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

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Abstract

The environmental benefits from Payment for Environmental Service (PES) schemes can often be enhanced if farmers can be induced to enrol land in a spatially-coordinated manner. This is because the achievement of many targets for biodiversity conservation policy or water quality improvements are 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 (AB). There has also been an interest within the literature on PES design in using "nudges" to enhance participation and scheme performance. This paper explores whether a specific nudge in the form of information provided to participants on the environmental performance of their group relative to others can improve participation and spatial coordination, and/or enhance the AB performance. We design a laboratory experiment whereby the environmental benefits generated by a PES scheme are materialized by real contributions to an environmental charity. We argue that this mirrors the situation in actual PES schemes where participants derive utility from contributing to the environmental outputs of the scheme, in addition to the monetary payoffs they receive. Our results confirm positive environmental outcomes derived under an AB, but the impact of the nudge is much less environmentally effective. Interestingly, we find that the nudge does not significantly supercharge the AB, and can even worsen its performance.

Keywords: Agglomeration bonus, Nudge, Laboratory experiments, Coordination games, Agricultural policy, Environmental performance, Agri-environmental schemes

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1. Introduction

The spatial coordination of land enrolment is often a key determinant of the effectiveness of Payment for Environmental Services (PES) schemes when the provision of such services depends on the spatial configuration of ecosystems or biodiversity (Goldman et al., 2007; Wünscher et al., 2008; Polasky et al., 2014; Cong et al., 2014; Fooks et al., 2016). Examples of environmental objectives which favour spatial coordination of participants include flood alleviation through wetlands enhancement, the creation of wildlife corridors, and species re-introductions where the species in question requires a minimum area of contiguous conservation land in which to survive. Parkhurst et al. (2002) propose the use of an Agglomeration Bonus (AB) to tackle this spatial coordination problem. The principle of this mechanism is that landholders get a payment for participating in the PES scheme, which is then topped-up with an additional payment if the enrolled plot is contiguous to a plot enrolled by another landowner.

The AB scheme, typically tested in decontextualized conditions in the laboratory, has been shown to have significant effects on spatial coordination. However, the implementation of such an incentive structure creates a coordination game, which typically has multiple Nash equilibria which can be Pareto-ranked (Parkurst et al., 2002; Parkhurst and Shogren, 2007). Given the existence of multiple equilibria, Banerjee et al. (2014) show with laboratory experiments, that providing players with information on their neighbours' land use choice can improve the efficiency of the AB for spatial coordination by directing them towards a Pareto-improving equilibrium. A complementary study has 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 between players (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.

The AB, as presented originally by Parkhurst et al. (2002), depends on landowners comparing the financial payoffs from alternative actions to enrol or not enrol land, given their beliefs about the likely actions of others. However, studies of what actually motivates farmers to participate in actual PES schemes have found that such monetary payoffs are only part of the story: a relatively small but emerging literature suggests a broader set of motivations of farmers participating in actual PES schemes, with factors such as altruism, moral reputation or conforming to social norms being important (Michel-Guillou and Moser, 2006; Sheeder and Lynn, 2011; Sorice et al., 2011; Banerjee and Shogren, 2012). Taking into account such non-pecuniary motivations in the design of PES schemes, and in particular in the implementation of the AB, could be a way of enhancing their performance. Indeed, the use of behavioural incentives to increase participation and performance in environmental policy has also been the focus of a growing literature in recent years.

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. In this paper, we are particularly interested in the last of these: social norms as "shared understandings of how individual members should behave in a community" (Chen et al., 2009, p.11812). These encompass both what an individual understands the actions of others in some relevant peer group to be, and what she believes is expected of her by members of this group (Abbott et al., 2013). 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). For instance, Ferraro and Price (2013) evaluate the effects of social comparison information on demand for water by residential customers in the US. They find 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 based on social norms (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, and (iii) how the nudge is delivered tends to be important.

In the context of PES schemes, analyses of social norm nudges are scarce. Chen et al. (2009) show that individual decisions to re-enrol in a PES scheme subsidising farmers for afforestation in China can be positively influenced by the information that neighbours also intend to re-enrol. Kuhfuss et al. (2016a) show that the introduction of a payment conditioned to a minimum level of participation by neighbours significantly increases farmers' participation in an agri-environmental scheme. Kuhfuss et al. (2016b) find 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.

In this paper, we evaluate the performance of the AB in a laboratory setting. We design the protocol (section 3) by introducing two aspects of farmers' behaviours which are likely to impact the efficiency of the AB. These are that (i) farmers' motivations to participate in a PES can include non-pecuniary motivations, in particular a concern to protect the environment; and (ii) some individuals are likely to be sensitive to the provision of social norm information in deciding whether to enrol in an AB-type PES scheme. A consequence for spatial coordination through the AB is that farmers might be more willing to cooperate (i) if they know that spatial coordination has a higher real beneficial impact on the environment and (ii) if they know that other farmers also participate and are able to coordinate. Therefore, we build on Banerjee et al. (2012, 2014) by modifying the AB protocol to account for individuals' environmental preferences, and additionally test the effect of information on group performance in relation to spatial coordination.

In order to capture the effects of non-pecuniary motivates on PES participation, some researchers recreate pro-environmental behaviour through donations to environmental charities. For example Clot et al. (2016) 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 into the PES scheme generate a real money donation paid by the experimenters to an environmental charity of the player's individual choice. Introducing some level of context around the charity donation in the AB coordination game is likely to reflect individuals' preferences in the environmental domain. For instance, in a laboratory experiment, Dubois et al. (2015) show 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. 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 payoffs from their choices.

Use of this donation mechanism also provides a means of generating a social norm toward the environment within the laboratory. As subjects play within groups of "networked farmers", ranking the donation of each group relative to the donations of other groups in the previous round gives information about a social norm. Ranking which introduces competition between groups has already been employed in public good games to reduce free riding issues (Gunnthorsdottir and Rapoport, 2006; Tan and Bolle 2007); and in coordination games as a way to address the issue of coordination failure (Bornstein et al., 2002; Riechmann and Weimann, 2008). Bornstein et al. (2002) introduce inter-group competition in a coordination game and show that ranking increases coordination only if it has payoff consequences (in their case, only the winning group was paid or the winning group received a bonus). However, Tan and Bolle (2007) show that introducing information on group ranking without monetary incentives in the context of a public goods game was enough to reduce free riding.

In summary, our paper tests three research questions. First, what is the performance of the AB when environmental benefits generated by a PES scheme, and thus non-pecuniary benefits to participants, are generated in the laboratory by real contributions to environmental charities? Second, can a nudge be as efficient as a financial incentive such as the AB to foster participation and spatial coordination? Third, can the use of a nudge based on group comparison "supercharge" the effects of an AB both in terms of participation and spatial coordination?

2. Modelling Framework

We consider a finite number of farmers $i = 1, \dots, N$ who can manage their land in two alternative and mutually-exclusive ways, labelled X, Y. Land management option X refers to a pro-environmental or conservation land management adopted under a PES, whilst Y indicates that the land is managed for conventional agricultural production. Following previous studies (e.g., Banerjee et al., 2012, 2014), we assume that land use option Y generates lower environmental benefits but greater revenue compared to land use X., i.e., $r(X) < r(Y)$. 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.

Farmers' participation in a PES scheme usually generates environmental benefits, e, which is considered a public good or a positive externality (e.g., improved biodiversity or better flood protection), from which the landowner might benefit, but which mainly generates benefits to the wider society at a larger spatial scale. This last point is crucial as, contrarily to previous papers on the AB, we do not assume here that "landowners receive the full social benefits generated by their pro-environmental land-use activities" (Banerjee et al., 2014, p.1013). The production of this environmental benefit is conditioned to spatial coordination on the adoption of pro-environmental land management, X. To emphasize the importance of spatial coordination, we assume that the environmental benefit is only produced if at least one of a farmer's direct neighbours also adopts the conservation land management practice X. 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 proportional to the number of direct neighbours and equal to 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 two neighbouring farmers with an agglomeration bonus only if both farmers manage to coordinate on X. With n_i neighbours, farmer i choosing X will receive a bonus bn_i. That is, the bonus paid and received is proportional to the environmental benefits generated through land management choices.

In view of the above setup, assuming to begin with that farmers only consider the monetary payment (agricultural revenue and bonus payment) and do not take into account how their land use strategy impacts the generation of environmental benefits, the monetary payoff $p_i(\sigma_i)$ of farmer $i = 1, \dots, N$ adopting land use strategy $\sigma_i = X, Y$ reads:

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

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

As noted in the preceding section, farmers may not only consider monetary revenues when choosing how to manage their land. Indeed, they may not only consider their financial gains following the payoff function specification in Equation (1), but may also feel concerned about the impact of their practices on the environment. Farmers may display altruistic preferences towards environmental conservation and may therefore value the environmental benefit generated by choosing a pro-environmental land management in coordination with their neighbours, even though they do not derive financial gains from it directly. Of course, farmers are typically heterogeneous in their preferences for the environment and/or their altruism (reflected by parameter a_i in equation (2)), but we assume that this non-monetary utility term is proportional to the environmental benefit they generate with their choice of X and therefore depends on their neighbours' choices. This is in line with a recent empirical study by Lawley and Yang (2015) who investigate the spatial interactions among neighbouring landowners in the context of conservation easements in Canada. 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 w_i in equation (2)), even though no significant environmental benefit is produced. 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 payoff function of choosing X or Y can be re-stated as follows:

$$(2) \quad U_i(\sigma_i) = r(\sigma_i) + b(\sigma_i)n_i + a_i e(\sigma_i)n_i + w_i(\sigma_i)$$

with $e(X) = e > 0,\ e(Y) = 0$, $w_i(X) \geq 0$ and $w_i(Y) = 0$.[1]

In the absence of an AB scheme, and when the only argument of farmers' utility is revenue, the unique Nash equilibrium is that all farmers choose Y, since $r(X) < r(Y)$. However, in the case of farmers' utility function (2), thereby bringing in environmental and altruistic preferences, some farmers might prefer to choose X over Y, even without the offer of an AB. Depending on the value of the behavioural parameters, this represents a situation where multiple Nash equilibria exist. If the AB is introduced and is sufficiently large $\left(b \geq \frac{r(Y)-r(X)}{N}\right)$, then there are two Nash equilibria: one in which all the farmers choose X (the Pareto dominant equilibrium) and one with all farmers choosing Y (the risk dominant equilibrium) This situation constitutes a coordination problem. .

As stated in the introductory section, one of the objectives of this paper is to test the impact of information about a social norm on farmers' behaviour. We speculate whether a nudge, based on social comparison information, may induce more farmers to coordinate on the Pareto dominant Nash equilibrium, X. Contrary to an AB, however, a nudge does not change farmers' monetary payoffs, but it can impact farmers' utility if they are sensitive to social comparisons. We propose a comparative nudge which consists of ranking farmers' networks according to the level of environmental benefits they generate as a group. This nudge should inform farmers on how their group performs compared to other groups of farmers, thus providing information about a descriptive norm (i.e., what most people do)[2] and additionally inducing some inter-group competition that could encourage the choice of X. This ranking also provides indirect information about the injunctive norm, i.e., the "perception of what most people approve or disapprove of" (Cialdini et al., 1991) since subjects get a congratulation message when their group is ranked first.

We hypothesise that belonging to a group which is ranked higher in terms of environmental benefits provided does increases individual farmers' utility, because they perceive themselves and the group as being aligned with social norms and performing better in favour of the environmental good. We adjust the Utility function as follows:

$$(3) \quad U_i(\sigma_i) = r(\sigma_i) + b(\sigma_i)n_i + a_i e(\sigma_i)n_i + w_i(\sigma_i) + f_i\big(rank(\sigma_i|\sigma_j, j \in \{1, \ldots, N\}, j \neq i)\big),$$

where $f_i(rank = 1^{st}) \geq f_i(rank = 2^{nd}) \geq f_i(rank = 3^{rd})$ as subjects are assumed to value social reward.

We can hypothesise that the choice of X increases the chances of creating more environmental benefits within a group, hence increases the probability of achieving a higher rank in the inter-group competition. Equation (3) shows that when farmers display pro-environmental social behaviour, then some might prefer to choose X over Y, even without the AB, either to satisfy their environmental preferences, as a warm glow effect, or to enter the inter-group competition.

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

[2] Note that another descriptive norm is conveyed by information on what others within a group do, in particular neighbouring farmers. We will discuss this in Section 4.3.

Under such circumstances multiple Nash equilibria may exist, depending on the value of the behavioural parameters.

3. Experimental Design and Hypotheses

3.1. General settings

Modelling the spatial connectivity between farmers requires the imposition of a spatial structure on subjects in a laboratory setting. In this respect, we follow the network structure used by Banerjee et al. (2012, 2014, 2017), where subjects are arranged on a circular network. 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 left-hand side and one on the right-hand side). Given a circular network, the number of farmers choosing X, n_i, can either be 0, 1 or 2. Note, however, that a subject is *indirectly* linked to all other subjects on the network through their direct neighbours. The direct and indirect linkages between subjects across space are essential in order to capture the environmental benefits through agglomeration. Moreover, the advantage of employing 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 (e.g., Alós-Ferrer and Weidenholzer, 2008). A farmer may know what land management actions his *direct* neighbouring farmer is pursuing but may not fully know the decisions of the *indirect* neighbouring farmers, i.e., the social interactions among more distant neighbours on the network tend to be weaker (e.g., Lawley and Yang, 2015). 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 extract rents because of their specific position on the network[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 laboratory with non-farmer participants, we told subjects that the choices they would make during the experimental session can generate a donation to an environmental charity[4]. The environmental charity implements actions from which subjects can benefit, but which mainly generate benefit to the wider society, just as environmental efforts provided by farmers are beneficial to them and their family, but also to other citizens. 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 a PES scheme for non-pecuniary motivations.

Following our theoretical model as discussed in the previous section, the level of the donation depends on the number of direct subject-neighbours also choosing X given that the subject

[3] For instance, a linear network is a spatial structure exhibiting more asymmetry where farmers located centrally may have a more favourable position for rent extraction.

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

chooses X. Subjects did not benefit from the donation directly. The donation generated by a subject was placed in an envelope (see Figure 1) at the end of each session in the presence of the subject. The experimenters subsequently sent the total amount of donations to the corresponding charities, and transferred to the subjects a confirmation of their donations by e-mail. Apart from using specifically-designated environmental charities, the rest of the experiment was decontextualized in order to purely consider how financial incentives and nudges affect the choices and outcomes in the experiment (Cason and Raymond, 2011). However, we decided to explicitly mention that the charities were environmental charities as we wished to capture subjects' preferences for the environment.

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

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

Each session was composed of 15 periods, where players were repeating the same choice under the same treatment within the same group and were keeping the same neighbours (partner design). After each period, each player was informed of their own monetary payoff, the donation generated given their choice of land use strategy, and the choices of their two direct neighbours. No communication was allowed within groups or between groups. At the end of a session, 3 periods were randomly selected and subjects were paid their average payoff for these 3 periods. The actual donation made to the charity was the average donation generated in these 3 periods.

In view of our treatments, we implemented a two-by-two design as shown in Table 2 below. We next outline each treatment in more detail by providing the underlying payoff tables and by deriving hypotheses. This is based on the 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
Revenue (r)	€7	€13
Agglomeration payment (b)	€3	€0
Donation (d)	€8	€0

3.2. Treatments and hypotheses

Control treatment (T0)

In the control treatment, subjects can choose X and receive a lower revenue, $r(X) = 7$, or they can choose Y and receive a higher 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 shown in (Table 4):

Table 4: Payoff table for the control treatment (T0) and the nudge-only treatment (T2)

		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 discussed in the previous section, if subjects' utility functions do not include any pro-social or pro-environmental component ($a_i = w_i = 0$ for all i) then the unique Nash equilibrium is reached by all players choosing Y (hypothesis 0.a). However, if the value subjects gain from the behavioural components a_i and w_i described in equation 2 is greater than the difference of revenue between Y and X, then multiple Nash equilibria can exist, Y remaining the risk dominant equilibrium. Therefore, we anticipate some participation since the donation may trigger altruistic behaviours (encapsulated in parameter a_i of our model) or/and warm glow feelings (parameter w_i). We hypothesize that a majority of subjects under T0 will choose Y and that few subjects i displaying high a_i and w_i may choose X (hypothesis 0(b)).

Hypothesis 0 (a): $\forall i \in \{1, \dots, N\}, a_i e(X) n_i + \omega_i(X) < r(Y) - r(X)$, therefore $\forall i \in \{1, \dots, N\}, \sigma_i = Y$ and all subjects choosing Y is the unique Nash equilibrium.

Hypothesis 0 (b): $\exists i \in \{1, \dots, N\} | a_i e(X) n_i + \omega_i(X) \geq r(Y) - r(X)$, therefore $\exists i \in \{1, \dots, N\} | \sigma_i = X$ and multiple Nash equilibria exist, all subjects choosing Y being the risk dominant equilibrium.

Agglomeration bonus treatment (T1)

In this treatment we implicitly introduce the agglomeration bonus by increasing the monetary payoff of choosing X when neighbours choose X as well. If only one neighbour chooses X, the subject receives $r(X) + b = 7 + 3 = 10$; when 2 neighbours choose X, the subject receives twice the agglomeration payment, $r(X) + 2b = 7 + 6 = 13$; if none of a subject's neighbours choose X, then no agglomeration bonus payment is received and the monetary payoff is only $r(X) = 7$, as in the control treatment. Table 5 summarizes the payoffs for this treatment.

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€

We have adjusted the rate of the AB so that the individual monetary pay-off of strategy X, when the two neighbours choose X, matches the pay-off of strategy Y. In the absence of any pro-social or pro-environmental behaviour ($a_i = w_i = 0$), there are two Nash equilibria of equal payoffs, one where all players choose X, the other risk-dominant one, where all players choose Y (Hypothesis 1.0). However, if at least one player displays a strictly positive a_i or w_i, then multiple Nash equilibria exist (hypothesis 1.1). Players with relatively low, but positive, values for the behavioural components (such as 0< $a_i e(X) n_i + \omega_i(X) < r(Y) - r(X)$) who would have chosen Y under T0 might therefore be induced to switch to X (hypothesis 1).

Hypothesis 1.0: $\forall i \in \{1, \ldots, N\}, a_i e(X) n_i + \omega_i(X) = 0$, therefore two Nash equilibria with equal payoff exist: one where all subjects choose X and one where all subjects choose Y, the latest being the risk dominant equilibrium.

Hypothesis 1.1: $\exists i \in \{1, \ldots, N\} | a_i e(X) n_i + \omega_i(X) > 0$, therefore $U(X | n_i = 2) > U(Y)$ and multiple Nash equilibria exist: all subjects choosing X becoming the Pareto dominant equilibrium while all subjects choosing Y remains the risk dominant equilibrium.

Nudge treatment (T2)

This treatment is similar to the control treatment in terms of payoffs (see Table 4), but now subjects are nudged, which in this case consists of a "group comparison" nudge. Before the start of the first period, subjects are told in the instructions of the game that after each period, each subject will be informed of the ranking of their group in terms of total donations to the environmental charities compared to the two other groups in the room (Figure 2). 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 a comparison to the other groups. The second (*third*) group received the message: "Your group is ranked second (*third*) in terms of donations". When two groups generated the same level of donations during a period, then they were ranked according to the number of subjects choosing X, where the group with the highest number of subjects choosing X obtained the higher ranking accordingly.[5]

[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, 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 each group had chosen Y.

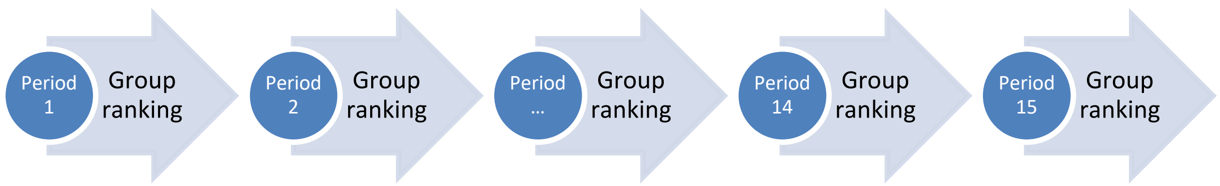

Figure 2: Succession of periods in the nudge treatment

With the introduction of the nudge in T2, and if $\exists i \in \{1, \ldots, N\} | a_i e(X) n_i + \omega_i(X) + f_i\big(rank(X)\big) - f_i\big(rank(Y)\big) \geq r(Y) - r(X)$, then multiple Nash equilibria exist, all subjects choosing Y being the risk dominant equilibrium.

Nudge plus agglomeration bonus treatment (T3)

In treatment T3, the payoffs are the same as in treatment T1 (see Table 5), but additionally subjects are nudged in the same way as in treatment T2. In this treatment, if $\exists i \in \{1, \ldots, N\} | a_i e(X) n_i + \omega_i(X) + f_i\big(rank(X)\big) - f_i\big(rank(Y)\big) > 0$, multiple Nash equilibria exist, all subjects choosing X being the Pareto dominant equilibrium while all subjects choosing Y being the risk dominant equilibrium.

For these last two treatments, we hypothesize that if players are sensitive to the announced ranking and reward message, and believe that by choosing X rather than Y they can increase the ranking of their group, then the choice of strategy X increases in treatments with nudge (T2 and T3) compared to their respective control treatment without nudge (respectively T0 and T1), therefore leading to higher numbers of subjects coordinating on X. This is stated in the following hypothesis.

Hypothesis 2.0: $\forall i \in \{1, \ldots, N\}, f_i\left(rank\big(\sigma_i = X | \sigma_j, j \in \{1, \ldots, N\}, j \neq i\big)\right) - f_i\left(rank\big(\sigma_i = Y | \sigma_j, j \in \{1, \ldots, N\}, j \neq i\big)\right) \leq 0$, therefore an equal number or fewer subjects will be willing to coordinate on X in T2 (*T3*) than in T0 (*T1*), since choosing X would require higher values of a_i and ω_i in T2 (*T3*) compared to T0 (*T1*).

Hypothesis 2.1: $\exists i \in \{1, \ldots, N\} | f_i\left(rank\big(\sigma_i = X | \sigma_j, j \in \{1, \ldots, N\}, j \neq i\big)\right) - f_i\left(rank\big(\sigma_i = Y | \sigma_j, j \in \{1, \ldots, N\}, j \neq i\big)\right) > 0$, therefore more subjects will be willing to coordinate on X in T2 (*T3*) than in T0 (*T1*), since subjects in T2 (*T3*) with lower a_i and ω_i than in T0 (*T1*) will choose X rather than Y.

Additionally, by comparing T1 to T2 we can assess the performance of the AB relative to the nudge alone. The nudge, being based on non-monetary incentives, might be less effective than the AB in inducing spatial cooperation if subjects are more responsive to monetary incentives compared to ranking. Alternatively, if some subjects are more responsive to the ranking than to the AB, then the nudge might perform better.

4. Results

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

Let us first look at the effect of the various treatments on participation, reflected by the number of subjects choosing X. Correspondingly, we can also look at the degree of spatial coordination on X, reflected by the level of environmental benefits produced at the group level through the lens of the total amount of donations. As predicted, the control treatment T0 displays the lowest levels of participation, which ranges from 15 to 40 percent (Figure 3). 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 a_i) and/or the warm glow feelings associated with choosing to play X (high w_i), rejecting hypothesis 0(a) in favour of hypothesis 0(b). However, the proportion of subjects choosing X decreases over time, with groups converging to the risk dominant equilibrium. This is also reflected when we consider spatial coordination (Figure 4), as the level of coordination quickly declines toward zero in the control groups, T0. This indicates that the choice of X is mainly led by environmental preferences (reflected in a_i), which relies on coordination, rather than by warm glow effects (reflected in w_i). Indeed, the subject displaying a strictly positive w_i derives additional utility from choosing X, no matter what the environmental outcome might be. There is therefore no reason why this warm glow should fade away with time. In contrast, the environmental/altruistic component of the utility depends also on the choices made by neighbours. If they repeatedly choose Y, then the environmental benefit is not created and the X strategy becomes less attractive.

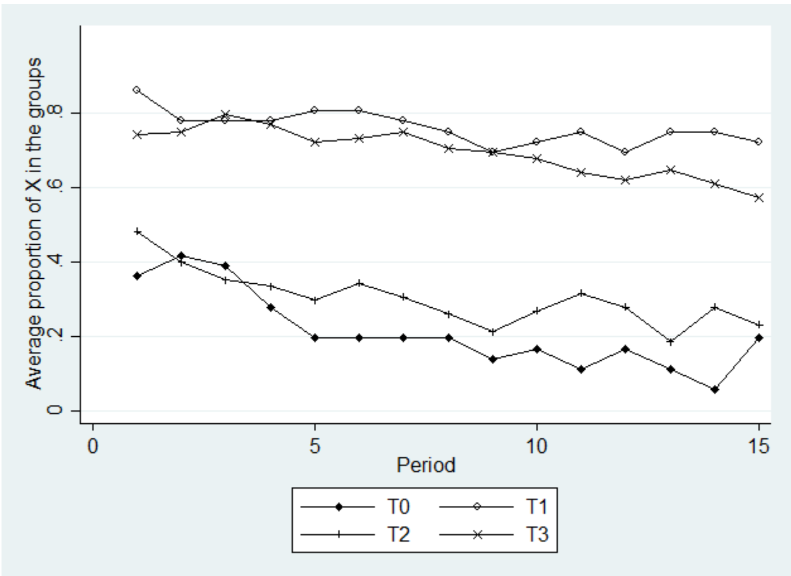

Figure 3: Average proportion of players choosing X by period and treatment

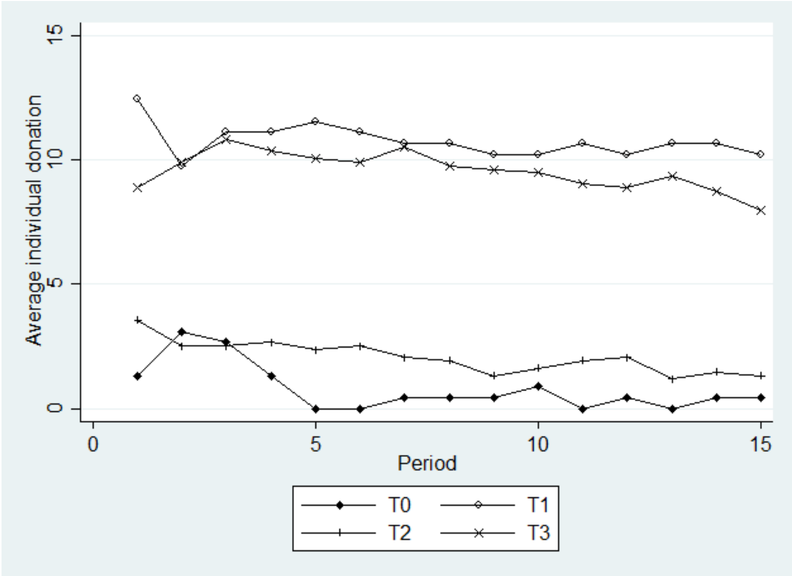

Figure 4: Average individual donation by period and treatment

Comparing T0 and T1 reveals that an AB increases participation (Figure 3) and enhances coordination (Figure 4). This effect is statistically significant (see Table 6). This result accords with findings in 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, as emphasized before, the rate of the agglomeration bonus was chosen so as to match the payoff of strategy X, when the two neighbours also choose X, with the payoff of strategy Y. In our setting, the choice of X is therefore motivated by environmental preferences (a_i), as no increase in individual financial payoffs can be expected from choosing X, but the AB incentivizes subjects with relatively lower values of a_i and ω_i to choose X (such as $0 < a_i E(X) n_i + \omega_i(X) < r(Y) - r(X)$[6]. The AB and donations induce players to coordinate on the Pareto optimal Nash equilibrium instead of selecting the risk dominant Nash equilibrium. Additionally, by triggering subjects' extrinsic and intrinsic motivations to choose X (through the AB and through the use of a real donation to charities, respectively), we obtain higher levels of participation and coordination and a comparatively smaller decline in these rates compared with previous experiments (e.g., Banerjee et al., 2014).

The introduction of inter-group competition via the nudge (T2 vs T0) seems to slightly improve the situation for both participation and spatial coordination. However, Mann-Whitney tests, comparing the average proportion of subjects choosing X and the average donation generated by subjects in both treatments, show that these differences between T2 and T0 are not significantly different from zero (see Table 6). This seems to indicate that the ranking component of the hypothesized subject's utility function has little average effect on choices, providing little support to hypothesis 2.1. Despite this non-significant average effect, however, we see that the nudge has a significant but small impact on participation and coordination for

[6] Since we found evidence with results from T0 that some subjects exhibit environmental preferences (high values of α_i, then hypothesis 1.0 is automatically rejected. The higher choice of X in T1 compared to T0 can be explained by the wider range of possible values for α_i and ω_i in hypothesis 1.1 compared to hypothesis 0(b).

some of the periods, including the first. This is encouraging, as it means that some improvement in coordination could be obtained at low cost by simply signalling relative group performance.

When comparing T1 and T2, we find a superior and statistically significant effect of the AB over the nudge. What is more surprising is the comparison of T1 versus T3. We speculated in hypothesis 2.1 that a nudge would "supercharge" the positive effect of the AB on both participation and spatial coordination, by providing a positive feedback to groups with the highest donations (and thus the highest level of environmental outputs). In fact, the analysis of pooled data suggests that the nudge combined with the AB has a slightly negative effect, although it is not statistically significant (see Table 6), refuting hypothesis 2.1. The reason why the nudge could in fact reduce the positive effect of the AB, thus revealing an unexpected negative synergy, will be investigated in more details in section 4.3.

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 independent 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

*** H0 rejected with 99% confidence level, ** H0 rejected with 95% confidence level, H0 rejected with 90% confidence level, H0 is the hypothesis that both mean values are equal

4.2. Efficiency analysis

Let us next define a variable representing a group's net benefits, denoted $groupB$, reflecting the total benefits produced at group level (comprising both individual payoffs and donations) net of the budgetary costs linked to AB payments. From a policymaker perspective this variable embodies the total benefits produced (agricultural production value derived from choices X and Y, and environmental benefits) from which we deduce the public spending (AB payments). This can be used as a proxy for net social welfare at the group level: $groupB = \sum_i (r_i + dn_i - bn_i)$ with i members of the group.

We can analyse the efficiency of a treatment as its capacity to induce spatial coordination and to generate the greatest net benefit at the group level. Under all treatments, the maximum net benefit can be obtained when all players coordinate on X without any public subsidy Numerically this amounts to: $groupB_{max} = 6 \times (13 + 16 - 6) = 138$. 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: $groupB_{min} = (3 \times 7) + (3 \times 13) = 60$. We can subsequently define the standardized average efficiency of a treatment as follows:

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

A treatment is fully efficient if *efficiency* = 1, meaning that the groups under this treatment generated the maximum net benefit. It is fully inefficient 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. A comparison of the treatments' relative efficiency brings an additional perspective to the results. Figure 5 shows that the AB increases the efficiency score from 0.19 in the absence of incentives (T0) to 0.71 (T1). We also observe that the AB yields greater efficiency than the nudge only, despite its cost. Group efficiency is also significantly improved (Table 6, last row) by the introduction of a nudge only (T2) compared to the control treatment (T0). This is due to the fact that the nudge, even if its effect is small, bears no budgetary costs. The efficiency comparison between T1 and T3 does not display a significant difference.

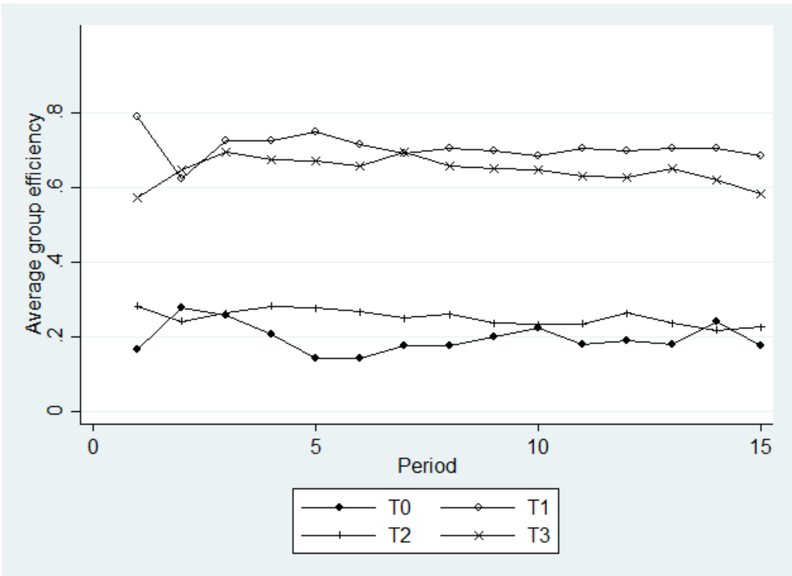

Figure 5: Average efficiency by period and treatment

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, 2014). We estimate the treatment effect ΔT in:

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

With $\sigma_{it} = X$, if $\sigma_{it}^{*} > 0$, and $\sigma_{it} = Y$ if $\sigma_{it}^{*} \leq 0$.

The probability that subject i chooses action X in period t depends on treatment T, period t, and neighbours' choices in the previous period (n_{it-1}: number of i's neighbours choosing X in previous period). Further, α is a constant, γ is a parameter to be estimated, u_i are individual random effects and ε_{it} is 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***
n_{it-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 analysis at the individual subject level confirms the results already suggested by the descriptive statistics of outcomes (Table 7). The AB (in treatments T1 and T3) significantly increases subjects' probability to choose strategy X, whereas the nudge alone (T2) has no real effect. Subjects' choices of X are also significantly and positively related to their direct neighbours' choice of X in the previous period; this holds for all treatments. With successive rounds, the tendency to choose X declines over time, as shown by negative value of the coefficient *t*.

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

1) The positive and significant effect of the AB 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 (T3),
3) The decay effect (reduction of participation with time) seems to be of similar intensity in all treatments, compared to T0, as if both types of public interventions, financial incentives (the AB) and nudges, or even the two combined, suffered from an equivalent disinterest from players. This might be explained by the prevalence of the environmental preference factor in the utility function over the warm glow factor.

We analyse the 4 treatments in a pooled model (using a random effects probit as previously) to confirm that the differences in parameters observed in Table 7 are actually significant (Table 8).

Table 8: Influence of neighbours' choices by treatment

Variable	**Coef.**
T1 (ref T0)	1.824***
T2 (ref T0)	0.363
T3 (ref T0)	0.663*
n_{it-1}	0.388***
n_{it-1} * T1	0.632*
n_{it-1} * T2	-0.111
n_{it-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 T1 and T3, the influence of neighbours' choices is much greater and significantly higher than in T0 and T2. A Wald test confirms that the difference of neighbours' effect between T1 and T3 is not significant (p-value = 0.11). This confirms our interpretation that the AB induces strategic behaviours (playing X and signalling to neighbours that playing X is a winning strategy), thus strengthening the positive effect of environmental preferences. Indeed, while the neighbours' influence in T0 and T2 only relies on the small number of subjects who exhibit sufficiently strong environmental preferences (high value of a_i) to compensate for the loss of revenue, the AB induces additional individuals with relatively lower values of a_i to choose X (see hypothesis 1.1). Note that the choice of X in this situation remains motivated by the perspective of a donation since individual monetary payoffs when choosing X are not higher than the monetary payoff of the risk dominant strategy, Y.

To gain more insight on how the nudge works, and to better understand the counterintuitive results obtained in treatment T3, we analyse the effect of subjects' group ranking in the previous period ($t-1$) on their choice of X in period t. Results of these random effect probit models are presented in Table 9. We find that in most cases the group ranking announced in period $t-1$ has a significant influence on subjects' choices in period t. Interestingly, the effect differs depending on the treatment. When the nudge is used on its own (treatment T2), being ranked third rather than first significantly increases a subject's probability of choosing X in period t (significant at 10% when ranked second). When the nudge is used in combination with the AB (treatment T3), then not being ranked first in period $t-1$ has a negative effect on subjects' probability to choose X in period t (significant at 10% only if ranked second), whilst the effect of being ranked third is not significant.

Table 9: Ranking effect on choice of X 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
n_{it-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*

The analysis of Treatment 2 shows that the expected positive impact of social comparison exists mostly when the group is lagging behind in terms of overall coordination on X. In other words, being ranked first and being congratulated for being first is less effective on subjects' participation than being ranked second or third. We can interpret this as follows. Subjects coordinate because they are sensitive to social comparison and to the injunctive norm. They play X also because they want to increase their rank to win the inter-group competition. The positive impact of neighbours' choice of X can be explained likewise: it reinforces the social norm (playing like others) but it also increases the chances to generate the environmental good via the donation, something that subjects motivated by environmental outcomes are sensitive to.

In contrast, when the nudge is used in conjunction with the AB (treatment T3), 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 being ranked second as a signal that his neighbours are not likely to be cooperative, inducing him to play the risk dominant strategy Y. This could indicate that subjects in treatment T3 are more motivated by the AB payment (extrinsic motivations) than by the intrinsic value of generating a donation or the social norm. The AB seems to crowd out the intrinsic motivation to select X. When combined with an AB, the comparative nudge has thus a counteractive effect: although it carries the same information to subjects, it does not trigger the same behavioural reactions. We speculate that the stand-alone nudge "activates" the social norm component of the utility function, whereas when combined with the AB, subjects use the information conveyed by the nudge as strategic information to increase their chance of being paid the bonus.

5. Conclusions

Two core ideas in the Payment for Ecosystem Service (PES) literature are that (i) private landowners can be encouraged to spatially coordinate their actions using some kind of agglomeration payment rewarding participation by neighbours; and (ii) behavioural interventions such as nudges can change participation in PES schemes. In this paper, we bring together these two ideas to address two main questions. First, can a nudge be used to “supercharge” – that is, to improve the performance of – the Agglomeration Bonus (AB)? Second, could a nudge actually be used in place of an AB, such that the effects of the AB on coordination are replicated by the nudge? We use a laboratory experiment to try to answer these questions, with a design that reflects a third feature of the PES literature, namely that farmers' desire to participate in such schemes is partly explained by the value they place on the environmental benefits generated.

Our laboratory results, transposed to the context of farmers and PES, show that an AB can be expected to significantly increase the level of participation and spatial coordination within a PES scheme. What is important to highlight is that the overall efficiency is increased significantly, even when accounting for the shadow price of public funds and when the environmental benefits are not completely included in the subjects' payment, but generated in the lab through donation to charities.

Our second conclusion is that replacing an AB by a comparative nudge leads to less socially-valued outcomes in terms of spatial coordination and environmental benefits/donations. Announcing rankings, based on relative group performance in terms of environmental benefits generated, is not enough to improve coordination. This is in line with the results obtained by Borsntein et al. (2002), but goes against the social norm literature based on theoretical (Rege, 2004) and empirical studies. The competition induced by providing information to participants on the ranking of their group appears to be stronger than the positive effects of this social norm on the desired outcome. Although we do obtain some efficiency gains with the nudge due to the fact that the nudge bears no budgetary costs, these gains remain low[7].

The third conclusion relates to the combination of a payment and a nudge. Our initial hypothesis was that the nudge would strengthen the effects of the AB, both in terms of participation and spatial coordination. However, we find that the nudge has no significant additional effect when implemented alongside the AB, and could even counteract the positive impact of the bonus payment. There seems to be a negative synergy between these two incentives. One explanation could be 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 could be that ranking the groups indirectly provides information on what other members of a subject's group choose, leading a subject to adjust their strategy towards the risk dominant equilibrium when informed that their group is not performing well in terms of coordination. Thus, it is not excluded that the positive impact of the AB could be enhanced with a different (more convincing) nudge. Another complementary explanation is that virtual groups formed in a laboratory, in which members have no information on each other's and are not allowed to communicate, bear little similarities with true social groups embedded in common institutions and sharing the same history. Therefore the power of the nudge in the laboratory is expectedly much smaller than in real life and it is understandable that the “game setting” of the protocol triggers more the strategic component of subjects' choices than their behavioural and social components. The fact that we do find an impact, even under these conditions, is very encouraging and is a strong argument in favour of nudges.

[7] The assumption of low costs 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.

Finally, we also observe that the effect of financial incentives and nudges are reduced over time, at a similar pace though. This suggests a challenging avenue for research, which is to design policy interventions, or a renewal of policy-interventions, which can have a longer-lasting effect.

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