The Impact of Information Provision on Agglomeration Bonus Performance:

An Experimental Study on Local Networks

Simanti Banerjee (Corresponding Author)
Department of Economics, 227 Rice Hall, 10. North Professor Street, Oberlin College, Oberlin, Ohio, USA, 44074. Ph: +1-440-775-8484, Fax: +1-440-775-6978.
Email: simanti.banerjee@oberlin.edu

Frans P. deVries
Division of Economics, 3B85 Cottrell Building, University of Stirling, UK, FK94LA. Ph: +44-1786-467485, Fax: +44-1786-467469.
Email: f.p.devries@stir.ac.uk

Nick Hanley
Division of Economics, 3B86 Cottrell Building, University of Stirling, UK, FK94LA. Ph: +44-1786-466410, Fax: +44-1786-467469.
Email: n.d.hanley@stir.ac.uk

Daan P van Soest
Department of Economics and Tilburg Sustainability Center, Tilburg University, P.O. Box 90153, Netherlands 5000 LE Tilburg, Ph: +31–13–466 2072,
Email: d.p.vansoest@uvt.nl

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Improvements to the delivery of ecosystem services from farmland such as habitat protection, biodiversity conservation, carbon sequestration and pest management, can be obtained by adopting pro-conservation land uses on properties otherwise devoted to profit-based agriculture (Swinton et al. 2007). Adopting such pro-conservation land uses is typically costly to the landowner/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 (Wunder 2005). 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; Ferris and Siikamäki 2009; Cowan 2010). 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 the spatial coordination of land management efforts can generate environmental benefits more effectively for an important set of ecological and biodiversity quality indicators (Hanley et al. 2012). Encouraging landowners 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 such as improved biodiversity benefits from spatially contiguous habitats than scenarios where the incentives are not spatially differentiated (Drechschler et al. 2010, Wätzold et al. 2010). In many instances, 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 which facilitate species mobility may be beneficial for biodiversity conservation (Margules and Pressey 2000; Dallimer et al. 2010). Further, spatial clustering of organic farm operations can lead to lower negative impacts on water quality by minimizing runoff, can mitigate losses from retiring land to create buffers preventing pesticide spill-over from neighboring conventional farms, and can even reduce certification costs of organic farmers (Parker and Munroe 2007). Finally, creation of large contiguous areas of non-crop habitat for natural predators in the landscape can be more successful in eradicating pests than strategies which ignore such spatially agglomerated habitat management (Landis et al. 2000; Zhang et al. 2010).

One approach to achieving spatial coordination of conservation 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 a base level compensation for all participants and a top-up bonus which they receive if their neighbors also participate and implement similar pro-conservation land use practices on their properties. By rewarding coordinated actions across space, land management decisions of neighboring landowners under the AB scheme can be considered to be strategic interactions in a coordination game. This game has multiple Nash equilibria which can be 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 (2005; 2007) and Warziniack et al. (2007) indicates that 1) repeated interaction between players during which they become increasingly familiar with the game and are able to view the land choice networks produced as a result of everyone's choices, 2) simple spatial targets to which

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

participants can coordinate with relative ease and 3) non-binding pre-play communication prior to making a choice, can lead to spatial coordination. Successful coordination on socially desirable land use outcomes is 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' land management choices. This article reports results of a laboratory experiment that varies the information each participant receives about the land use decisions others make within the purview of an AB scheme. 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 private properties' locations on the farming landscape. Farmers may routinely lend and 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 generation and flow of information which is conducive to cooperation with respect to (local) biodiversity and natural resources management (Pretty and Ward 2001; Pretty and Smith 2004; Schusler and Decker 2004; Isaac et al. 2007).

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 change their land use decisions and conservation payments earned. 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; Devetag 2003) 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. 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 determining the effectiveness of an AB based policy scheme in delivering environmental benefits via spatially coordinated land management, we need to explicitly consider the impact of varying the information available to landowners, on their land use actions.

This article analyses the impact of varying the information available to student subjects who assume the role of landowners in a laboratory experiment. The laboratory allows us to exercise control over the strategic environment – the testbed (Plott 1997) – and to evaluate the impact of the information treatment on land management decisions and types of spatial patterns produced. The controlled (and context free) laboratory environment permits the "wind-tunnel testing" of the AB incentive scheme for internal validity and analysis of general principles of human behavior under the treatment conditions (Schram 2005) before it can be tested in richer field contexts with actual landowners whose motivations for participation (or not) in conservation programs have both economic and non-economic drivers (Bowers and Lane 2009, Sheeder and Lynne 2011).

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 (a direct neighbor each in the clockwise and anti-clockwise direction) and *indirectly* to everyone else through their direct linkages (Jackson 2010). Within this network setup, we vary the information subjects receive by way of feedback after they have made a choice in the AB coordination game. In the baseline control sessions, subjects obtain information about the choices and payoffs of their two direct neighbors. This information feedback format is similar to those implemented in prior AB experiments. In the treatment sessions subjects' information sets additionally include knowledge about the choices and payoffs of their closest indirect neighbors, i.e., their direct neighbors' direct neighbors. This treatment specification is different from existing AB research and is motivated by the fact that while people may be aware of the strategic interactions within their closest domain of interaction i.e. their neighbors, friends, and/or networked partners, they usually do not have full information about all relevant strategic interactions in the economy or within their social network beyond this closest domain (Alós-Ferrer and Weidenholzer 2008). Moreover it is quite likely that the impact of indirectly linked networked individuals' choices on a single player's behavior is decreasing with the distance between them. Given these factors, our experimental treatment investigates the role of the extra feedback information on the emergence and persistence of efficient coordination and effective ecosystem services provision in a strategic AB policy environment.

Note that the impact of more information is ex ante unclear. Receiving information about actions selected by one's neighbors and neighbors' neighbors may facilitate coordination on the efficient Nash equilibrium; but the opposite outcome may be obtained as well – if one observes that the more distant subject did not choose the Pareto efficient strategy, one may anticipate that one's direct neighbor may also decide the same implying that one is better off refraining from choosing the efficient strategy too. Our experimental results indicate that providing more information 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. The positive impact of extra information on coordination is substantial, but we also find that, given our payoff parameterization, providing the extra information is not able to prevent the decrease in the share of subjects coordinating on the Pareto efficient equilibrium over time. 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 switches towards the inefficient, Nash equilibrium with efficient coordination persisting at the localized level only.

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. This network representation simultaneously introduces a spatial component into the strategic setting and captures the features of farming communities in which social networks play an important role in sustainable resource management (Bodin 2009). On this circular landscape the neighborhood structure is symmetric whereby all K landowners have two direct neighbors: one each in the clockwise and anti-clockwise direction.[2] These two individuals make up the local

[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 in the coordination game) on 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.

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

< Figure 1 about here >

A landowner's choice set in the AB game is related to how they manage their land. Each landowner i owns one plot of land, and can choose between two land management options: $\sigma_i = G, N$. Option G refers to conservation management on agricultural land ("land sharing": Balmford et al. 2012), and N refers to retirement of cropland such as under the CRP with land being converted to nature farming, what Balmford et al. (2012) call "land sparing". Both land management options thus provide conservation services, but the N type more so than G.[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 management option yields ecosystem service benefits, $s(\sigma_i)$, and let these "stand-alone" benefits be larger under N than under G.[4] Let us assume that $s(G) = 5$ and $s(N) = 10$. Environmental agglomeration

[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 landowners' choice of one conservation strategy over the other. We thus implicitly assume that compensation is sufficiently generous for both conservation strategies to make participation incentive compatible. This assumption is not at odds with reality as PES schemes have been known to overcompensate landowners in order to guarantee participation (Kirwan et al. 2005, Munoz-Pina et al. 2008).

[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 (Keinath and McGee 2005) and birds like the sage grouse (Crawford et al. 2004). 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

benefits exist for both types of land management options. We assume that these benefits are larger for choice N than for G given the nature of ecosystem services delivered from land sparing and sharing options. Also regardless of network size K, we assume that agglomeration benefits denoted by $b(\sigma_i)$ are generated on the basis of similar land use choices made by player i's direct neighbors only.

Let $n_{i\sigma}$ denote the number of neighboring plots adjacent to that of landowner i, that are under the same land management option σ_i as the plot of landowner i. Then the total agglomeration benefits are denoted by $n_{i\sigma}b(\sigma_i)$ for $\sigma_i = G, N$. Let the benefit 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. We assume that the landscape-level environmental benefit contribution of a landowner choosing a management option depends on the direct neighbors' decisions, but not on those of their indirect neighbors in order to capture the spatial nature of environmental processes and hence benefits, which are often decreasing with increasing geographical distance. Also, the conservation benefits provided by selecting *N* are the same independent of whether the direct and indirect neighbors to one's left (right) choose *GN(NG),* or *NN*. The same is true for the *G* option.

In addition to the conservation benefits of land use, society values agricultural profits too, and these are larger under G than under N. Let $r(\sigma_i)$ denote a landowner's profits from agriculture. When land is managed for agricultural production, profits are positive ($r(G) =$

cultivated land management option G is conducive to species that like the "openness" of such fields. Meadow birds such as the burrowing and short-eared owls (Holt and Leasure 1993) typically rely on grasslands for nesting and hunting but thrive less well on land retired from agriculture and abandoned to nature.

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 landowner i's land use choice reads as:

$$w(\sigma_i) = r(\sigma_i) + s(\sigma_i) + n_{i\sigma} b(\sigma_i), \quad \sigma_i = G, N, \quad \forall i = 1, 2, \dots, K \tag{1}$$

We are interested in the efficiency of land use decisions in the presence of agglomeration benefits, and not in how rents are allocated between landowners and the government (or the tax payer). For simplicity, we therefore assume that landowners 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 implements a payment scheme where the subsidy is set at the Pigouvian level[5,6] and expression (1) is the total payment received by landowner 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.

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[5] 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.

[6] 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 landowners choose *N*, and zero otherwise. This will make choosing *N* a dominant strategy, independent of what the other landowners 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 landowners the social benefits of their actions would ensure that social welfare is maximized with certainty.

Using the AB payoff function from 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 landowner and their two direct neighbors. On the basis of this payoff table, the AB scheme resembles the Stag-Hunt coordination game. This three-player game has two pure strategy Nash equilibria where all players choose G or N. These Nash equilibria are Pareto ranked in terms of payoffs. The payoffs for coordination on N is 90 while the payoffs for coordination on G is 80 – implying that the all-N equilibrium is the Pareto dominant one. On the other hand the Nash equilibrium corresponding to G is the risk dominant Nash equilibrium as the 1) the cost imposed on a player when neighbors deviate and 2) the range within which the payoffs for selecting G for any combination of neighbors' strategy choices vary is lower if the player chooses G than N.[7] At the network level, choice of the same strategy by all K players creates a convention: the Pareto efficient convention *all-N* or the risk dominant *all-G* convention.

Harsanyi and Selten (1988) 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 when neighbors don't coordinate on N. In an 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 players' strategic uncertainty even further. These features, in turn, may prevent the achievement of the social optimum and lead to the inefficient outcome – a

[7] Following Harsanyi and Selten (1988), the deviation loss associated with G is 70 and with N is 30.

scenario referred to as coordination failure. On the basis of this setup and our conjectures, this 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.

Experimental Design and Procedures

We consider twelve subjects arranged on a circle with every subject having a direct neighbor to their left and right. These direct neighbors are referred as the clockwise (left) and anti-clockwise (right) neighbors in the experimental instructions. All subjects are randomly assigned an ID ranging from 1 to 12 to preserve player anonymity and identify their direct neighbors. For example, the player with ID equal to 1 is directly linked to players with IDs 12 and 2. Every subject is *indirectly* connected to the remaining nine players via their direct neighbors. Since landowner identity and location does not change regularly on actual geographical landscapes, we adopt a fixed matching scheme whereby all networked players' IDs and location remain unchanged during the lifetime of the experiment. Additionally, the fixed matching scheme permits us to study the impact of subjects' reputation for the play of a particular strategy on other subjects' choices.

Each session has 30 periods during which the subjects play the game whose payoffs are shown in table 1, with their two direct neighbors. We record data for 12 sessions: 6 baseline sessions termed 2INFO and 6 treatment sessions termed 4INFO. The baseline is referred to as 2INFO as each subject receives feedback about their two direct neighbors' previous and all other past periods' actions. The label 4INFO signifies that in the treatment sessions a subject receives choice information about four players' actions closest to them on the network: their direct neighbors and their direct neighbors' direct neighbors' (closest indirect neighbors).[8] Per our model specification, in both treatments payoffs are determined by own and direct neighbors' choices only.

< Table 1 about here >

The experiments for this study were conducted at the Laboratory for Economics, Management and Auctions (LEMA) at the Pennsylvania State University in February 2012 using student subjects. In total 144 subjects participated in twelve 12-subject sessions resulting in 6 independent observations for each treatment. The show-up fee was US$5 and experimental earnings were converted into actual currency at the rate of 150 experimental dollars to one U.S. dollar. The experiments were implemented using z-Tree (Fischbacher 2007) and sessions lasted between 45 and 60 minutes. Average subject earning for the 2INFO and 4INFO sessions was US$19.95 and US$22.38 respectively.

At the beginning of every session a figure representing the networked landscape and players' neighbors was shown to the subjects. Figure 1 represents the landscape information shown to subjects in the 2INFO sessions. In the 4INFO sessions, the location of the closest indirect neighbors were labeled in the figure as well. This diagram is provided in the Appendix. The instructions (which are included in the Appendix) were made available on the computer screen and were read aloud to maintain an environment of common knowledge. Subjects

[8] In order to keep the instructions simple, we used the phrase local neighborhood in the instructions for 4INFO sessions to refer to the set of direct & indirect neighbors whose responses would be visible to players in all periods. However, in the Results section of the article, the phrase local neighborhood refers to the set of direct neighbors only.

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.

We adopted this context free approach to 1) study behavior and land use outcomes while subjects were responding to financial incentives generated by the AB payments and reputational incentives generated during repeated interactions with the same set of neighbors under the two information conditions, and because 2) explicit consideration of non-economic motivations towards conservation that typically vary between private landowners would impose subject heterogeneity in our experiment which although realistic can potentially confound the results of our information treatment (in addition to being orthogonal to it). 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 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 strategic environment, the game choices and the associated payoffs.

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.

General results

Figure 2 and table 2 present the average share of *N* choices for all sessions for both treatments over 30 periods. We make two observations. First, the average share of *N* choices in 2INFO falls from 63% to almost zero after 20 periods and then stays under 10% for the remaining periods. In 4INFO, *N* choices fall from 73% in Period 1 to 18% in Period 30 as well. Hence, with increasing experience the vast majority of the subjects end up choosing the risk-dominant option. This long run result corresponds to theoretical evidence on contagion of risk dominant choices on local networks provided by Ellison (1993) & Weidenholzer (2010) and experimental evidence recorded in Keser et al. (1998) and Berninghaus et al. (2002). The reduction in the frequency of efficient *N* choices and the increase in instances of coordination failure is also consistent with experimental evidence obtained in other non-network coordination game environments such as the minimum and average effort games (Van Huyck et al. 1990, 1991) and public good games (Andreoni 1988, Keser and Van Winden 2000).

An explanation for this result is that over multiple periods of interaction, most subjects' strategic uncertainty in the game gets resolved in favor of *G* since this can reduce the magnitude of payoff loss in the event of their neighbors' failure to coordinate on the efficient *N* strategy. This result is however markedly different from the previous AB studies by Parkhurst and colleagues given their experimental designs which 1) implement a random matching protocol, 2) includes non-binding pre-play communication both of which have been known to increase the frequency of efficient choice (Parkhurst et al. 2002), 3) don't consider any network effects and 4) at the end of every period announces the spatial configurations produced as a result of every subjects' choices.

The second observation is that, while the average share of *N* choices is falling in 4INFO, in every period the value is higher in 4INFO than in 2INFO. Thus, information about choices of more players on the network delays the decay in efficient coordination but cannot prevent it: if Player i observes that their direct neighbor Player $(i+1)$ chooses *N* but that their indirect neighbor Player $(i+2)$ chooses *G*, they may anticipate that Player $(i+1)$ will most likely switch to *G* (since choosing *G* is the best response when neighbors choose different strategies) inducing Player i to choose *G* as well.

In our experiments, transition to *G* following the above reasoning is likely as the payoff matrix produces conditions which are quite adverse for coordination on the efficient equilibrium. The payoff difference between the *NNN* and *GGG* outcomes is 10. This difference is less than the loss associated with choosing *N* when at least one neighbor deviates from *NN* to *NG* (40). Additionally, the payoff difference between a choice of *N* and *G* when facing previous choices corresponding to *NG* is 20. Hence, a player stands to lose much higher payoffs from choosing *N* repeatedly to influence *G* playing neighbors to choose *N* in order to earn a payoff of 90. Thus, the prospect of generating an *NNN* outcome is not worth the payoff losses needed to do so. As a result, the tendency of voluntary loss making to influence neighbors to choose *N* is weakened contributing to the decrease in the likelihood of efficient coordination with increasing experience. In fact debriefing of subjects after every session revealed that an increasing number of subjects chose *G* or switched from *N* to *G* owing to the magnitudes of the out-of equilibrium payoffs relative to the Nash equilibrium ones.

The importance of the relative magnitudes of these out-of-equilibrium payoffs on equilibrium selection has been documented in relation to Stag Hunt games by Straub (1995) as well. In light of this scenario, the fact that 1) extra information on the network is able to increase the frequency of *N* choices under the current adverse payoff circumstances and 2) that in the previous non-network AB studies information about everyone's choices improves coordination strengthens our result: with more information coordination is less likely to unravel if the circumstances for coordination are already favorable.

< Table 2 about here >

< Figure 2 about here >

Let us analyze the result more formally. Table 3 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 6 independent observations from 6 sessions in each cell of the table) and the same averaged over all 30 periods for 6 groups. Using standard Mann-Whitney tests[9] (with corresponding *p*-values presented in table 3) we find no significant treatment effect in the first period but over the experimental lifetime of 30 periods there is a significant impact of information (at 5% 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. Considering all 30 periods together, relative to 2INFO, in 4INFO, subjects' strategic uncertainty associated with choosing the risky payoff efficient strategy is lower since they are able to view the current and all previous choices of their direct and closest indirect neighbors. As a result, strategic uncertainty for many players gets resolved in

[9] Table I in the Appendix contains data used for the Mann-Whitney tests.

favor of *N*, leading to an upfront increase in *N* choices in 4INFO and significantly more *N* choices on average in 4INFO relative to 2INFO. This result holds regardless of the fact that owing to the adverse payoff conditions and lack of visibility of more than 50% of the participants' choices, *N* choices fall in both treatments with repeated interactions. Our findings are also supportive of the theoretical model by Alós-Ferrer and Weidenholzer (2008) in which players successfully choose the efficient strategy when receiving information from two direct and two closest indirect neighbors.

< Table 3 about here >

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 3-5 we present snapshots of the network configurations in each of the six sessions for periods 1, 15 and 30[10] where *N* choices are marked with red triangles and *G* choices with black circles. 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, in the final period, very few adjacent *N* choices remain.

[10] 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 can be determined on the basis of data in the supplementary appendix.

Table 4 presents the number of groups and the earliest period in which any group reached an equilibrium configuration. We find that there is only one cohort which is able to reach an *all-N* equilibrium in 4INFO. This efficient land use configuration is produced in Period 7 in the sixth cohort and is stable with some variation till Period 22. Beyond this period, only a few localized *N* choices persist. Of the remaining five 4INFO groups, localized *N* choices transition to the *all-G* outcome (which is produced earliest in any of the groups in Period 23) in three groups. In the remaining two, only isolated *N* choices remain. In 2INFO on the other hand, *all-N* is never produced and the *all-G* outcome is obtained earliest in Period 12. This risk dominant network level configuration is both stable and resilient. Of the five groups that reach this pattern in Period 30, two groups never deviate away from it and the three which do revert back to it in 1-2 periods. The stability and resilience of the *all-G* outcome is consistent with theoretical evidence provided by Alós-Ferrer and Weidenholzer (2006).

< Figures 3-5 about here >

<Table 4 about here>

To support a formal analysis of these land use outcomes, we construct a metric to measure the degree of spatial contiguity generated by the AB scheme in terms of contiguous *N* and *G* choices on the circular network. This metric measures the number of localized clusters of similar land use decisions produced by any 3 adjacent players, i.e., a player and their direct neighbors on the network.[11] Formally the cluster metric reads as:

[11] We conducted the contiguity analysis with cluster sizes of 3 and 2 (which is a weaker measure of contiguity) and obtained the same qualitative results. Owing to the similarity in results and the fact that our AB game is a three-player game nested in a larger local network, in which a 2-sized cluster does not capture all the strategic effects faced by a player, we only include the 3-cluster analysis in this article.

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

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. This metric can take a minimum value of 0 when no three adjacent players make the same choice implying that subjects cannot coordinate their decisions even within their local neighborhood where choices are always visible. The maximum value of the metric is *K=12* which is obtained when a *G* or *N* convention is produced. This is because every player is at the center of one distinct local neighborhood. 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.[12] Figure 6 (panels a and b) and table 2 present 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 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, variation in information available about players' choices produces significant differences in the nature of these spatial patterns. Table 5 reports the *p*-values associated with Mann-Whitney tests for

[12] We do not present our analysis in terms of the *N* convention as it originates in only one group and in terms of *G* convention as most groups coordinate to it with increased experience regardless of treatment. The analysis of localized choices on the other hand is more informative in representing the variability in the land choices observed on the network owing to the treatment implementation and game experience.

the *N*-clustering and *G*-clustering metric for all 30 periods (6 independent observations per cell in both cases)[13].

<Insert Figures 6a and 6b about here>

< Table 5 about here >

We find that the level of *N*-clustering is significantly different (p-value: 0.045) 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 at least within players' local neighborhoods. However, with limited information flows and repeated interactions over all 30 periods, nearly all subjects (69 out of 72) switch to *G* in 2INFO (while there are many subjects still selecting *N* in 4INFO), so that on average a significant treatment induced difference (p-value: 0.03) in the overall levels of *G*-clustering emerges as well.

Analysis of individual behavior

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 lagged-endogenous to subjects within a dynamic random effects probit regression framework with the subject representing the random effect. 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 ($i = 1,2, \dots ,144$) in period t ($t = 1, 2, \dots ,30$).

[13] Data for the Mann-Whitney tests are included in Tables II & III in the Appendix.

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 the Period variable denoted by t that controls for the impact of subjects' game experience and familiarity within the experimental environment on their likelihood of making an *N* choice. In addition to these exogenous variables, in Model II the effect of a player's previous period choice on the likelihood of selecting *N* in any period is considered. This variable controls for an effect which has been variously termed strategy inertia, a precedence effect or simply "force of habit". An interaction term between the Period variable and the lagged choice is included to evaluate whether the role of precedence in determining the likelihood of an *N* choice in the current period varies as subjects become more experienced with the game.

Since neighbors' choices influence own action, another Model III includes 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 Period variable is considered to explore the effect the frequency of neighbors' choices have on a subject's likelihood of choosing *N* at different levels of subject experience. A third interaction term between n_{it-1} and $y_{i(t-1)}$ is included to analyze whether force of habit gets reinforced within the local neighborhood depending on circumstances favorable for efficient strategy choice i.e. the number of neighbors choosing *N*. 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 and ρ the omitted categories. In evaluating model performance, we use the value of the log-likelihood generated during the estimation.

$$y_{it} = \rho + D + \beta y_{i(t-1)} + \gamma t + \delta t y_{i(t-1)} + \theta n_{i(t-1)} + \pi t n_{i(t-1)} + \mu y_{i(t-1)} n_{i(t-1)} + u_i + \varepsilon_{it}$$

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

<Table 6 about here>

Table 6 presents the regression estimates for the three models. Consistent with our prior discussion the information treatment dummy effect estimate is positive and significant (at 1% level) in all the models. We also obtain a negative and significant estimate for the Period variable in all models providing support for the negative trend in *N* choices observed for both treatments. This result follows from the strategic uncertainty in the game getting resolved in favor of *G* owing to the adverse payoff circumstances associated with making an *N* choice and suffering high payoff losses (20 or 70) given neighbors' selections.

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. Thus there is a positive precedent for the choice of *N* and this effect can be attributed to 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, one explanation for the strategy lock-in is 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* and build a reputation for selecting *N*. Such costly signaling can be 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 act consciously which is cognitively effortful (Kahneman 2003; Thaler and Sunstein 2008).

The estimate for the interaction between precedence and Period variable is positive and significant in Model II. Per figure 7a that presents the marginal effect of the interaction between own previous choice and Period variable with 95% confidence intervals (generated using routines suggested by Xu and Long (2005) in Stata on the basis of Ai and Norton (2003)) to interpret interactions in non-linear regressions, we obtain a positive and significant interaction effect for all values of Period (none of the confidence intervals include 0). Although the estimate of the interaction term is not significant in Model III, figure 7b indicates a positive and significant interaction effect as well given the nature of the confidence intervals. Thus, per figures 7a & 7b, the effect of precedence on current choice is significantly different at varying levels of subject experience. With increased familiarity in the game habit is harder to break: an *N* choice made in the previous period in later phases of the game is more likely to be reinforced than when this choice is made in the early phases of the game.

<Insert Figures 7a, b, c & d about here>

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 the 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 center 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, we focus on the two interaction effects which try to explain subject behavior given a favorable situation for efficient coordination within their local neighborhood. The estimate for the interaction term between the precedent and neighbors' previous choice variable is positive. Figure 7c provides the diagrammatic representation of the marginal effect of interaction between precedent and number of neighbors selecting *N* in the previous period for three candidate Period values, 1, 15 and 30. We find the true interaction effect to be significant since 0 is not in any of the confidence intervals. Thus, strategy inertia associated with an efficient *N* choice is even stronger if more neighbors chose *N* previously. The interaction term between Period variable and neighbors' choices is positive and significant (at 1% level of significance). Figure 7d represents the true interaction effect which is positive and significant and interpreted in the same manner. Thus 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* in order to avoid suffering payoff losses, with more 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.

These two interaction effects pertaining to the local neighborhood represent the relative impact of the strategic interactions within the local neighborhood and the overall network environment. They suggest 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 resolved in favor of *G*. The value of the log-likelihood is the highest for Model III as well, indicating that this model most accurately explains the variability in subject behavior in the experiments that produces different spatial patterns and corresponding conservation benefit streams.

Conclusion

Improving the design of agri-environmental policy involving Payments for Ecosystem Services often requires attention to the spatial configurations of land uses that generate conservation benefits. In such cases the AB can serve as a policy mechanism to incentivize coordination when landowners/farmers can voluntarily choose how to manage their land. However, under a conservative payoff scenario, risk and payoff dominance may select different Nash equilibria in the AB game leading to the problem of potential coordination failure on the Pareto efficient equilibrium (Straub 1995). 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 under two information conditions within such a payoff scenario.

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 limited. Then information on the choices of other landowners in the network can reduce strategic uncertainty and improve likelihood of coordination towards the socially optimal outcome. We find that spatial coordination to the Pareto efficient outcome is significantly higher when subjects have more information available about the land management choice and payoffs of their neighbors.

Given that there is considerable generalizability of results from the lab to the field (Camerer forthcoming; Kessler and Vesterlund forthcoming), our study result lends scope for improved coordination to enhance ecosystem services delivery if restrictions on information exchange between landowners are relaxed. One of the many ways to do so would be for university extension staff to liaise with potential participants in an AB-type scheme in a neighborhood (e.g., a catchment), although this comes at a cost. Experience with conservation auctions in Australia suggests that such close contacts between extension personnel and farmers can be crucial to determining the extent of participation and the quality of outcomes (Reeson et al. 2011). Another method would be to disseminate information in farming community networks through internet bulletin boards and key actors ("model" or "demonstration" farmers) who are linked to many others and can serve to reduce the levels of strategic uncertainty facilitating spatial coordination (Prell et al. 2009)

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 found. Such a result is contrary to the previous AB studies by Parkhurst and colleagues and is a consequence besides other design aspects, of the realistic network representation since this increases the strategic uncertainty of players to an extent greater than that in the earlier studies; and the experimental parameterization which is adverse to efficient coordination and was chosen keeping in mind that current conservation subsidy budgets have declined following the 2008 recession. In the context of improving the delivery of ecosystem services and other conservation benefits through land management on local networks, this result implies that when participants respond only to financial incentives, in the long run the AB may prove to be only *partially* effective in generating localized coordination patterns for ecosystem services delivery. For an environmental regulator or conservation agency who is constrained by tight budgets so that they cannot increase the subsidies associated with the conservation-friendly land management actions, finding a way of ameliorating this tendency of coordination to move away from the Pareto optimal outcome (maybe by appealing to participants' non-economic behavioral & environmental motivations) is important if the conservation benefits of spatial coordination via an AB scheme are to be maintained in the long run.

Appendix

Experimental Instructions[14]

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

[14] In 4INFO sessions, in addition to all instructions, subjects saw the italicized text as well. In the instructions, strategy *M* refers to choice *N* and strategy *K* to choice *G*. We include the unchanged instructions in the article to maintain consistency with the actual instructions provided to the subjects during the experiment.

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.

*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 (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 your neighbors *players in your local neighborhood.* **TRUE**

Spatial Grid

< Figure about here>

Tables Reporting Mann-Whitney Tests

Table I: Period 1 and Period 30 Average *N* Choices

	Period 1		30 Period Average	
	2INFO	**4INFO**	**2INFO**	**4INFO**
Group -Level *N* Choices	9	9	4.66	6.43
	7	7	1.7	3.26
	7	9	2.7	3.1
	7	10	1.66	3.7
	6	9	1.36	3.76
	9	9	2.1	10.66
Wilcoxon Mann Whitney Test	0.109		0.03	

Table II: Period 1 and Period 30 Average Localized *N* Cluster values

	Period 1		30 Period Average	
	2INFO	**4INFO**	**2INFO**	**4INFO**
3-player Localized *N* Clusters by Group	4	5	2.60	4.07
	2	3	0.87	1.33
	0	5	1.27	1.17
	2	8	0.27	1.73
	0	4	0.23	1.63
	4	4	0.73	9.10
Wilcoxon Mann Whitney Test	0.03		0.045	

Table III: Period 1 and Period 30 Average Localized *G* Cluster values

	Period 1		30 Period Average	
	2INFO	**4INFO**	**2INFO**	**4INFO**
3-player Localized *G* Clusters by Group	0	0	5.20	3.27
	1	1	9.43	6.77
	0	0	7.77	6.90
	1	0	8.73	6.00
	0	0	9.30	6.27
	0	0	8.33	0.27
Wilcoxon Mann Whitney Test	0.93		0.03	

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Footnotes:

1. An alternative approach investigated in the literature is auctions for spatially-coordinated land management project procurement (e.g., Windle et al. 2009).
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 in the coordination game) on 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.
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 landowners' choice of one conservation strategy over the other. We thus implicitly assume that compensation is sufficiently generous for both conservation strategies to make participation incentive compatible. This assumption is not at odds with reality as PES schemes have been known to overcompensate landowners in order to guarantee participation (Kirwan et al. 2005, Munoz-Pina et al. 2008).
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 (Keinath and McGee 2005) and birds like the sage grouse (Crawford et al. 2004). 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 burrowing and short-eared

owls (Holt and Leasure 1993) typically rely on grasslands for nesting and hunting but thrive less well on land retired from agriculture and abandoned to nature.

5. 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.
6. 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 landowners choose *N*, and zero otherwise. This will make choosing *N* a dominant strategy, independent of what the other landowners 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 landowners the social benefits of their actions would ensure that social welfare is maximized with certainty.
7. Following Harsanyi and Selten (1988), the deviation loss associated with *G* is 70 and with *N* is 30.
8. In order to keep the instructions simple, we used the phrase local neighborhood in the instructions for 4INFO sessions to refer to the set of direct & indirect neighbors whose responses would be visible to players in all periods. However, in the Results section of the article, the phrase local neighborhood refers to the set of direct neighbors only.
9. Table I in the Appendix contains data used for the Mann-Whitney tests.
10. 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 can be determined on the basis of data in the supplementary appendix.

11. We conducted the contiguity analysis with cluster sizes of 3 and 2 (which is a weaker measure of contiguity) and obtained the same qualitative results. Owing to the similarity in results and the fact that our AB game is a three-player game nested in a larger local network, in which a 2-sized cluster does not capture all the strategic effects faced by a player, we only include the 3-cluster analysis in this article.
12. We do not present our analysis in terms of the *N* convention as it originates in only one group and in terms of *G* convention as most groups coordinate to it with increased experience regardless of treatment. The analysis of localized choices on the other hand is more informative in representing the variability in the land choices observed on the network owing to the treatment implementation and game experience.
13. Data for the Mann-Whitney tests are included in Tables II & III in the Appendix.
14. In 4INFO sessions, in addition to all instructions, subjects saw the italicized text as well. In the instructions, strategy *M* refers to choice *N* and strategy *K* to choice *G*. We include the unchanged instructions in the article to maintain consistency with the actual instructions provided to the subjects during the experiment.

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**

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	2.00	4.83	0.33	0.17
2	0.61	0.67	4.00	4.17	1.00	0.83
3	0.51	0.68	3.00	5.00	2.67	1.17
4	0.51	0.61	3.50	3.83	3.00	2.00
5	0.49	0.65	2.50	4.67	2.83	1.50
6	0.46	0.65	3.33	4.33	4.17	1.33
7	0.36	0.65	2.33	5.33	5.67	1.83
8	0.32	0.61	1.67	5.17	5.83	2.50
9	0.33	0.53	1.67	3.67	5.50	3.17
10	0.25	0.47	1.00	3.50	6.67	3.67
11	0.22	0.39	0.83	2.83	7.33	5.67
12	0.17	0.39	0.50	2.50	8.00	5.50
13	0.17	0.40	0.83	3.50	8.50	5.83
14	0.14	0.43	0.67	3.33	9.00	5.17
15	0.11	0.40	0.50	3.33	9.33	5.67
16	0.08	0.39	0.33	3.17	10.00	5.67
17	0.08	0.38	0.17	3.00	9.67	5.83
18	0.07	0.35	0.17	2.83	10.17	6.17
19	0.03	0.35	0.00	2.83	11.00	6.17
20	0.01	0.36	0.00	3.00	11.50	6.17
21	0.03	0.38	0.00	3.17	11.33	5.83
22	0.06	0.38	0.33	3.17	11.00	5.83
23	0.03	0.33	0.00	2.50	11.33	6.50
24	0.03	0.32	0.00	2.33	11.33	6.67
25	0.04	0.29	0.17	2.00	11.17	6.67
26	0.03	0.26	0.00	1.67	11.33	6.67
27	0.06	0.26	0.17	1.50	10.67	7.00
28	0.03	0.18	0.00	1.17	11.17	8.83
29	0.03	0.21	0.00	1.50	11.17	8.50
30	0.04	0.18	0.17	1.33	11.17	8.83

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

Table 4: Number of Groups and Earliest Period in which *N* and *G* Conventions Reached

	2INFO		4INFO	
	# of groups reach at least once	Period in which first originated	# of groups reach at least once	Period in which first originated
all-N	0	--	1	7
all-G	5	12	3	23

Table 5: Mean Shares of Localized *N* and *G* Cluster for Period 30

Averaged over all 30 periods	**Treatment**		**Mann Whitney Test**
	2INFO	**4INFO**	**p-value**
Share of *N* clusters	0.10 (0.08)	0.3 (0.25)	0.045
Share of *G* clusters	0.70 (0.12)	0.44 (0.23)	0.03

Table 6: Results of Random Effects Probit Regressions for Land Management Decisions

Explanatory Variables	Probit (=1 if strategy *N* is chosen)		
	Model I	**Model II**	**Model III**
Information Treatment Dummy	1.241 **	0.737***	0.199**
	(0.262)	(0.157)	(0.092)
Period	-0.108***	-0.075***	-0.037***
	(0.004)	(0.006)	(0.009)
Action in Previous Period	--	1.354***	1.39***
		(0.136)	(0.188)
Action in Previous Period × Period	--	0.029***	0.003
		(0.008)	(0.009)
Number of Neighbors Choosing *N* in Previous Period	--	--	0.812***
			(0.116)
Number of Neighbors Choosing *N* in Previous Period × Period	--	--	0.024***
			(0.006)
Action in Previous Period × Number of Neighbors Choosing *N* in Previous Period	--	--	0.102
			(0.111)
Constant	0.058	-0.78***	-1.755***
	(0.31)	(0.143)	(0.164)
Log Likelihood	-1446.9489	-1073.4032	-868.329
$i = 144; t = 30$			

Note: *** and **, represent significance at 1% and 5%.

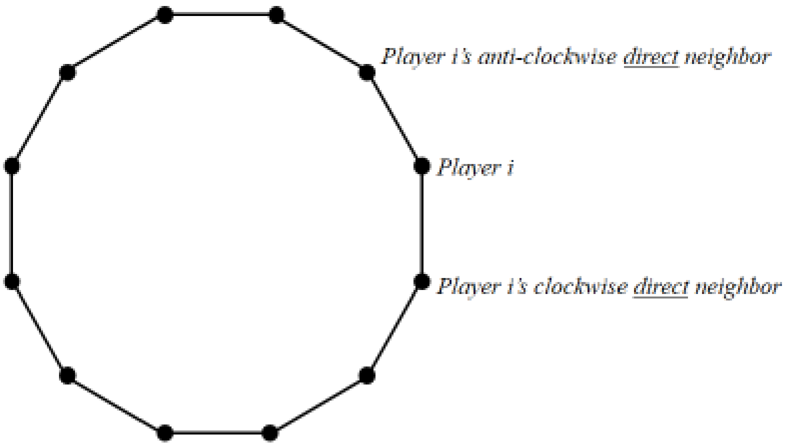


Figure 1: Circular local network

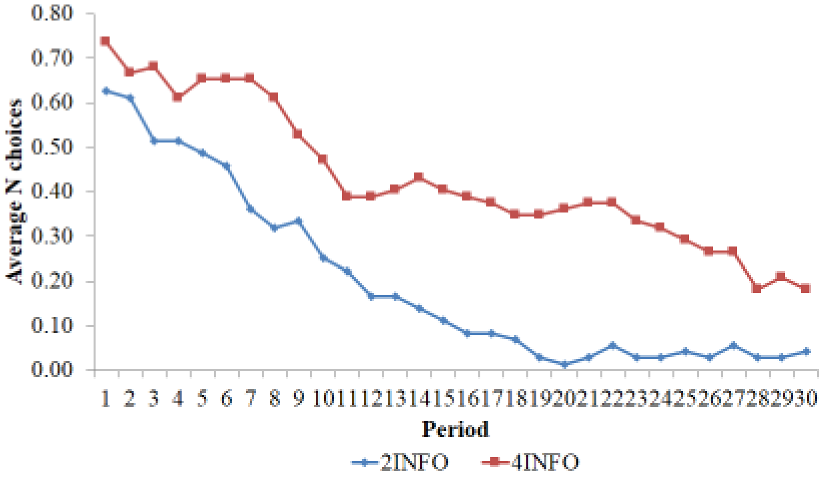


Figure 2: Average share of *N* choices by period & treatment

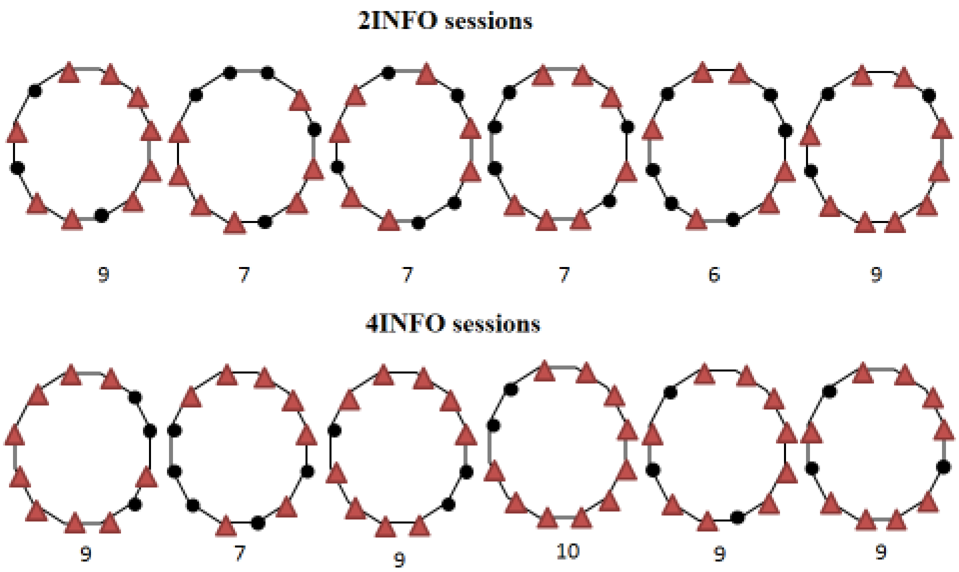


Figure 3: Period 1 choices

Note: ▲ ***N*** **choice** ● ***G*** **choice**

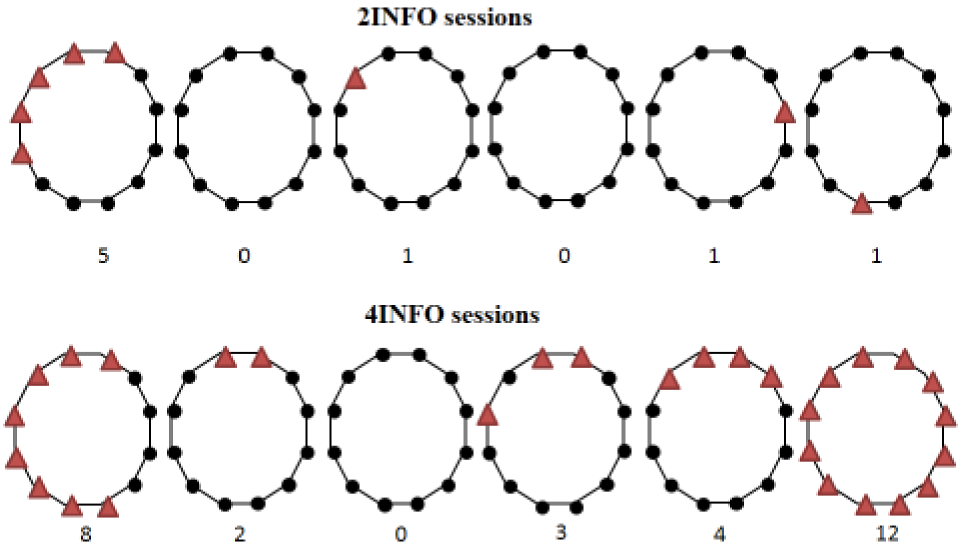


Figure 4: Period 15 choices

Note: ▲ ***N*** **choice** ● ***G*** **choice**

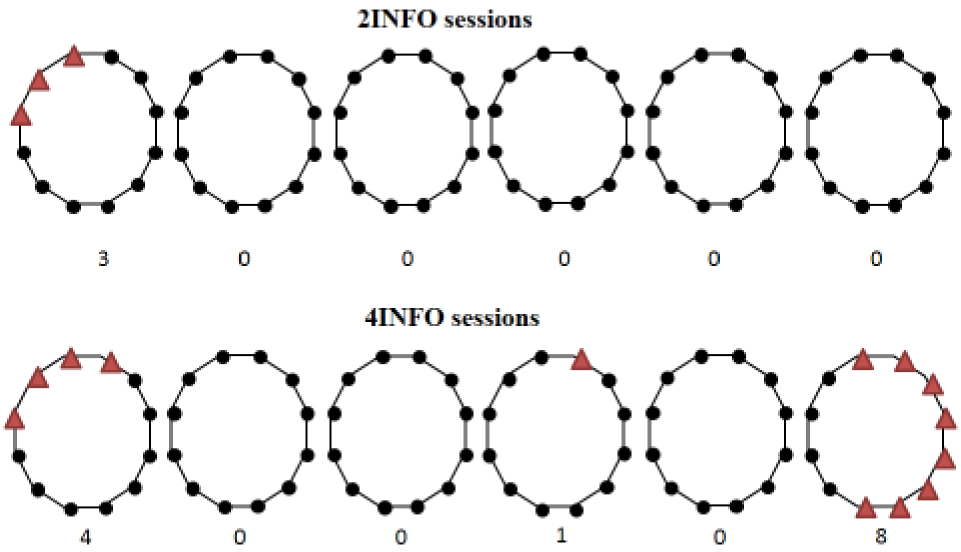


Figure 5: Period 30 choices

Note: ▲ *N* choice ● *G* choice

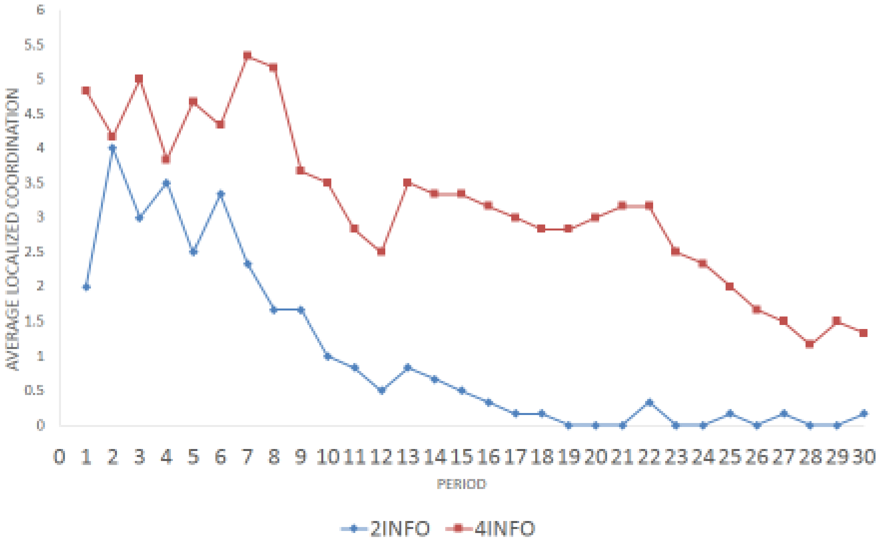


Figure 6a: Average Localized N-Clustering by Treatment & Period

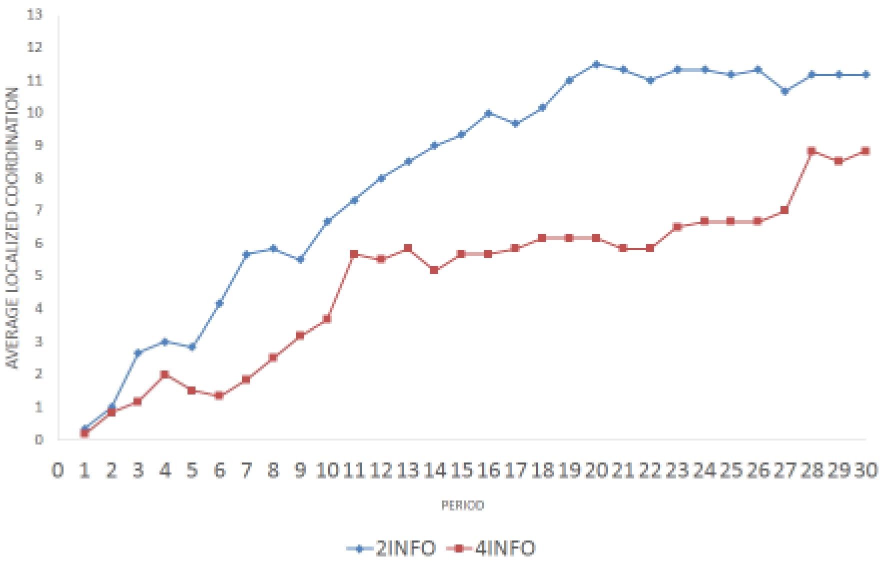


Figure 6b: Average Localized G-Clustering by Treatment & Period

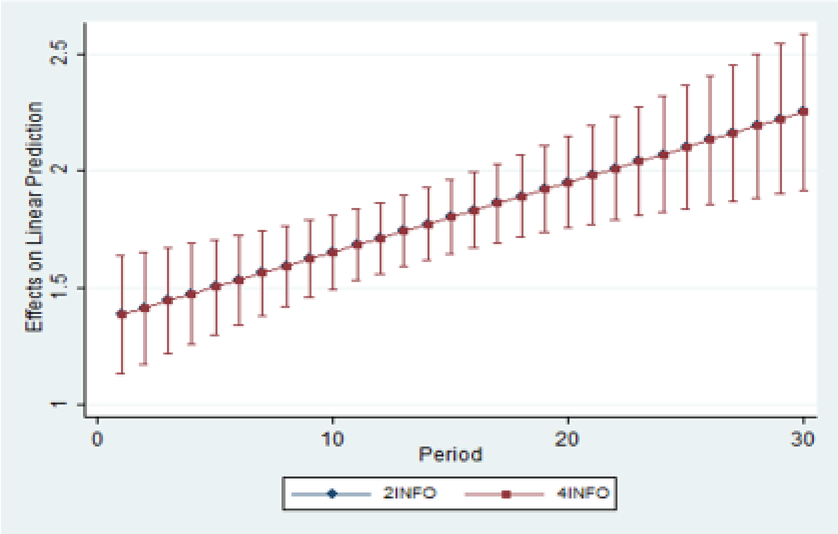


Figure 7a: Marginal Effect of Interaction Between Own Previous Choice & Period Variable with 95% Confidence Intervals

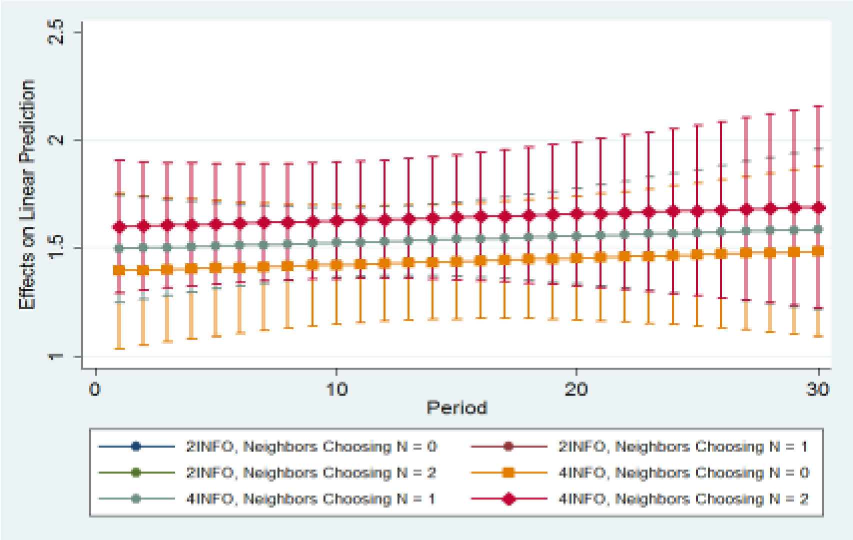


Figure 7b: Marginal Effect of Interaction Between Own Previous Choice & Period Variable with 95% Confidence Intervals calculated at three values of N choice by neighbors in previous period – 0, 1, 2

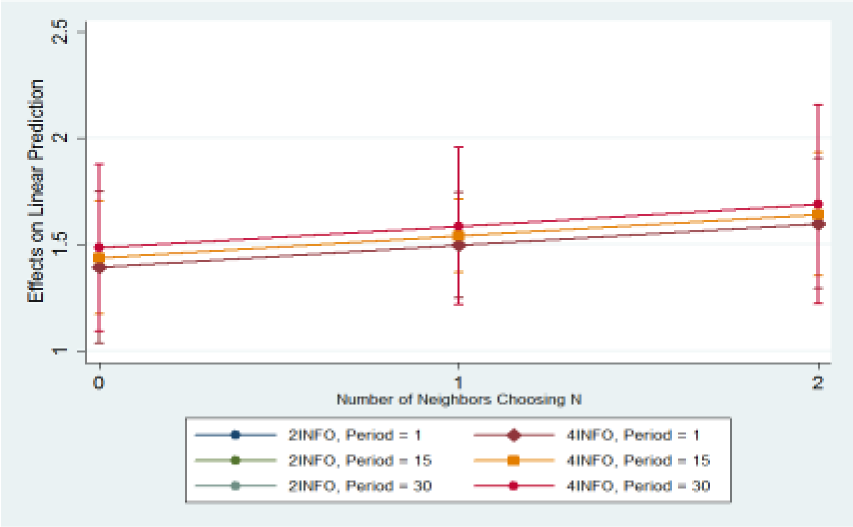


Figure 7c: Marginal Effect of Interaction Between Own Previous Choice & Number of Previous Efficient Choice by Neighbors Variable with 95% Confidence Intervals calculated at 3 period values – 1, 15, 30

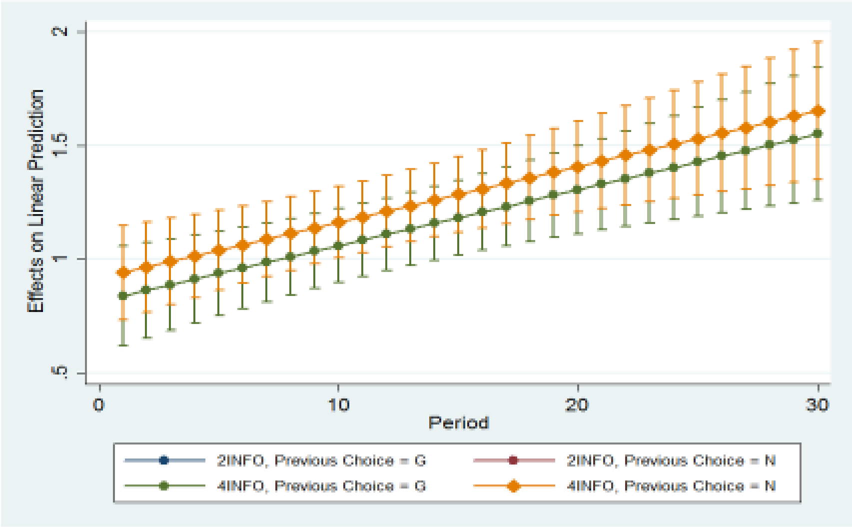
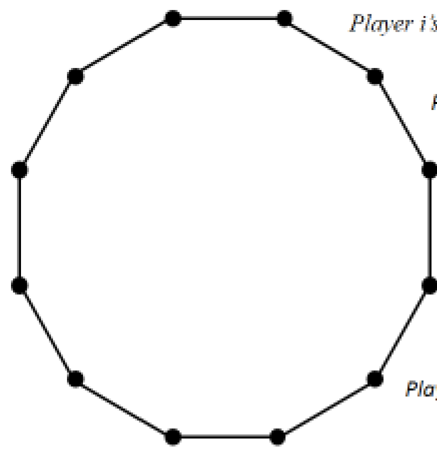


Figure 7d: Marginal Effect of Interaction Between Number of Previous Efficient Choice by Neighbors & Period Variable with 95% Confidence Intervals calculated at two values of previous choice 0(G) & 1(N)



Appendix: Circular local network – 4INFO