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The Impact of Information Provision on Agglomeration Bonus Performance: An Experimental Study on Local Networks*

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Abstract

The Agglomeration Bonus (AB) is a mechanism to induce adjacent landowners to spatially coordinate their land use for the delivery of ecosystem services from farmland. This paper uses laboratory experiments to explore the performance of the AB in achieving the socially optimal land management configuration in a local network environment where the information available to subjects varies. The AB poses a coordination problem between two Nash equilibria: a Pareto dominant and a risk dominant equilibrium. The experiments indicate that if subjects are informed about both their direct and indirect neighbors' actions, they are more likely to coordinate on the Pareto dominant equilibrium relative to the case where subjects have information about their direct neighbors' action only. However, the extra information can only delay – and not prevent – the transition to the socially inferior risk dominant Nash equilibrium. In the long run, the AB mechanism may only be partially effective in enhancing delivery of ecosystem services on farming landscapes featuring local networks.

JEL classification: C72, C73, C91, C92, Q24, Q57

Keywords: Agglomeration bonus, agri-environment schemes, biodiversity conservation, ecosystem services, information spillovers, Payments for Ecosystem Services, spatial coordination

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1. Introduction

Improvements to the delivery of ecosystem services from farmland such as carbon sequestration, pest management, and biodiversity and habitat protection, can be obtained by adopting pro-conservation land uses on these properties otherwise devoted to profit-based agriculture (Swinton et al. 2007). Adopting such pro-conservation land uses is typically costly to the farmer, meaning that they may require financial compensation for implementing them (Armsworth et al. 2012). As a result, Payment for Ecosystem Services (PES) schemes have been introduced by conservation agencies in many countries to incentivize these changes in land management. For example, the Conservation Reserve Program (CRP) in the U.S. has disbursed nearly $26 billion to retire 36.8 million acres of farmland from agriculture to reduce soil erosion and preserve approximately 1.8 million acres of wetland habitats (Kirwan et al. 2005). In Europe an increasing fraction of total spending on agriculture goes to funding agri-environmental schemes (Cooper et al. 2009) with further increases planned under reforms to the post-2013 Common Agricultural Policy.

In the context of increasing the environmental benefits from farmland management, an important issue is that spatial coordination of land management efforts can generate ecological benefits more effectively (Hanley et al. 2012). Encouraging farmers to enrol adjacent land parcels which are of high ecological value by attaching greater sign-up payments to them has been shown to generate higher environmental benefits than scenarios where the incentives are not spatially differentiated (Wätzold et al. 2010). Land management of geographically proximate (or even adjacent) parcels/properties for creating contiguous habitat of at least a critical minimum size, and establishing connections between patches to create habitat corridor linkages facilitating species mobility is beneficial for biodiversity conservation (Margules and Pressey 2000; Dallimer et al. 2010). Further, spatial clustering of organic farm operations can have lower negative impacts on local biodiversity and water quality, can mitigate losses from retiring land to create buffers preventing pesticide spill-over from neighbouring conventional farms, and can even reduce certification costs of organic farmers (Parker and Munroe 2007). Finally, landscape-level creation of non-crop habitat for natural predators on the landscape is more successful in eradicating pests than strategies which ignore such habitat management (Landis et al. 2000; Zhang et al. 2010).

One approach to achieving this spatial coordination of land uses and land management is the Agglomeration Bonus (AB) subsidy scheme (Parkhurst et al. 2002; Parkhurst and Shogren 2007).[1] The AB is a two-part payment scheme, comprising of a base level compensation for all participants and a top-up bonus that they receive if their neighbors participate and implement similar land use practices on their properties. By rewarding coordinated actions across space, land management decisions of neighbouring farmers under the AB scheme can be considered to be strategic interactions in a coordination game, with multiple Nash equilibria being Pareto ranked in terms of payoffs. The existence of multiple equilibria can, however, give rise to coordination failure. Experimental evidence provided by Parkhurst and Shogren (2007) and Warziniack et al. (2007) indicates that the incidence of coordination failure can be reduced by repeated interaction that increases participant experience and builds reputation for spatial coordination, by setting simple spatial targets to which participants can coordinate with relative ease, and by permitting participants to communicate prior to choosing their actions. Successful coordination on socially desirable land use outcomes are also more likely on landscapes with fewer participants owing to the difficulty of coordination in larger groups (Banerjee et al. 2012).

A key issue that has received limited attention in the AB literature, and which forms the focus of this article, is that the outcome of strategic interactions between landowners depends on the amount of information available to them about other landowners' choices. This article report results of a laboratory experiment in which the information each participant receives about the land use decisions of others is varied. Our interest in this issue is motivated by both the nature of relationships within farming communities and the existing scientific literature on equilibrium selection and individual behavior in coordination games. Interpersonal relationships in agricultural communities are a product of socio-economic ties and the properties' locations on the farming landscape. Farmers may routinely lend and

[1] An alternative approach investigated in the literature is auctions for spatially-coordinated project procurement (e.g., Windle et al. 2009).

borrow machinery to/from neighbors, lobby together to influence local or national policy determination, or become members of the same (regional) input-purchasing and marketing cooperatives (Hanson et al. 2004; Parker and Munroe 2007). These ties facilitate the flow of information which may be conducive to cooperation with respect to (local) biodiversity management (Pretty and Smith 2004).

Under the AB scheme, where the economic returns to farmers from land management actions are a product of strategic interactions with their neighbors, varying the levels of information available to a farmer about their neighbors' actions is likely to impact their land use decisions and subsequent payoffs. The literature on the impact of information on individual decisions in strategic settings supports this claim. Experimental studies suggest that providing more information to subjects increases economic efficiency in terms of Nash equilibria selected in coordination games (Berninghaus and Ehrhart 2001) and trust games (Bracht and Feltovich 2009). Yet Wilson and Sell (1997) find that more information reduces efficiency in public good games, while in the study by Duffy and Feltovich (2002) there is no significant impact of providing information about others' choices on game outcomes at all. Thus, the impact of information on choices and the Nash equilibria selected is a function of the nature of the strategic environment and the features of the game itself. Therefore, in the context of the AB scheme, any claim about land use, environmental outcomes and policy effectiveness needs to explicitly consider the impact of varying the information available to individuals on their choices and land use configurations obtained.

This article analyses the impact of varying the information available to human subjects who assume the role of farmers in an experimental laboratory environment. The laboratory allows us to exercise control over the strategic environment – the testbed (Plott 1997) and to evaluate the impact of varying the amount of information provided to subjects on land management decisions and types of spatial patterns produced. The experiments involve subjects arranged on a circular local network where each subject is *directly* linked to a subset of all individuals in the group (the direct neighbors) and *indirectly* to everyone else through their direct linkages (Jackson 2010). Within the circular network structure every subject has two direct neighbors: one to the left-hand side and one to the right-hand side. Given this spatial setup, the information treatment involves changing the number of individuals whose choices are visible to players during the experiment. In the baseline sessions, visibility of actions is limited to a subject's two direct neighbors only, while in the treatment sessions subjects receive information about the actions and payoffs of both their direct neighbors and their neighbors' direct neighbors. These latter we refer to as a subject's (two) *indirect* neighbors.

The experiments indicate that information variability produces a significant difference in subject behavior and resultant AB configurations. Overall there is more efficient coordination in the groups with more information relative to those where information exchange is limited to direct neighbors only. However, over time, the beneficial impact of extra information on efficient coordination falls. While in early periods of the experiments more information results in a larger share of subjects coordinating on the efficient Nash equilibrium, with repeated interaction subjects' behavior reveals a transition towards the inefficient, risk dominant Nash equilibrium.

The rest of the article is organized as follows. In section 2 we present the model and explain the functioning of the AB mechanism on a circular local network structure. Section 3 describes the experimental design and the implementation of the model in the laboratory. The experimental results are presented in section 4 and conclusions given in Section 5.

2. The Model

Consider K players, indexed $i = 1, \dots, K$, representing landowners, each of whom has a fixed position on a landscape represented by a circular local network. On the circular landscape the neighborhood structure is symmetric whereby each landowner has two direct neighbors: one each in the clockwise and an anti-clockwise direction.[2] These individuals

[2] As there are no edge effects, employing a circular network structure implies that all subjects face identical decision problems. This ensures that we are able to isolate the impact of the information treatment (that changes the subjects' strategic uncertainty) on land management choices and AB performance without having to worry about potential confounding problems arising from subjects having different levels of strategic uncertainty owing to a varying number of neighbors.

make up the local neighborhood of a player. Landowners are indirectly linked to other networked individuals via their direct neighbors. This is illustrated in figure 1.

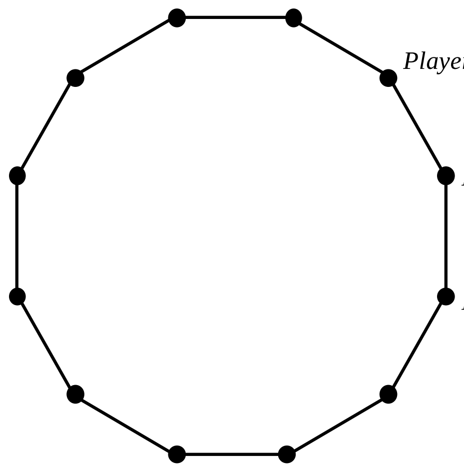

Figure 1: Circular Local Network

A landowner's choice set in the AB game is related to how they manage their land. Each farmer i can choose between two land management options: $\sigma_i = G, N$. The option G refers to conservation management on agricultural land, and N refers to retirement of cropland such as under the CRP and converted to "nature farming" referred to as land sparing (Balmford et al. 2012). Both land management types thus provide conservation services, but N parcels more so than G parcels.[3]

Let us now specify society's benefits from environment friendly land management under the two options G and N. Any parcel of land under either land option yields ecosystem service benefits, $s(\sigma_i)$, and let these "stand-alone" benefits be larger under N than under G.[4]

[3] Of course, the third option is not participating and using the land for intensive agriculture. This possibility is however not implemented in the experiment as our focus is on the role of information in influencing farmers' choice of one conservation strategy over the other. We thus implicitly assume that compensation is sufficiently generous for both conservation strategies so that it is in the interest of farmers to participate.

[4] Uncultivated or retired land, N, usually provides good habitat for those species that do not prefer the open nature of cultivated land, such as the boreal toad and leopard frog and birds like the sage grouse and white-faced ibis. Non-crop habitats on retired tracts like flower patches and hedgerows are beneficial for increasing the populations of natural pollinators such as honey bees (Carvell et al. 2007). On the other hand, the cultivated land management option G is conducive to species that like the "openness" of such fields. Meadow birds such as the

Let us assume that $s(G) = 5$ and $s(N) = 10$. Environmental agglomeration benefits exist for both types of land management options as well. We assume that these benefits are larger for strategy N than for G given the nature of ecosystem services delivered from these management options as mentioned above. Let $n_{i\sigma}$ denote the number of direct neighbors of landowner *i* that choose land management option σ_i on the network (landscape). Then the agglomeration benefits are denoted by $n_{i\sigma}b(\sigma_i)$ for $\sigma_i = G, N$. Let the values for each strategy be $b(G) = 10$ and $b(N) = 40$. Hence, for any given value of $n_{i\sigma}$ (which, in our circular local network setup is equal to 0, 1 or 2), both the benefits, $s(\sigma_i)$, and the agglomeration conservation benefits, $b(\sigma_i)$, are strictly larger for N than for G.[5]

In addition to the conservation benefits of land use, society values agricultural profits too, and these are larger under G than under N. Let us use $r(\sigma_i)$ to denote a farmer's profits from agriculture. When land is managed for agricultural production, profits are positive ($r(G) = 55$)) whilst they are zero when land is abandoned to nature ($r(N) = 0$). Depending on the land use choice of direct neighbors, the social benefits provided by farmer *i*'s land use choice read as:

$$w(\sigma_i) = r(\sigma_i) + s(\sigma_i) + n_{i\sigma}b(\sigma_i), \qquad \sigma_i = G, N \tag{1}$$

We are interested in the efficiency of land use decisions in the presence of agglomeration benefits, and not in how rents are allocated between farmers and the government (or the tax payer). For simplicity, we therefore assume that farmers receive the full social benefits generated by their pro-environmental land use activities, i.e., they receive subsidies equal to $s(\sigma_i) + n_{i\sigma}b(\sigma_i)$. On the basis of our model, the government thus

burrowing and short-eared owls typically rely on grasslands for nesting and hunting but thrive less well on land retired from agriculture and abandoned to nature.

[5] Note that we assume that the landscape-level environmental benefit contribution of a farmer choosing management option N depends on the direct neighbors' decisions, but not on those of their indirect neighbors. That is, we assume that the conservation benefits provided are the same independent of whether the direct and indirect neighbors to one's left (right) choose GN (NG), or whether they choose NN or GG both to their left and right. This assumption explicitly captures the spatial nature of environmental processes and hence benefits, which is often decreasing with increasing distance.

implements a payment scheme where the subsidy is set at the Pigouvian level[6,7] and expression (1) is the payment received by farmer i when choosing land option σ_i. This specification of the payoff function is similar to the one implemented by Parkhurst et al. (2002) and Parkhurst and Shogren (2007) where landowners' payoffs depend upon the management option and the number of participating neighbors choosing that same action.

Using the AB payoff function shown in equation (1), table 1 presents the social (and private) welfare associated with each land management option and corresponding payoffs associated with the AB scheme involving a farmer and their two direct neighbors. On the basis of this payoff table, the AB scheme resembles the Stag-Hunt coordination game. This game has two pure strategy Nash equilibria: σ_G $(\forall i)$ and σ_N $(\forall i)$ which are Pareto ranked in terms of payoffs. The payoffs for σ_N are 90 while they are 80 for σ_G hence the *all-N* outcome is the Pareto efficient (or payoff dominant) Nash equilibrium. In contrast, the *all-G* outcome is the risk dominant Nash equilibrium as the deviation loss associated with *N* is (90–60) = 30 which is less than the deviation loss for *G*, which is (80–10) = 70. Given these two outcomes, coordination of choices on *N* or *G* produces outcomes presented in figure 2.

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[6] By making this assumption we ignore the fact that raising funds for subsidies results in welfare losses to society because taxes tend to be distortionary. For second-best considerations, see Mirrlees (1971) and Smith and Tomasi (1995).

[7] The reader may argue that given these modeling decisions the regulator can implement the optimal pattern by setting the subsidy equal to 55 or higher if farmers choose *N*, and zero otherwise. This will make choosing *N* a dominant strategy, independent of what the other farmers choose – there is no coordination problem. While this is correct, this scheme is not informative in explaining how subjects behave in the presence of subsidies where their payoffs depend on both their own and others' decisions. Moreover, in the real world, the regulator may not be fully aware of both the opportunity costs of land conservation and the conservation benefits from agglomeration. Then paying the farmers the social benefits of their actions would ensure that the policy would not be welfare-decreasing.

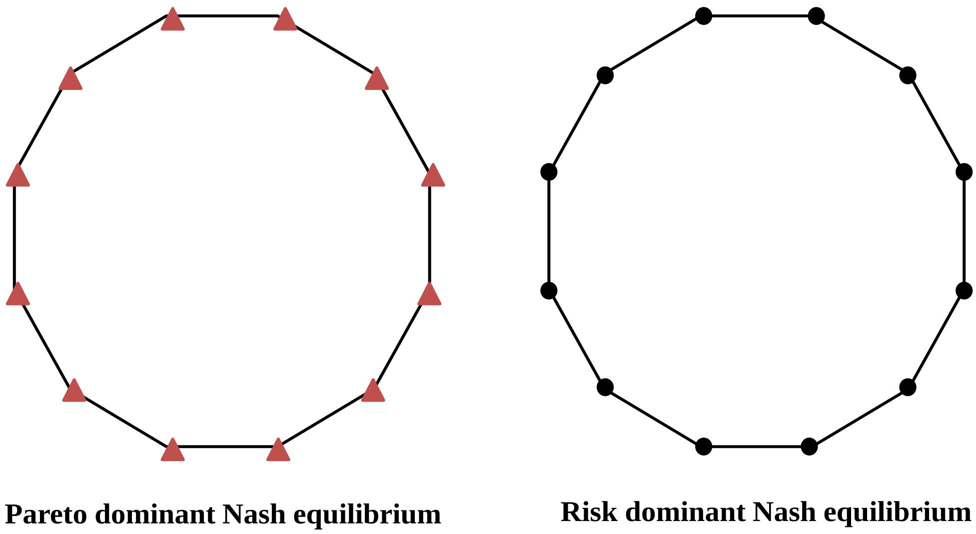

Figure 2: Nash Equilibria on Circular Network (red triangles and black circles represent *N* and *G* choice respectively)

Harsanyi and Selten (2003) argue that in such coordination games the players' collective rationality regarding higher payoffs will lead them to coordinate to the Pareto efficient Nash equilibrium. Yet this outcome is predicated on the risk and payoff dominant Nash equilibria corresponding to the same strategy. In our AB policy setting this is not the case as choosing the natural land management option N, while lucrative, is riskier relative to strategy G as it yields a higher payoff loss upon coordination failure. In a strategic environment where every individual is subject to strategic uncertainty about other players' choices, this relative risk ranking may make G more likely than N. The combination of direct and indirect links on local networks increases the strategic uncertainty even further. This feature, in turn, may prevent the achievement of the social optimum and lead to the inefficient outcome – a scenario referred to as coordination failure. Given this setup, our study explores the impact of varying the amount of information available to subjects about their neighbors' previous choices, on their likelihood of choosing N and coordinating on the socially optimum *all-N* outcome.

3. Experimental Design and Procedures

We consider a circular network of twelve subjects with every subject having a direct neighbor to their left and right. These direct neighbors are referred as the clockwise and anti-clockwise neighbors in the experimental instructions. In addition, every subject is *indirectly* connected to the remaining nine players via their direct neighbors. Group composition and neighbor identity is kept constant during the experiment. We adopt this fixed matching scheme since on geographical landscapes farm locations and farmer identity are usually exogenously given. Additionally, this matching scheme permits us to test the impact of subjects' reputation for the play of a particular strategy on other subjects' choices. Each session has thirty periods during which the subjects play the game whose payoffs are shown in table 1. We record data for 12 sessions: 6 baseline sessions termed 2INFO and 6 treatment sessions termed 4INFO. The baseline is referred to as 2INFO where each subject is informed about the previous and all other past periods' actions of their two direct neighbors. The label 4INFO represents the treatment sessions where a subject receives choice information of four participants: two direct neighbors and their neighbors' direct neighbors.

Table 1: Summary of Parameter Values and Game Payoffs

Market return to abandoned land: $r(N) = 0$
Market return to managed agricultural land: $r(G) = 55$
Participation component abandoned land: $s(N) = 10$
Participation component managed agricultural land: $s(G) = 5$
Bonus component abandoned land: $b(N) = 40$
Bonus component managed agricultural land: $b(G) = 10$

	Direct neighbors' choices		
Landowner choice	NN	NG	GG
N	**90**	50	10
G	60	70	**80**

The experiments for this study were conducted at the Laboratory for Economics Management and Auctions (LEMA) at the Pennsylvania State University in February 2012 with subjects recruited randomly from the student population. In total 144 subjects participated: 6 sessions, with 12 subjects per session, were implemented for each of the two treatments, resulting in 6 independent observations. The show-up fee was $5 and experimental earnings were converted into actual currency at the rate of 150 experimental dollars to one real U.S. dollar. The experiments were implemented using z-Tree (Fischbacher 2007) and lasted between 45 and 60 minutes per session.

During a session, each subject received an ID that determined their position on the circular network. Figure 3 represents the networks for 2INFO and 4INFO treatments that were shown to subjects during a session. The instructions were made available on the computer screen and were read aloud to maintain an environment of common knowledge. Subjects were informed about their role as a landowner with two types of land management actions, which would generate payoffs. No other contextual terminology such as ecosystem services, biodiversity conservation or endangered species was included in the experimental instructions, so that subjects would respond only to financial incentives. In keeping with the game theoretic nature of the experiment, the instructions mentioned that subjects' payoffs would be influenced by their neighbors' actions. They were also informed that the AB game would be repeated for 30 periods. Before starting the experiment, all subjects participated in a quiz about different features of the experiment to verify their understanding of the choices in the game and the associated payoffs.

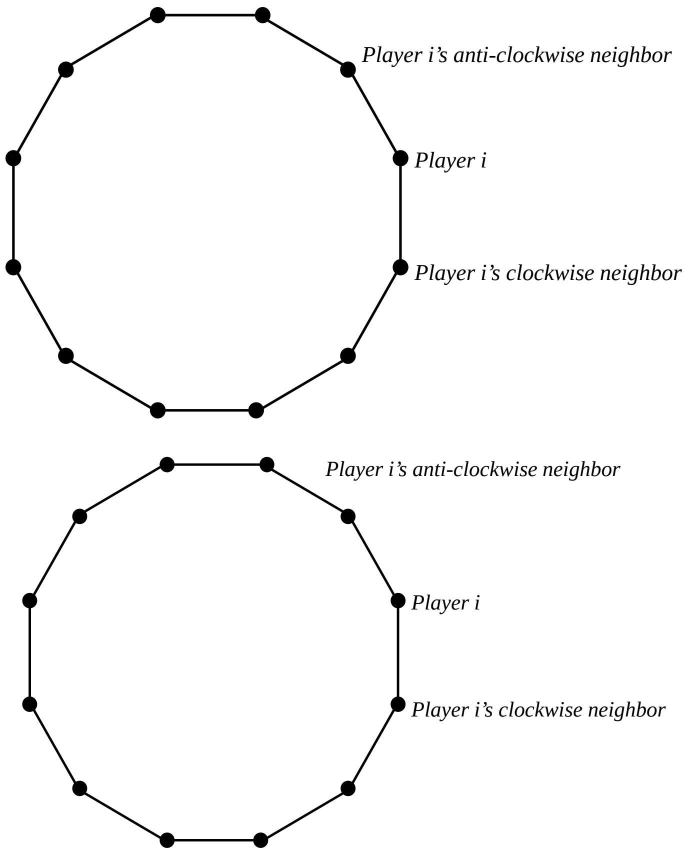

Figure 3: Circular Local Network 2INFO treatment (top panel) and 4INFO treatment (lower panel)

4. Results

This section is organized into a discussion of individual choices and spatial configurations on the network followed by the analysis of underlying behavior explaining the experimental outcomes.

4.1 General Results

Figure 4 and table 2 present the share of efficient *N* choices for both treatments over 30 periods. We make two observations. First, the average share of *N* choices in every period is higher in 4INFO (where subjects are informed about the decisions of both their two direct and two indirect neighbors) than in 2INFO (where subjects receive information about their direct neighbors' choices only). Second, when subjects gain more experience during the game, the average share of *N* choices falls in both treatments. In 2INFO the value falls from 63% to almost zero after 20 periods and then stays under 10% for the remaining periods; in 4INFO subjects are able to sustain positive levels of *N* choices in all periods although they fall from 73% in Period 1 to 18% in Period 30 as well. These results indicate that information about choices of more players on the network effectively sustains coordination on the Pareto-dominant outcome in the short run but not in the long run.

Table 2: Average share of *N* choices and Cluster metric by Period and Treatment

Period	Average *N* Choice		N-Clustering		G-Clustering	
	2INFO	4INFO	2INFO	4INFO	2INFO	4INFO
1	0.63	0.74	0.26	0.47	0.06	0.05
2	0.61	0.67	0.38	0.41	0.15	0.10
3	0.51	0.68	0.31	0.48	0.28	0.14
4	0.51	0.61	0.34	0.39	0.31	0.21
5	0.49	0.65	0.26	0.45	0.28	0.17
6	0.46	0.65	0.32	0.43	0.40	0.15
7	0.36	0.65	0.24	0.49	0.51	0.19
8	0.32	0.61	0.18	0.47	0.53	0.25
9	0.33	0.53	0.18	0.35	0.51	0.31
10	0.25	0.47	0.11	0.32	0.60	0.35
11	0.22	0.39	0.10	0.27	0.65	0.50
12	0.17	0.39	0.06	0.25	0.70	0.49
13	0.17	0.40	0.08	0.32	0.74	0.51
14	0.14	0.43	0.07	0.31	0.78	0.46
15	0.11	0.40	0.05	0.31	0.81	0.50
16	0.08	0.39	0.03	0.29	0.85	0.51
17	0.08	0.38	0.02	0.28	0.83	0.52
18	0.07	0.35	0.02	0.26	0.87	0.55
19	0.03	0.35	0.00	0.26	0.93	0.55
20	0.01	0.36	0.00	0.27	0.97	0.54
21	0.03	0.38	0.01	0.28	0.95	0.52
22	0.06	0.38	0.03	0.28	0.92	0.52
23	0.03	0.33	0.01	0.24	0.95	0.57
24	0.03	0.32	0.01	0.22	0.95	0.58
25	0.04	0.29	0.02	0.19	0.94	0.59
26	0.03	0.26	0.01	0.15	0.95	0.60
27	0.06	0.26	0.02	0.15	0.90	0.62
28	0.03	0.18	0.00	0.12	0.94	0.76
29	0.03	0.21	0.00	0.15	0.94	0.73
30	0.04	0.18	0.02	0.13	0.94	0.76

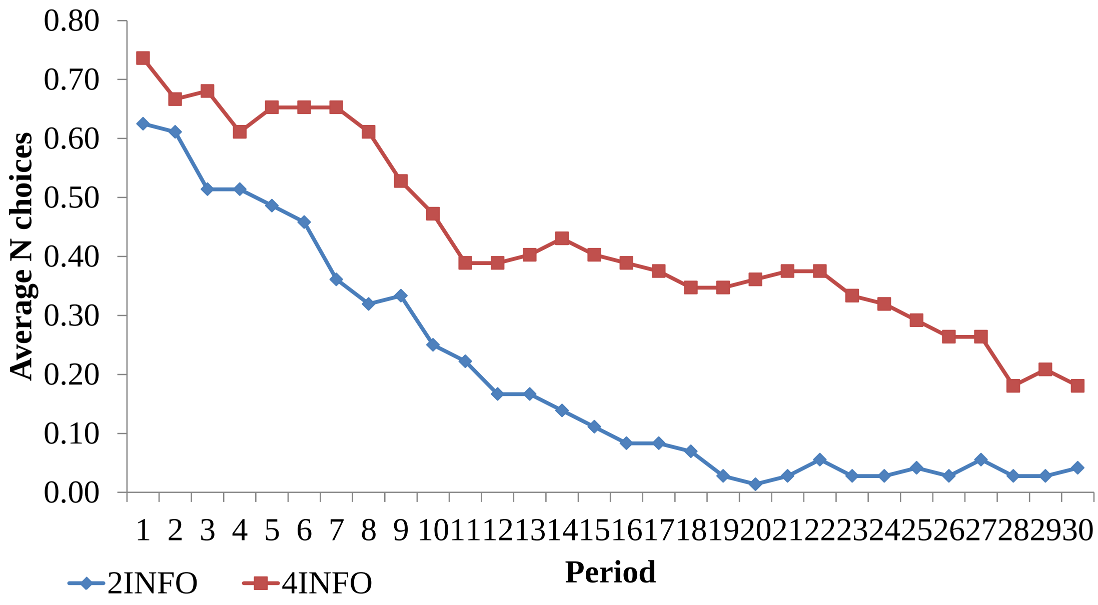

Figure 4: Average Share of *N* Choices by Period and Treatment

Let us next analyze these results formally. Table 3a reports the shares of *N* choices for both treatments using two types of observations: average *N* choices for the first period taking each subject's action as an independent observation (implying that there are 72 independent observations in each cell of the table) and the same averaged over all 30 periods for 6 groups (i.e., 6 independent observations per cell). Using Mann-Whitney tests with corresponding *p*-values presented in table 3a we find that there is no significant treatment effect in the first period. However, over all 30 periods there is a significant impact of information (at 1% level of significance). Lack of significance in Period 1 is to be expected as subjects are randomly assigned to both treatments, face the same payoff table, and make decisions without receiving any feedback about others' choices. Taking all periods together, during the lifetime of the experiment there is a significant impact of providing information about more neighbors to a subject. Relative to 2INFO, in 4INFO, subjects' strategic uncertainty associated with choosing the risky payoff efficient strategy is lower. Thus, significantly more players' strategic uncertainty gets resolved in favor of *N*, leading to more *N* choices on average in 4INFO relative to 2INFO. This result holds regardless of the fact that with repeated interactions many subjects switch to the risk dominant equilibrium in both treatments. Since at any given point of the experiment choices of more than 50% individuals who have an indirect effect on players' choices is not visible, subjects are considerably uncertain about their higher order neighbors' likelihood of choosing *N*. As a result, even if *N* yields a higher payoff, a majority of players choose and/or switch to the risk dominant strategy *G*.

Table 3a: Mean Shares and Standard Deviations (in parentheses) of *N* Choices for Period 1 and for all 30 Periods

Share of N choices	Treatment		Mann Whitney Test
	2INFO	**4INFO**	***p*-value**
Average in Period 1	0.63 (0.98)	0.74 (1.22)	0.11
Averaged over all 30 periods	0.19 (1.22)	0.43 (5.16)	0.03

4.2 Analysis of Spatial Patterns on Local Networks

Having presented the impacts of information and repeated interactions on the frequency with which the Pareto efficient *N* choice is selected, we now analyze the location of these *N* choices and the development of the land choice configurations over multiple periods. In figures 5-7 we present snapshots of the network configurations in each of the six sessions for periods 1, 15 and 30[8] where *N* choices are marked with red triangles and *G* choices with black dots. The spatial patterns in these periods reflect the difficulty of coordinating on the Pareto dominant *all-N* equilibrium. While all groups start with between 7 and 9 subjects (mostly adjacent) choosing *N* in the first period, only the sixth cohort in 4INFO manages to reach the *all-N* equilibrium in Period 15. And while there is no incentive for subjects to change from *N* to *G*, as all of them are earning the highest payoffs (90) by Period 30, four adjacent subjects in this session switch to *G*. Strategy switches are observed in other groups

[8] We classify our 30-period experiment into three equally spaced time intervals signifying the initial, intermediate and final stages. Configuration of choices from all other periods is available upon request.

as well: barring the first session in 2INFO and 4INFO, most of the adjacent *N* choices are replaced by contiguous *G* choices in the remaining cohorts.

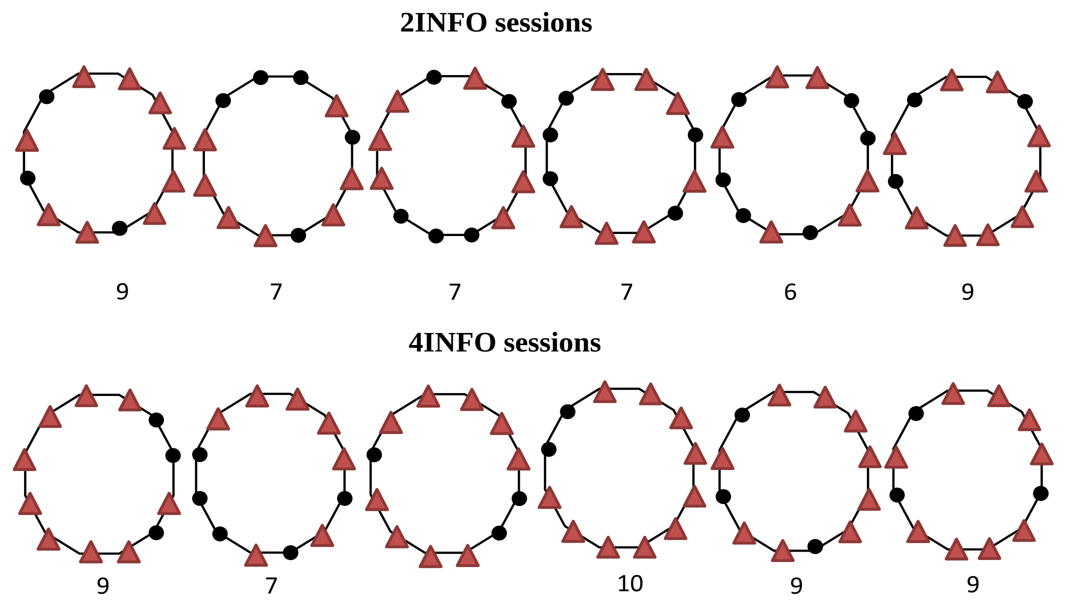

Figure 5: Period 1 Choices in 2INFO and 4INFO sessions

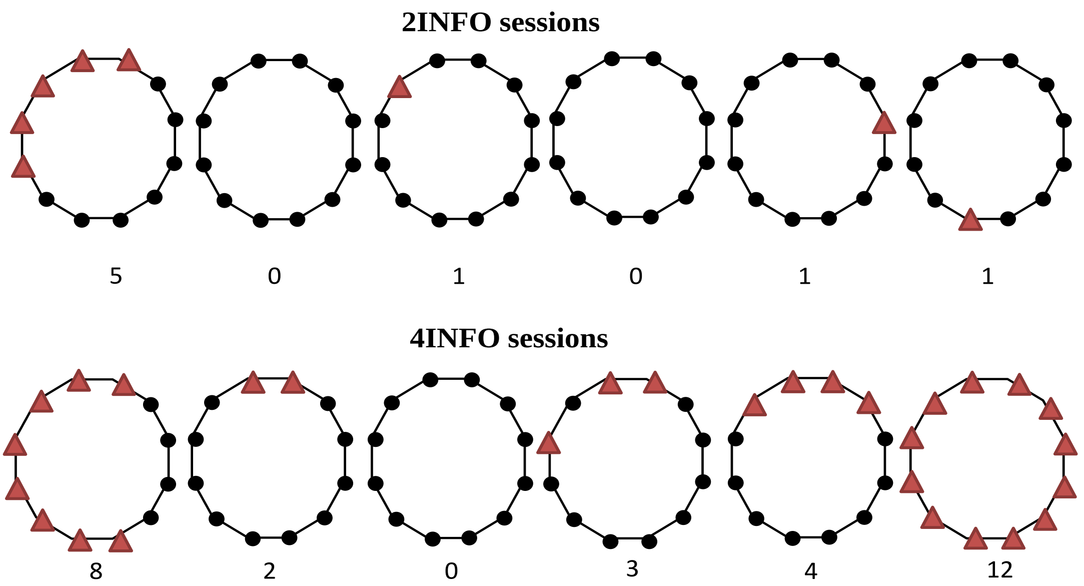

Figure 6: Period 15 Choices in 2INFO and 4INFO sessions

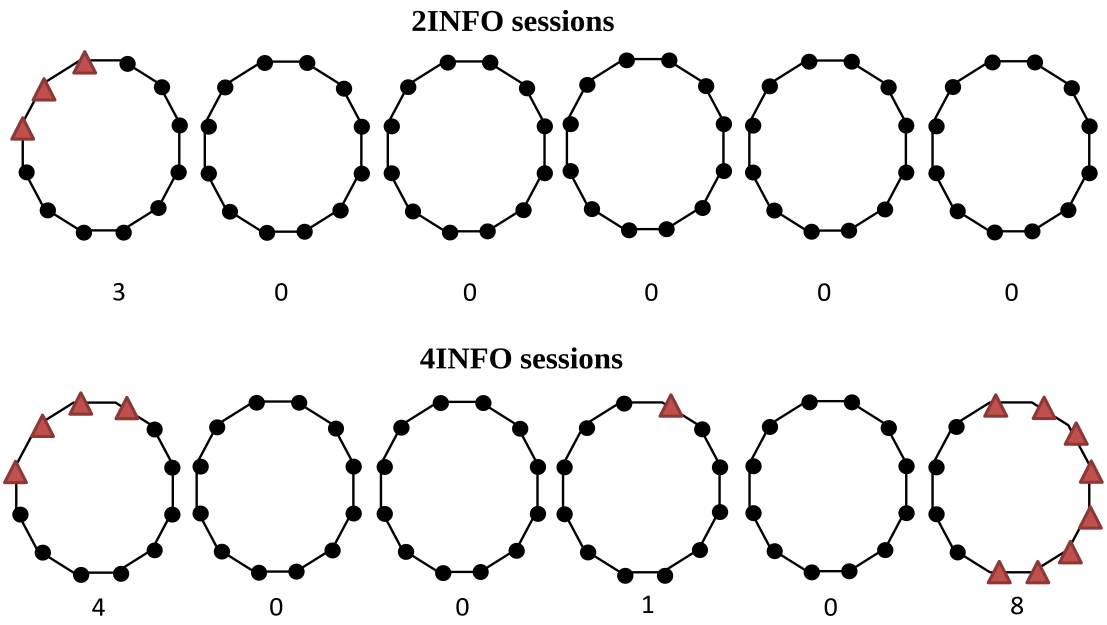

Figure 7: Period 30 Choices in 2INFO and 4INFO sessions

To support a formal analysis of these outcomes, we construct a metric to measure the degree of spatial contiguity generated by the AB scheme in terms of both the frequency and location of contiguous *N* and *G* choices on the circular network. This metric reflects the frequency with which localized clusters of similar land use decisions are produced by 2 and/or 3 adjacent players. Formally the cluster metric reads:

$$C_t^{D,Z} = \frac{\sum_{i=1}^{K-1} y_{it}y_{(i+1)t} + y_{Kt}y_{1t} + \sum_{i=2}^{K-1} y_{(i-1)t}y_{it}y_{(i+1)t} + y_{Kt}y_{1t}y_{2t} + y_{(K-1)t}y_{Kt}y_{1t}}{2K} \quad (2)$$

where $D \in \{2INFO, 4INFO\}$ refers to the treatment, $Z \in \{G, N\}$ indicates whether the metric measures the share of clusters of *N* choices or *G* choices, t =1,…,30 denotes period, and y_{it} = 1 if $\sigma_i = Z$ or y_{it} = 0 otherwise. The first two terms on the RHS of (2) sum up the number of clusters consisting of two subjects choosing land use option *Z* in period *t* and the last three terms do the same for the clusters consisting of three subjects choosing the same option. Because the number of two-player and three-player clusters is maximally *K*, dividing by 2*K* ensures that the cluster metric is a number between 0 (if there are zero two-person clusters choosing Z in period *t*) and 1 (if all subjects in a group choose *Z* in that period). On the basis of this metric we can evaluate the development of $C_t^{D,Z}$ over time to identify how coordinated land use patterns on the network change during the experiment. Figure 8 and table 2 presents the average values of $C_t^{2INFO,N}$, $C_t^{4INFO,N}$, $C_t^{2INFO,G}$, and $C_t^{4INFO,G}$ for all thirty periods.

The positive values of the metric in all periods imply that within our strategic environment, the AB is able to reduce fragmentation of land uses and incentivize the creation of localized clusters of *N* and *G* choices and the *all-N* and *all-G* outcome for the enhanced delivery of ecosystem services such as habitat protection and biodiversity conservation. Additionally, information about players' choices produces significant differences in the nature of these spatial patterns. Tables 3b and 3c report the *p*-values associated with Mann-Whitney tests for the *N*-clustering and *G*-clustering metric respectively both for all 30 periods and for Period 1 (6 independent observations per cell in both cases).

Table 3b: Mean Shares of *N* Cluster for Period 1 and for all 30 Periods

Share of N clusters	Treatment		Mann Whitney Test
	2INFO	**4INFO**	***p*-value**
Average in Period 1	0.26 (0.14)	0.47 (0.14)	0.03
Averaged over all 30 periods	0.10 (0.08)	0.3 (0.25)	0.03

Table 3c: Mean Shares of *G* Cluster for Period 1 and for all 30 Periods

Share of G clusters	Treatment		Mann Whitney Test
	2INFO	**4INFO**	***p*-value**
Average in Period 1	0.06 (0.06)	0.05 (0.04)	0.8
Averaged over all 30 periods	0.70 (0.12)	0.44 (0.23)	0.03

We find that the level of *N*-clustering is significantly different (at 5% level of significance) in strategic environments with information exchange between more participants than in those where information flows are limited. Thus additional information incentivizes land use patterns corresponding to the efficient Nash equilibrium configuration. The fact that the treatment effect is significant for efficient *N*-clustering in Period 1 also suggests that the location of players choosing *N* on the network is significantly different in both treatments even if their number is not. Of the players who choose *N*, a majority are adjacent in 4INFO while in 2INFO these players are separated by others choosing *G*. In terms of *G*-clustering there is no significant difference in Period 1 as shown in table 3b. This result is to be expected since there are few *G* choices in the first period in both treatments: 6% in 2INFO and 5% in 4INFO. However, with limited information flows and repeated interactions over 30 periods, many subjects switch to *G* in 2INFO, so that on average a significant difference (at 5% level of significance) in the overall levels of *G*-clustering is obtained with 4INFO.

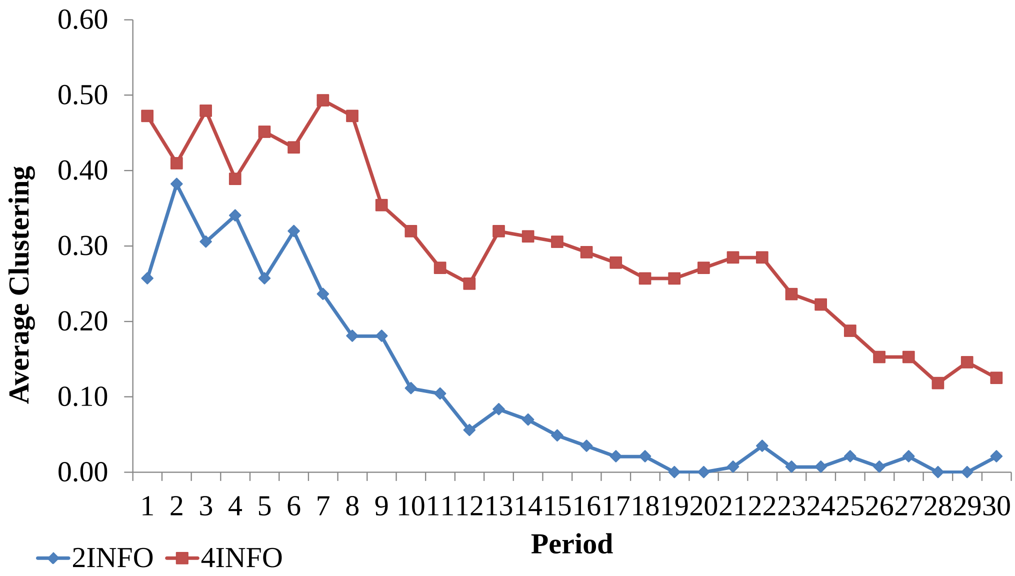

Figure 8a: Average *N*-clustering by Treatment and Period

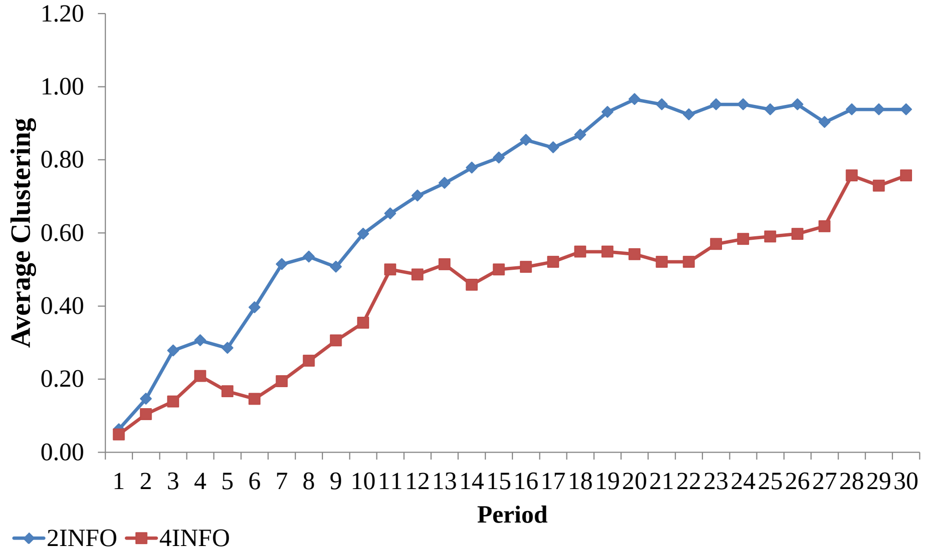

Figure 8b: Average *G*-clustering by Treatment and Period

4.3 Analysis of individual behavior

Given the significant differences in outcomes between treatments, this section presents an analysis of factors affecting individual behavior in the experiment. We model the likelihood of making a socially efficient *N* choice as a function of a series of factors exogenous and endogenous to subjects within a dynamic random effects probit regression framework with the subject representing the random effect.[9] The dependent variable is a binary variable y_{it} taking a value of 1 for an *N* choice and 0 for a *G* choice by subject i $(i = 1,2, \ldots, 144)$ in period t $(t = 1, 2, \ldots, 30)$.

Three separate models are presented. Model I considers the impact of the two exogenous variables: the information treatment *D* to which every subject is randomly assigned and a variable $1/t$ that controls for the impact of subjects' learning on their likelihood of making an *N* choice.[10] In addition to these exogenous variables, in Model II we consider the effect of a player's choice in the previous period on the likelihood of selecting *N* in any period. This variable controls for the effect variously termed strategy inertia,

[9] Errors are clustered at the session level following routines suggested by Rabe-Hesketh et al. (2005).
[10] We use the reciprocal of the time period as a measure of learning, since learning is typically substantial in early periods of the experiment.

precedence effect or simply "force of habit." An interaction term between the reciprocal of the period variable and the lagged choice is included to evaluate whether varying levels of subject learning impacts the role of precedence in determining the likelihood of an *N* choice in the current period. Given the strategic setting where neighbors' choices influence own action, a third Model III is considered with a variable n_{it-1} measuring the frequency of direct neighbors' previous period *N* choices. This variable can take a value between 0 and 2, depending upon the number of neighbors selecting N. An interaction term between the neighbor choice variable and the inverse period measure is considered to explore the effect the neighbors' choices have on a subject's likelihood of choosing *N* at different levels of subject learning. All other variables from the two previous models are included in Model III as well. The random effects structure of the error term has a component u_i, which is the time invariant unobserved heterogeneity associated with subject i and the random component ε_{it} for every period. Expression (3) represents the full model with all variables. In evaluating model performance, we use the value of the log-likelihood generated during the estimation.

$$y_{it} = \propto + D + \beta y_{i(t-1)} + \gamma\left(\frac{1}{t}\right) + \delta\left(\frac{1}{t}\right) y_{i(t-1)} + \theta n_{i(t-1)} + \pi\left(\frac{1}{t}\right) n_{i(t-1)} + u_i + \varepsilon_{it}$$

$$(i = 1,2, \dots\dots.144; t = 1,2, \dots\dots 30) \qquad (3)$$

Table 4 presents the results from the three models. Consistent with our prior discussion the dummy estimate is negative and significant (at 1% level) in all the models. We also obtain a positive and significant estimate for the period reciprocal variable in all models providing support for the negative trend in *N* choices observed for both treatments, as also shown in figure 4. Results from Model II indicate that own past behavior has a positive and significant (at 1% level of significance) impact on current period choice of *N*, i.e., subjects are significantly more likely to choose *N* if they chose *N* in the previous period. There is thus a positive precedent for the choice of *N* and this effect is a result of strategy lock-in or strategy-inertia (Blume 1993). Once having selected a certain strategy subjects maintain that choice for a few periods. The fact that this estimate is positive and significant in Model III as well indicates that strategy inertia may delay subjects' response to their neighbors' past choices for a few periods even if the switch may be the best response. In coordination games such as the AB, this strategic lock-in can be attributed to subjects' voluntary loss-making behavior (Brandts and Cooper 2006). Players voluntarily inflict payoff losses upon themselves by choosing *N*, even if their neighbors are choosing *G* in order to signal their sustained commitment towards choosing *N*. Such costly signaling is useful in reducing neighbors' strategic uncertainty in favor of *N*, leading them to switch from *G* to *N* in subsequent periods. More generally, the precedent effect also captures the role of human habit in economic decision making: subjects often adhere to what they have done in the past regardless of consequences, since a change requires them to make a conscious cognitive effort (Kahneman 2003; Thaler and Sunstein 2008). The estimate for the interaction between precedence and subject learning is negative and significant in Model II only suggesting that the effect of precedence is different at different levels of subject learning.[11] We also note an improvement in the value of log-likelihood from Model I to Model II suggesting a more precise modeling framework.

Table 4: Regression Results: Random Effects Models for Land Management Decisions

Explanatory Variables	**Probit (=1 if *N* strategy is chosen)**		
	Model I	**Model II**	**Model III**
Treatment	1.054 ** (0.413)	0.611*** (0.2)	0.188*** (0.066)
1/Period	2.981*** (0.468)	4.235*** (0.592)	2.87*** (0.757)
Action in Previous Period	--	2.227*** (0.246)	1.494*** (0.153)
Previous Action * 1/Period	--	-2.279*** (0.7)	0.038 (0.608)
Neighbors in Previous Period Choosing N	--	--	1.484*** (0.081)
Previous Neighbors * 1/Period	--	--	-2.03*** (0.337)
Constant	-1.754*** (0.211)	-2.298*** (0.149)	-2.675*** (0.151)
Log Likelihood	-1673.3806	-1092.3514	-864.99581
$i = 144; t = 30$			

Note: *** and **, represent significance at 1% and 5%. Robust standard errors (clustered at group level – Rabe-Hesketh et al. 2005) in parentheses

[11] We do not elaborate on the significant estimate of the interaction term as it is not significant in Model III.

Results from Model III provide insights about the likelihood of strategy selection and behavior consistent with the principle of Nash equilibrium. The estimate for the number of direct neighbors choosing *N* in the previous period is positive and significant (at 1% level). Sustained choice of *N* by neighbors reduces a subject's strategic uncertainty in favor of *N* at least within their local neighborhood. Consequently, subjects are more likely to make an *N* choice in the current period in order to create or increase the likelihood of creating an *N*-cluster at the centre of which they earn a payoff of 90. This significant effect of neighbors' choices – taken together with the precedent effect – explains the appearance of the *all-N* outcome and localized *N* clusters in both treatments. Finally, the estimate for the interaction term between the reciprocal of the period variable and neighbors' choices is negative and significant (at 1% level of significance), indicating that a subject's likelihood of selecting *N* as a function of their neighbors' previous *N* choices is higher in later periods. Despite being more likely to choose *G*, at higher levels of experience more *N* choices in a player's local neighborhood in the previous period may serve as a credible signal to them to choose *N* in the current period in order to generate an *N*-cluster and earn higher payoffs. This result represents the relative impact of the strategic interactions within the local neighborhood and the overall network environment. It suggests that the effect of direct neighbors' choices are stronger relative to all indirect ones, whereby *N*-clusters survive in 3 of the 12 experimental sessions in the final Period 30 even if many subjects' strategic uncertainty is considerably resolved in favor of *G*. The value of the log-likelihood is the highest for Model III as well, indicating that it most accurately explains the variability in subject behavior in the experiments that produces different spatial patterns and corresponding conservation benefit streams.

5. Conclusions

Improving the design of agri-environmental policy involving Payment for Ecosystem Services schemes requires attention to the spatial configurations of land uses that generate conservation benefits such as enhanced ecosystem services delivery. In cases where spatial coordination between landowners in undertaking conservation-friendly land management is important, the Agglomeration Bonus can serve as a policy mechanism to incentivize coordination when landowners/farmers can voluntarily choose how to manage their land. Given the AB mechanism comprises multiple Nash equilibria — a Pareto dominant and a risk dominant Nash Equilibrium — there is the problem of potential coordination failure to the efficient equilibrium. In this article, we experimentally investigate in the laboratory the extent of spatial coordination to the socially optimal, Pareto efficient land management outcome on local networks. Our study is based on the fact that both *direct* and *indirect* linkages between landowners in networks can impact the nature of strategic interactions and the resultant likelihood of coordination when information flows between landowners are different. Information on the choices of other landowners in the network can reduce strategic uncertainty and might thus improve coordination towards the socially optimal outcome.

We find that spatial coordination to the Pareto efficient outcome is significantly higher when farmers have more information available about the land management choice and payoffs of their neighboring farmers. This result is policy relevant since it lends scope for improved coordination to the social optimum if restrictions on information exchange between landowners are relaxed. However, despite the fact that more information induces a higher degree of coordination towards selecting the Pareto optimal equilibrium, over time a switch to the risk dominant outcome is also found. In the context of improving the delivery of ecosystem services and other conservation benefits through land management on local networks, this result implies that, although the AB scheme can enhance such a delivery, in the long run it may only be *partially* effective. Finding a way of ameliorating this tendency of coordination to move away from the Pareto optimal outcome would be important in any actual policy application of the AB if the conservation benefits of spatial coordination are to be realized in the long run.

Appendix: Experimental Instructions

(Instructions in *italics* represent 4INFO sessions)[12]

General Information:

This is an experiment in decision making. In today's experiment you will participate in a group decision task which involves choosing between **two actions**. In addition to a $5 participation fee, you will be paid the money you accumulate from your choices which will be described to you in a moment. Upon the completion of the experiment, your earnings will be added up and you will be paid privately, in cash. The exact amount you will receive will be determined during the experiment and will depend on your decisions and the decisions of others. From this point forward all units of account will be in experimental dollars. At the end of the experiment, experimental dollars will be converted to U.S. dollars at the rate of 1 U.S. dollars for every **150 experimental dollars**. **If you have any questions during the experiment, please raise your hand and wait for the experimenter to come to you. Please do not talk, exclaim, or try to communicate with other participants during the experiment**. Participants intentionally violating the rules may be asked to leave the experiment and may not be paid.

Group Decision Task:

The experiment will have **thirty periods**. In each period you will be in a group with **11** other participants. During this experiment each of you will assume the role of a landowner who can adopt one of two types of land use actions on their property. Let these land uses be denoted by **M** and **K**. You will receive payoffs from choosing any one of these actions. All the players including you are arranged around a circular which is shown on the board. The black dots on the circle represent the locations of your properties. On this circle, you have two neighbors - a clockwise (C) and an anti-clockwise (AC) neighbor. Your neighbors will be the **same** in all periods. You will never know the identity of your neighbors. Your ID will determine who your neighbors are. Thus if you are player **11** then your neighbors are players **10** and **12**. Player **12** has **you** and player **1** as neighbors. Please keep in mind that every player has a **different** set of neighbors.

[12] Strategy *M* refers to choice *N* in the article and strategy *K* to choice *G*. We did not make changes to the instructions in the article to maintain consistency with the instructions provided to the subjects during the experiment.

*Your two neighbors and your neighbors' neighbors together form your local neighborhood. For example if you are player **11**, then players **9, 10, 12 and 1** make up your local neighborhood. Note that player **9** is the anti-clockwise neighbor of player **10** and player **1** is the clockwise neighbor of player **12**.*

In each period, each one of you will make a choice between action **M** and action **K**. You will each receive money based on your choice and the choices of your neighbors. In a moment we will give you a detailed description of your choices and how your payment will be determined. Please raise your hand if there are any questions otherwise click "Continue".

Your Payment from Group Decision Task:

In each period of the experiment, the computer will display the table shown below. Please take a moment to look over the table. Whenever you are making a choice, you will be able to see this table. This table is the same for everyone and is the same for all thirty periods of this experiment. The amounts shown in the table reflect the possible payments you might receive for that period. Each number in the table corresponds to a payment (b in experimental dollars) resulting from a possible combination of your choice of M or K (row) and your clockwise & anti-clockwise neighbors' choices (column). In general, your payoff increases when you choose the same strategy as your neighbors.

Making a Choice in a Period:

Once the period starts, each of you will choose a strategy (M or K) by clicking on one of the buttons that will appear on the right of your screen. You may change your choice as often as you like, but once you click on OK your choice for that period is final. Note that when you are making your choice, you will not know the choices of others. Also, remember that you will never know the identity of anyone else in your group, meaning that all choices are confidential and that no one will ever know what choices you make.

At the end of each period, your screen will display your choice and payoff and the choices & payoffs of all players in your local neighborhood for the current period - i.e. your neighbors' and your neighbors' neighbors' choices and payoffs. Information on your accumulated payment through the current period will also be provided.

At the end of each period, your screen will display your choice and payoff and the choices & payoffs of your neighbors for the current period. Information on your accumulated payment through the current period will also be provided. At the end of the experiment, you will receive the sum of your payments from all thirty periods converted to real dollars. This will be paid to you privately in cash.

We are now ready to begin the experiment. On the next screen you will participate in a quiz. Please note that you will not earn any money from participating in the quiz i.e. this is a non-paying period. Your answers in this quiz will not influence your payoffs at the end of the experiment.

Quiz:

1) Suppose one of your neighbors plays strategy M and the other plays strategy K. Then your payoff from playing strategy M is **50**.
2) My neighbor has the same neighbors as I do. **FALSE**
3) Your neighbors change in every period. **FALSE**
4) What is your payoff when you chose K and all your neighbors chose M? **60**
5) At the end of every period you will be able to see the choices and payoffs of players in your local neighborhood. **TRUE**

Screen Shots and z-Tree files are available upon request.

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