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Simanti Banerjee

Anthony M. Kwasnica

James S. Shortle

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Simanti Banerjee
simanti.banerjee@stir.ac.uk
Division of Economics,
University of Stirling
Stirling, UK
FK9 4LA
P: +44(0)1786-467277
F: +44(0)1786-467469

Anthony M. Kwasnica
kwasnica@psu.edu
Department of Insurance and Real Estate
332 Business Building
Penn State University
University Park, PA, 16802

James S. Shortle
jshortle@psu.edu
Department of Agricultural Economics and Rural Sociology
112C Armsby Building
Penn State University
University Park, PA, 16802

Abstract

The Agglomeration Bonus (AB) – a subsidy mechanism can incentivize neighboring landowners to spatially coordinate their land use decisions for effective provision of ecosystem services such as biodiversity protection. In this paper we explore individual AB performance on a local network in a laboratory setting. In our experiments, we vary the local network size while keeping the number of neighbors for each player same. Results suggest better AB performance and greater spatial coordination in smaller groups relative to bigger ones. In bigger groups however we observe localized areas of coordinated land use choices which indicate partial AB effectiveness.

Key Words: Agglomeration Bonus, coordination failure, local networks, experiments

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

Section 1: Introduction

Ecosystem services such as biodiversity protection, improvement in water quality, reduction in soil erosion and many others can be supplied by bringing about changes in private land uses. These changes are costly indicating that property owners have to be financially compensated for implementing them. Payment for Ecosystem Services (PES) schemes have been formulated by regulatory agencies for this purpose. Notable examples of PES schemes include the Conservation Reserve Program (CRP) in the US and the Stewardship Scheme in the UK. One key issue which is receiving increasing attention in the implementation of these payment schemes is how to incentivize the creation of spatially contiguous areas of similar land uses on private properties. This spatial goal is relevant to the delivery of biodiversity protection services such as increase in the population of species with limited mobility like amphibians, natural pollinators who provide pollination services on agricultural land to mention a few (Margules and Pressey 2000, Willis 1979, Bartelt et al. 2010).

One approach to creating these spatial patterns is the Agglomeration Bonus (AB) proposed by Parkhurst et al. (2002, 2007). The AB is a subsidy mechanism consisting of two incentive payments. The first is a participation payment and is independent of neighbors' actions and is received by landowners who choose to participate and implement designated conservation practices. The second is the bonus paid when enrolled parcels border those enrolled by others. The format of the AB is flexible and the payments can be adjusted to incentivize the creation of various land use patterns . Under this mechanism since landowners can obtain the full payment only if they coordinate their land management decisions with their neighbors, inter-neighbor interactions take the form of a coordination game. These games have multiple Nash equilibria which are Pareto ranked in their payoffs and hence differ in their efficiency properties. Selection of any of the Nash equilibria other than the

Pareto efficient one is economically inefficient and corresponds to the scenario of coordination failure. There is an extensive theoretical and experimental literature on equilibrium selection and coordination failure in these games. In the context of the AB non-participation and inability to coordinate decisions on a square spatial grid leads to coordination failure. Repeated interactions which builds reputation and reduce the strategic uncertainty in the game (Parkhurst and Shogren 2007) and non-binding pre-play communication between players (Warziniack et al. 2008) are found to improve the likelihood of coordination in the AB game in an experimental environment.

In our paper, we are interested in exploring the coordination features of the AB scheme and the equilibrium selection process as well. We pursue this objective with a modified AB in a new game environment which is representative of strategic interactions between landowners on agricultural landscapes where the AB can be implemented. The modified AB scheme includes two strategies pertaining to the supply of two types of ecosystem services in addition to the opt-out alternative. This strategy set reformulation is based on the fact that land can deliver different types of ecosystem services.

Our new game environment is prompted by landscape features which can impact the strategic interactions in the coordination game affect AB performance. Depending upon the nature of property boundaries and the total area under the jurisdiction of the regulator there may be few or many farms who are eligible to participate in the AB program. Van Huyck, Battalio and Beil (1990, 2007) (VHBB) have found that the incidence of coordination failure is greater in games with more players. Given this result, we experimentally evaluate the impact of varying the number of AB participants on the landscape on spatial coordination and AB performance. We consider small and large landscape grids with six and twelve players respectively arranged in a circular network. The circle specification is relevant to our study for two reasons. First, while the work of VHBB and others have shown that groups larger than 3 or 4 almost always fail to coordinate on the efficient equilibrium; they also find that small groups of 2 or 3 often manage to coordinate successfully. Therefore, the circle network structure presents an interesting middle ground. Since all the players are indirectly connected in the network inefficient coordination may be expected if the network has more than three players. However, players only directly interact with a small set of neighbors - two (one to the left and right each) so the small size of their immediate interactions may lend hope for successful coordination. Second the circle network allows us to consider a landscape where neighbors' neighbors are not a player's neighbor. This neighborhood pattern is distinct from the more traditional global interaction setup where every individual directly interacts with everyone else. Yet it is representative of neighborhood linkages between landowners which are determined by geography and where the identity of neighbors of every landowner may vary. These circular networks are referred to as local networks (Cassar 2007, Weidenholzer 2010). In our experiments on AB performance, we vary the overall network size (between 6 and 12) but keep the number of direct neighbors the same at 2 in all sessions. This size treatment allows us to inspect the incidence of coordination in the context of the AB and also evaluate the generality of the VHBB result in local networks.

The laboratory experimental method is appropriate to our study for various reasons. First, by controlling the features of the laboratory environment or testbed (Plott 1997), we are able to wind-tunnel test the performance of the AB in new strategic environments prior to costly field testing. Second, by using human subjects we can analyze human behavior in local networks in addition to performance of the AB scheme. Finally, the experimental approach allows us to evaluate the performance of the AB instrument in a strategic environment which has policy relevance.

Our experiments demonstrate that there is greater incidence of spatial coordination failure through the selection of the inefficient equilibrium in the large local network relative to the small one. This difference is significant despite individuals having two neighbors in both the treatments. In addition we also find that many players frequently fail to converge to any equilibrium strategy. This scenario of mis-coordination gives rise to hubs of players choosing different strategies at different parts of the networks. These hubs are more prevalent in the large networks relative to the small ones and limit the payoffs of players at the hubs' edges, economic efficiency and AB performance.

The paper is arranged as follows. In Section 2, we describe the AB game and relate it to the existing literature on coordination games In network and non-network settings. Section 3 describes the experimental design followed by the Results in Section 4. Section 5 concludes.

Section 2: The Agglomeration Bonus Game

We present the structure of a general AB coordination game with N players on the landscape. We consider every player's property to have two parcels.[1] These parcels can deliver two different types of ecosystem services. Thus rather than looking at the creation of different spatial patterns we focus on the provision of two types of ecosystem services via spatially contiguous land uses. A parcel can also be placed in conventional land use indicating non-participation in the AB scheme. Let α represent parcel type and take the value of M or K. The participation component of the AB scheme is denoted by $s(\alpha)$ and the bonus by $b(\alpha)$. The bonus is received when neighbors produce the same ecosystem service on adjacent parcels. The opportunity cost of enrolling parcels of type α in the conservation program is $c_i(\alpha)$. It is assumed to be the same for all players. The number of neighbors for the i^{th} player is denoted by n_i. Of the n_i neighbors, $n_{i\alpha}$ represents the set of neighbors choosing strategy α. The payoff function of player i is represented by $u_i(\sigma_i, \sigma_{-i})$. In the game $\sigma_i =$

$M(K)$ indicates that player i has opted to place land M(K) in conservation use and $\sigma_i = \phi$ indicates non-participation. Given this setup, the payoff function for any player i where $-i$ represents the set of neighbors is given by

$$u_i(\sigma_i, \sigma_{-i}) = \begin{cases} s(\alpha) + n_{i\alpha} b(\alpha) - c(\alpha) & if\ \sigma_i = \alpha \\ 0 & if\ \sigma_i = \phi \end{cases} \quad (1)$$

We now make some assumptions to lend a specific structure to the game environment. Since, the costs of changing land uses to deliver various ecosystem services on different parcels is different, without any loss of generality, we assume that the opportunity cost of conservation use on K parcels is higher than on M parcels. Hence the participation payments for enrolling K net of opportunity costs are higher than that for enrolling M. This scenario represents the costs of producing ecosystem services on marginal cropland which is lower than the same from agriculturally fertile tracts. Here the opportunity cost associated with the former parcels is lower relative to the latter. Second, the bonus for M parcels is higher than that for K. This assumption reflects various institutional criteria related to PES scheme implementation. Since PES budgets are limited, the regulator may want to balance a higher participation payment for K with a lower bonus payment. The ranking of bonus payments may also reflect the agency's preference for procuring ecosystem services from contiguous M parcels relative to K ones. Finally, since the participation payment for M parcels is lower than that of K, a higher bonus may be necessary to incentivize any enrollment of M parcels at all. The third assumption is that absent AB payments, returns from placing land in conservation uses is less than that from placing land in conventional uses. This assumption implies that landowners don't provide ecosystem services voluntarily. Fourth, there are no transaction costs of spatial coordination and participation in the AB scheme. Fifth, net returns inclusive of AB payments are higher than placing land solely in conventional uses. Assumptions four and five together imply that non-participation is a strictly dominated strategy for all players. Finally, the agency provides AB payments for only one parcel per landowner so that landowners cannot enroll both M and K parcels into the AB scheme. This last condition represents the political constraints facing the agency whereby they have to maximize both landowner participation and supply of ecosystem services within the budget constraint.

INSERT TABLE 1 HERE

To illustrate the features of our AB game, we consider a three player environment. In this game $n_i = 2\ \forall i = 1,2,3$. Let the AB payments menu be the following - net payments from participation be $s(M) - c(M) = 10$, $b(M) = 20$, $s(K) - c(K) = 25$, and $b(K) = 12$. Table 1 represents the payoff table and $\sigma_i = M$ for all i and $\sigma_i = K$ being the two pure strategy Nash equilibrium. Also given the coordination game format, these Nash equilibria can be payoff ranked with $\sigma_i = M$ for all i being Pareto superior to $\sigma_i = K$ for all i. In addition, since the participation component for M is lower than that for K, higher overall payoffs from M can be obtained if and only if the bonuses are earned. Thus if a player believes that at least one of their neighbors might make a mistake and not choose M, choosing K is a safer option for them. In other words, by choosing K a player is less reliant on their neighbors for their payoffs than if they chose M. Thus payoff-wise K is a less risky strategy than M. We can use the Nash equilibrium selection principles of risk and payoff dominance (Harsanyi and Selten 1988) to formally characterize the riskiness of M relative to K. For this we calculate the deviation losses[2] for the two strategies. In our example, the deviation loss for M (25) is less than that associated with K (39). Thus M and K are respectively the payoff dominant and risk dominant strategies[3]. Harsanyi and Selten have indicated that since utility is increasing in payoffs, players' collective rationality regarding obtaining higher payoffs will lead them to coordinate on the Pareto efficient payoff dominant Nash equilibrium. They however don't focus on the scenario when the deviation loss ofr the Pareto superior strategy is lower than that for the other strategies. Subsequent experimental evidence by Straub (1995) however established that when the above is the case, the risk dominant Nash equilibrium is more likely Intuitively the choice of the risk dominant strategy is more likely as individuals are more inclined to minimize risk and losses in the event of coordination failure than maximize their payoffs from coordination. The choice of the risk dominant strategy (here K) indicates the failure to coordinate to the economically efficient outcome which limits the economic efficiency of the game mechanism (here AB).

We have not imposed any local network structure on the strategic environment of the above game yet. There are however many studies on coordination games with properties similar to our AB game on local networks . Berninghaus and Schwalbe (1996) present theoretical evidence on the importance of risk dominance as a Nash equilibrium selection principle in local networks. Keser et al. (1998) use lab experiments to suggest that the risk dominant strategy is more common in local networks relative to global non-network environments. Alos-Ferrer and Weidenholzer (2006, 2008) have focused on equilibrium selection and efficiency in local networks with coordination games. Berninghaus et al. (2002) have considered the impact of network size on coordination failure in two types of networks – circle and lattice. They find a result similar to VHBB’s result - coordination to the payoff dominant Nash equilibrium is more common in smaller local networks. However in their study, the size treatment is introduced by varying both the number of neighbors and overall network size. The change in the number of neighbors represents a change in the clustering coefficient and increase in overall group size implies an increase in the characteristic path length[4] of the network. The change in neighbors also indicates that the payoffs are different between treatments. By varying these two features, their study does not identify the intrinsic impact of an increase in overall network size on coordination. This reveals a gap in the experimental game theoretic literature which we address in our experiments in addition to the study of coordination failure in the context of the AB. In our study, we isolate the size impact by embedding our three-player coordination game on a six and twelve player local network where every individual has two neighbors. We explain the resultant design that we use in our experiments and other procedures in the next section.

Section 3: Experimental Design

Experiments were conducted at the Laboratory of Economics, Management and Auctions (LEMA) at Penn State University between March and April 2009. All subjects were selected from Penn State's student population. In all experiments subjects played the game presented in Table 2. We considered experiments with six and twelve players. The 6 player sessions are termed SMALL and the 12 player sessions LARGE.

Section 3.1: The Spatial Grid

The local network constitutes a one dimensional circle presented in Figure 1. On this circle for any player $i = 2, 3, \ldots\ldots N-1$, the set of neighbors is given by $N_i \in \{i-1, i+1\}$. For $i = 1, N_1 \in \{N, 2\}$ and for $i = N$, $N_N \in \{N-1, 1\}$ denote the neighbors. Players on the SMALL and LARGE networks have the same number of neighbors so that the clustering coefficient is the same (equal to 0). However the larger network has a longer characteristic path length. The smaller circle in the centre of the network indicates that diametrically opposite players are not in a player's local neighborhood. Every property has two parcels.

The interior parcel near the centre is the M and the outer parcel is the K parcel. Any three consecutive players on the spatial grid nests the same coordination game presented in Table 2.

INSERT FIGURE 1 HERE

INSERT TABLE 2 HERE

Section 3.2: Experimental Procedure

Table 3 presents the experimental design for this study. At the beginning of a session, players were shown their positions on the grid and given an ID. The ID identified the players' neighbors during the session. The experiment adopted a fixed matching scheme whereby the location of a player and their neighbors remained the same throughout the session. This scheme was adopted to promote learning from past play and to facilitate reputation building and also because on actual landscapes a landowner's neighbors are fixed over time unless they change owing to exogenously determined factors. The size variation was introduced as a between-subject treatment.

Players were provided information about their positions on the local network and total number of players in the group. Instructions explicitly mentioned that a player’s payoffs would be directly determined by neighboring players’ actions. We included this information as we wanted subjects to understand the difference between the direct and indirect impacts of neighbors' and non-neighbors' actions on their own actions. Each experimental session had twenty periods during which the game was repeated. The payoff table was visible to players whenever they made a decision in a period. Information about neighbors’ choices from all past periods was available in a history table that was displayed at the end of every period.

INSERT TABLE 3 HERE

Players were informed about their role as a landowner whose actions would determine a land use outcome. However all other contextual terminology related to ES provision such as ecosystem services, biodiversity conservation, endangered species etc were excluded to ensure that subjects responded only to financial incentives. The instructions did not mention that land use activity on M parcels is more profitable than on K parcels. This information was provided in the payoff table. The subjects participated in a quiz before they started the first period. The show up fee was $5 and experimental money earned was converted into actual currency at the rate of 35 experimental dollars to one real dollar. The experiment was programmed and conducted with the experiment software z-Tree (Fischbacher, 2007).

Section 4: Results

In this paper we consider how increase in overall group size impacts spatial coordination in an AB coordination game on a local network. We first analyze outcomes at the group/cohort level. Next we discuss results at the level of the local neighborhood of every player. The local neighborhood constitutes a player and their neighbors. At the group level, we evaluate how overall cohort size and experience with spatial coordination influences behavior. Individual level analysis within players' local neighborhood provides insights about differences in coordination patterns given the local network setting when size of the local neighborhood is same across both treatments.

Section 4.1: Analysis of Behavior at Cohort Level

Figure 2 presents the percentage of M choices by all subjects across time for both the treatments. The percentage of M decisions in the first period (in Table 6) is similar in both the treatments – 66.67% in the SMALL and 62.5% in the LARGE groups (a chi-squared test indicates no significant difference). In the final period the percentage of M decisions is 64.58% for SMALL and 33.33% for LARGE (this difference is significant at 1% level). Considering choices by session, of the eight SMALL sessions there are three where all players choose M in Period 20 while in LARGE only one such session exists. Again of the eight LARGE sessions, there are three sessions where every individual chooses K in Period 20 and one session where everyone chooses M. These results suggest that choice of K and coordination failure is more common in bigger local networks than smaller ones even if players face the same payoffs on both networks. No significant differences in the earlier periods' choices imply that subjects initially respond only to the value of payoffs. However, the higher degree of anonymity between players (owing to a longer characteristic path length) in the larger group causes them to have greater doubts about neighbors' propensity to choose M in LARGE relative to SMALL. As a result there is a predominance of the risk dominant strategy in LARGE relative to SMALL over time. We can thus conclude that 1) the AB can induce spatial coordination to the ecologically beneficial payoff dominant Nash equilibrium more often in smaller less anonymous landscapes than in larger ones which have greater anonymity. Second, over time coordination causes a decrease in the percentage of payoff dominant decisions in LARGE sessions while the value remains stable in SMALL. Finally, in the final period of the game in some sessions, players choose M and K and are not able to coordinate to a Nash equilibrium outcome. Thus neither an M nor a K convention is obtained on the network. . This outcome is contrary to the past experimental studies on coordination games with varying group sizes such as in VHBB and games considered in Berninghaus et al. We refer to this inability of groups to reach a convention as mis-coordination.

INSERT FIGURE 2 HERE

We test the significance of the above results using a probit model with random effects to represent the probability of M and K choices for all individuals in any period. We investigate how players' own past period's action, their experience with coordination and the group size impact their probability of choosing M or K in any period. We follow Stewart (2006) to estimate an autoregressive random effects probit model given the inclusion of past period's value of the dependent variable as an explanatory variable. We expect a player's choice of M in the preceding period to have a positive impact on the probability of an M choice in the current period. This effect indicates a tendency to coordinate to the payoff dominant Nash equilibrium to obtain a higher payoff (Berninghaus et al. 2002). We also expect that experience induced by repeated game interactions (controlled by including the Period variable) will have a negative impact on probability of M choices in LARGE and a positive impact in SMALL, i.e. subjects will be able to coordinate to the payoff dominant Nash equilibrium in SMALL and subjects in LARGE sessions will move to the risk dominant Nash equilibrium over time. Our chief premise here is that the VHBB outcome will be obtained in local networks. In addition, we conjecture that the impact of own choice from the past period on current period's choice will be influenced by how familiar the player is with coordination. Thus over time as familiarity with coordination increases, if a player chooses M in the preceding period, they are more likely to do so in the current period. Finally we include a dummy variable in the analysis to capture the size treatment effect on the probability of M choices. The estimate for the dummy should have a negative sign. The regression equation is

$$y_{it} = \propto + D + \gamma y_{it-1} + \beta t + \delta t^{*} y_{it-1} + u_i + \varepsilon_{it}$$

$$(i = 1,2, \dots \dots .144; t = 1,2, \dots \dots 20)$$

(2)

Here y_{it} is the dependent variable taking a value of 1 for every M choice and a 0 for every K choice by subjects and is expressed as a function of the treatment dummy D, own lagged value y_{it-1}, the Period variable t and an interaction between the Period variable and the own lagged value of Action. Since we consider a random effects structure the error term comprises of the component u_i which is the time invariant unobserved heterogeneity associated with every subject *i* uncorrelated with the independent variables in the model and the random component ε_{it}.[5]

INSERT TABLE 4 HERE

Table 4 presents the estimation results. The constant term is negative and significant (at 5%). The dummy estimate is negative and significant (at 1% level). Thus relative to the SMALL sessions, the probability of choosing M in LARGE is lower indicating a greater incidence of coordination failure. This result extends the size result of VHBB in global interaction settings to local networks.

We obtain a positive and significant (at 1%) estimate for “own action” in the past period. This finding is consistent with Warziniack et al. where past period's behavior is found to be a significant determinant of strategy choice in the present period. This result is true irrespective of the treatment effect. The positive sign captures players' inherent tendencies to try to coordinate to the payoff dominant Nash equilibria via their own actions.

We also find that the estimate for the Period variable is negative and significant (1% level) suggesting that experience gathered over time has a negative impact on subjects' probability of choosing the payoff dominant strategy. However there is no significant downward trend in SMALL and the percentage of M decisions remain constant between 60-70% in all periods of the game as seen in Figure 2.Thus the estimate picks up the negative trend for the LARGE sessions as seen in Figure 2. One reason for no trend in SMALL can be the presence of a tension between two effects; the effect of the local network on which greater levels of anonymity decreases the probability of M choices and the smaller overall group size effect whereby information about coordination behavior in one part of the network is easily transmitted to other parts given smaller characteristic path lengths between players increasing the probability of M choices. These opposite forces remain during the entire session and maintain the percentage of M decisions in SMALL at a stable value around 60%-70% in all periods with M conventions attained in three sessions in Period 20. In the LARGE sessions, with characteristic path lengths, information transmission along the network is relatively harder and the greater anonymity leads to a pre-dominance of K decisions although localized M clusters remain. Thus it is very likely that if the number of periods were to increase beyond 20, the percentage of M decisions in LARGE would fall to zero.

Finally the estimate for the interaction term is positive and significant at 1% level. This result is contrary to our expectations especially since the estimate for Period is negative. The positive sign however indicates that when players have gathered sufficient experience, they will try to choose M in the current and future periods if they chose M in the immediate past. This behavior supports subjects' propensity to build up reputation for play of M and their tendency to signal neighbors to choose M as well.

Section 4.2: Analysis of Behavior with respect to the Local Neighborhood

At the local neighborhood level we investigate behavior of the player and their neighbors who together form a *cluster*. There are six unique clusters in the SMALL and twelve in the LARGE games. Every individual is at the centre of one cluster and at the periphery of two others. When all players in a cluster choose the same strategy a *Local Nash Equilibrium* (LNE) is obtained. Let M-LNE denote clusters where all players choose M and K-LNE denote those choosing K. For any LNE achieved in a period, the players at the centre of the cluster earn Nash equilibrium payoffs and can be considered to be in a *Nash Equilibrium state.* Neighbors on both sides of these players may not be in Nash equilibrium states if they are not at the centre of a LNE. For example in a game with five players, consider the choice of the central players in three consecutive clusters –$(KMM), (MMM), (MMK)$. Here only player 3 in cluster 2 is in a Nash equilibrium state. Player 2 at the centre of cluster 1 and player 4 at the centre of cluster 3 are in a sub-optimal non NE state. This possibility of a sub-optimal state for a player is a consequence of the local network structure with a zero clustering coefficient where neighbors of a player are not connected to each other. For players in a Nash equilibrium state, unilateral deviation is not beneficial in the next period if they conjecture that their neighbors will not change their choices in the next period.

INSERT FIGURE 3 HERE

Figure 3 shows the percentage of M-LNE across periods. We find no significance treatment effect on the percentage of M-LNE in the initial periods of the game (established by a chi-sq test). This result contrasts with the findings of VHBB where the size treatment leads to significant differences from the onset of the session and choices diverge sharply. This difference in results between our study and that of VHBB can be attributed to the same sized local neighborhoods across all sessions. In our study, players face the same payoffs in both SMALL and LARGE treatments unlike in VHBB, where number of neighbors and hence payoffs are different across small and large groups. Thus, with same sized clusters and insufficient experience with coordination, there is no significant difference in behavior on networks with varying anonymity levels. Beyond Period 6 however differences appear in the percentages of M-LNEs and the value is consistently greater in SMALL. In the final period of the SMALL games, there are 47.91% M-LNE and 18.75% K-LNE compared to 22.91% M-LNE and 53.12% K-LNE in LARGE (this difference is significant at 1% using a chi-sq test)[6]. Thus while agents face the same set of payoffs within a cluster on both networks, information about creation of M-LNE is transmitted faster within the smaller network relative to the larger one leading to a significantly greater percentage of K-LNE in LARGE relative to SMALL in the final period.

We next focus on the final period choices. Berninghaus and Schwalbe (1996) provide theoretical evidence indicating that it is not possible to have agents playing different strategies in the final period of a repeated coordination game when they are arranged on a circular local network. We however find evidence contrary to this result. We base this result on two explanations. First Berninghaus and Schwalbe's theoretical result is predicated on the circular network having a clustering coefficient greater than zero. However our circular networks are similar to the two dimensional lattice networks which have zero clustering coefficients and where multiple conventions co-exist in the final period. Examining the final period choices, we find four LARGE and four SMALL sessions where players choose M and K strategies in the final period leading to mis-coordination and coexistence of M-LNE and K-LNE. The presence of M and K choices indicates that there are many players who are in a sub-optimal out-of-equilibrium state at the end of the game. This sub-optimal state refers to the instances of mis-coordination we have mentioned earlier. These results indicate that mis-coordination is a general feature of networks with zero clustering coefficients which in turn implies higher levels of anonymity. Coexistence of multiple strategies with players in a LNE state in some sessions however implies localized areas of spatial coordination and partial ecological effectiveness of the AB. We can also use information on the percentage of M-LNE in the intermediate periods (in Figure 3) to inform our discussion on coordination and performance of the AB on local networks. The choice of M by players in intermediate periods pertains to voluntary loss making behaviors of players in coordination games. Such behavior has been observed in studies by Brandts and Cooper (2006) and reflects players' tendency to influence their neighbors to choose the payoff dominant strategy by establishing their own commitment towards that strategy over time. Such performance can lead to coordination and improve AB performance. In our experiments, since the percentage of K-LNE is always less than 100%, it implies that many players are choosing M in the current period even if both their neighbors chose K or one chose M and other K in the previous period However such behavior is exhibited by players only when they are caught in between two neighbors choosing M and K. If both neighbors continue choosing K, loss-making players switch to K as well. In fact considering penultimate and final period choices there are only 3 out of 96 individuals across all LARGE sessions choosing M when both their neighbors chose K in the previous period. We find no individuals in a similar state in SMALL in the final period.

Finally we can also use cluster-level analysis to evaluate the economic efficiency of the AB in the current environment where coordination failure and mis-coordination co-exist. In our setup both whether an M choice was made but also where this choice was located on the grid (at the centre of a cluster forming a M-LNE or at the periphery of one not forming a M-LNE) determines the economic efficiency of the AB. Let us define an efficiency metric e_t for every period t as the following

$$e_t = \frac{\sum_{i=1}^{N-1} x_{it}x_{(i+1)t} + x_{Nt}x_{1t} + \sum_{i=2}^{N-1} x_{(i-1)t}x_{it}x_{(i+1)t} + x_{Nt}x_{1t}x_{2t} + x_{(N-1)t}x_{Nt}x_{1t}}{2N}$$

The denominator is the sum of the total number of shared borders and M-LNE possible in any period of the game. The value of both these figures is N . In the numerator, $x_i \in \{0,1\}\ \forall i = 1,2, \ldots N$ with $x_i = 1$ represents an M choice by the i^{th} player and K otherwise. Then the sum of the first two terms is the actual number of shared borders between M parcels and the remaining terms is the actual number of M-LNEs in period t.

INSERT FIGURE 4 HERE

INSERT TABLE 5 HERE

This metric captures the localized aspect of coordination. For example in the SMALL group with $N = 6$ the value of the denominator is 12. On this network, two shared borders between players choosing M can be obtained in two ways. First, if three players are adjacent to each other and second, if two adjacent players each out of four players are adjacent to each other. In the first case the value of the numerator is 3 and $e_t = 0.25$ and in the second case the value of the numerator is 2 and $e_t = 0.16$. Thus even if we have the same number of shared borders and more players choosing to place land M in conservation use, the economic effectiveness of the AB is lower since clusters of players are unable to form a M-LNE as opposed to the former case where they do. In fact in the first case only 2 players choosing M are in a sub-optimal state while in the second case all four players are in sub-optimal state. Thus both the number of shared borders and their locations determine the economic effectiveness of the AB scheme. Table 5 presents the efficiency values for all sessions for the final period. There are three SMALL and 1 LARGE session where efficiency is equal to 1 and three LARGE sessions and 1 SMALL session where efficiency is 0. For all other sessions the values lie between 0 and 1. A Wilcoxon Mann Whitney test using the final period values for e_t indicates a significant difference in efficiency by treatment at the 10% level of significance. Table 6 and Figure 4 represent the average value of e_t across all sessions for the 20 periods of the game by treatment. We find that between Periods 1 and 5 there is no significant difference in the value of the metric between SMALL and LARGE. Beyond this period however the average value of the metric rises from 44% in Period 6 to 52% in Period 20 in SMALL and falls from 42% to 23% in the final period in LARGE. Thus over time incidence of spatial coordination failure rises and performance of the AB falls in LARGE relative to SMALL groups.

Section 5: Conclusion

This paper provides experimental evidence on the performance of the AB in small and large landscapes arranged on local networks of varying size. In addition the local network refinement allows us to consider spatial coordination in a strategic environment which is similar to real working landscapes where strategic interactions between landowners are limited by geography and where their neighbors' identity and number may vary. We obtain two key results. First, there are fewer instances of coordination to the ecologically superior payoff dominant Nash equilibrium in bigger cohorts than in smaller ones. Second, in the presense of strategic uncertainty in the coordination game environment, variation in the size of the local network gives rise to mis-coordination in the final period of the AB games. This mis-coordination has greater incidence in LARGE than in SMALL.

The question of whether mis-coordination and coordination failure will persist on real landscapes with actual landowners requires field experimentation. Since the presence of anonymity owing to lower levels of clustering on the local networks drives coordination outcomes in our study, a way to promote coordination on real landscapes would be to reduce this anonymity. Since geographical configurations of properties and social ties/connections within farming communities are predetermined to some extent, external interventions are necessary to reduce anonymity levels for landowners and promote coordination behavior to improve the AB's performance. Interactions with university extension personnel, regular meetings of watershed groups (who make many conservation decisions especially with respect to water quality trading and reduction in nutrient runoff) etc can enable landowners to learn about the importance of spatial coordination and their neighbors actions and attitudes towards ecosystem service protection and spatially coordinated land management. Additionally, landowners with pro-conservation attitudes can also promote coordinated participation of their neighbors by acting as responsible environmental stewards and continually signing up in the scheme regardless of their neighbors' decisions. Although these stewards don't earn the bonus, their commitment to conservation signal their willingness to coordinate spatially and over time can change neighbors' attitudes and lead to spatially coordinated land use patterns for greater ES delivery.

Appendix

Experimental Instructions:
Thank you for participating in today's experiment. You have been provided with a sheet which has your unique participant number for this experiment. This is your ID. This number is private and should not be shared with anyone. Please enter your ID before continuing. Please enter the number exactly as it appears on your sheet.

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 35 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 **twenty 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 has two kinds of parcels on their property denoted by **M** and **K**. You will receive payoffs from managing the land on any of these parcels. All the players including you are arranged around a circular grid which is shown in the handout that you have been provided. This grid represents the landscape on which your properties are located. On this grid every parcel is marked by **M** or **K**. The number attached to both M and K denotes subject ID. Thus if your ID is **8**, then parcels **M8** and **K8** constitute your property.
On this grid you have two neighbors, one on each side. The hole in the centre indicates that the player diametrically opposite to you is not your 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. Please keep in mind that every player has a **different** set of neighbors. Thus if you are player **11** then your neighbors are players **10** and **12**. Player **12** has **you** and player **1** as neighbors.

In each period, each one of you will make a choice between managing **parcel M** and **parcel 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. This table is the same for everyone and is the same for all periods of this experiment. The amounts shown in the table reflect the possible payments you might receive for that period, based on your choice and the choices of your neighbors. Each number in the table corresponds to a payment (**in experimental dollars**) resulting from a possible combination of your choice (row) and your neighbors' choices (column). Your choice of strategy M corresponds to your position on the grid on the parcel marked by **M and your ID**. Your choice of strategy K corresponds to your position on the parcel marked by **K and your ID**. Please take a moment to look over the table. Whenever you are making a choice, you will be able to see this table. Your payoff depends upon your management decision **(M or K)** and that of your two neighbors. In general, your payoff increases when you manage the same parcels.

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 strategy and the choices of other players, your payment for the current period, your neighbors' payments and your accumulated payment through the current period. At the end of the experiment, you will receive the sum of your payments from all twenty periods. 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 this is a non-paying period and your answers in this quiz will not influence your payoffs at the end of the experiment.

Quiz (non-paying period):
Before we begin the experiment, we would like you participate in the quiz below. Your answers should be based on the payoff table shown. Please raise your hand if you are having trouble answering any of the questions. Once you are finished please click "Continue".

Suppose one of your neighbors plays strategy M and the other plays strategy K. Then your payoff from playing strategy M is? 18
My neighbor has the same neighbors as I do. FALSE
Your neighbors change in every period. FALSE
What is your payoff when you chose K and all your neighbors chose M? 27

We are now ready to begin the experiment. On the next screen you will be able to see the payoff table. Please make a choice. You will be paid on the basis of all the choices you make henceforth.

How to read the Results Table:
On the next screen you will be able to see two tables. The first table records your and your neighbors' choices for **the present period**. Your choice is in the cell at the centre of the table. Your neighbors' choices are recorded in cells on your left and right. The second table is the **History Table** and records your choices and those of your neighbors for **all periods** of this experiment. It also shows your profit for the present period as well as your total profit across all periods. Please raise your hand if there are any questions otherwise click "Continue"

Screen Shots and Z-TREE files are available upon request.

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Table 1 Payoff Table

	Neighbors' Choices		
Player's actions	**Both neighbors chose M**	**One chooses M &other K**	**Both neighbors choose K**
M	50	30	10
K	25	37	49

Table 2 Payoff Table for Experimental Sessions

	Neighbors' Choices		
Player's actions	**Both neighbors chose M**	**One chooses M &other K**	**Both neighbors choose K**
M	36	18	0
K	27	24	21

Table 3 Experimental Design

	Treatment	
	SMALL	**LARGE**
Number of sessions	8	8
Number of players in a session	6	12
Number of periods per session	20	20
Payment structure	$5 show up fee Exchange rate – 40 experimental dollars for every US $	

Table 4 Estimates of Dynamic Random Effects Probit Regression

Dependent Variable	Probability of Choosing M
Independent Variable	**Estimate (Standard Error)**
Constant	-.2455** (.1027)
Own Action in the Past Period	1.231* (.1254)
Period	-.0485* (.0079)
Own Action × Period	.0646* (.0107)*
Dummy	-.2480* (.0622)
# of Observations	2736
# of Groups	144

* represents 1% level of significance, ** represents 5% level of significance

Table 5: Percentage of Shared Borders in Final Period

	Session 1	Session 2	Session 3	Session 4	Session 5	Session 6	Session 7	Session 8
SMALL	0.41	0.41	0.25	0	1	1	0.08	1
LARGE	0	0.25	0.33	0.04	0.29	0	0	1

Table 6 Percentage of Average M Decisions, M-LNE and Efficiency Levels

	% M Choices		% M-LNE		% Efficiency	
Period	**SMALL**	**LARGE**	**SMALL**	**LARGE**	**SMALL**	**LARGE**
1	66.7	62.5	29.2	32.3	37.5	35.4
2	66.7	58.3	39.6	34.4	44.8	39.1
3	62.5	58.3	29.2	33.3	35.4	37.5
4	58.3	58.3	27.1	35.4	33.3	37.5
5	62.5	64.6	39.6	34.4	44.8	42.2
6	62.5	54.2	37.5	29.2	44.8	34.9
7	68.8	54.2	45.8	28.1	51.0	33.3
8	70.8	52.1	58.3	30.2	57.3	32.8
9	62.5	56.3	41.7	30.2	47.9	36.5
10	64.6	49.0	50.0	26.0	54.2	30.2
11	66.7	44.8	56.3	26.0	58.3	29.7
12	66.7	44.8	54.2	26.0	57.3	28.6
13	60.4	49.0	47.9	25.0	51.0	29.7
14	64.6	44.8	56.3	24.0	58.3	26.6
15	62.5	39.6	52.1	20.8	54.2	24.5
16	66.7	40.6	52.1	20.8	54.2	24.0
17	60.4	35.4	35.4	19.8	41.7	22.9
18	64.6	35.4	50.0	20.8	53.1	23.4
19	70.8	35.4	58.3	21.9	61.5	24.5
20	64.6	33.3	47.9	21.9	52.1	24.0

Figure Titles:

Figure 1: Spatial Grid for the Experiments

Figure 2: Percentage of M Choices

Figure 3: Percentage of M Clusters

Figure 4: Percentage Inter-temporal Efficiency

Grouped Footnotes:

[1] In the Parkhurst and Shogren study, N=4 and every individual has 25 parcels on their properties which they can enrol in the AB. Thus there are potentially numerous landuse configurations which can be created under the scheme of which only one is the Pareto superior one.

[2] In a coordination game, the deviation loss associated with a strategy is the loss from choosing that strategy when all other opponents choose another strategy.

[3] The payoff dominant Nash equilibrium is the high risk high paying Pareto superior Nash equilibrium and the risk dominant Nash equilibria are the low risk low paying Nash equilibria in a coordination game.

[4] The clustering coefficient represents the extent to which a player's neighbors are connected with each other. The characteristic path length is the average distance between pairs of individuals in the network (Jackson 2008). The extent to which responses of individuals in one part of the network is transmitted to the other is a function of this characteristic path length. Smaller local networks usually have smaller characteristic path lengths than bigger ones since on an average one has to pass more individuals to reach another individual in a bigger network than in a smaller one. These two features together influence the degree of anonymity between individuals in the network and hence propensity to coordinate in coordination games (Berninghaus and Schwalbe 1996).

[5] We find no significant difference in the variability in the number of neighbors making an M choice in any period between SMALL and LARGE (standard deviation for SMALL is 0.79 and for LARGE is 0.8). Consequently, we did not include the variable representing number of M decisions by neighbors' from the preceding period in the analysis.

[6] M-LNE and K-LNE figures don't add up to 100% since some players at the centre of clusters are in a sub-optimal state with both their neighbors choosing different strategies or strategies different from the players