Incentive mechanisms for spatially contiguous habitat management:
The Agglomeration Bonus in the presence of technological externalities in different neighbourhoods

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Abstract

Recent advances in ecological research indicate that there are substantial benefits from conservation of parcels of lands which are contiguous to each other. The Agglomeration Bonus is an incentive mechanism which has been proposed to this effect and has been experimentally validated to achieve desired spatial patterns. In this study we analyze the effect of this payment scheme in the presence of technological interdependencies (externalities) between different landowners participating in the conservation activity. We show that in the presence of such externalities, the Agglomeration Bonus is not successful in achieving the desired spatial pattern in conservation behaviour. To this effect, we change the structure of the Agglomeration Bonus by introducing a third pay component into it. This payment compensates farms who suffer the negative effects of the externality and is successful in theory in spatially coordinating landowner decisions to the ecologically beneficial management pattern.

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1 Introduction

The ecological result of conservation actions that protect any particular patch of habitat depends on which other areas are being protected, because of meta-population dynamics and community complementarity (Margules & Pressey 2000, Armsworth et al. 2004). In consequence, spatial patterns in habitat protection are an important factor in conservation planning. However, spatial pattern is not addressed explicitly in many existing incentive schemes, including major programmes like the Conservation Reserve Programme (US)(Kirwan et al., 2005) and Environmental Stewardship Scheme (EC). Moreover, there is a need for research on the design of efficient policy mechanisms that explicitly promote the creation of habitat corridors of specific spatial configurations (tailored towards effective conservation of different species) on private lands.

The most noted incentive structure that has been proposed for achieving desired patterns in habitat conservation is the Agglomeration Bonus (AB) subsidy scheme of Parkhurst et al. (2002, 2007). This scheme rewards landowners who spatially coordinate their decisions to participate in habitat conservation programs to conserve contiguous parcels. In its present form, the structure of the AB is quite flexible and can be changed to include various phenomena which are observed at the ground level. One such is the presence of technological interdependencies (externalities) between properties which in turn influence their participation decisions. Henceforth, without any loss of generality the terms properties and farms will be used synonymously. This is in accordance with scenarios where most managed ecosystems are found on private farmland. Here different kinds of externalities can emerge whereby actions of one farm show up as a cost or a benefit in their neighbours' accounts. For example voluntary reduction in nutrient pollution by farms arranged around a lake might benefit a fishery located in that area. Here habitat conservation leads to benefits for the fishery as well as the farms. In the present study however we focus on externalities that make the payoffs from participation in conservation activities by a farmer contingent on the activities of another. We emphasize production externalities which arise from changes in land use patterns on these farms. Specifically we will focus on externalities which arise from participation in the AB scheme whereby the participant suffers losses and the neighbours are benefited in the event of their non-participation.

In keeping with the above discussion the main objective of this research is to analyze the performance of the AB in the presence of technological interdependencies. Here we state and prove different propositions about the coordination games considered in this study and we are able to show that in its present form the AB is not successful in coordinating agent behaviour to the ecologically beneficial outcome. To this effect, we propose a few changes to the incentives provided under the AB and derive conditions whereby the new payment scheme is theoretically successful in achieving the desired objectives.

An important feature of our study is the geography of the landscape itself which determines the nature of interactions for each farmer. These interactions define the neighbourhood structure for every player. In this study we spend some time discussing the effects that different kinds of neighbourhoods have on the outcomes in spatial coordination games. This provides directions for future research which may involve an experimental economic study to analyze agent behaviour in simulated laboratory environments. Results from these experiments can be used to test the extent to which the performance of economic constructs like those discussed in this study differs under different realistic situations.

The paper is arranged as follows. Sections 3 and 4 deal with the issue of coordination failure in relation to the issues of externalities and the neighbourhood structure which are presented in this study. This is followed by Section 5 where we provide the theoretical structure of the AB payment scheme and the coordination game which results in the presence of the externalities. Respective payoff functions and the strategy set are defined here. In Section 6 we deal with the proofs of various hypotheses regarding the present class of spatial coordination games. In Section 7, we introduce a new form of the AB which helps to achieve the desired spatial patterns in the presence of the externalities. This is followed by the conclusion. Here we provide a description about the future course of research. This involves a brief discussion on experimental economics and how it can be used to analyze the effectiveness of the payment mechanism and test various hypotheses in relation to it.

2 Coordination failure and Externalities

The principle aspect of this study is the coordination of conservation behaviour across space to create habitat reserves which take advantage of the spatial complementarity that exist in habitat dynamics and species conservation. The main hindrance documented in Parkhurst and Shogren (2007) in achieving the desired spatial outcomes is landowner inexperience about new environmental objectives. Repeated interaction between neighbours however promotes learning and develops experience which solves the coordination problem. Warziniack et al. (2007) also document the importance of communication and repeated play in coordinating player responses to the ecologically feasible outcomes.

In many areas especially in Europe, valuable species habitats are located on managed ecosystems, mostly farmland. And very often, different kinds of externalities exist across property borders which directly impact the production activities of the farms. With respect to the present problem, this is an important issue as there are cases where externalities will weaken a farmer's incentives to participate in land management if their neighbours are participating. For example on the farms in the Peak District (UK) externalities arise owing to the change in land use on the moors. When all parts of the moors are in the same land use - sheep rearing, no externalities exist. In this setting in the event of participation the AB compensates farmers for the loss of income arising from reducing the number of sheep. A reduction in the number of sheep improves the moors as breeding grounds for birds like twite, curlew and lapwing (species of Conservation Concern as per the UK's Biodiversity Action Plan). However if a farmer reduces the number of sheep the neighbours' incentives to do the same is reduced. With less sheep on participating lands, animals from adjoining farms can now trespass into these less crowded managed lands to graze since there are no fences. Such trespass considerably reduces the quality of the moors as breeding grounds and reduces participation leading to fragmented land management while maintaining profits of neighbours from sheep rearing. In situations like this, the incentive to manage the moors is considerably weakened. In these circumstances the AB may not be able to generate desirable spatial patterns.

Here, consideration of an externality between participating landowners introduces the issue of strategic uncertainty into the coordination problem. Strategic uncertainty arises when players are uncertain about the strategies which will be played by others in the game (Van Huyck et al. 1990). This is owing to the varying levels of risk associated with the play of different strategies. In such games the probability associated with playing the payoff dominant strategy is less than the same associated with choosing other non-cooperative strategies (which yields lower payoffs). Based on the results of Harsanyi and Selten (1988), the low risk strategies risk-dominate the high risk one. Here management of Type 1 land is deemed riskier compared to management of Type 2 land and coordination focuses management to the ecologically inefficient outcome.

3 Coordination failure and neighbourhood structure

An interesting feature in the study of spatial games is how agents coordinate under different neighbourhood structures. Two kinds of neighbourhoods can be defined - closed and open. The closed neighbourhoods are where every player interacts with every other player while the open ones are those where local interactions exist with players interacting only with their immediate neighbours in sub-neighbourhoods which overlap amongst each other. The type of the neighbourhood structure depends on the arrangement of farms within a particular landscape which in turn determines the nature of the personalized interactions and the extent to which it extends across space between different landowners.

There are many studies like those by Ellison (1993), Keser et al. (1998), Berninghaus et al. (2002) and others which have considered both kinds of neighbourhoods. These studies reveal that there is difference in play of strategies in different neighbourhoods. Thus local interaction in open neighbourhoods lead to the play of the risk dominant strategies more often than in closed neighbourhoods. This is largely driven by the fact that players' actions are contingent on their neighbours and their neighbours' neighbours' actions in open neighbourhoods. However evidence is sparse regarding the extent to which players' actions outside the immediate neighbourhood of a player affects their own actions. Under the assumption of local best response as in Berninghaus et al. (2002) (where each player chooses the strategy which maximizes their payoff given the distribution of choices in their neighbourhood), there is no effect of the size of the neighbourhood on the players' strategies. With regards to the performance of the AB we however expect local landowner relationships to influence decisions of farmers in overlapping and non-overlapping sub-neighbourhoods. Given this reality at the ground level, whether the size of the neighbourhood matters in determining player behaviour when the assumption of local best response is relaxed is an experimental question. We intend to test this in the context of the performance of the AB in a future study.

Another issue with respect to open neighbourhoods as presented by Kandori et al. (1993) is the presence of clusters of players playing a particular strategy (not necessarily optimal) which causes behaviour of others to evolve to that strategy. This implies that in the present case, play of payoff dominant strategies towards the attainment of the desired spatial pattern might be possible if there exists clusters of farms that are cooperating among themselves to manage the ecologically preferred land. In the terminology of Brandts and Cooper (2006) these farms are acting as leaders who repeatedly play the cooperative strategy and incur losses in the hopes of influencing the "laggards" - the non-cooperating farms, to coordinate their actions to the better outcome. However the main hindrance for the above outcome is that the basin of attraction for the risk dominant strategy is much bigger than the payoff-dominant strategy. This implies that even in the presence of such clusters play might converge in the long run to the bad equilibrium. With regards to the present problem of biodiversity conservation, in the presence of the externality, farmer interactions are expected to lead to the management of ecologically less preferred lands, reducing the effectiveness of the AB in fulfilling the desired spatial objectives.

4 Theoretical foundation of this study

In this section we set up the theoretical framework of the payment scheme. This is followed by the description of the coordination game and the payoffs which are obtained by players from the play of different strategies.

5 The Context

Suppose there are $j = 1, 2, .., n$ farms. By participating in the environmental stewardship programme farmers offer to manage the parcels for which they receive the AB. Let each farm have lands of different types indexed by t. The AB varies according to the market and conservation value of the parcels but is a uniform payment across all landowners.

Assumption 1: In the present study we assume that each farm has two types of land t_1 and t_2 with say $t_1 > t_2$ implying that type 1 land provides higher ecological benefits from management that type 2.

Assumption 2: Each farm is also assumed to have only one parcel of each type of land.

5.1 The structure of the Agglomeration Bonus

The AB consists of flat participatory payment which covers the costs of different pro-environmental activities on the farms and a bonus which pays farmers for every border shared between managed parcels. Let the fee paid for enrolling t_1 and t_2 type land into the programme be $s(1)$ and $s(2)$. The bonus for each shared border of t_1 land is $b(1)$ and the same for t_2 land is $b(2)$ with $b(1) > b(2)$ reflecting the regulator's preference for more land of type 1.

5.2 The Cost structure of the farms

For any farm j in the region, $c_i(t_1) < c_i(t_2)$ i.e the costs of conservation activities on type 1 land is lower than the same for type 2. Thus $s(1) < s(2)$.

Assumption 3: Since type 1 land is more expensive to manage, the regulator sets up the payments such that

$$s(1) - c_i(1) \geq s(2) - c_i(2) \forall i = 1, 2, ...N \tag{1}$$

The externality is faced across lands of type 1. It is of the type as mentioned Section 2 and reduces the benefits to the farms from the AB. Owing to the presence of this externality, farmers' incentives to manage type 1 land maybe reduced even if it costs less and pays more (in terms of the bonus) to do so.

5.3 The Game and the Payoffs

In the present study the game is represented by $[N, A, u_i(.)]$ where the payoff function $u_i(.)$ is a mapping from the set of strategies to the real line, $u_i(.) : A \rightarrow \Re$. N represents the total number of farms in the region. A is the set of strategies with a total of $(t+1)$ elements.

$$A_i = 0, 1, 2, ..t \forall i = 1, 2, N \tag{2}$$

Each of the t elements represents management of a particular type of land, t_i and the first element 0 refers to non-participation in the conservation programme. θ refers to the type of farm which determines costs of managing different types of land and is indexed by $i = 1, 2, N$ for the N farms that exists in the landscape. In the present study, the benefit to the government from coordinated management is high enough to cover the costs associated with different land types. Thus the budget is never binding

$$s_t - c_i(t) > 0 \forall t = 1, 2, ...T \tag{3}$$

Let $N_i \subset N$ represent the set of neighbours of farm i. The payoff to the i^{th} farm of type θ_i depends upon its own actions, a_i and those of its neighbours, a_j. α_i is the loss to farm i from the externality when a neighbour does not participate or manages land of the other type. The payoff to a farm from a particular action depends on what its neighbours are doing as well. Thus the payoffs for managing land of type 1(across which the externality exists) is represented by

$$u_i(a_i, a_j) \approx u_i(1, n_i(1), n_i(2))$$

which can be written as

$$u_i(1, n_i(1), n_i(2)) = s(1) + p_i(a_i)b(1) - c_i(1 : \theta_i) - q_i(a_i)\alpha_i \tag{4}$$

$$q_i(a_i) = \sum_{j \in N_j} n_j \tag{5}$$

$$p_i(a_i) = N_i - q_i(a_i) \tag{6}$$

$$n_j = \left\{ \begin{array}{ll} 0 & \text{for } a_j = 1 \\ 1 & \text{for } a_j = 2 \end{array} \right\} \tag{7}$$

n_j represents the j^{th} neighbour of farm i. The payoff function for management of type 2 land is given by

$$u_i(2, n_i(1), n_i(2)) = s(2) + t_i(a_i)b(2) - c_i(2 : \theta_i) + d_i(a_i)\tau_i \tag{8}$$

$$t_i(a_i) = \sum_{j \in N_j} n_j \tag{9}$$

$$d_i(a_i) = N_i - t_i(a_i) \tag{10}$$

$$n_j = \left\{ \begin{array}{ll} 0 & \text{for } a_j = 1 \\ 1 & \text{for } a_j = 2 \end{array} \right\} \tag{11}$$

Since there are externalities, payoffs to farm i from non-participation will be positive if at least one of their neighbours manages land of type 1. If all neighbours manage type 2 lands then total benefits from non-participation is zero. Thus the maximum payoff from non-participation is given by

$$u_i(0, n_i(1)) = N_i\tau_i \tag{12}$$

6 Different hypotheses on spatial coordination games

On the basis of the above payoff functions we state and prove a few hypotheses about the spatial coordination games considered in this study. These hypotheses are general and apply to player behaviour in both closed and open neighbourhoods.

Hypothesis: In present set of spatial coordination games, with externalities, non-participation is a strictly dominated strategy.

Proof: Let us consider expressions (8). From here we can calculate the range within which the payments to a farm, managing type 2 land will lie. The minimum payment that can be obtained by the i^{th} farm from playing strategy 2 is

$$u_i(a_i, a_j) = s(2) - c_i(2 : \theta_i) \tag{13}$$

This is the case where none of the neighbours N_i participate in the conservation programme at all. The maximum payment that can be obtained from the play of strategy 2 is

$$u_i(a_i, a_j) = s(2) - c_i(2 : \theta_i) + N_i\tau_i \tag{14}$$

This is when all the neighbours of the i^{th} farm are managing land of type 1 so that the i^{th} player is obtaining the maximum spillover benefits that can be obtained. Combining (13) and (14) the range of payoffs is

$$s(2) - c_i(2 : \theta) < s(2) + t_i(2)b(2) - c_i(2 : \theta_i) + d_i(1)\tau_i < s(2) - c_i(2 : \theta_i) + N_i\tau_i \tag{15}$$

In a similar manner, a range can be obtained for the payoffs from non-participation. The minimum payoff from non-participation is 0 and the maximum payoff is given by (12). Thus the range of payoffs lie between

$$0 < d_i(1)\tau_i < N_i\tau_i \tag{16}$$

Comparing (15) and (16), it is seen that the range within which the payoffs from play of strategy 0 varies is wholly contained within the range of payoffs from play of strategy 2 for strategy 0 and 2 chosen by the farms' neighbours. This leads to the following general proposition.

Proposition 1: In simultaneous move coordination games of complete information with $(t + 1)$ strategies, non-participation is strictly dominated by the non-cooperative strategies.

On the basis of Proposition 1 the final strategy set consists of t strategies each corresponding to the management of lands of t types. In the present study, $t = 2$.

Hypothesis: Strategic uncertainty in simultaneous move coordination games gives rise to risk dominant equilibria in addition to the payoff dominant ones.

Proof: In order to prove the above hypothesis, we have to prove the existence of multiple Nash Equilibria one of which is payoff dominant and the others are risk dominant. For the general formulation of the game with a reduced strategy set of t elements, a total of t Nash Equilibria are obtained. In the present model with 2 strategies pertaining to two land types, we have to prove the existence of 2 Nash Equilibria one of which is Risk Dominant. This is done below.

Given expressions (4) and (8), we have to prove that unilateral deviation from play of strategy 1 or 2 is not profitable for any player. Thus

$$u_i(1, a_j(1)) > u_i(2, a_j(1)) \forall i = 1, 2, ...N \tag{17}$$

where $a_j(t)$ refers to the play of the t^{th} strategy by the N_i neighbours. Similarly for the play of strategy 2 by the i^{th} player we have

$$u_i(2, a_j(2)) > u_i(1, a_j(2)) \forall i = 1, 2, ...N \tag{18}$$

Now the payoffs to the i^{th} player when opponentes are playing strategy 1 is given by

$$u_i(1, a_j(1)) = s(1) - c_i(1 : \theta_i) + N_i b(1) \tag{19}$$

Again the payoff to the i^{th} player from unilateral deviation to the play of strategy 2 is given by

$$u_i(2, a_j(1)) = s(2) - c_i(2 : \theta_i) + N_i \tau_i \tag{20}$$

Then deducting (20) from (19) we have the following.

$$u_i(1, a_j(1)) - u_i(2, a_j(1)) = \{s(1) - c_i(1 : \theta_i)\} - \{s(2) - c_i(2 : \theta_i)\} + N_i\{b(1) - \tau_i\} \tag{21}$$

Now given that the government sets the magnitude of the bonus equal to or greater than the value of the externality (to make management of shared borders of type 1 lands profitable), and that *Assumption (3)* holds, then expression (21) is a positive number. This proves that $(1, a_j(1))$ is a Nash Equilibrium.

Similarly the payoffs to the i^{th} player when all opponents are playing strategy 2 is given by

$$u_i(2, a_j(2)) = s(2) - c_i(2 : \theta_i) + N_i b(2) \tag{22}$$

The payoff to the i^{th} player from unilateral deviation to the play of strategy 1 is given by

$$u_i(1, a_j(2)) = s(1) - c_i(1 : \theta_i) - N_i \alpha_i \tag{23}$$

Then deducting (23) from (22) we have

$$u_i(2, a_j(2)) - u_i(1, a_j(2)) = \{s(2) - c_i(2 : \theta_i)\} - \{s(1) - c_i(1 : \theta_i)\} + N_i\{b(2) + \alpha\} \tag{24}$$

One the basis of (1), the first two positive terms in the above expression together yield a non-positive number. Focusing on the last term on the RHS of (24), owing to the presence of N_i, the third term takes on a high positive value and

$$N_i\{b(2) + \alpha\} >> \{s(2) - c_i(2 : \theta_i)\} - \{s(1) - c_i(1 : \theta_i)\} \tag{25}$$

so that (24) is still positive. This implies that when all players are playing strategy 2, unilateral deviation to the play of strategy 1 is not profitable. Hence $(2, a_j(2))$ is a Nash Equilibrium.

Now we need to prove that $(2, a_j(2))$ risk dominates $(1, a_j(1))$. This is easily obtained by evaluating the *deviation losses* for each farm from each of the two Nash Equilibria.

The deviation loss to any farm from moving away from management of type 2 land to type 1 land is given by the RHS of (24).

$$u_i(2, a_j(2)) - u_i(1, a_j(2)) = \{s(2) - c_i(2 : \theta_i)\} - \{s(1) - c_i(1 : \theta_i)\} + N_i\{b(2) + \alpha\}$$

The corresponding deviation loss to any farm from moving away from type 1 land to type 2 land is given by the RHS of (21).

$$u_i(1, a_j(1)) - u_i(2, a_j(1)) = \{s(1) - c_i(1 : \theta_i)\} - \{s(2) - c_i(2 : \theta_i)\} + N_i\{b(1) - \tau_i\}$$

Then in order for management of type 2 land to be risk dominant, the value of the expression in (24) should be greater than the value of expression in (21). This requires that for negligible values of surplus generated by the flat payments (i.e. for small values of the first two terms in the two expressions),

$$b(2) + \alpha_i > b(1) - \tau_i \forall i = 1, 2, ...N \tag{26}$$

This gives rise to the following proposition.

Proposition 2: For any neighbourhood structure, there exists a first best payoff dominant Nash Equilibrium and other payoff dominated Risk Dominant Nash Equilibria in a spatial coordination game with externalities.

In the present setup, for land of two types, as mentioned the strategy set A now has two elements and as per Proposition 2, the game has 2 Nash Equilibria in pure strategies - a payoff dominant one and a risk dominant one. Owing to the presence of the externality it is riskier for any farm to manage type 1 land than manage type 2. Here the Nash Products (NP) associated with the outcome where players coordinate to manage the ecologically less favoured land is higher than that associated with the strategy to manage the ecologically superior land. Thus owing to the presence of the externality a risk dominant Nash Equilibrium emerges where all farms manage type 2 land as opposed to the payoff dominant Nash Equilibrium where lands of type 1 are managed. This is in line with the results of Keser et al. (1998). Thus given the presence of the risk dominant equilibrium, the AB is not able to successfully focus landowner decisions towards the ecologically feasible outcome.

Experimental research on coordination failure in static games such as the present ones reveals that with 2 players, the games converge to the Pareto Dominant outcome in a majority of the cases. Here the players coordinate to the payoff dominant outcome if communication is allowed (Van Huyck et al., 1990, Berninghaus et al. 2002, Parkhurst et al. 2004). Even in the absence of communication, repetition will lead to convergence to the payoff dominant outcome provided the *optimization premium* is small enough (Battalio et al. 2001).

The optimization premium is the difference in payoffs from playing the best strategy and the inferior strategy, given opponents' responses. Let us consider a coordination game with 2 strategies X and Y, where (X, X) is the payoff dominant outcome and (Y,Y) is the risk dominant one. Let $\pi(X, p)$ be the expected payoff to a player from playing X, when their opponent plays X with probability q. Correspondingly $\pi(Y, p)$ can be accordingly defined. Then the optimization premium for this game is the function $r(p) : [0, 1] \rightarrow \Re$ such that

$$r(p) = \pi(X, p) - \pi(Y, p) \tag{27}$$

With a small value of this optimization premium, the 2 player game converges to the payoff-dominant equilibrium with greater speed given repeated play. With respect to n-player coordination games as the ones considered in this study, evidence is inconclusive regarding the effect of the optimization premium. Many studies, most notably the one by Van Huyck et al. (1990) documents that with a large number of players, uncertainty regarding play of strategies other than the payoff dominant one leads to defection away from the Pareto Efficient outcome. They test this experimentally in the context of a minimum effort game. Future directions of this research might look at the effects of the optimization premium in spatial games of the present type in open neighbourhoods.

7 Structure of the Externality corrected Agglomeration Bonus

Studies by Ellison (1993), Kandori et al. (1993), Battalio et al. (2001) all reveal that in repeated coordination games, the pre-dominant outcome is the risk dominant one. This is especially true for open neighbourhoods. Thus the question that begs to be answered is whether there is some mechanism which can lead to the payoff dominant outcome. In this section we present the theoretical formulation of a new incentive which we append to the structure of the AB so that it can coordinate player behaviour to the ecologically beneficial outcome.

This is done by incorporating a third pay component into the AB. This component referred to as E is a payment to a farm towards damages incurred for every neighbour who manages type 2 land and imposes losses α_i on the farm. Under this new scheme the payoff function for managing type 1 land is given by (28) where all other symbols have usual meaning.

$$u_i(1, n_i(1), n_i(2)) = s(1) + p_i(a_i)b(1) - c_i(1 : \theta_i) - q_i(a_i)(\alpha_i - E) \tag{28}$$

The payoffs from managing type 2 land is still (8)

$$u_i(2, n_i(1), n_i(2)) = s(2) + t_i(a_i)b(2) - c_i(2 : \theta_i) + d_i(a_i)\tau_i$$

Now in order for this restructured AB to work, we need to establish a few conditions for the parameters of the payment scheme given the magnitude of costs and externalities. Here we derive conditions for strict dominance for the management of type 1 lands. This is represented in (17) and (29).

$$u_i(1, a_j(1)) > u_i(2, a_j(1)) \forall i = 1, 2, ...N$$

$$u_i(1, a_j(2)) > u_i(2, a_j(2)) \forall i = 1, 2, ...N \tag{29}$$

Now as per (21)

$$u_i(1, a_j(1)) - u_i(2, a_j(1)) = \{s(1) - c_i(1 : \theta_i)\} - \{s(2) - c_i(2 : \theta_i)\} + N_i\{b(1) - \tau_i\}$$

Now on the basis of (1) which indicates that notwithstanding the value of the bonus tied to each type of shared border, greater payments can be obtained from the management of type 1 land than type 2, the first two terms in (21) yield a positive value. Then in order for the expression to be positive, the magnitude of the bonus from managing type 1 land should be greater than the externality benefits that can be obtained from the management of type 1 parcels by their neighbours.

With reference to the relation in (29), we have

$$u_i(1, a_j(2)) - u_i(2, a_j(2)) = \{s(1) - c_i(1 : \theta_i)\} - \{s(2) - c_i(2 : \theta_i)\} + N_i\{E - \alpha_i - b(2)\} \quad (30)$$

In order for (30) to be positive, in addition to (1) it requires that the bonus obtained from sharing a common border of type 2 land is less than the net benefits obtained from managing type 1 land after accounting for the losses to the participant due to the externality. We can list the above conditions in the proposition below.

Proposition 3:In the present class of spatial coordination games, coordination to the ecologically efficient outcomes requires

$$b(1) > \tau_i \quad (31)$$

$$E - \alpha_i > b(2) \quad (32)$$

The main objective of this third component is to change the characteristic of the coordination game and make play of strategy 1 strictly dominant even in the presence of the externalities. However it is an experimental query as to whether players will be able to coordinate to this outcome particularly in open neighbourhoods. This is the subject of future experimental research.

8 Conclusion

The present study on spatial incentives demonstrates that the conventional form of the AB is not successful in achieving desired spatial objectives in the presence of externalities and different neighbourhood structures. To this effect we provide the theoretical formulation of a restructured AB which attains the desirable spatial objectives in the presence of the externality. However like many concepts in economics, whether this new AB will in fact be able to attain the desired spatial configuration is an experimental question. The Nash Equilibrium concept is useful in indicating the payoff dominant and risk dominant equilibrium in the present class of coordination games. However it does not make any predictions about the nature of play out of equilibrium, nor does it help to determine which of the two outcomes will in fact emerge in the actual play of the games in the presence of the externality in the presence of both closed and open neighbourhoods. Experimental analyses are required to answer such questions. The importance of experimental analysis is widely recognized as it allows consideration of different realistic scenarios unlike theoretical models (which must be simple) and can be complex and involve real human decision makers. In this way, they can account for bounded rationality, equity considerations, or psychological biases that are not typically included in theory models but play an important role in reality in determining the performance of different economic institutions and constructs like the present one.

With regards to the payment scheme developed in this study, experiments can be conducted under different treatments in a dynamic setting of repeated play. Two main treatments can be identified, the externality and the open neighbourhood structure. Experimental analyses would then involve recording player behaviour under a baseline treatment where agents are allowed to interact with each other in a simple open neighbourhood in the absence of the externality. These results can then be compared with those obtained from the treatment where agents interact in open neighbourhoods with the externality. This will allow us to answer questions regarding the extent to which the performance of the simple AB differs in the presence of externalities. Experimental analyses can also be used to answer questions regarding the influence of the neighbourhood structure on the play of the ecologically beneficial strategy and more importantly to analyze whether the new AB scheme developed in this study will actually be able to align landowner incentives towards the management of the ecologically desired parcels. This forms the foundation of future research.

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