can observe individual B, but individual B cannot observe individual A.

[5]The star network allows the middle player to observe the behavior of the peripheral players.

[6]The first behavior characterizes the "tendency for subjects in certain network positions to make contributions early in the game in order to encourage others to contribute". The second behavior characterizes the "tendency for subjects in certain network positions to delay their decisions until they have observed a contribution by a subject in another position" (Choi *et al.* 2011).

Second, our experiment is also related to experiments on agglomeration bonus scheme due to the type of our incentive. In the environmental context, the agglomeration bonus scheme has the objective of linking agents' payments according to their neighbors' behaviors. A bonus is given to forest or agricultural landowners conditional on the adoption of conservation activities by their neighbors and themselves. In a laboratory experiment, Banerjee *et al.* (2012) studied the spatial coordination of landowners, varying the size of the group (six or 12 players). They focused on groups located in a circle network.[7] The authors showed that subjects more often succeeded in coordinating on the socially optimal outcome when the group size was small compared to a larger group size. In a similar experiment (still focusing on the circle network), Banerjee *et al.* (2014) studied the effect of information provision about the behavior of direct and indirect neighbors on the performance of the agglomeration bonus scheme. They reported that providing the subjects with such information increases the emergence of socially optimal outcomes. However, it is worth noting that these authors also highlight that, over time, information provision is no longer efficient since the subjects turn to risk-dominant outcomes. Finally, Banerjee *et al.* (2017), still using a similar experiment, varied the transaction costs (high and low), and allowed for communication between neighbors (circle network). The authors reported that less coordination on the socially optimal outcome is observed when the transaction costs are high. However, even in the case of low transaction costs, full coordination at the level of a network is seldom observed. Instead, the authors observe local coordination. Moreover, Banerjee *et al.* showed that (costly) communication between neighbors significantly improve the performance of the agglomeration bonus scheme. Our experiment differs from these in that we do not vary the size of the network, and our subjects were not allowed to communicate. Moreover, contrary to these experiments, we also considered the star network.

Third, our experiment is related to those in which the nature and the implementation of nudges are studied. In a common pool resource game, Delaney and Jacobson (2016) implemented normative messages to reduce the extraction of resources. In particular, they compared informative messages (informing those over-extracting to reduce their extraction level) with normative ones (in which the monetary gains of those over-extracting were compared with those who were extracting in an optimal way). The highest decrease

[7] Each player has two direct neighbors: one on the right and one on the left.

in the extraction was observed under normative message implementation. Contrary to these authors, Boun My and Ouvrard (2017) considered neutral messages to increase the level of investments in an environmental public goods game. In their experiment, the level of pollution was stochastic, and subjects could invest tokens to reduce the damage from pollution. Their choice of neutral messages was chosen for ethical considerations. We assumed their point of view in this experiment. In another experiment, Lefebvre and Stenger (2016) considered a different nudge (approval/disapproval points) to give incentives to subjects to invest in a public good.[8] They obtained the highest level of investments under approval points implementation.

Finally, our experiment differed from those focusing on network formation (Corbae and Duffy 2008, Goeree *et al.* 2009, Corten and Buskens 2010)[9] because we considered that the network was exogenous. Indeed, in our setting, groups of individuals (neighborhood, professional networks) are already formed and we are not interested in their formation. We want to capture the effect of nudges in fixed groups. Our experiment also differs from coordination games (Keser *et al.* 1998, Berninghaus *et al.* 2002, Cassar 2007) because coordination games require subjects to coordinate on an efficient strategy. Subjects have no incentive to free-ride and to choose another action. It would lower their profit. However, cooperation games require subjects to cooperate to achieve a common objective. In that case, subjects have incentives to free-ride.

3 Behavioral hypotheses

Before discussing the design of our experiment, we formulate the hypotheses we test in this paper. The model is based on the one proposed by Bramoullé and Kranton (2007).

We consider an economy with n agents in a fixed network involved in the supply of a local public good (common garden, water quality of a lake or river, etc.). Agents can voluntarily invest in a local public good, at a constant marginal cost c. Agent i's level of investment is denoted as x_i, $x_i \in \mathbb{R}^+$. In the network, agents i and j are direct neighbors if a link exists between them: $g_{ij} = 1$. In that case, agent j benefits from the

[8] Approval/disapproval points were also considered by Masclet *et al.* (2003), Rege and Telle (2004) and Dugar (2010, 2013).

[9] Overall, these authors show that subjects create new links with other subjects (and thus create a network) when the others tend to act in a similar way.

investment made by agent i, and conversely.[10] Note that agent i benefits from his/her own investment: $g_{ii} = 1$. If agent j is not a direct neighbor of agent i, then $g_{ij} = 0$, and agent j cannot benefit from the investment made by agent i. The set of agent i's direct neighbors is N_i, where $N_i = \{j \in N \setminus i : g_{ij} = 1\}$, and his/her total number of direct numbers is given by k_i, the cardinal of the set N_i.

The voluntary investments benefit the agents according to the concave benefit function $f(X)$, where $X = \sum_{i=1}^{N_i} x_i$. The agent's total utility is thus:

$$U_i(x_i) = f\left(x_i + \sum_{i \in N_i} x_j\right) - cx_i \tag{1}$$

In this paper we are interested in the study of social optimum. Let us consider the following utilitarian welfare function:

$$W(\mathbf{x}) = \sum_{i \in N} f\left(x_i + \sum_{j \in N_i} x_j\right) - \sum_{i \in N} cx_i \tag{2}$$

where $\mathbf{x} = (x_1, ..., x_n)$ is the profile of contributions. The first-order condition is given by

$$f'\left(x_i + \sum_{j \in N_i} x_j\right) + \sum_{j \in N_i} f'\left(x_j + \sum_{l \in N_j} x_l\right) - c = 0 \tag{3}$$

We focus on the circle and the star networks (see Fig. 1). Other structures exist such as the complete and the line networks. The complete network is similar to the circle one because in both structures all individuals have the same number of direct neighbors (preferences are homogeneous). Thus, evaluating Eq. (3) for each individual we obtain a symmetric system of equations, and the social optimum may be implemented with symmetric investments. The line network is similar to the star network because some individuals have more direct neighbors than other individuals in the network (as those in the periphery for instance). Then, evaluating Eq. (3) for each individual we do not obtain a symmetric system of equations anymore. Bramoullé and Kranton (2007) emphasize that the individual in the center should be the only one investing at the social optimum because when he/she invests, his/her investments benefit to the entire network (contrary to individuals in the periphery).

Knowing that the Nash equilibrium level of investments is lower than the socially optimal one, we consider the implementation of a nudge consisting of the announcement

[10] We consider non-directed links: $g_{ij} = g_{ji}$.

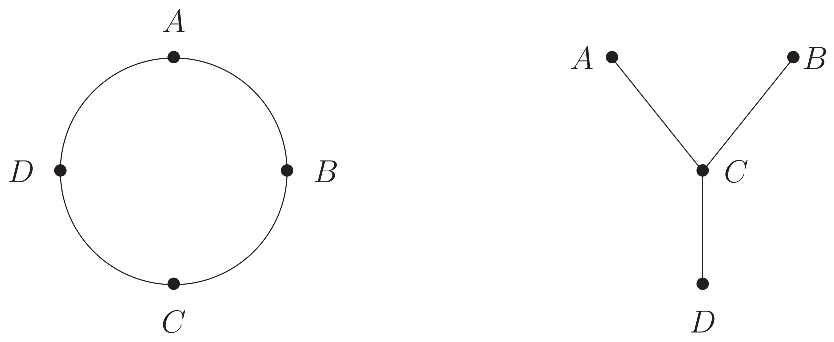

Figure 1: Circle and star networks.

of the socially optimal level of investment for a given agent.[11] Moreover, it may be difficult for agents to coordinate on one equilibrium due to the multiplicity of Nash equilibria. Thus, the second objective of the nudge is to reduce strategic uncertainty (Van Huyck *et al.* 1990).

In particular, we consider nudge implementation both under complete and incomplete information. Under complete information, the regulator knows each individual's position in the network. Thus, it is possible to adapt the content of the nudge depending on agents' position in the network. On the contrary, under incomplete information, it is not possible to make the content of the nudge dependent on the agent's position, because the regulator only knows the structure of the network (circle or star) and does not know his/her exact position inside the network. We thus consider that the regulator implements the same nudge for everyone (the content is the same). As emphasized previously, incomplete information is not a concern for the circle network (everyone has the same number of direct neighbors), contrary to the star network. Our strategy is to target the individual in the center under complete information for efficiency reasons: this is the only individual who shoud contribute at the social optimum (Bramoullé and Kranton 2007).

Finally, considering the results obtained by Welsch and Kühling (2009), Cavalcanti *et al.* (2013) and Primmer *et al.* (2014), we may expect that networks of individuals with a high sensitivity to the environment react the most to the nudge. The intuition is that it would be less "costly" for individuals with a low sensitivity to environmental matters to deviate from the announcement (they would suffer less than individuals with a high

[11] Agents underinvest because they do not take the impact of their investment on the benefit of their direct neighbors into account when solving their private program.

sensitivity).

Hypothesis 1: Under complete and incomplete information, the total level of investments increases following nudge implementation in both types of networks, provided that the environmental sensitivity of the individuals is high enough.

In the circle network, our nudge suggests the same level of investment to each individual, contrary to the star network (it suggests to the individual in the center to invest his/her ten tokens, while those in the periphery should not invest). We thus propose the following hypothesis:

Hypothesis 2: The nudge induces more coordination on the social optimum in the circle network than in the star network.

Indeed, on the basis of the results of Keser and van Winden (2000) and Fischbacher *et al.* (2001), who showed that subjects are (imperfect) conditional cooperators in public goods game, we may indeed expect that suggesting to some individuals to invest more than others may reduce their willingness to invest if the *so-called* others do not.

Finally, the different models proposed so far on voluntary investments in a local public goods in network (Allouch 2015, Bloch and Zenginobuz 2007, Bramoullé and Kranton 2007, Bramoullé *et al.* 2014) do not integrate psychological dimensions that can explain the agent's behavior. More precisely, Bramoullé and Kranton (2007) and Bramoullé *et al.* (2014) focus on the study of Nash equilibria (what they expect to observe). However, agents are not necessarily the perfect utility maximizers we generally expect them to be. Inequity aversion (Fehr and Schmidt 1999, Teyssier 2012) may also be a determinant to explain why the subjects do not necessarily free ride when investing in public goods, thus explaining why it may be difficult for the subjects to coordinate on one equilibrium.

Hypothesis 3: Inequity aversion is a determinant of a subject's decision to invest in the public good.

These different hypotheses in the experiment proposed in the next section.

4 Experimental design

The experiment was conducted in February 2017 at the Laboratory of Experimental Economics of Strasbourg (LEES).[12] On average, sessions were completed in 70 minutes, including payment of the subjects.

At the beginning of the experiment, the subjects randomly picked a number in order to assign them to a computer. The instructions were then read aloud, informing the subjects that they would participate in an economic experiment with five independent stages and with the final earnings being the sum of their earnings at each stage. The subjects did not receive any feedback on their earnings before the end of the experiment: everything was determined at the end of the fifth stage. In the event subjects had a question, an experimenter answered them individually.

The five stages of this experiment are detailed below. The order of the protocol was chosen so that the most difficult tasks from a cognitive point of view were carried out last.

4.1 First stage: General Ecological Behavior (GEB) scale

To determine the subjects' environmental sensitivity, we first implemented the General Ecological Behavior (GEB) scale (Davis *et al.* 2009, 2011).[13] This questionnaire measures to what extent a given individual takes into account the environment when undertaking an action (in different aspects of his/her life). The subjects had to complete a questionnaire of 28 items (detailed in the Appendix), with five possible answers for each of them: "never", "seldom", "sometimes", "often" and "always", scored from 1 for "never" to 5 for "always".[14]

The mean score of the first session (M=103) was used for the other sessions to determine whether the subjects were little or highly sensitive to the environment. The subjects with a score higher than the mean were the most sensitive to environmental matters, and conversely for those below the mean. For the analysis of this experiment, those that were

[12] The program for this experiment was designed by Kene Boun My with the web platform EconPlay (www.econplay.fr).

[13] Boun My and Ouvrard (2017) adopted the same strategy to create groups of subjects with the same environmental sensitivity.

[14] The opposite code was implemented for the 11 unecological items.

the least sensitive to environmental matters were considered as A players, while the most sensitive were considered as B players. They were asked to answer honestly, and were paid 3 euros for this stage. The subjects did not know that their answers to this questionnaire would help us to construct networks with subjects that shared the same environmental sensitivity in the fourth stage.

4.2 Second stage: Advantageous inequity aversion

We implemented a modified dictator game to elicit the subjects' advantageous inequity aversion, following Blanco *et al.* (2011) and Teyssier (2012). The subjects successively played the role of *receiver* and *dictator*, without knowing which role the computer would randomly allocate them at the end of the experiment.

As a receiver, the subjects first chose whether to opt out of the game and to immediately receive 5 points, or to play the game. As a dictator, they had to determine a distribution between the receiver and themselves. More precisely, they had 21 decisions to make between two options (presented as lists). In the left option, the distribution was always 18 points for the dictator and 2 points for the receiver, denoted as (18;2). In the right option, a menu of equal distributions was presented in increasing order: in the first line, the distribution was 0 point each (denoted as (0;0)), whereas it was 20 points each in the last line (denoted as (20;20)).

At the end of the experiment, each dictator was randomly matched with a receiver, and they received the corresponding payoff. The conversion rate was 1 point = 0.25 euro.

4.3 Third stage: Disadvantageous inequity aversion

In the third stage, we determined the subjects' disadvantageous inequity aversion with an ultimatum game (Blanco *et al.* 2011, Teyssier 2012).

The subjects played this game as an *X player* (sender), and then as a *Y player* (responder). Similarly to the previous stage, they knew that they would play these two roles, and that the computer would randomly determine their role at the end of the experiment. Once their role was determined, they were matched with a corresponding partner: if they were an X player, they were matched with a Y player (and conversely).

As an X player, the subjects had to determine how to share an amount of 20 points between the Y player and themselves. Then, as a Y player, the subjects faced a list of

21 repartitions between the X player and themselves, starting from (20;0) - *i.e.*, 20 points for the X player and 0 for themselves - to (0;20) - *i.e.*, the opposite repartition. For each repartition, the subjects had to choose to "Accept" (left option) or to "Reject" (right option) the proposition. Obviously, they did not know the proposition made by the X player. Moreover, they knew that if they chose to "Reject" the proposition made by the X player, then both of them would earn nothing for this task. The rate of conversion was the same as for the previous stage (1 point = 0.25 euro).[15]

4.4 Fourth stage: Local public goods game

For this stage, subjects were randomly assigned to fixed groups of four individuals. Depending on their results with the GEB scale, we formed groups of A players only, and groups of B players only to directly compare groups with a different environmental sensitivity (with a random repartition of the subjects). Note that the subjects were not aware of the way we formed the groups.[16]

The subjects played a ten period public goods game in one structure only (circle or star network). They were given a fixed amount of ten tokens that could be invested in an environmental account to improve environmental quality. We explained in the instructions that tokens invested in the environmental account would benefit the subjects and their direct neighbors only. Using examples (with visual illustrations following Fig. 1), we emphasized that tokens invested in this account would not necessary benefit the entire group (for those in the circle network or in the periphery of the star network). The subjects knew that the non-invested tokens would be lost at the end of each period.

Subjects' earnings were given by the following payoff function:

$$\pi_i = 3 + 4ln\left(1 + x_i + \sum_{N_i} x_j\right) - x_i \tag{4}$$

where x_i was the subject i's investment, and $\sum_{N_i} x_j$ the sum of the investments made by his/her direct neighbors.[17]

The Nash equilibrium was $X^{NE} = 3$ tokens. In the circle network, the socially optimal profile of investments was such that each subject should invest $x^* = 4$ tokens. In the star

[15] We used the same wording as for the previous stage, and talked about "points" to be shared.

[16] For instance, in groups of A players, the subjects did not know that they were part of a group with a low sensitivity to environmental matters.

[17] Rosenkranz and Weitzel (2012) also implemented a logarithmic payoff function.

network, it was such that the individual in the center should invest $x^* = 10$ tokens, while the individuals in the periphery should not invest. We gave the subjects a table for their payoff (expressed in ECU), depending on their level of investment and the one of their direct neighbors. The rate of conversion was 1 ECU = 0.50 euro.[18]

In Rosenkranz and Weitzel (2012), the subjects could invest between 0 and 1, with two decimals. Contrary to them, we did not focus on Nash equilibria but on the social optimum. This is why we allowed the subjects to invest up to 10 tokens.

At the end of each period, the subjects received feedback on the total level of investment of their direct neighbors, as well as their gain for the period. To provide sufficient incentive, they knew that one period out of ten would be randomly selected at the end of the experiment to determine their earnings for this stage.

4.5 Fifth stage: Local public goods game with nudge implementation

For the last stage, we informed the subjects that they would play the same game as in the previous one (with the same conversion rate), except that a piece of information would be disclosed on their screen at the beginning of each period (before they made their decision). To limit demand effects (Zizzo 2010), we reminded the subjects that their decisions would be anonymous. Moreover, the sessions were conducted by an experimenter who was not a teacher at the university.

In the circle network, the subjects could read the following message on their screen:

“ *If each subject participates by investing 4 tokens in the environmental account, then the whole group may benefit from the highest environmental quality* ”

In the star network, we implemented two different messages in order to test the first and the second hypotheses of the previous section (corresponding to two different treatments).[19] We first considered a non-targeted (N.T) message, *i.e.*, the content was the same for everyone:

[18]Contrary to the two previous stages, we did not use the term “point” but “ECU” since the conversion rate was not the same.

[19]The subjects played in one treatment only.

“ *If the player C participates by investing 10 tokens in the environmental account, then the whole group may benefit from the highest environmental quality* ”

with Player C being the player in the center of the star network (Fig. 1). This message was implemented to mimic a situation of incomplete information from the regulator's point of view (he has no knowledge of the individuals' exact positions in the network).

Second, we considered targeted (T.) messages, corresponding to messages in which the content varied depending on individuals' positions in the network (to mimic a situation of complete information from the regulator's point of view). Individuals in the periphery (players A, B and D) could read the following message on their screen:

“ *If you choose not to invest in the environmental account, then the whole group may benefit from the highest environmental quality. Indeed, your investment would be redundant with the one of player C* ”

while player C could read:

“ *If you participate by investing 10 tokens in the environmental account, then the whole group may benefit from the highest environmental quality* ”

A summary of the different steps of this public good game is presented in Table 1.

Table 1: Summary of the fourth and fifth stages.

	Circle		**Star**		
	Periods 1-10	Periods 11-20	Periods 1-10	Periods 11-20	Periods 11-20
Groups A	baseline	nudge	baseline	non-targeted nudge	targeted nudge
Groups B	baseline	nudge	baseline	non-targeted nudge	targeted nudge

5 Results

In this section, we describe the results we obtained. A total of 144 subjects participated in the six sessions that were conducted (with 54.86% of females and 63.89% of students in economics). On average, the subjects earned 16.37 euros (with a standard deviation of 3.06 euros). We obtained six groups of subjects differing in their environmental sensitivity (*i.e.*, groups composed of A and B players) that we did not take into account in the analysis below. We thus considered a total of 120 subjects.

5.1 Environmental sensitivity and inequity aversion

We first focus on the study of subjects' environmental sensitivity and inequity aversion (both advantageous and disadvantageous). We then compare the results we obtained with other studies in which these tests were implemented (Blanco *et al.* 2011, Teyssier 2012).

Environmental sensitivity

Concerning the measurement of environmental sensitivity, the mean score per item (a total of 28 items) was 3.61 (SD = 0.72). The GEB scale was found to be acceptable ($\alpha = 0.73$). With the same scale, internal reliability in other studies was 0.76 in Davis *et al.* (2009), 0.75 in Davis *et al.* (2011) and 0.74 in Boun My and Ouvrard (2017). Consequently, we cannot reject the hypothesis that this questionnaire measured only one dimension (environmental sensitivity).

Inequity aversion

The procedure to compute the coefficients for advantageous and disadvantageous inequity aversion is detailed in the Appendix.

The distribution of the coefficients α (disadvantageous inequity aversion) and β (advantageous inequity aversion) is displayed in Fig. 2. On the basis of a Spearman correlation test, the coefficients α and β are not significantly correlated ($\rho = -0.071$, $p - value$=0.440). This result is in line with those obtained in Teyssier (2012), but not with those in Blanco *et al.* (2011).

5.2 Do subjects increase their level of investment under nudge implementation?

The level of investment, per network, is presented in Table 2. Groups of B players (the most sensitive) systematically invest more than groups of A players, regardless of the network and the sequence of the public goods game.

Non-parametric tests on the mean investments at the level of the network were conducted. We start with the circle network. For each type of player, we did not find significant differences in the level of investments between periods 1-10 and 11-20 (Wilcoxon signed rank test, *p-value* = 1.00 for A players, and *p-value* = 0.313 for B players). It

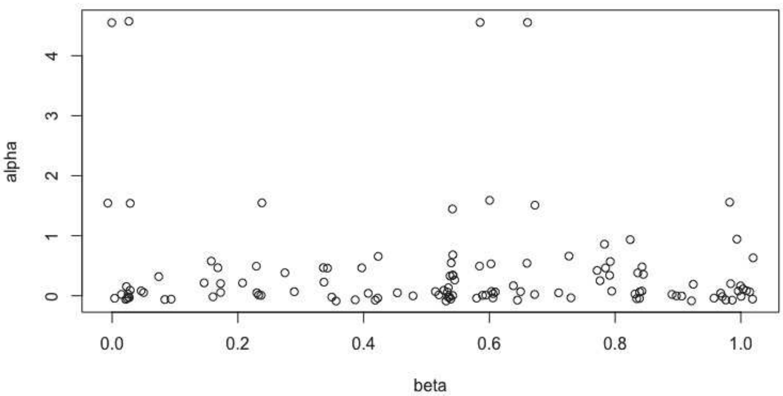

Figure 2: Joint distribution of the values of the coefficients alpha and beta (inequity aversion).

Table 2: Mean investment per network and per treatment (standard deviation in parenthesis).

	Circle		Star		
	1-10	11-20	1-10	11-20 (N.T.)	11-20 (T.)
Groups A	7.88	7.98	8.32	8.26	7.50
	(2.67)	(3.98)	(4.27)	(2.71)	(4.31)
	4 groups		**11 groups**	**5 groups**	**6 groups**
			(5 gr. N.T. + 6 gr. T.)		
Groups B	11.48	10.87	9.39	10.32	8.45
	(4.87)	(3.92)	(3.53)	(5.10)	(3.37)
	6 groups		**9 groups**	**5 groups**	**4 groups**
			(5 gr. N.T. + 4 gr. T.)		

therefore seems that the nudge does not induce higher investments from the subjects. Moreover, it is worth noting that both before and during nudge implementation, groups of B players significantly invested more than groups of A players (Mann-Whitney Wilcoxon rank sum test, *p-value* = 0.043 during periods 1-10, and *p-value* = 0.087 during periods 11-20). This result may appear to be surprising given that B players had the same payoff function as A players (they did not have any monetary incentives to invest more). This could be explained by the difference in environmental sensitivity, as emphasized by the analysis of individual decisions (see below). This result corroborates the observations made by Welsch and Kühling (2009), Cavalcanti *et al.* (2013) and Primmer *et al.* (2014).

Considering the star network, the one significant effect was a decrease in the level of investments for groups of A players following targeted nudge implementation (Wilcoxon signed rank test, *p-value* = 0.063 for A players, and *p-value* = 1.00 for B players). Non-targeted nudge implementation had no significant effect in comparison to the baseline for both types of players (Wilcoxon signed rank test, *p-value* = 0.625 for A players, and *p-value* = 1.00 for B players). In the baseline, we did not find any significant difference between groups of A and B players (Mann-Whitney Wilcoxon rank sum test, *p-value* = 0.159). This result does not change under nudge implementation since there are no significant differences between groups of A and B players either under targeted or non-targeted nudge implementation (Mann-Whitney Wilcoxon rank sum test, *p-value* = 0.241 with the targeted nudge, and *p-value* = 0.209 with the non targeted one).

Finally, we compare the levels of investments between the circle and star networks. In the baseline, there is no significant difference between structures (Mann-Whitney Wilcoxon rank sum test, *p-value* = 0.896 for A players, and *p-value* = 0.175 for B players). As for periods 11-20, the only significant difference is between the circle and the star with B players under targeted nudge implementation (Mann-Whitney Wilcoxon rank sum test, *p-value* = 0.043). [20]

These observations lead to the following result:

Result 1: (a) Nudge implementation seems to be most suited for circle networks since a decrease in the level of investments is observed with the targeted nudge in the star network (A players).

(b) Nudge implementation does not lead to an increase in the level of investments.

Contrary to our hypotheses, an increase in the level of investments is not observed (Point (b)). Notwithstanding, this result is not surprising for B players since we observed that they invested at higher levels than A players. Overall, **Hypothesis 1** is only partially validated because we do not observe an increase in investments from B players.

Even if the level of investments does not vary under nudge implementation, we may observe a change in the profile of investments. This possibility is analyzed in the next subsection.

[20]For A players (circle vs star): *p-value* = 0.748 (targeted nudge) and *p-value* = 0.902 (non-targeted nudge). For B players: *p-value* = 0.583 (non-targeted nudge).

5.3 Does nudge implementation lead to more coordination?

Following Rosenkranz and Weitzel (2012), we now study local coordination. Contrary to these authors, we also studied local coordination on the social optimum in addition to the one on Nash equilibria, since we allowed the subjects to invest at the socially optimal level. Note that we did not focus on any form of global coordination because it would not be relevant for the analysis, given that such coordination did not occur often.

5.3.1 Local coordination on the Nash equilibrium

On the basis of the predictions from the function chosen for the monetary payoffs, a subject is said to be in a local equilibrium if the sum of his/her investment and of the investments of his/her direct neighbors is equal to 3, or if he/she does not invest and the sum of his/her direct neighbors investments is greater than or equal to 3.

The mean number of local coordinations on the Nash equilibrium per type of group and per treatment is given in Table 3.

Table 3: Mean number of local coordination on the Nash equilibrium per network and per treatment.

	Circle		Star		
	1-10	11-20	1-10	11-20 (N.T.)	11-20 (T.)
Groups A	0.725	0.875	1.136	1.82	1.40
Groups B	0.767	0.583	1.20	1.36	1.25

In the circle network, we observed two opposite dynamics: A players seem to coordinate their actions more on the Nash equilibrium under nudge implementation, and the contrary is true for B players. However, these are not significant differences (Wilcoxon signed rank test, *p-value* = 0.423 for A players, and *p-value* = 0.361 for B players). Moreover, we did not observe any significant difference between the two types of groups (Mann-Whitney Wilcoxon rank sum test, *p-value* = 0.915 for periods 1-10, and *p-value* = 0.387 for periods 11-20).

In the case of the star network, it seems that nudge implementation increases the number of local equilibria on the Nash equilibrium. However, only the targeted nudge induces a significant increase with A players in comparison to the baseline (Wilcoxon signed rank test, *p-value* = 0.063 with a targeted nudge, and *p-value* = 0.125 with a non-targeted nudge). We did not observe any significant differences with B players (Wilcoxon signed rank test, *p-value* $= 0.875$ with a targeted nudge, and *p-value* $= 0.201$ with a non-targeted nudge). Note that there are no significant differences between groups of A and B players either before and during nudge implementation (Mann-Whitney Wilcoxon rank sum test, *p-value* $= 0.879$ for periods 1-10, *p-value* $= 0.593$ with a targeted nudge, and *p-value* $= 0.599$ with a non-targeted nudge).

Finally, we compared structures. Surprisingly, there were no significant differences in the number of local coordinations on the Nash equilibrium between the circle and the star networks during the baseline (Mann-Whitney Wilcoxon rank sum test, *p-value* $= 0.238$ for A players, and *p-value* $= 0.214$ for B players). Similarly, non-targeted nudges did not induce significant differences between these two structures (Mann-Whitney Wilcoxon rank sum test, *p-value* $= 0.138$ for A players, and *p-value* $= 0.117$ for B players). However, targeted nudge implementation did induce a significant difference (Mann-Whitney Wilcoxon rank sum test, *p-value* $= 0.037$ for A players, and *p-value* $= 0.087$ for B players).

Result 2: The targeted nudge (star network) is the only nudge leading to more coordination on the Nash equilibrium for A players, in comparison to the baseline.

This result seems to corroborate **Hypothesis 2**. As discussed in Section 7, it seems to indicate that such a nudge is best suited for the circle network. Moreover, this observation is in line with the previous result: the subjects did not increase their level of investment in the star network because they coordinated more on the Nash equilibrium.

5.3.2 Local coordination on the social optimum

We now focus on the study of local coordination on the social optimum. In a circle network, individuals are (locally) coordinated on the social optimum if their two direct neighbors and themselves invest exactly four tokens each. In a star network, such a local coordination is considered if, individuals in the periphery, do not invest while, the individual in the center invests ten tokens. For the individual in the center, all individuals in the periphery should not invest, whereas he/she invests ten tokens.

The mean number of local coordinations on the social optimum per type of group and per treatment is given in Table 4.

Again, two different dynamics are observed in the circle network: A players did not seem to coordinate much on the social optimum under nudge implementation, whereas B

Table 4: Mean number of local coordination on the social optimum per network and per treatment.

	Circle		Star		
	1-10	11-20	1-10	11-20 (N.T.)	11-20 (T.)
Groups A	0.000	0.025	0.036	0.060	0.150
Groups B	0.033	0.750	0.022	0.040	0.050

players did. For B players, this increase is a significant one (Wilcoxon signed rank test, *p-value* = 0.036, and *p-value* = 1.00 for A players). Moreover, before nudge implementation, A and B players did not significantly differ whereas they did during periods 11-20 (Mann-Whitney Wilcoxon test, *p-value* = 0.540 for periods 1-10, and *p-value* = 0.017 for periods 11-20).

As expected from the previous analysis, no significant differences were observed in the star network following targeted (Wilcoxon signed rank test, *p-value* = 0.588 for A players, and *p-value* = 1.00 for B players) and non-targeted nudge implementations (Wilcoxon signed rank test, *p-value* = 1.00 for A players, and *p-value* = 1.00 for B players). Moreover, the dynamics for A and B players did not differ (Mann-Whitney Wilcoxon test, *p-value* = 1.00 for periods 1-10, *p-value* = 0.180 with a targeted nudge, and *p-value* = 1.00 with a non-targeted nudge).

Finally, the dynamics between structures (circle and star) were also exacerbated both for A players (Mann-Whitney Wilcoxon test, *p-value* = 0.074 with a targeted nudge, and *p-value* = 1.00 with a non-targeted nudge) and B players (Mann-Whitney Wilcoxon test, *p-value* = 0.023 with targeted nudge, and *p-value* = 0.011 with non targeted nudge). They were not exacerbated during periods 1 to 10 (Mann-Whitney Wilcoxon test, *p-value* = 0.651 for A players, and *p-value* = 0.842 for B players).

Result 3: In the circle network, nudge implementation leads to more coordination on the social optimum for B players.

Thus, even if we did not observe an increase in the level of investments for the most sensitive subjects (B players), we cannot reject the hypothesis that their investments were made in a more efficient way because they coordinated more on the social optimum. As a consequence, **Hypothesis 2** is validated for B players.

5.4 Individual decisions

Following Rosenkranz et Weitzel (2012), we analyzed individual decisions concerning their investments with Tobit regressions. We separated them for the circle and the star networks. The results are reported in Table 5.

The explanatory variables are: $Neighbors_{t-1}$, capturing the total level of investment of an individual's direct neighbors in the previous period; *Period*, to capture the trend in time; $Nb.Neighbors$, for the number of direct neighbors (only for the star network); and $T2$ a dummy for the treatment with a non-targeted nudge.

The following psychological variables were also included: α, corresponding to disadvantageous inequity aversion; β, for advantageous inequity aversion; and *Sensitivity*, a dummy for subjects' environmental sensitivity.[21]

Finally, socio-economic variables were included in addition to a variable for subjects' *Gender* (not reported here since the corresponding coefficients are not significant): *Age*; a dummy *Background* to capture whether subjects are studying economics; $Conf.friends$ and $Conf.work$ to capture subjects' confidence towards their friends and their work colleagues, respectively (this last variable is not reported since the corresponding coefficient is never significant); *Activity*, which is a dummy that takes the value of 1 if the subject is a member of an association (charitable, sportive, religious, political); and $Influence$, which is a dummy that takes the value of 1 if the subject is influenced in his/her daily life by the values of the association.

Except for the star network under nudge implementation, subjects' environmental sensitivity is always a positive and significant determinant of their decisions (as emphasized in the previous subsections). In their environmental public goods experiment, Boun My and Ouvrard (2017) obtained a similar result. This may be explained by the fact that subjects have a greater interest in the environment. In the circle network, a student's background is also a positive and significant determinant of his/her investment (both before and during nudge implementation). Surprisingly, subjects' age is also a positive and significant determinant of their decision to invest in the circle network during periods 1-10. During periods 11-20, both the period and the subjects' confidence towards their friends

[21] We included the two variables for inequity aversion because we found that they were not significantly correlated.

Table 5: Tobit estimation of individual investments.

	Circle		Star	
	(1-10)	(11-20)	(1-10)	(11-20)
Variable	Coeff. (S.E)	Coeff. (S.E)	Coeff. (S.E)	Coeff. (S.E)
Neighbors$_{t-1}$	-0.031	0.001	-0.053	-0.055
	(0.123)	(0.052)	(0.107)	(0.057)
Period	-0.111	-0.140*	-0.158***	-0.208***
	(0.092)	(0.074)	(0.054)	(0.057)
Nb. Neighbors	-	-	0.271	-0.649**
			(0.359)	(0.317)
T2	-	-	-	0.475
				(0.442)
α	-0.476	-0.136	-0.295	-0.198
	(0.122)	(0.229)	(0.229)	(0.192)
β	-0.283	-0.121	1.620*	-0.281
	(0.952)	(0.640)	(0.927)	(0.782)
Sensitivity	1.364**	1.599***	0.849**	0.382
	(0.641)	(0.552)	(0.327)	(0.460)
Age	0.370*	0.194	-0.058	0.109
	(0.192)	(0.143)	(0.157)	(0.155)
Background	1.317**	1.555***	0.307	-1.029**
	(0.506)	(0.573)	(0.359)	(0.473)
Conf. friends	-1.651	-1.504**	0.983**	0.510
	(1.135)	(0.746)	(0.496)	(0.488)
Activity	-0.332	-0.041	1.654***	0.118
	(0.599)	(0.970)	(0.337)	(0.524)
Influence	-0.916	-0.295	-0.772*	-0.664
	(0.776)	(0.654)	(0.430)	(0.613)
Constant	-3.459	-0.242	-0.329	3.954
	(3.867)	(3.747)	(3.388)	(3.373)
Log-likelihood	-412.878	-386.179	-930.769	-924.918
Number of individuals	24	24	54	54
Number of observations	216	216	486	486

Standard errors (in parenthesis) are clustered by groups

Significance level: 1% (***), 5% (**) et 10% (*)

negatively and significantly explain their level of investment. Such a negative trend is generally observed in public goods games (Ledyard 1995, Chaudhuri 2011). The negative coefficient associated with the variable that captures subjects' confidence towards their friends is surprising, and may suggest that nudge implementation has an impact on the norm of investment established in the first series of ten periods. Indeed, the subjects learned from their group and invested accordingly. However, nudge implementation suggests a given level of investment to them that may differ from the norm of investment that the group created. Finally, the variables capturing inequity aversion do not explain subjects' decisions in the circle network.

However, in the star network, advantageous inequity aversion significantly explains them. An interpretation may be that an individual discovering that he/she invests less than his/her direct neighbors increases his/her investment because he/she does not like inequity. Both during periods 1-10 and periods 11-20, the period also negatively explains decisions. During periods 1-10 in the star network, decisions to invest are positively explained by subjects' confidence towards their friends and by the fact of being part of an association, two variables that may indeed explain cooperation. Finally, in periods 11-20, the number of neighbors and the subject's background negatively explain his/her decisions. The intuition may be that under nudge implementation subjects expect their neighbors to invest more, and, in particular, students in economics.

Result 4: Inequity aversion is not a determinant of subjects' decisions, except advantageous inequity aversion in the star network. Under nudge implementation, inequity aversion is not a determinant of subjects' decisions in either type of network.

As a consequence, **Hypothesis 3** is only partially confirmed.

6 Study of the determinants of the emergence of local equilibria on the Nash equilibrium

Contrary to Rosenkranz and Weitzel (2012), we propose to study the determinants favoring the emergence of local equilibria on the Nash equilibrium.[22] Estimating a model

[22]We focused on Nash equilibria only because there were too few observations concerning the emergence of the social optimum in the star network.

in which the lag of the dependent variable is an explanatory variable may lead to an endogeneity bias. We thus estimated a dynamic probit model following Wooldridge (2005). The results are reported in Table 6.

In addition to the explanatory variables used in the previous regressions to explain local coordination on the Nash equilibrium, we also considered the variable *Local eq. 1st period*, which is a dummy that takes the value of 1 if a local equilibrium on the Nash solution is implemented for individual i in the first period (following Wooldridge 2005); and *Local eq.*$_{t-1}$, which is the lag of our dependent variable.

There are few similarities between the two types of networks concerning the variables explaining the probability for a subject to coordinate on the Nash equilibrium. In the circle network during periods 1-10, the probability of coordinating on the Nash equilibrium is positively explained by the subject's confidence towards his/her friends, and negatively by the existence of a Nash equilibrium in the previous period and by the subject's confidence towards work colleagues. This may indicate that the nature of the network (friends or work colleagues) is of importance when explaining cooperation. For instance, Akerlof (1997) explains that individuals interact the most with socially close individuals. This may thus explain the sign of the coefficients. During periods 11-20, the probability of coordinating on the Nash equilibrium is now positively explained by a constant, and negatively by the subject's sensitivity and background. The negative coefficient associated with environmental sensitivity corroborates the results of the non-parametric tests concerning coordination on the social optimum in the previous section. Indeed, as emphasized in the previous section, even if the number of local equilibria on the Nash equilibrium is not reduced for the most sensitive subjects, we highlighted the fact that they coordinated significantly more on the social optimum. Concerning subjects' backgrounds, we showed in the previous section with the Tobit regressions that students in economics invested significantly more in the local public good. Our result in this section is thus consistent with our past observations.

In the case of the star network, both during periods 1-10 and 11-20, the probability of coordinating on the Nash equilibrium is positively affected by the emergence of a Nash equilibrium in the first period of the game, the number of neighbors and the period. Note also that subjects' backgrounds positively explain the emergence of a local Nash equilibrium. The results thus suggest that subjects learn how to coordinate on the Nash

Table 6: Dynamic probit estimation.

	Circle		Star	
	(1-10)	(11-20)	(1-10)	(11-20)
Variable	Coeff.	Coeff.	Coeff.	Coeff.
	(S.E)	(S.E)	(S.E)	(S.E)
Local eq. 1st period	-0.648	-2.261	1.210***	0.775**
	(1.471)	(3.204)	(0.293)	(0.338)
Local eq.$_{t-1}$	-1.018**	0.331	0.054	0.085
	(0.469)	(0.329)	(0.186)	(0.180)
Decision$_{t-1}$	-0.116	-0.022	0.041	0.021
	(0.093)	(0.084)	(0.039)	(0.037)
Nb. Neighbors	-	-	0.369***	0.600***
			(0.129)	(0.190)
T2	-	-	-	0.101
				(0.256)
Period	0.049	0.020	0.085***	0.093***
	(0.048)	(0.045)	(0.026)	(0.028)
α	0.530	0.573	0.059	0.012
	(0.357)	(0.694)	(0.139)	(0.201)
β	-0.799	-0.008	-0.197	-0.479
	(1.185)	(0.467)	(0.356)	(0.496)
Sensitivity	-0.190	-0.966**	-0.134	-0.236
	(0.721)	(0.391)	(0.197)	(0.274)
Age	-0.058	-0.292**	-0.087	0.024
	(0.210)	(0.116)	(0.078)	(0.104)
Background	-0.522	-1.677***	0.146	0.764**
	(0.819)	(0.459)	(0.218)	(0.321)
Conf. friends	1.835**	0.793	-0.202	-0.020
	(0.883)	(0.467)	(0.269)	(0.370)
Conf. work	-1.383**	-0.216	0.143	0.231
	(0.697)	(0.364)	(0.215)	(0.299)
Constant	0.589	4.374*	0.225	-2.648
	(4.179)	(2.425)	(1.732)	(2.358)
Log-likelihood	-77.579	-78.437	-258.425	-259.014
Number of individuals	24	24	54	54
Number of observations	216	216	486	486

Significance level: 1% (***), 5% (**) et 10% (*)

equilibrium over time, and that the emergence of a local Nash equilibrium in the first period may be a factor explaining a form of inertia on the Nash equilibrium. Finally, having a central position in the network is also a key determinant.

Result 5: Environmental sensitivity explains the probability of coordinating on the Nash equilibrium in the circle network. However, inequity aversion is not a determinant in either structure.

This result seems to indicate that nudge implementation should target some individuals only (the most sensitive to environmental matters in the case of environmental regulation).

7 Discussion and conclusion

In this paper, we proposed a laboratory experiment to test whether the efficiency of a nudge based on information disclosure depends on the network structure and on the sensitivity of individuals to the environment. We decided to focus on two networks (circle and star), which are not necessarily representative of all the situations that could actually occur. However, the results we obtained may still provide policymakers with some keys regarding nudge implementation.

As in Boun My and Ouvrard (2017), the effectiveness of the proposed nudge we propose differs depending on individuals' sensitivity to environmental matters. Even if we do not observe an increase in the level of investments (at the level of the network), we still observe more coordination on the socially optimal profile of investments for the most sensitive individuals. This result confirm those obtained in Banerjee *et al.* (2014): information provision (on the behaviors of neighbors in Banerjee *et al.* (2014) or on the socially optimal investment in this paper) is an efficient incentive. However, our result also seems to suggest, as emphasized by Sunstein (2013), that nudge implementation should take individuals' heterogeneity into account so that nudge implementation should target some individuals. Moreover, our results seem to highlight a better suitability of our nudge for circle networks, as opposed to star networks.

Our results also emphasize that there is a form of inertia in the emergence of local Nash equilibria in star networks that the nudge cannot account for. Indeed, in the previous section, we found that the emergence of a local Nash equilibrium in the first period positively and significantly explains the probability that subjects coordinate on a Nash equilibrium. In the circle network, on the contrary, this probability is negatively and significantly explained by subjects' sensitivity to environmental matters, age and background (under nudge implementation). Thus, this result reinforces the idea that nudge implementation needs to be considered for specific structures.

Moreover, in the circle network, we discussed the fact that the nature of the network is of importance. Indeed, depending on the type of relationship (friends or work colleagues), the investment pattern is affected. This result adds some complexity regarding the conditions under which a nudge may be efficient. By comparison, we may assume that a green tax implemented to increase the level of investments in the public good would not suffer from such considerations. Notwithstanding, it would still be necessary for the regulator to know individuals' positions in the network because they determine the socially optimal level of investments.

In sum, this paper contributes to existing knowledge on nudge implementation, and suggests clear policy implications: even if the nudge we considered may be an efficient tool for given structures and individuals, it still has some limits that should be considered by policymakers. In particular, the apparent simplicity of the method (provision of a piece of information) may be offset by the necessity to know the intrinsic characteristics of the agents (such as environmental sensitivity, interest in the public good, etc.) and their network's structure for the nudge to be efficient.

Even if these information may be difficult to obtain, one solution could be to implement surveys *ex ante* (as in marketing) to better know individuals and to be able to implement the good nudge. One alternative could be to implement a nudge to reveal preferences *ex post*, and then to adjust the nudge.

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Appendix A: GEB questionnaire (Davis *et al.* 2009, 2011)

1) I use energy-efficient bulbs.

2) If I am offered a plastic bag in a store, I take it.

3) I kill insects with a chemical insecticide.

4) I collect and recycle used paper.

5) When I do outdoor sports/activities, I stay within the allowed areas.

6) I wait until I have a full load before doing my laundry.

7) I use a cleaner made especially for bathrooms, rather than an all-purpose cleaner.

8) I wash dirty clothes without prewashing.

9) I reuse my shopping bags.

10) I use rechargeable batteries.

11) In the winter, I keep the heat on so that I do not have to wear a sweater.

12) I buy beverages in cans.

13) I bring empty bottles to a recycling bin.

14) In the winter, I leave the windows open for long periods of time to let in fresh air.

15) For longer journeys (more than 6h), I take an airplane.

16) The heater in my house is shut off late at night.

17) I buy products in refillable packages.

18) In winter, I turn down the heat when I leave my house for more than 4 hours.

19) In nearby areas, I use public transportation, ride a bike, or walk.

20) I buy clothing made from all-natural fabrics (e.g. silk, cotton, wool, or linen).

21) I prefer to shower rather than to take a bath.

22) I ride a bicycle, take public transportation, or walk to work or other.

23) I let water run until it is at the right temperature.

24) I put dead batteries in the garbage.

25) I turn the light off when I leave a room.

26) I leave the water on while brushing my teeth.

27) I turn off my computer when Im not using it.

28) I shower/bathe more than once a day.

Appendix B: Computation of the coefficients of advantageous and disadvantageous inequity aversion (Fehr and Schmidt 1999, Blanco *et al.* 2011, Teyssier 2012)

In Fehr and Schmidt (1999), the agent's utility function is defined as:

$$U_i(x_i, x_j) = \begin{cases} x_i - \alpha_i (x_j - x_i) & \text{if } x_i \leq x_j \\ x_i - \beta_i (x_i - x_j) & \text{if } x_i > x_j \end{cases} \tag{5}$$

where x_i and x_j are, respectively, the monetary payoffs of agents i and j.

The coefficient of advantageous inequity aversion β_i is determined according to the subjects' decision as a dictator. Let us assume that a subject switches from the distribution (18;2) to the egalitarian one $(\omega_i; \omega_i)$. This subject prefers therefore the distribution $(\omega_i; \omega_i)$ over (18;2), but prefers the distribution (18;2) over $(\omega_i - 1; \omega_i - 1)$. Following Blanco *et al.* (2011) and Teyssier (2012), we obtain that $u_i(\tilde{\omega_i}; \tilde{\omega_i}) = u_i(18; 2)$, with $\tilde{\omega_i} \in [\omega_i - 1; \omega_i]$, $\omega_i \in \{0, ..., 20\}$, and $u_i(.)$ corresponding to Eq. (5). Setting $\tilde{\omega_i} = \omega_i - 0.5$ and rearranging the equation, we obtain that:

$$\beta_i = \frac{18.5 - \omega_i}{16} \tag{6}$$

The coefficient for disadvantageous inequity aversion α_i is determined according to the subject's decision as an X player (sender) in the third task. Following Blanco *et al.* (2011) and Teyssier (2012), let us assume that r_i is the decision number, minus one, of the first decision in which a Y player (responder) accepts the distribution proposed by an X player (sender). In that case, $r_i - 1$ is the decision number, minus one, of the last decision such that the Y player rejects the distribution proposed by the X player. Thus, the Y player is indifferent between accepting a distribution $\tilde{d_i} \in \{d_i - 1; d_i\}$, with $d_i \in \{0, ..., 20\}$, and rejecting the distribution and earning nothing. Similarly to the advantageous inequity aversion, for this agent we get that $u_i(\tilde{d_i}; 21 - \tilde{d_i}) = u_i(0; 0)$. Setting $\tilde{d_i} = d_i - 0.5$ and rearranging according to Eq. (5), we obtain:

$$\alpha_i = \frac{d_i - 0.5}{21 - 2d_i} \tag{7}$$

Appendix C: Instructions (Circle network)

Welcome

You are going to participate in an experiment on decision-making. The rules are simple. If you follow them carefully and if you make good decisions, you may obtain considerable earnings.

All your decisions will be treated anonymously. You will indicate your decisions on the computer to which you have been assigned.

This experiment is comprised of five stages. These instructions are for the first one. You will receive the instructions for the second stage after the end of the first one, and so on. Your payment will be equal to the sum of your earnings for these five stages. At the end of the experiment, you will be called up individually for your payment.

From now on, we ask you not to talk anymore. If you have any questions, please raise your hand and an experimenter will come to answer you individually.

Instructions for the first stage

In this stage, we ask you to give your opinion on 28 affirmations. These are affirmations to learn more about you. There are no good or bad answers. Try to answer on the basis of your own personal experience.

At the end of this stage you will be paid 3 euros. This payment is fixed and does not depend on your answers. Answer honestly: answers are anonymous!

Instructions for the second stage

Note: the instructions for advantageous and disadvantageous inequity aversion have been, in part, adapted from Teyssier (2012).

This stage is independent of the previous one.

The rate of conversion is 4 points = 1 euro (1 point = 0.25 euro)

In this stage, you will play as an **A player** and then as a **B player**. As an **A player**, you will have to choose between "Participate" in the game detailed below, or "Not to participate", and earn imediately 5 points.

As a **B player**, you will have to choose between two earning distributions for the **A player** and yourself in 21 different decision problems. If the **A player** decides to participate in the game, then he/she automatically accepts the earning distribution proposed by the **B player**.

You will make your decisions as an **A player** and then as a **B player**. At the end of the experiment, the computer will randomly determine if you were an **A** or **B player**. You will then be randomly matched with another type of player (e.g.: if you are an **A player**, you will be matched with a **B player**).

Your decisions as a B player will be presented as follows:

Example 1: This corresponds to the 5th decision.

	Left	Right	
(18 ;2)	○	○	(4 ;4)

As a **B player**, if you choose the *left* option, then you earn 18 points, and the **A player** will earn 2 points. If you choose the *right* option, then both of you will receive the same earnings (4 points each in this example).

The other decisions are similar, but the *right* option will be increasing.

Example 2: This corresponds to the 16th decision.

	Left	Right	
(18 ;2)	○	○	(4 ;4)

You will have to choose between the *left* and *right* options for each of the 21 lines on your screen. At the end of the experiment, the computer will randomly assign the role of an **A** or **B player** to you. The computer will then randomly select one of the 21 lines for the earnings.

Your earnings will be determined as follows:

• If you are assigned the role of an **A player**:

- You receive a fixed amount of 5 points if you selected the option "Not to participate"

- If you chose to "Participate", then your earnings depend on the choice made by the **B player**, according to the randomly selected line by the computer.

• If you are assigned the role of a **B player**, you will earn the amount you chose, according to the randomly selected line by the computer.

Example 3: Assume that the computer selected the 5th decision.

i) The **A player** decided to "Participate" in the game:

• If the **B player** chose the *right* option, then:

- Earnings of the **A player** are 4 points

- Earnings of the **B playe**r are 4 points

• If the **B player** chose the *left* option, then:

- Earnings of the **A player** are 2 points

- Earnings of the **B player** are 18 points

ii) The **A player** decided "Not to participate" in the game:

• If the **B player** chose the *right* option, then:

- Earnings of the **A player** are 5 points

- Earnings of the **B playe**r are 4 points

• If the **B player** chose the *left* option, then:

- Earnings of the **A player** are 5 points

- Earnings of the **B player** are 18 points

Instructions for the third stage

This stage is independent of the previous one.

The rate of conversion if 4 points = 1 euro (1 point = 0.25 euro).

In this stage, you will play as an **X player** and then as a **Y player**. The **X player** will receive a total of 20 points and will determine how he/she wants to share these 20 points between the **Y player** and him/herself.

The **Y player** knows that the **X player** has chosen a distribution. As a **Y player**, you can choose to "Accept" or "Reject" the distribution made by the **X player**.

If the **Y player** accepts the distribution chosen by the **X player**, then the earning distribution is implemented.

If the **Y player** rejects the distribution chosen by the **X player**, then both players receive nothing (0 point each).

The Y player does not know the distribution chosen by the X player. He/she will have to choose between the options "Accept" or "Reject" for each of the 21 lines presented on the screen.

Example 1: This corresponds to the 7th decision.

	Accept	Reject
(14 ;6)	○	○

If the **Y player** chooses to "Accept" this distribution, then the **X player** earns 14 points, and the **Y player** earns 6 points.

At the end of the experiment, the computer will randomly assign the role of an **X** or **Y player** to you. You will then be randomly matched with another type of player (e.g., if you are an **X player**, you will be matched with a **Y player**).

If you are assigned the role of an **X player**, you will then receive the earnings corresponding to your distribution if the **Y player** has accepted this distribution. If the **Y player** has rejected this distribution, then both of you earn nothing (0 point each).

If you are assigned the role of a **Y player**, then you will receive the earnings corresponding to the distribution proposed by the **X player** if you accepted this distribution. If you rejected this distribution, then both of you earn nothing (0 point each).

Example 2: Assume that you are an **X player**, and that you propose the following distribution: 17 points for yourself and 3 points for the **Y player**.

- If the **Y player** chose the option "Accept" for this line, then this distribution is implemented.

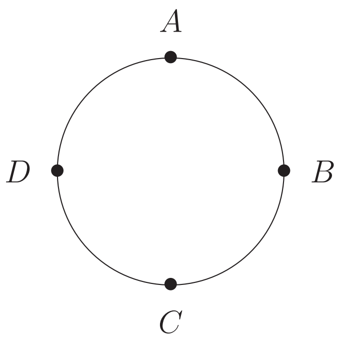
- If the **Y player** chose the option "Reject" for this line, then both players earn nothing.

Instructions for the fourth stage

This stage is independent of the previous one.

At the beginning of this stage, the 24 subjects (you included) will be randomly assigned to one of six groups of four individuals. Your group will not change during this experiment. You will never know the identity of the three other members of your group.

Each group will be composed of **A**, **B**, **C** and **D players**. At the beginning of this game, the computer will give you your type. You will be the same type of player until the end of this game.



The instructions will then explain the decisions you will have to make.

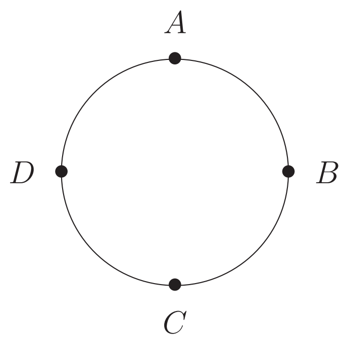
Context

You live in a community in which you have the possibility to invest in order to improve environmental quality. You and the three other members of your group will receive an endowment of 10 tokens that you may invest in an **environmental account**.

The **environmental account** is a collective account that will be used to improve environmental quality. When investing one token in the environmental account to improve environmental quality, your investment benefits you and all the members of your group linked to you.

Your total payoff, in relation to your investment in the environmental account, is indicated in the table we have provided you with. However, your payoff will depend on your position on the following representation. More precisely, your payoff will depend on your investment, and on the one of your neighbors, that is to say those individuals sharing a link with you. Note that you cannot save the tokens you do not invest for the next period. The table gives you your net payoff (including the non invested tokens).

The following example will help you understand how your payoff depends on your neighbors.



Example 1: If you are an **A player**, then your payoff will depend on your investment in the environmental account, as well as the one made by the **B** and **D players**. However, your payoff will not depend on the investment made by the **C player** because there is no link between the two of you.

Similarly, if you are the **D player**, then your payoff will depend on your investment in the environmental account, as well as the one made by the **A** and **C players**, but not on the one made by the **B player**.

The payoff is expressed in ECUs, with 2 ECUs = 1 euro (1 ECU = 0.50 euro). For your payoff, one period out of the ten will be randomly selected by the computer at the end of the experiment.

Example 2: Assume that you are an **A player** and that you invest 1 token in the environmental account. Assume also that the **B player** invests 4 tokens and the **D player** invests 8 tokens (correponding to a total investment of 12 tokens from your neighbors). Your payoff will then be 12.56 ECUs.

Example 3: Assume that you are a **D player**, and that you invest 8 tokens in the environmental account. Assume also that the **A player** invests 7 tokens and the **C player** invests 9 tokens (corresponding to a total investment of 16 tokens from your neighbors). Then, your payoff is 7.88 ECUs.

Stage procedure

Before the beginning of this stage, you will have to answer questions to test your understanding of this game.

The game will begin once everyone has answered the questions. You will play for ten periods. At the end of each period, the computer will indicate a summary of useful information.

Instructions for the fifth stage

You are going to play to the same game as in the fourth stage.

You will stay with the same group and you will keep your type of player: if you were an **A player**, then you will be an **A player** for this stage, etc.

Your total payoff, in relation to your investment in the environmental account, is still indicated in the table we have provided you with.

However, before you make your decision, a piece of information will appear on your screen. You are completely free to follow, or not, this piece of information. We remind you that all your decisions are anonymous.

You will play for ten periods. At the end of each period, the computer will indicate a summary of useful information.

For your payoff, one period out of the ten will be randomly selected by the computer at the end of the experiment.

Your investment

Investments of your neighbours	0	1	2	3	4	5	6	7	8	9	10
0	3,00	4,77	5,39	5,55	5,44	5,17	4,78	4,32	3,79	3,21	2,59
1	5,77	6,39	6,55	6,44	6,17	5,78	5,32	4,79	4,21	3,59	2,94
2	7,39	7,55	7,44	7,17	6,78	6,32	5,79	5,21	4,59	3,94	3,26
3	8,55	8,44	8,17	7,78	7,32	6,79	6,21	5,59	4,94	4,26	3,56
4	9,44	9,17	8,78	8,32	7,79	7,21	6,59	5,94	5,26	4,56	3,83
5	10,17	9,78	9,32	8,79	8,21	7,59	6,94	6,26	5,56	4,83	4,09
6	10,78	10,32	9,79	9,21	8,59	7,94	7,26	6,56	5,83	5,09	4,33
7	11,32	10,79	10,21	9,59	8,94	8,26	7,56	6,83	6,09	5,33	4,56
8	11,79	11,21	10,59	9,94	9,26	8,56	7,83	7,09	6,33	5,56	4,78
9	12,21	11,59	10,94	10,26	9,56	8,83	8,09	7,33	6,56	5,78	4,98
10	12,59	11,94	11,26	10,56	9,83	9,09	8,33	7,56	6,78	5,98	5,18
11	12,94	12,26	11,56	10,83	10,09	9,33	8,56	7,78	6,98	6,18	5,36
12	13,26	12,56	11,83	11,09	10,33	9,56	8,78	7,98	7,18	6,36	5,54
13	13,56	12,83	12,09	11,33	10,56	9,78	8,98	8,18	7,36	6,54	5,71
14	13,83	13,09	12,33	11,56	10,78	9,98	9,18	8,36	7,54	6,71	5,88
15	14,09	13,33	12,56	11,78	10,98	10,18	9,36	8,54	7,71	6,88	6,03
16	14,33	13,56	12,78	11,98	11,18	10,36	9,54	8,71	7,88	7,03	6,18
17	14,56	13,78	12,98	12,18	11,36	10,54	9,71	8,88	8,03	7,18	6,33
18	14,78	13,98	13,18	12,36	11,54	10,71	9,88	9,03	8,18	7,33	6,47
19	14,98	14,18	13,36	12,54	11,71	10,88	10,03	9,18	8,33	7,47	6,60
20	15,18	14,36	13,54	12,71	11,88	11,03	10,18	9,33	8,47	7,60	6,74
21	15,36	14,54	13,71	12,88	12,03	11,18	10,33	9,47	8,60	7,74	6,86
22	15,54	14,71	13,88	13,03	12,18	11,33	10,47	9,60	8,74	7,86	6,99
23	15,71	14,88	14,03	13,18	12,33	11,47	10,60	9,74	8,86	7,99	7,11
24	15,88	15,03	14,18	13,33	12,47	11,60	10,74	9,86	8,99	8,11	7,22
25	16,03	15,18	14,33	13,47	12,60	11,74	10,86	9,99	9,11	8,22	7,33
26	16,18	15,33	14,47	13,60	12,74	11,86	10,99	10,11	9,22	8,33	7,44
27	16,33	15,47	14,60	13,74	12,86	11,99	11,11	10,22	9,33	8,44	7,55
28	16,47	15,60	14,74	13,86	12,99	12,11	11,22	10,33	9,44	8,55	7,65
29	16,60	15,74	14,86	13,99	13,11	12,22	11,33	10,44	9,55	8,65	7,76
30	16,74	15,86	14,99	14,11	13,22	12,33	11,44	10,55	9,65	8,76	7,85