Spatial coordination in Payment for Ecosystem Service schemes: can we nudge the agglomeration bonus to enhance its effectiveness?

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Abstract

The ecological effectiveness of Payment for Ecosystem Service (PES) schemes can often be enhanced if farmers can be induced to enrol in a spatially-coordinated manner. This is because the achievement of many targets for biodiversity conservation policy or water quality improvement is increasing in the spatial connectedness of enrolled land. One incentive mechanism which has been proposed by economists to achieve such connectedness is the Agglomeration Bonus (the AB). There has also been an interest within the literature on PES design in using "nudges" to enhance participation and performance. In this paper, we test whether a specific nudge, more precisely an environmental performance group ranking, can enhance or even replace the impacts of the AB in terms of participation and spatial coordination. The social norm is generated in the lab based on real contributions to an environmental charity representing the environmental benefits generated by a PES scheme, making use of the idea that in real PES schemes, participants may derive utility from the environmental outputs of the scheme as well as the monetary payoffs they receive. Interestingly, we find that this nudge do not significantly supercharge the AB, and can even worsen its performance. Moreover, the nudge mechanism generates too little of incentive to be able to replace the monetary rewards offered by the AB.

Keywords: agglomeration bonus, nudge, experiment, coordination, agriculture, environment

JEL codes: C91, C92, Q15, Q18, Q57

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1. Introduction

The spatial coordination of participants can be a determinant of the effectiveness of PES schemes when the provision of ES depends on the spatial configuration of ecosystems (Cong *et al.,* 2014, Banerjee *et al*., 2014). Examples of environmental objectives which favour spatial coordination of participants include reduction of pesticide leaching in rivers, flood alleviation, the creation of wildlife corridors, and species re-introductions where the species in question requires a minimum area of conservation land to survive. Parkhurst *et al.* (2002) propose the use of an Agglomeration Bonus (AB) to tackle this issue. The principle of this mechanism is that landholders get a payment for participating in the PES, which is then topped-up with an additional payment if the plot is contiguous to another plot enrolled by another landowner. The implementation of such an incentive structure creates a coordination game, which typically has multiple Nash equilibria which can be Pareto-ranked. The AB scheme, typically tested in decontextualized conditions in the laboratory, has been shown to have significant effects on plot agglomeration. In a recent experiment Banerjee *et al.* (2014) show that providing players with information on their neighbours' choice can improve the efficiency of the AB for spatial coordination. Other studies have shown that the performance of the AB depends on the size of the network over which the coordination game is played out, the transactions costs of participating in the scheme, and opportunities for communication (Banerjee et al, 2017). Moreover, the performance of the AB has been found in some settings to decline over time, in the sense that participants increasingly switch away from the Pareto-dominant equilibrium of participation to the risk-dominant equilibrium of non-participation. This is a rather gloomy finding for the potential of the AB to generate the kinds of spatial coordination over time desired by the policy planner.

In parallel with academic interest in using financial incentives to improve spatial coordination in PES schemes, one can observe an increasing focus on the use of behavioural incentives to increase participation and performance in environmental policy. Behavioural incentives consist of any policy intervention which aims to change the behaviour of economic agents (households, farmers) by changing the framing or information context of economic decisions, without changing the financial payoffs from alternative actions (Croson and Treich, 2014). Examples of behavioural interventions include changing the default option, sending positive messages about individual behaviour, and providing information on social norms. Social norms are "shared understandings of how individual members should behave in a community" (Chen et al, 2009). They take in both what an individual understands the actions of other to be, and what she believes is expected of her (Abbott et al, 20013). If individuals derive dis-utility from diverging from a social norm, then providing information of this kind can be expected to change behaviour if the weight the individual places on the opinions of others or her own selfish concern for social ranking is strong enough (Czajkowski et al, 2015). Ferraro and Price (2013) evaluate the effects of social comparison information on demand for water by residential customers in the USA. They found that such information had a bigger effect on consumption than simply asking people to reduce water use or telling them how to do so; and that the effects of social comparison information was greatest for those consumers who had relatively high water use. There are now many other examples of the effects of such nudges (Alcott 2011). A summary of this evidence would be that (i) the effects of nudges tend to be rather small (ii) the effects may erode over time (iii) how the nudge is delivered may be important.

In the context of a PES scheme subsidising farmers for afforestation in China, Chen *et al.* (2009) show that individual decision to re-enrol can be positively influenced by the information that the neighbourhood is also intending to re-enrol, affecting the durability of the scheme. In another example Kuhfuss *et al.* (2016a) show that the introduction of a bonus, which payment is conditioned to a minimum level of participation and adds to the standard AES payment, can highly increase farmers' uptake of an AES. Kuhfuss *et al.* (2016b) found that providing information on what percentage of other farmers said they would carry on with "green" farm practices after the end of a PES contract had a significant effect on the stated intentions of study participants to behave likewise. These results suggest that some farmers value conforming to social norms and are more likely to participate if they know that others also participate.

Finally, studies of what motivates farmers to participate in actual PES schemes have found that monetary pay-offs are only part of the story. The AB as presented originally by Parkhurst *et al.* (2002) depends on landowners comparing the financial pay-offs from alternative actions, given their beliefs about the likely actions of others. However, an empirical literature suggests a broader set of motivations for farmers participating in actual PES schemes (Michel-Guillou and Moser 2006, Sheeder and Lynn, 2010). Dubois et al. (2015) show in a very recent experiment that introducing context in a repeated coordination game (stag hunt game), stating that "X (or Y) has a positive (or negative) impact on the environment", is enough to change individual choices during the game.

In this paper, we thus evaluate the performance of the AB in the context of these two aspects which may be important to understanding the effects of such PES schemes. These are that (i) some individuals are likely to be sensitive to the provision of social norm information; and (ii) farmers' motivations to participate in a PES can include non-pecuniary motivations, in particular, a concern to protect the environment. A consequence for spatial coordination through the AB is that farmers might be more willing to cooperate if (i) if they know that spatial coordination has a higher, beneficial impact on the environment and (ii) if they know that other farmers will also participate.

Some experiments recreate pro-environmental behaviour through donations to environmental charities. For example Clot et al. (2014) use an adapted dictator game to mimic pro-environmental behaviours, where players are asked how much of their endowment they are willing to give to an environmental charity. We make use of this idea, by implementing an experimental design whereby players' choices of opting in to the PES scheme generate a real money donation paid by the experimenters to an environmental charity of the player's individual choice. We interpret the size of donations as the change in the supply of an environmental public good from which individuals may derive direct utility in addition to the monetary pay-offs from their choices. Using this donation mechanism also provides a means of generating a social norm within the lab. As subjects play within groups of "networked farmers", the donation of each group relative to the donations of other groups in the previous round forms the social norm used here.

Thus, the paper tests two research questions. First, can the use of a social norm supercharge the effects of an AB both in terms of participation and spatial coordination? Second, can a social norm actually replace the AB in terms of delivering the desired degree of spatial coordination of "farmers" switching to a greener system of farming?

2. Modelling Framework

We consider a given number of farmers $i = 1, \dots, N$ who can employ their land in two ways, labelled X, Y. Land management option X refers to a pro-environmental or conservation land management, whilst Y indicates that the land is used for agricultural production. Following previous studies (e.g., Banerjee et al., 2012, 2014), we assume that the agricultural revenue under conventional land use is higher than under land used for conservation purposes, i.e., $r(X) < r(Y)$.[1] Farmers' participation in a PES usually generates environmental benefits, e, which is considered a public good or a positive externality (e.g., improved biodiversity or better flood drainage), from which they might benefit but which mainly generate benefits for the wider society at a larger spatial scale. The production of this environmental benefit is conditioned to spatial coordination on the adoption of pro-environmental land management, X. To emphasize the issue of spatial coordination, we assume that the environmental benefit is only produced if at least one of a farmer's direct neighbours also adopts this similar type of land-management practice. Let n_i be the number of direct neighbours of farmer i who choose X. We assume that the aggregate environmental benefit generated by farmer i choosing X is simply en_i.

To facilitate an effective delivery of environmental benefits, and as long as the environmental benefit generated outweighs the loss of agricultural revenue ($e > r(Y) - r(X)$), it is the policymaker's objective to foster contiguous adoption of land use X in order to maximize social welfare. To this end, the policymaker can individually incentivize neighbouring farmers with an agglomeration bonus, b, only if both farmers manage to coordinate on X. Thus, given that farmer i chooses X, she receives the agglomeration bonus bn_i. Therefore, the agglomeration bonus is proportional to the environmental benefits.

In view of the above setup, assuming that farmers do not take into account their impact on the environment and only consider the monetary payment (agricultural revenue and agglomeration payment), the payoffs of farmer $i = 1, \dots, N$ can now be summarized as follows. In case farmer i adopts land use strategy $\sigma_i = X, Y$, her monetary payoff $p_i(\sigma_i)$ reads:

$$(1) \quad p_i(\sigma_i) = r(\sigma_i) + b(\sigma_i)n_i$$

with $b(X) = b > 0$ the agglomeration bonus, $b(Y) = 0$, and n_i the number of direct neighbours of farmer i choosing X.

Now, if we consider farmers' utility functions, and from a behavioural perspective, farmers may not only consider the monetary revenue when choosing how to manage their land. Indeed, they may not only consider their financial gains, represented by the above payoff functions, but may also feel concerned about the impact of their practices on the environment and thus deviate from the standard economic model. That is, farmers may display altruistic preferences towards environmental conservation and therefore may value the environmental benefit generated by choosing a pro-environmental land management (X) in coordination with their neighbours, even though they do not derive financial gains from it. To take this into account we propose to enrich our model. Of course, farmers are heterogeneous about their preferences for the environment and/or their altruism (parameter α_i), but we assume that this non-monetary utility term is proportional to the environmental benefit they generate with their choice of X. One step further is to consider that farmers may also derive utility from choosing X independently of the choice of their neighbours, a "warm glow" effect (Andreoni 1989, 1990) reflected by parameter β_i. Indeed, what might be important to farmers is to do their best in choosing X for their self-esteem and/or to signal they are "responsible citizens," and maybe to induce others to choose X as well. Taking into account these additional two elements, the utility function of choosing X or Y can be stated as follows:

$$(2) \quad u_i(\sigma_i) = r(\sigma_i) + b(\sigma_i)n_i + \alpha_i(\sigma_i)e(\sigma_i)n_i + \beta_i(\sigma_i)$$

[1] To keep the payoff structure simple and transparent, we abstain from including a fixed subsidy for enrolling in the PES, although the revenue under land used for conservation purposes, $r(X)$, could include such a component.

with $e(X) = e > 0$, $e(Y) = 0, \alpha_i(X) \geq 0$, $\alpha_i(Y) = 0$ and $\beta_i(X) \geq 0$, $\beta_i(Y) = 0$.[2]

If we consider the payoff function (1), that is assuming that farmers have no consideration for the environment, and in the absence of an AB scheme, the only Nash equilibrium is that all farmers choose Y. However, if we consider farmers' utility function (2), thereby bringing in environmental and altruistic preferences, some farmers might prefer choosing X over Y, even without the agglomeration bonus. In this case there exist many Nash equilibria, depending of the value of the behavioural parameters. If the agglomeration bonus is introduced and is sufficiently large $\left(b \geq \frac{r(Y)-r(X)}{N}\right)$, there are two Nash equilibria: one in which all the farmers choose X and one with all farmers choose Y. The latter constitutes a coordination problem with X being the Pareto dominant equilibrium and Y the risk dominant equilibrium.

As announced in the introduction, one of the objectives of this paper is to test the impact of information about the social norm. Indeed, we wonder whether a nudge based on a social comparison information may induce more farmers to coordinate on the Pareto dominant Nash equilibrium, X. Contrary to the agglomeration bonus, a nudge does not change farmers' monetary pay-offs not the environmental benefits but might impact farmers' utility. We propose a nudge which consists of ranking farmers' networks according to the level of environmental benefits they generate as a group through their choice of farming practices. This nudge should inform farmers on how they perform compared to other groups thus providing information about the descriptive norm (i.e., what most people do) and additionally induce some inter-group competition that could encourage the choice of X. This ranking also provides information about the injunctive norm, i.e., what most people think should be done. Announcing a ranking according to environmental benefits emphasizes the importance of the environment in the choice of farming practices. In addition, the group ranked first is congratulated to encourage farmers belonging to this group to carry on their efforts for the environment. We hypothesise that this nudge may impact positively on the choice of X over Y. Nevertheless, this nudge may also have a negative impact for the group ranked last, which might be discouraged to coordinate on X. Indeed, farmers of the last group might believe that most farmers of their network choose Y, hence may infer that it does not pay off to choose X.

The ranking might affect farmers' utility in the following way:

$$(3) \quad u_i(\sigma_i) = r(\sigma_i) + b(\sigma_i)n_i + \alpha_i e(\sigma_i)n_i + \beta_i(\sigma_i) + f_i(rank)$$

With $f_i(rank1) > f_i(rank2) > f_i(rank3)$.

Theoretical predictions are the same as those previously described when considering utility function 2. .

3. Experimental Design and Hypotheses

The experiment consisted of four treatments: a control treatment (T0), a treatment which includes the agglomeration bonus only (T1), a treatment which includes the nudge only (T2), and a treatment which includes both the agglomeration bonus and the nudge (T3).

To model the spatial connectivity between farmers requires imposing a spatial structure of subjects' position. In this respect, we follow the network structure proposed by Banerjee et al. (2012, 2014),

[2] Note that this utility function does not include the aggregate level of the environment. Indeed, we are only interested in the difference $u_i(Y) - u_i(X)$.

where subjects' locations are arranged on a circular network. For a given number of N subjects, the size of the network is fixed. We have a fixed matching of players on the circular networks as this seems closer to what farmers experience in real life (neighbouring land-managers are not likely to change over time). The main advantage of utilising a circular network configuration is its symmetry, with each subject having a similar number of *direct* neighbours (i.e., one on the LH-side and one on the RH-side); thus the number of farmers choosing X, n_i, can either be 0, 1 or 2. However, a subject is *indirectly* linked to all other subjects on the network. The direct and indirect linkages between subjects across space are essential in order to capture the environmental benefits through agglomeration. Furthermore, a fixed and symmetric network structure ensures that the decision problems faced by all subjects are identical given they all face the same degree of strategic uncertainty. That is, a farmer may know what land management actions his *direct* neighbouring farmer is pursuing, but may not fully know the decisions of other *indirect* neighbouring farmers on the network. As a consequence, a symmetric network structure of a given size allows us to identity the impact of a nudge on spatial coordination and hence environmental benefits without having to worry about confounding factors, such as subjects being able to exercise bargaining power and extract rents because of their specific position[3]. Therefore, in this experiment, under each treatment, subjects are placed around a circular network in groups of 6 ($N = 6$). In addition, each session includes 3 groups of 6 subjects. Each subject was asked to choose between action X or Y.

To recreate the environmental benefits of farming practices in the lab with non-farmers subjects, we told to subjects that their choice may generate a donation to an environmental charity[4]. The environmental charity implements actions from which subjects can benefit, but which mainly generate benefits for the wider society as it is the case for more environmentally friendly practices of farmers. In this setup, subjects who want to behave pro-environmentally will choose X at the cost of a lower individual monetary payoff, just as some farmers decide to participate in PES for non-pecuniary motivations. As assumed in the theoretical model in previous section, the level of the donation depends on the number of direct neighbours also choosing X given the subject chooses X. Subjects do not benefit from the donation directly. The donation generated by a subject is placed in an envelope at the end of each session in the presence of the subject (Figure 1). The experimenters subsequently sent the total amount of donations of each envelop to the corresponding charities, and transferred to the subjects a confirmation of their donations by email.

[3] For example, a linear network is an example of a spatial structure that exhibits more asymmetry where farmers located centrally may have a more favourable position for rent extraction.

[4] Subjects had to choose, after reading the instructions and before the start of the experiment, one charity to which their donation would be sent. The choice included 1 international charity (WWF), 2 French national charities France Nature Environnement and Fondation Nicolas-Hulot pour la nature et l'homme) and 1 local charity (Ouvre-Tête).

Figure 1: Envelopes used to put cash donations to the charities

Apart from using specific designated environmental charities, the rest of the experiment was a decontextualized version in order to purely consider how financial incentives affect the choices and outcomes in the experiment (Cason and Raymond, 2011). We decided to explicitly mention that the charities were environmental charities as we wish to capture subjects' preferences for the environment.

16 sessions with 18 subjects each were run between April and September 2016 at the LEEM (Economic Experimental Laboratory of Montpellier) in France, for a total of 288 participants. We aimed at obtaining 6 independent observations for each treatment. In treatments T0 and T1 with no nudge, an independent observation is that obtained at the group level (6 subjects). In treatments T2 and T3 with nudge, as information on the performance of the other 2 groups present during the session is provided, then, the choices subjects make are not independent from the performance of other groups in the session. Hence, an independent observation for these treatments is a session. Therefore, as show in Table 1, we had 6 groups participating in treatments T0 and T1 and 6 sessions of 3 groups for each treatment with nudge (T2 and T3).

Table 1: Number of participants per treatment

Treatment	Number of participants
T0	2 sessions, 3 groups of 6 players each = 36 participants
T1	2 sessions, 3 groups of 6 players each = 36 participants
T2	6 sessions, 3 groups of 6 players each = 108 participants
T3	6 sessions, 3 groups of 6 players each = 108 participants
	Total 16 sessions, 288 participants

Each session was composed of 15 periods, where players were repeating the same choice under the same treatment, within the same group and keeping the same neighbours (partner design). After each period, each player was informed of their own monetary payoff, the donation generated given their choice, and the choices of their two direct neighbours. No communication was allowed within groups.

In view of our treatments, we consider a two-by-two design as shown in Table 2 below. Let us next systematically outline each treatment in more detail by providing the underlying payoff tables and by deriving hypotheses. This is based on a numerical implementation using parameter values reported in Table 3.

Table 2: Treatments

		Nudge	
		NO	YES
Agglomeration bonus	NO	T0	T2
	YES	T1	T3

Table 3: Parameter values

Parameters	X	Y
Agricultural revenue (r)	€7	€13
Agglomeration payment (b)	€3	€0
Donation (d)	€8	€0

Since the environmental benefit (e) defined in the model is split between the two neighbours, the donation actually corresponds to $d = e/2 = €8$. Note that the pay-off for choosing Y is 13, which is the same in all 4 treatments .

Control treatment (T0)

In the control treatment, subjects can choose X and receive a lower agricultural revenue, $r(X) = 7$, or they can choose Y and receive a higher agricultural revenue equal to $r(Y) = 13$. When choosing X, they can generate a donation $d(X) = 8$ if one of their neighbours also chooses X, or $2d(X) = 16$ if both neighbours choose X.

The payoff table for the control treatment is (Table 4):

Table 4: Payoff table for the control treatment (T0) and nudge the only treatment (T1)

		Your Direct Neighbours' Choices		
		Both choose X	One chooses X, the other one chooses Y	Both choose Y
Your Choice	X	Your payoff: €7 Donation generated: €16	Your payoff: €7 Donation generated: €8	Your payoff: €7
	Y	Your payoff: €13	Your payoff: €13	Your payoff: €13

As presented in previous section, if subjects only maximize their own monetary pay-off (payoff function 1), the unique Nash equilibrium is reached by all players choosing X. Though, taking into account the environmental benefits that are produced, from the policy maker perspective, the Pareto optimal situation is reached by all players choosing X. This situation might be an equilibrium if subjects do account for the environmental benefits and/or perceive a warm glow effect from choosing X, as proposed in the utility function 2. Indeed, depending on the individual values of α_i and β_i, multiple Nash equilibria can exist, Y remaining the risk dominant equilibrium. Therefore, according to our behavioural model (utility function 2), we anticipate some participation due to the presence of the donation that will trigger altruistic behaviours (encapsulated in parameter α of our model) and to warm glow feelings (parameter β_i). We hypothesize that a majority of subjects will choose Y and that few subjects i displaying high α_i and β_i may choose X.

Agglomeration bonus treatment (T1)

In this treatment, we implicitly introduce the agglomeration bonus to the protocol, which only changes the monetary payoff of choosing X described in T0. When choosing X, each player receives a different payoff, depending of their neighbours' choices. If one neighbour chooses X, the player receives $r(X) + b = 7 + 3 = 10$, when 2 neighbours choose X, they receive twice the agglomeration payment $r(X) + 2b = 7 + 6 = 13$,. If none of their neighbours also choose X, then they do not receive agglomeration bonus and their monetary payoff is only $r(X) = 7$, as in the control treatment. The payoff table for this treatment is:

Table 5: Payoff table for the AB treatment (T1) and the AB and nudge treatment (T3)

		Your neighbours' choices		
		Both choose X	One chooses X, the other one chooses Y	Both choose Y
Your choice	X	Your payoff: 13€ Donation generated: 16 €	Your payoff: 10€ Donation generated: 8€	Your payoff: 7€
	Y	Your payoff: 13€	Your payoff: 13€	Your payoff: 13€

When looking at payoff functions only, all players choosing X and all players choosing Y are both Nash equilibria with equivalent payoffs, all players choosing Y being the risk dominant equilibrium. However, when considering the overall utility functions (2a and 2b), then all players choosing X is the Pareto dominant equilibrium (if at least 1 subject values the choice of X, i.e. $\exists i|\alpha_i > 0$ or $\beta_i > 0$).

Therefore, compared to the control treatment, we expect to have more subjects choosing X, as the risk of a lower monetary pay-off is lower (null) in T1 compared to T0 if a neighbour (both neighbours) also choose X.

Nudge treatment (T2)

This treatment is similar to the control treatment (same payoff table, see Table 4) but subjects are submitted to a nudge.

As presented in previous section, we use a "group comparative" nudge. Before the first period starts, subjects are told in the instructions of the game that after each period, each participant is informed of the ranking of their group in terms of total donations compared to the two other groups in the room, as illustrated in Figure 2. Three groups of 6 subjects were participating to the experiment simultaneously during a session. The group who generated the highest donation during a period received the following message at the end of that period: "Well done, your group is ranked first in terms of donations". This includes an injunctive norm (judgment of "well done") as well as the comparison to the other groups. The second (*third*) group received the message: "Your group is ranked second (*third*) in terms of donations".

Figure 2: Succession of periods with the nudge

When two groups generated the same level of donations during a period, then they were ranked according to the number of players choosing X. The group with the highest number of players choosing Xobtained the best ranking.[5]

Again, looking at payoffs, the only Nash equilibrium is reached by all players choosing Y. However if we consider the utility functions 3a and 3b, then multiple equilibria arise.

Nudge and agglomeration payment treatment (T3)

The payoffs remain the same as in T1 (see Table 5), but additionally, subjects were nudged, such as described for T2. The theoretical prediction is the same as in T1, if we consider payoffs only. Though when considering utility functions 3a and 3b, X can become a utility maximizing strategy.

4. Results

4.1. Effect of treatments on participation and coordination at group level

We first look at the effect of treatments on participation, reflected by the number of players choosing X, and on coordination on X, reflected by the level of environmental benefits produced at the group level (amount of donations). Figure 3 shows that, as predicted, treatment T0 displays the lowest levels of participation, ranging from 15 to 40%. Since choosing X leads to lower individual payoffs, this result clearly indicates that a share of subjects do value the potential donation to an environmental charity (high αi) and/or the warm glow feelings associated with choosing to play X (high βi). However this proportion decreases over time. This is also reflected when looking at coordination (Figure 4), as the level of coordination quickly declines toward zero in the T0 control groups.

The introduction of the social norm nudge (T2) seems to slightly improve the situation for both participation and coordination. However, Mann-Whitney tests (Table 6), comparing the average proportion of subjects choosing X and the average donation generated by player in both treatments show that these differences are not significantly different from zero. This seems to indicate that the $f_i(rank)$ component of the hypothesized player's utility function does weigh very little on average. Despite this non-significant average effect, we see that the nudge has a significant small impact on

[5] When groups could not be discriminated based on their donations or the number of players choosing X, then they were considered equal and given the same ranking. In this case, if two groups could not be discriminated, they were ranked first if the third group was worse off, or third if the third group was better. When the three groups in a session were equal, they were all ranked first if they had all chosen X (to "reward" pro-environmental behaviour), but third if at least one player in a group had chosen Y.

participation and coordination for some of the periods, including the first one. This is encouraging as it means that some improvement in coordination could be obtained at low cost, by simply signalling that relative group performance in terms of donation is made public.

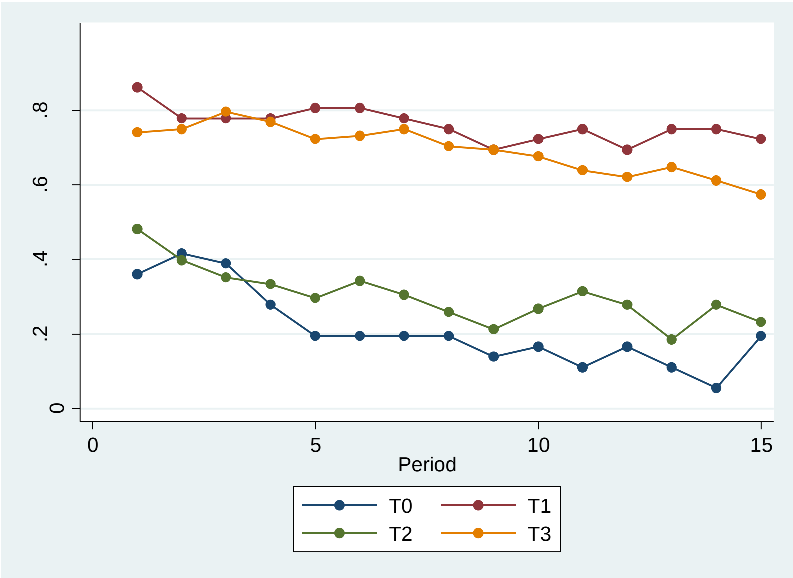

Figure 3: Average proportion of players choosing X by period and treatment

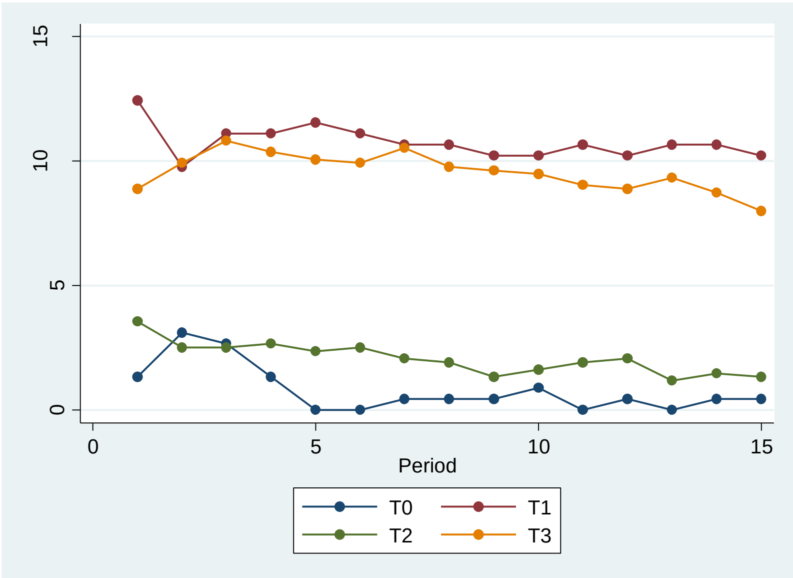

Figure 4: Average individual donation by period and treatment

Comparing T0 and T1 reveals that the agglomeration bonus does increase participation (Figure 3) and coordination (Figure 4), and this effect is statistically significant (Table 6). This result confirms what has already been demonstrated by previous experimental papers, either with different settings (Parkhurst et al, 2002) or with similar protocols (Banerjee et al, 2014). However, our results show a more robust effect since in our setting we have adjusted the rate of the agglomeration bonus so that the individual monetary pay-off of strategy X, when the two neighbours also choose X, matches the pay-off of strategy Y. The agglomeration bonus induces players to coordinate on the Pareto optimal Nash-equilibrium instead of picking the risk-dominant Nash-equilibrium.

Additionally, by triggering subjects' extrinsic and intrinsic motivations to choose X, through higher monetary payoffs and through the use of a real donation to charities, we obtain higher levels of participation and coordination and a comparatively smaller decline in these rates in regards with previous experiments (Banerjee et al. 2014).

Finally, when comparing T1 and T2, we find a superior and statistically significant effect of the agglomeration bonus over the nudge. Despite its budgetary cost, the agglomeration bonus creates more net benefits than the nudge.

What is more surprising is the outcomes of T1 versus T3. We expected that the nudge would supercharge the positive effect of the agglomeration bonus on participation and coordination by providing a positive feedback to groups with the highest donations. In fact the analysis of pooled data suggests that the nudge combined to the agglomeration bonus has a slightly negative effect, although non-significant statistically (Table 6). Further analysis will help us understand what can explain this counterintuitive outcome.

Table 6: Results - treatment effects

	Mean value (*Standard Deviation*)				Tests (Mann-Whitney) results: Prob > |z|			
Variable	T0: control	T1: AB	T2: Nudge	T3: AB+nudge	T0vsT1	T0vsT2	T1vsT2	T1vsT3
Number of observations	6	6	6	6				
Choice of X (proportion)	0.21 *(0.10)*	0.76 *(0.29)*	0.30 *(0.14)*	0.70 *(0.19)*	0.006	0.262	0.016	0.423
Donation €/player	0.80 *(0.89)*	10.76 *(5.83)*	2.07 *(1.57)*	9.56 *(4.07)*	0.007	0.150	0.016	0.631
Efficiency	0.19	0.71	0.25	0.65	0.007	0.078	0.016	0.631

4.2. Efficiency analysis

We define a variable of group net benefit $groupB$, reflecting the total benefits produced at group level (individual payoffs and donations), net from the budgetary costs linked to AB payments. From a policy-maker perspective, it embodies the total benefits produced (agricultural production and environmental benefits) from which we deduce the public spending (AB) and can be a proxy for net social welfare (at group level): $groupB = \sum_i \ revenue\ r_i \quad + donation_i - AB_i$ with i members of the group.

We analyse the efficiency of a treatment, as its capacity to induce coordination and to generate the greatest net benefit at group level. Under all treatment, the maximum net benefit can be obtained under the Pareto optimal equilibrium, reached when all players coordinate on X. Numerically it amounts to: $groupB_{max}$ = 6*(13 + 16 – 6) = 138. Conversely, the minimum net benefit that can be produced is reached when no neighbours coordinate to choose the same action, i.e. the pattern of choices at the group level is: X-Y-X-Y-X-Y. In this case the group net benefit is: $groupB_{min}$ = 3*7 + 3*13 = 60. We define the average efficiency of a treatment as:

$$efficiency = \frac{1}{n_{groups}} \sum_{groups} \frac{groupB - groupBmin}{groupBmax - groupBmin} \in [0,1]$$

A treatment is perfectly efficient if *efficiency* = 1, meaning that the groups under this treatment all generated the maximum net benefit. It is perfectly un-efficient if *efficiency* = 0, meaning that all the groups in this treatment generated the minimum net benefits possible, i.e. reached the minimum level of coordination.

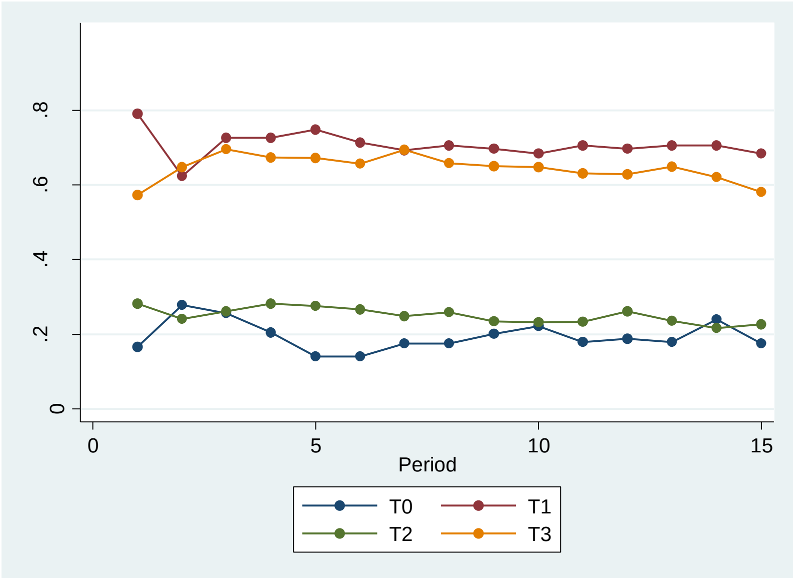

Figure 5: Average efficiency by period and treatment

The comparison of the different treatments' efficiency brings an additional perspective to the results (Figure 5). The AB increases the efficiency score from 0.19 in the absence of incentives (T0) to 0.71. We also observe that group efficiency is significantly improved (Table 6) by the introduction of a nudge only (T2) compared to T0. This is due to the fact that the nudge bears no budgetary costs. The efficiency comparison between T1 and T3 does not display a significant difference.

4.3. Analysis of individual strategies

In order to analyse how treatments impact individual decisions, we use random effects probit regressions (Banerjee et al. 2012; Banerjee et al. 2014). We estimate the treatment effect Δ in:

$$y_{it} = \alpha + \Delta T + \theta n_{i(t-1)} + \gamma t + u_i + \varepsilon_{it}$$

Player *i*'s action in period *t*, y_{it} *(X is chosen, 0* if *Y is chosen)* depends on the treatment *T,* period *t,* and neighbours' choices in the previous period (n_{it-1}: number of *i*'s neighbours choosing *X* in previous period). α is a constant term, u_i, individual random effects and ε_{it} the error term.

Table 7: Effect of treatments on individual choices of *X* (random effect probit models)

Variable	Treatment 1 AB	Treatment 2 Nudge	Treatment 3 AB + nudge
T (ref T0)	2.724***	0.287	1.963***
ni(t-1)	0.490***	0.317**	0.966***
t	-0.063**	-0.053***	-0.070***
_cons	-1.169**	-1.036***	-1.434***
Statistics			
N	*1008*	*2016*	*2016*
ll	*-323.92*	*-831.43*	*-584.695*
aic	*657.84*	*1672.87*	*1179.39*

*p<0.1; **p<.05; *** p<.01
Standard errors clustered by independent observation.

The individual analysis (Table 7) confirms the results already suggested by the descriptive statistics of outcomes. The agglomeration bonus (in T1 and T3) increases significantly players' probability to choose strategy X, whereas the nudge alone (T2) has no impact Players' choices of X are also significantly and positively influenced by their neighbour's choice of X at the previous period, in all treatments.

Since we have similar models, we can compare the value of estimated parameters to compare the intensity of effects. We can conclude that:

1) The positive and significant effect of T1 and T3 on participation appears to be stronger under AB (T1) than when the nudge and AB are combined (T3),
2) The positive and significant effect of participation by neighbours at the previous period appears to be the strongest when both nudge and AB are activated simultaneously,
3) The decay effect (reduction of participation with time) seems to be of similar intensity in the 3 treatments as compared to T0

We analyse the 4 treatments in a pooled model (random effects probit as used previously), to confirm differences in parameters (Table 8).

Table 8: Influence of neighbours' choices by treatment

Variable	Coef.
T1	1.824***
T2	0.363
T3	0.663*
ni(t-1)	0.388***
ni(t-1) * T1	0.632*
ni(t-1) * T2	-0.111
ni(t-1) * T3	1.186***
t	-0.054***
_cons	-1.159***
Statistics	
N	*4032*
LL	*-1287.91*

* p<0.1; **p<.05; *** p<.01, standard errors clustered by independent observation

Table 8 shows that in T0 and T2, neighbours' choices in the previous period have a similarly small effect on individual decision to choose X. This signals that the choice of X is led mainly by intrinsic motivations (encapsulated in the β parameter) – those subjects who choose X do so because they believe it's the right thing to do and to signal to others, even though their neighbours have not done so in the previous period and no donation has been produced.

In T1 and T3, the influence of neighbours' choices is much greater and significantly higher than in T0 since both interaction terms are significant (Table 8). A Wald test shows that the difference of neighbours' effect between T1 and T3 is not significant (p-value = 0.11). Our interpretation is that the agglomeration bonus triggers strategic behaviours, since neighbours' choices condition the bonus payment. However, the choice of X in this situation remains motivated by the perspective of a donation since payoffs remain the same under the two strategies.

To gain more insights on how the nudge works we analyse the effect of subjects' group ranking in the previous period (t-1) on their choice of X in the following period t. Results of these random effect probit models are presented in Table 9.

Table 9: Ranking effect in T2 and T3, all periods included

Variable	T2	T3
Ranked second (t-1) (ref: ranked first)	0.219*	-1.004*
Ranked Third (t-1) (ref: ranked first)	0.281**	-0.823
ni(t-1)	0.359**	1.330***
t	-0.045***	-0.080***
_cons	-1.073***	0.598
Statistics		
N	*1512*	*1512*
LL	*-612.74*	*-341.40*
AIC	*1237.48*	*694.79*

We find that the group ranking announced at (t-1) has a significant influence on players' choices. Though, the effect differs depending on the treatment. When the nudge is used by itself, being ranked second rather than first increases a player's probability of choosing X in t. The effect of being ranked third is even higher. When the nudge is used in combination with the AB, then being ranked second in t-1 has a negative effect of players' probability to choose X in t. The effect of being ranked third is not significant.

With the nudge only, this analysis shows that the expected positive impact of comparison exists. It is effective when the group is lagging behind in terms of overall coordination on X. In other words, being ranked first (and being congratulated for this success: remember when ranked first, subjects receive a "well done!" message) is less effective on players' participation than being ranked second or third. We can interpret this as follows. Being ranked second or third have two effects on the subject: it might induce him to cooperate more, simply because he is sensitive to social comparison and wants to increase his rank. Another interpretation is that it is a signal that there is a risk not to generate the donation since his group is not cooperating well. This can induce the subject to play X in order to increase the chances that the donation is generated. The positive impact of neighbours' choice of X is explained by the same reasons: it increases the chances to generate the donation and it reinforces the social norm effect (playing like others).

With treatment T3 (AB + nudge), the information of being ranked second has a negative effect on participation. Indeed the nudge carries also information on the probability of coordination failure: a subject can interpret a second ranking as a signal that his neighbours are not likely to be cooperative, inducing him to play on the risk dominant strategy Y. This could indicate that subjects under T3 are more motivated by the AB payment (extrinsic motivations) than by the intrinsic value of generating a donation or the social norm signal. The payment seems to crowd out the intrinsic motivation to play X. When combined with a payment, the comparative nudge has a counteractive effect: although it carries the same information to players, it does not trigger the same behavioural reactions by players. The standing alone nudge activates the social norm part of the utility function whereas when combined with AB, players use it as a strategic information to increase their chance to be paid the bonus.

5. Discussion and conclusion

Our results first show that mobilizing an agglomeration bonus increases significantly the level of participation and coordination. What is important to highlight is that the overall efficiency (in terms of net global welfare) is increased significantly, even when accounting – generously - for the shadow price of public money. Our second conclusion is that replacing an agglomeration bonus by a comparative nudge does lead to much lower outcomes in terms of coordination and environmental benefits/donation. Although we do obtain some efficiency gains, due to the fact that the nudge bears no budgetary costs, these remain very low. This hypothesis could be challenged in the real world since announcing the relative success of various groups of farmers would of course induce administrative and communication costs. The third conclusion relates to the combination of a payment and a nudge. Our initial hypothesis was that the nudge would supercharge the effects of the agglomeration bonus, both in terms of participation and spatial coordination. In fact, we demonstrate that the nudge has no significant additional effect when implemented alongside the agglomeration bonus, and could even counteract the positive impact of the bonus. There seems to be a negative synergy between these two incentives. One explanation is that the payment crowds out the intrinsic motivations triggered by the nudge, thus leading to more strategic behaviour instead of encouraging more altruistic strategies. Another explanation is that ranking the groups indirectly provides information on what other members of a subject's group choose, leading the subject to adjust their strategy towards the risk dominant equilibrium when informed that their group is not performing well in terms of coordination.

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