The Agglomeration Bonus in the Presence of Private Transaction Costs

Simanti Banerjee
Frans P. de Vries
Nick Hanley

University of Stirling, UK
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Abstract

The Agglomeration Bonus (AB) is an incentive mechanism which has been proposed to incentivize neighbouring private landowners to create a spatially contiguous area of managed habitat for ecosystem services (ES) delivery. The AB gives rise to a spatial coordination game with the Nash Equilibria corresponding to different spatial patterns. In this paper we analyze the features of this coordination game in the presence of increasing values of transaction costs associated with participation and provision of a particular type of ES. Inclusion of these transaction costs are important as they form a significant part of agri-environmental schemes and can often deter participation altogether (Falconer 2000). We find that in the absence of transaction costs, for a given menu of AB payments, the coordination game has two Pareto ranked Nash Equilibria with non-participation being strictly dominated. However as the value of the costs go up, three scenarios emerge. If the provision of the high priority ES is associated with higher transaction costs than the low priority one, for small positive values of the costs, risk and payoff dominance may select the same strategy. In this case repeated interactions between players can lead to the ecologically and economically superior outcome in repeated interactions of the game. Non-participation is still dominated but by the risk dominant strategy only. However as the costs increase, risk and payoff dominance may not select the same strategy leading to different payoff dominant and risk dominant Nash Equilibria. This divergence in turn exacerbates the likelihood of coordination failure and chances of obtaining the payoff inferior risk dominant outcome. With further increase in the costs, the characteristic of the coordination game changes completely. Now in addition to non-identical Payoff Dominant and Risk Dominant Nash Equilibria there is a third Nash Equilibrium that corresponds to the non-participation scenario. This third scenario implies that with high enough transaction costs of participation there is an increased likelihood that the high priority ES will not be delivered, or individuals will coordinate to deliver the low priority service or that all or some individuals will not participate in the scheme at all. These scenarios indicate suboptimal policy performance and/or complete failure.

Section 1: Introduction

Spatially coordinated pro-conservation land uses on habitat patches are important for the delivery of various types of ES such as biodiversity protection for different types of birds (Willis 1979), for large carnivores who have large home ranges (Newark 1987), amphibians such as toads which need connective habitats for free movement (Bartelt et al. 2010) to name a few. This importance of spatial connectivity between habitats and spatially coordinated land uses on private properties has given rise to the literature on the Agglomeration Bonus (AB) - an incentive payment scheme that can incentivize neighbouring landowners to coordinate their land management decisions to obtain a spatially connected configuration of land uses on the landscape. The AB, first proposed by Parkhurst et al. (2002), consists of two incentive payments. A participation payment is made to landowners who choose to enrol parcels in the program and implement conservation practices. This payment is independent of neighbours' actions. The second is the bonus paid to landowners when their enrolled parcels border those enrolled by their neighbours. The bonus is intended to incentivize landowners to spatially coordinate their land uses. Specifically, contingent on the type of ecosystem services (ES) to be delivered, the structure and value of the payments can be adjusted to produce different types of spatial configurations. For example, suppose conservation of an endangered species requires the creation of a regional east-west corridor. Then the bonus can be attached to east and west borders of parcels to incentivize landowners to retire lands in the east-west direction. Theoretically, the AB can be designed to implement a Nash Equilibrium (NE) in a spatial coordination game and lead to the desired spatial patterns of land use. The performance of the AB in achieving spatial patterns has been evaluated in lab experiments by Parkhurst and Shogren (2007) and Warziniack et al. (2008). In this paper, we extend the literature on the AB by explicitly considering how private transaction costs which need to be incurred by participants in participating in AES can impact spatial coordination and participation. In addition, we modify the structure of the scheme so that payoffs are a function of the type of ES to be delivered. Two types of ES are considered here. These are a connectivity based ES which can be delivered via connections/corridors between habitat patches and distance based ES which can be delivered by land use changes on parcels within some specific distance of each other. The current research agenda is targeted at examining the features of the AB coordination game in this more general environment and provide theoretical foundations for future experimental research which will highlight the performance of the AB with TC. The paper is organized as follows. Section 2 provides a background on the issue of TC associated with AES. Section 3 presents the description of the strategic environment of the AB followed by the new AB game including the TC in Section 4. Section 4 presents some proofs on the existence of Nash Equilibria followed by numerical illustration of the new game in Section 5. Section 6 concludes with a description of ongoing research.

Section 2: Transaction Costs of AES Participation

Extensive research on participation in agri-environmental schemes indicates that both administrative authorities and participants incur transaction costs (TC) in implementing these schemes. There is an extensive literature on TC associated with participation in water quality trading programs in US (McCann and Easter 1999) and AES in the EU (Mettepenningen et al. 2009, 2011). The costs incurred by the agency are termed public TC and those incurred by the landowners are termed private TC. Private TC typically can be classified into search, negotiation, monitoring and enforcement costs (Dahlman 1979, Hobbs 2004). Of these, search and negotiation costs are ex-ante costs incurred prior to participation and placing the lands in conservation uses and the remaining are ex-post costs which are incurred after the conservation plan under the AES is in place (Mettepenningen et al. 2009). Estimating these TC especially the private costs are important to obtain insight about whether farmers will end up participating in the schemes. The studies by Mettepenningen et al. (2009, 2011) and McCann and Easter (1999) estimate the TC for farmers and public agencies for AES participation in different parts of the EU and for water pollution reducing programs in the Minnesota river in the US. The first study estimates that there is a mean increase in time spent in administrative work for the uptake of the AES scheme by participants by 17.2% and an increase of 11.4% in time spent in searching and collecting technical information, going through training exercises etc. There is a positive opportunity cost of this time spent away from agricultural activities which may create problems for private participation in these schemes. The next two studies provide estimates of total costs incurred by the governmental agencies in implementing these schemes. these costs indicate that AES involving simple contracts and procedures and which don't put too high an informational burden on the participants have a higher chance of success in terms of increasing landowner participation . The importance of simplification is underscored by the claims made by Falconer (2000) who mentions that greater targeting of Agri-environmental schemes (AES) increases the magnitude of private TC.

Yet schemes like the AB which aim at spatially coordinated land management for eco-delivery are targeted at specific ecological outcomes and hence expected to incur higher TC. This higher TC is manifested via costs of going to information sessions to know more about the issues of spatially coordinated land management, meetings with administering agencies, joint consultation and planning exercises with neighbours, extension personnel etc. The extent of such joint decision making is again a function of the type of ES to be generated. For example, one way of improving numbers of native pollinators such as bees is to create flower patches on marginal land along the bees' flight paths within their dispersal/home ranges. These activities don't incur high TC (Carvell 2006). In contrast creation of habitat linkages or corridors between wetlands for movement of mammals amphibian species etc will require consultation and planning between neighbours on issues like location and dimensions of the corridor, the nature of land uses on the connecting patches etc. In this second case the level of consultation necessary between neighbours and hence the TC will be greater than in the first case. This variation in the magnitude of the TC poses an interesting problem for participation and spatial coordination. Suppose the magnitude of the AB payments reflect the conservation agency's preference for one type of ES over the other. Then if AB payments associated with the low TC ES is higher than that for the high TC ES, spatial coordination is incentivized by the bonus with minimal risk of coordination failure. The problem is however not trivial when the ranking is reversed. If both the AB payments and TC associated with the delivery of an ES is higher, then the degree of strategic uncertainty and incidence of coordination failure is exacerbated. Moreover for a high enough value for TC, scenarios where non-participation is the best option in the presence of strategic uncertainty is possible as well. This scenario of joint existence of coordination failure and non-participation or holdouts as a function of the magnitudes of TC has not been explored in the AB literature. We address this issue in this paper. We provide the structure of an AB game environment and describe the features of a new AB game that results from the inclusion of TC.

Section 3: The Strategic Environment of the AB without Transaction Costs

We assume that land use changes on a property can deliver two types of ES. Let the provision of the first type of service be contingent on similar land uses on patches within a given geographical radius of each other. Let this service be denoted by R to represent the radius or distance determined service. Conversely let the supply of the second type of service be associated with connectivity between habitat patches. In this second situation, both habitat linkages and distance between patches determine the delivery of the service. Connections between patches closer to each other generate a higher supply of ES than those farther apart and/or separated by a constraint or barrier such as a road or areas with unsuitable commercial land uses which can limit species mobility . Let this service be denoted by C for connectivity. Without any loss of generality we assume that the delivery of service C is a higher priority for the agency relative to R. An AB scheme can be introduced with payments for both C and R reflecting this preference ranking. The conservation authority's AB scheme has two components. The participation component denoted by $s(\alpha)$ is paid for placing land in the conservation use and is independent of neighbours' actions. The second component is the bonus denoted by $b(\alpha)$ which can be obtained for similar conservation uses or connections between neighbouring patches (for C) or for conservation uses within a given radius (for R).

Let the strategic environment of the AB be represented as a symmetric normal form game $\Gamma_N[I, \Sigma, u_i(\cdot)]$ where $I = 1,2, \ldots N$ are the players, $\Sigma = \{X, C, R\}$ is the strategy set, σ is vector of strategies and $u_i(\sigma_i, \sigma_{-i})$ is the payoff function. In the game $\sigma_i = C$ indicates that player i has opted to deliver service C, $\sigma_i = R$ indicates that player i has opted to supply R and $\sigma_i = X$ indicates non-participation in the conservation scheme. In this strategic environment a set of neighbours for player i is given by $N_i \subset I$ such that neighborhood membership is symmetric, $j \in N_i$ if and only if $i \in N_j$ and irreflexive – $i \notin N_i$. The cardinality (size) of N_i is denoted by n_i where $n_i = N - 1$. Given a chosen strategy vector σ, define $N_{i\alpha} = \{j \in N_i | \sigma_j = \alpha\}$ for all $\alpha \in \Sigma$ as the set of neighbors of i who have chosen a particular strategy α in the game. Similarly, let $n_{i\alpha}$ be the size of $N_{i\alpha}$. Thus $\sum_{\alpha \in \Sigma} n_{i\alpha} = n_i$.

Assumption 1: Total returns from conservation land use and agriculture is greater than the conventional land use only when the government payment is available. Thus farmers will not voluntarily practice ES provision on their lands in the absence of the AB payments.

Assumption 2: The conservation agency provides AB payments for only one type of service per land owner. This assumption indicates that the agency is interested both in increasing ES supply (ecological goal) and increasing landowner enrolment (political goal). The latter goal in the presence of limited AB budgets implies that conservation uses on multiple parcels on the same property is not possible even if it will generate higher environmental benefits.

We next impose some spatial structure on the strategic environment. Let us consider a representative landscape with private properties intercepted by hard boundaries such as roads and other obstructions (buildings) which create a barrier for mobility of species whose populations improve with greater connectivity between patches. On this landscape, properties on the same side of the mobility barrier are termed proximate or close neighbours and denoted by n_p and those on both sides of it are termed far neighbours denoted by n_f. This distinction is irrelevant for the provision of distance based R services such as improvement of native pollinator populations and bird species since their mobility is not hindered by the mobility barriers.

Assumption 3: Let the neighbourhood size for every player is the same regardless of the ES. Thus $n_{ip}(C) + n_{if}(C) = n_{ip}(R) + n_{if}(R) = n_i(R)$.

Next, we define a variable $d \in \{0,1\}$ with $d = 1$ for $\sigma_i = C$ and 0 otherwise such that the payoff function is given by

$$u_i(\sigma_i, \sigma_{-i}) = \begin{cases} s(\alpha) + \left[n_{ip}(\alpha)(1+d) + n_{if}(\alpha)\right]b(\alpha) + \pi(\alpha) & if\ \sigma_i = C, R \\ \pi(X) & if\ \sigma_i = X \end{cases} \tag{1}$$

In the above payoff function $d = 1$ for $\sigma_i = C$ reflects a higher (double) AB payment from connected habitats on properties on the same side of the mobility barrier relative to those on opposite sides. Since animals do possess limited ability to cross the mobility barrier, presence of suitable quality habitat on the other side of the barrier can provide bonus payments as well. However the bonus payment for connected patches between far neighbours is less than that obtained for the connectivity between proximate neighbours in this case by half. When $\sigma_i = R$, the barrier does not matter so that $d = 0$ and the total AB bonus from participating neighbors are determined solely by their number and whether they are within the flight path or nesting and foraging range of the species concerned. Given this payment set-up, the agency can set the values of $s(\alpha)$ and $b(\alpha)$ on the basis of the costs associated with the changes in land use and the relative desirability of providing one ES over the other.

Assumption 4: With the delivery of C services being a higher priority than R we have

$s(C) > s(R)$ and $b(C) > b(R)$ for all $i \in I$

In addition, the total income from agriculture when service C is produced is less than when the landowners choose R. This is because delivery of R may entail changing land uses on marginal land which has low opportunity costs in terms of returns from agriculture. Thus $\pi(R) > \pi(C)$

Assumption 5: In the absence of private TC, with the AB payments, net returns to the landowners are higher than having lands solely in conventional use. This assumption implies that non-participation in the AB scheme is a strictly dominated strategy.

Proposition: When $n_i = N - 1$ for all i $\sigma_i = C$ for all i and $\sigma_i = R$ for all i are the two Pure Strategy Nash Equilibria (NE).

We provide the proofs and conditions for this below.

PROOF: To prove the existence of the two NE we need to demonstrate that unilateral deviation from $\sigma_i = C$ for all i is not profitable, and identify the conditions such that unilateral deviation from $\sigma_i = R$ for all i is not profitable. Consider the payoff for player i from $\sigma_i = C$ when $\sigma_j = C$ for $j \in N_i$,

$$u_i(C,C) = s(C) + \left(2n_{ip} + n_{if}\right)b(C) + \pi(C) \quad (2)$$

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

$$u_i(R,C) = s(R) + \pi(R) \quad (3)$$

The difference between (2) and (3) is given by

$$u_i(C,C) - u_i(R,C) = \{s(C) - s(R)\} + \left(2n_{ip} + n_{if}\right)b(C) - \{\pi(R) - \pi(C)\} \quad (A)$$

By *Assumption 4*, the first term is positive. The second term is positive and captures the maximum possible bonus attainable. Then if difference in profits when land is in R use and not C use is not that large, then unilateral deviation from $\sigma_i = C$ for all i is not profitable. Hence $\sigma_i = C$ for all i is a Pure Strategy NE of the coordination game.

Next consider the payoff from $\sigma_i = R$ when $\sigma_j = R$ for $j \in N_i$. Then

$$u_i\,(R,R) = s(R) + n_i b(R) + \pi(R) \quad (4)$$

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

$$u_i(C,R) = s(C) + \pi(C) \quad (5)$$

Now the difference between (4) and (5) is given by

$$u_i(R,R) - u_i(C,R) = \{s(R) - s(C)\} + n_i b(R) + \{\pi(R) - \pi(C)\} \quad \text{(B)}$$

In the above expression, the last two terms are positive. Then for small enough differences in the participation components and agricultural profits under the two scenarios, the value of the whole expression is positive. In that case unilateral deviation from $\sigma_i = R$ for all i is not profitable. Under this condition, $\sigma_i = R$ for all i is a Pure Strategy NE of the coordination game. ■

The mixed strategy Nash Equilibrium $\{p(C), p(R), p(X)\}$ is given by the following

$$p(C) = \frac{s(R) + n_i b(R) - s(C)}{[n_{ip}(1+d) + n_{if}]b(C) + n_i b(R)};$$

$$p(R) = \frac{s(C) + [n_{ip}(1+d) + n_{if}]b(C) - s(R)}{[n_{ip}(1+d) + n_{if}]b(C) + n_i b(R)};$$

$$p(X) = 0$$

In the expression for the mixed strategy Nash Equilibrium, the probability associated with a strategy is dependent on the sum of maximum bonus payments possible for any player in the denominator and the deviation loss associated with unilateral deviation from the Nash Equilibrium corresponding to the other strategy in the numerator. By Assumption 5, non-participation is strictly dominated so that $p(X) = 0$.

In addition, in order for the equilibrium selection principles of Risk and Payoff Dominance to select the same strategy, namely the Payoff Superior strategy C, the following conditions should hold for the payoffs

- $s(C) + [n_{ip}(1+d) + n_{if}]b(C) - s(R) > s(R) + n_i b(R) - s(C)$

This condition implies that the deviation loss associated with strategy C should be greater than that for strategy R. Given the assumptions of the model, the first two terms on the left hand side of the expression are greater than the first two terms on the right hand side. Also since $s(C) > s(R)$, the net value of the expression after the deduction of the third term on the left hand side is greater than the same on the right hand side. Thus the deviation loss associated with C is higher than that for R. A greater deviation loss associated with C implies that the loss to a player from making a mistake and choosing R when all their neighbours choose C is higher than the loss associated with choosing C when everyone else chooses R. This high loss associated with C indicates that risk of strategic uncertainty driven coordination failure is not high enough to cause coordination failure and focus the game on the payoff inferior NE rather the Pareto superior NE. In this game, $\sigma_i = C$ for all i is both the Risk Dominant and Payoff Dominant NE (Harsanyi and Selten 1988, Straub 1995).

Numerical illustration:

To illustrate the features of the AB game, we consider a simple representative landscape with four properties and a road running through the middle so that there are two properties on each side of it. All the properties are within the flight path and or nesting/foraging grounds of some target species. Thus coordinated land uses by at least two farms will yield bonus payments. Let the magnitude of the bonus payments under the AB scheme and neighbourhood structure be the following.

$$S(C) = 25;\ S(R) = 20\ ; b(C) = 20; b(R) = 8\ ;\ n_p = 1;\ n_f = 2;\ \pi(C) = 100;\ \pi(R) = 110;\ \pi(X) = 120$$

Neighbours' Choices

Player	CCC	CCR	RRC	RCC	CRR	RRR	CXX	XXR	CCX	CRX	RCX	RRX	X
C	205	185	165	165	145	125	165	125	185	165	145	125	125
R	130	138	146	138	146	154	146	138	130	138	138	146	130
X	120	120	120	120	120	120	120	120	120	120	120	120	120

Table 1: Example I

The payoff matrix for the given landscape is given by Table 1. In this game, non-participation is a strictly dominated strategy since the payoffs from both C and R are higher than those from X for any strategy selection by the neighbours. Thus the game reduces to the following.

Neighbours' Choices

Player	CCC	CCR	RRC	RCC	CRR	RRR
C	**205**	185	165	165	145	125
R	130	138	146	138	146	**154**

Table 2: Non-participation Strictly Dominated

Here there are two pure strategy Nash Equilibria $\sigma_i = C$ and $\sigma_i = R\ \forall i\ \in I$. In addition, the selection principles of RD and PD choose the same strategies given that the deviation loss associated with C (75) is higher than that for R (29).

Section 4: AB game with Private Transaction costs of Participation

we consider now how the introduction of TC impacts features of the AB game. Let the TC be a lumpsum amount which is increasing in the number of neighbors that a player has. Then the payoff function for each player is given by the following

$$u_i(\sigma_i, \sigma_{-i}) =$$

$$\begin{cases} s(\alpha) + [n_{ip}(\alpha)(1+d) + n_{if}(\alpha)]b(\alpha) + [(1+d)n_{ip} + n_{if}]T(\alpha) + \pi(\alpha) & if\ \sigma_i = C, R \\ \quad \pi(X) & if\ \sigma_i = \phi \end{cases} \tag{6}$$

Assumption 6: We assume that $T(C) > T(R)$ implying greater costs of setting up habitat connectivity relative to changing land uses on marginal lands.

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Proposition: When $n_i = N - 1$ for all i $\sigma_i = C, \sigma_i = R$ and $\sigma_i = X\ \forall i\ \in I$are the three Pure Strategy Nash Equilibria (NE) of the AB coordination game with TC.

We provide the proofs and conditions for this below.

PROOF: To prove the existence of the two NE we need to demonstrate that unilateral deviation from $\sigma_i = C$ for all i is not profitable, and identify the conditions such that unilateral deviation from $\sigma_i = R$ for all i and $\sigma_i = X$ for all i is not profitable. Consider the payoff for player i from $\sigma_i = C$ when $\sigma_j = C$ for $j \in N_i$,

$$u_i(C,C) = s(C) + (2n_{ip} + n_{if})b(C) + \pi(C) - (2n_{ip} + n_{if})T(C) \quad (7)$$

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

$$u_i(R,C) = s(R) + \pi(R) - n_{if}T(R) \quad (8)$$

The difference between (7) and (8) after some mathematical manipulation is given by

$$u_i(C,C) - u_i(R,C) = \{s(C) - s(R)\} + (n_{ip} + n_{if})[b(C) + T(R) - T(C)] + n_{ip}[b(C) - T(C)] - \{\pi(R) - \pi(C)\}$$

(C)

By *Assumption 4*, the first term is positive. Now if $b(C) > T(C)$, then the second and third terms are positive as well. Then for small differences in agricultural returns under C and R land uses, the above difference is positive and unilateral deviation from $\sigma_i = C$ to $\sigma_i = R$ is not profitable. Next, consider the payoff for player i from $\sigma_i = X$ when $\sigma_j = C$ for $j \in N_i$. Here we have

$$u_i(X,C) = \pi(X) \quad (9)$$

Then the difference between (7) and (9) is

$$u_i(C,C) - u_i(X,C) = s(C) + (2n_{ip} + n_{if})\{b(C) - T(C)\} + \pi(C) - \pi(X)$$

In the above expression, the first two terms are positive. Then for small enough differences in opportunity costs of agriculture, the above expression is positive. Hence $\sigma_i = C$ for all i is a Pure Strategy NE of the coordination game. Next we consider the payoff from $\sigma_i = R$ when $\sigma_j = R$ for $j \in N_i$. Then

$$u_i(R,R) = s(R) + n_i[b(R) - T(R)] + \pi(R) \quad (10)$$

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

$$u_i(C,R) = s(C) + \pi(C) - \left(2n_{ip} + n_{if}\right)T(C) \tag{11}$$

Now the difference between (10) and (11) after some manipulation is given by

$$u_i(R,R) - u_i(C,R) = \{s(R) - s(C)\} + \left(n_{ip} + n_{if}\right)[b(R) + T(C) - T(R)] + n_{ip}T(C) + \{\pi(R) - \pi(C)\} \qquad \text{(D)}$$

In the above expression, on the basis of *Assumptions 4* and *6*, all but the first term is positive. Then if the participation components of the AB are such that the first term is small then unilateral deviation is not profitable from $\sigma_i = R$ for all i. Under the given set of assumptions $\sigma_i = R$ for all i is a Pure Strategy NE of the coordination game as well. Next, consider the payoff for player i from $\sigma_i = X$ when $\sigma_j = R$ for $j \in N_i$.

Here we have

$$u_i(X,R) = \pi(X) \tag{12}$$

Then the difference between (10) and (12) is given by

$$u_i\,(R,R) - u_i(X,R) = s(R) + n_i[b(R) - T(R)] + \pi(R) - \pi(X)$$

In above expression for small enough differences in income losses from agriculture from participation in the schemes, the expression is positive. In fact if R service involves changes in land uses of marginal cropland, then the last term has a very small value. Thus non-participation is not a best response when all neighbours are choosing strategy R. Thus $\sigma_i = R$ for all i is a Pure Strategy NE of the coordination game. Now considering the deviation losses associated with C and R we have the expressions (C) and (D) respectively.

$$\{s(C) - s(R)\} + \left(n_{ip} + n_{if}\right)[b(C) + T(R) - T(C)] + n_{ip}[b(C) - T(C)] - \{\pi(R) - \pi(C)\}$$

$$\{s(R) - s(C)\} + \left(n_{ip} + n_{if}\right)[b(R) + T(C) - T(R)] + n_{ip}T(C) + \{\pi(R) - \pi(C)\}$$

When $T(C) = 0 = T(R)$ then as per the model, $\sigma_i = C$ for all i is both the PDNE and RDNE. However for positive value of TC with $T(C) > T(R)$, the two selection principles may select different NE. Thus with increasing TC of participation in a spatially targeted scheme, the Risk Dominant Nash Equilibrium (RDNE) and Payoff Dominant Nash Equilibrium (PDNE) may differ exacerbating strategic uncertainty driven coordination failure. An increase in the propensity of coordination failure in turn reduces the effectiveness of the AB.

Finally we consider strategy X. Here we have

$$u_i(X,X) = \pi(X) \tag{13}$$

$$u_i(C,X) = s(C) + \pi(C) - \left(2n_{ip} + n_{if}\right)T(C) \tag{14}$$

$$u_i(R,X) = s(R) + \pi(R) - n_i T(R) \tag{15}$$

Then from (13) and (14) we have

$$u_i(X,X) - u_i(C,X) = \pi(X) - \pi(C) + \left(2n_{ip} + n_{if}\right)T(C) - s(C)$$

In this expression, the difference of the first two terms are positive. Then for a particular neighbourhood structure, with increasing TC, choosing X relative to C when no one else is participating becomes profitable. Also as transaction costs increase, strategy X cannot remain strictly dominated by C anymore. Again considering (13) and (15) we have

$$u_i(X,X) - u_i(R,X) = \pi(X) - \pi(R) + n_i T(R) - s(R) \tag{E}$$

In this expression, if $T(R) = 0$, then non-participation is dominated under the assumption that $\pi(X) - \pi(R)$ has a small value. If $T(R) > 0$, then for a high enough value of the private TC, the first two terms are positive and for a particular neighbourhood structure, it is always beneficial to not participate when neighbours don't participate.

However whether $\sigma_i = X$ for all i is a Pure Strategy NE of the coordination game will depend on whether non-participation is dominated by a mixed strategy profile of C and R or not. This mixed strategy profile exists as long as X is strictly dominated by strategy R. In this case, despite the presence of private TC, landowners will choose either C or R. However once the TC of participation are high enough so that X is not strictly dominated by R anymore, the mixed strategy profile does not exist so that X is not strictly dominated by a mixed strategy of C and R anymore. In this scenario $\sigma_i = X$ for all i can be sustained as a Pure Strategy NE of the coordination game as well. We highlight these aspects of the game with numerical examples below.

Numerical Examples:

We use the same menu of AB payments from the earlier example and varying TC values to illustrate the different types of games that emerge in the presence of increasing TC. Let the parameters C be the following.

$$S(C) = 25;\ S(R) = 20\,; b(C) = 20; b(R) = 8\,;\ n_p = 1;\ n_f = 2;\ \pi(C) = 100;\ \pi(R) = 110;\ \pi(X) = 120, T(C) = 5; T(R) = 3$$

Neighbours' Choices

Player's Choices	CCC	CRC	CRR	RCC	RRC	RRR	CXX	XXR	CCX	CRX	RCX	RRX	X
C	**165**	145	125	125	105	85	125	85	145	125	105	85	85
R	121	129	137	129	137	145	146	129	121	129	129	137	**121**
X	120	120	120	120	120	120	120	120	120	120	120	120	120

Table 3: C Risk & Payoff Dominant; X dominated by Mixed Strategy

In the above example, the deviation losses associated with C (44) is greater than that associated with R (36) indicating that both the Payoff Dominance and Risk Dominance criteria choose the same strategy C. In addition X is strictly dominated by a strategy $0.05^{*}C + 0.95^{*}R$. This game is similar to the games represented in Cooper Dejong, Forsythe and Ross (1990) where the RDNE and PDNE are the same (here C) and there exists another strategy (here X) which is strictly dominated by a mixed strategy and strategy R but not strategy C. Experimental evidence from their paper suggests that the magnitude of payoffs associated with X can influence whether the payoff superior NE can be achieved or not

Let us consider another example with higher values for the TC figures for both C and R.

$$S(C) = 25;\ S(R) = 20\ ; b(C) = 20; b(R) = 8\ ; n_p = 1;\ n_f = 2;\ \pi(C) = 100;\ \pi(R) = 110;\ \pi(X) = 120, T(C) = 15; T(R) = 5$$

Neighbours' Choices

Player's Choices	CCC	CRC	CRR	RCC	RRC	RRR	CXX	XXR	CCX	CRX	RCX	RRX	X
C	**145**	125	105	105	85	65	105	65	125	105	85	65	65
R	115	123	131	123	131	**139**	146	123	115	123	123	131	115
X	120	120	120	120	120	120	120	120	120	120	120	120	**120**

Table 4: RDNE & PDNE different; X not dominated by Mixed Strategy

In this example, the magnitude of the transactions costs are high enough so that the deviation losses associated with R (74 for deviating to C and 19 for deviating to X) is greater than the same associated with C (50 for deviating to R) and X (5 for deviating to R). Thus when every neighbour chooses R, the loss from deviating from R to any other strategy is the highest. Thus $\sigma_i = R\ \forall\ i$ is the RDNE of the coordination game. In addition, X is not strictly dominated by R anymore and so there does not exist any mixed strategy profile that dominates X. Thus $\sigma_i = X\ \forall\ i$ is a NE of the game as well. Thus depending on its magnitude the presence of the TC has the potential to change the characteristic of the AB coordination game completely.

Conclusion

The present study indicates that for a fixed menu of payments, the performance of the AB is a function of the TC associated with participation and provision of a particular ES. Furthermore, the magnitude of the TC plays a key role as it can essentially rank different strategies (C, R and non-participation) in order of riskiness associated with coordination failure. In this paper we have shown that consideration of the TC in a general ecological and economic model of spatial coordination, changes the features of the coordination game completely. For low values of TC, risk and payoff dominance criteria can select the same strategy so that the Pareto superior outcome can be attained in experimental settings. However, increase in the magnitude of TC intensifies the likelihood of coordination failure through divergence of risk dominant and payoff dominant NE of the coordination game. In this scenario, as long as payoffs from non-participation are less than those from participation in the scheme, we can expect that at least the distance based service (pertaining to the RDNE) will be provided. However for higher values of TC, the payoffs from non-participation when some neighbors don't participate are greater than the payoffs from participation. In this situation, scenarios may emerge where players may hold out and not participate altogether leading to policy failure. This is a serious limitation of the scheme. Following the experimental evidence by Cooper DeJong, Forsythe and Ross (1990) we can conclude that it is possible to achieve the RDNE in a setting where the risk dominant strategy dominates the non-participation strategy. Yet there is no experimental evidence to suggest the outcome of the game when this is not so. Thus a comprehensive analysis of the consideration of private TC on AB performance requires experimental research to observe which outcome (NE) will prevail under actual interactions between players. In pursuing this experimental agenda future work on the AB with the TC can focus on performance/coordination failure in local and global environments (Berninghaus et al. 2002) which are realistic representations of farming landscapes where the AB is to be implemented.

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