Incentives for Spatially Coordinated Land Conservation: A Conditional Agglomeration Bonus

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Abstract
The agglomeration bonus literature has not recognized the potential of conditional agreements to overcome the informational requirements, particularly those of landowners, necessary to induce spatially coordinated land conservation. The model presented in this paper shows that the net social benefits produced by a conditional agglomeration bonus program are at least as large as those produced by a traditional uniform subsidy whenever the benefit function exhibits threshold effects and the uniform and CAB subsidies are equal. This result requires no assumptions about the information available to landowners. A regulator’s informational requirements are limited to the shape of the benefit function.


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Introduction

Land conservation is a tool extensively used by governments and environmental organizations to obtain environmental benefits such as habitat preservation, biodiversity, and improved water quality. Annual expenditures for land conservation range in the billions of dollars making the efficient allocation of funds a subject of interest to economists.

Often, the marginal benefits from conservation efforts are small until some threshold level of conservation has been reached (e.g. the creation of contiguous habitat). In circumstances where such a “threshold effect” is present, greater environmental benefits can be obtained through the spatial concentration of conservation efforts. Ignoring threshold effects can result in an allocation of conservation effort that is overly dispersed geographically (Lewis and Plantinga, 2007, Wu, et al., 2000, Wu and Boggess, 1999).

An incentive mechanism proposed in the literature to encourage spatially concentrated conservation is the agglomeration bonus, which awards landowners bonus payments for the conservation of adjacent parcels (Parkhurst and Shogren, 2008, Parkhurst and Shogren, 2007). In an experimental study, Parkhurst and Shogren found that players in a coordination game with an agglomeration incentive were able to achieve desired spatial configurations of land conservation (e.g., a wildlife corridor or core habitat) with over 90% efficiency. However, this level of success was contingent on players having information about neighbors’ opportunity costs, gaining experience with the game, and being able to send one non-binding message during the game. Furthermore, the design of the incentive structure implied the regulator had knowledge of landowners’ opportunity costs.

A real-world application of an agglomeration bonus is Oregon’s Conservation Reserve Enhancement Program (CREP), established in 1998 with the goal of assisting the recovery of salmon and trout species through the creation of riparian buffers along stream habitat. The program includes a
provision that awards a “Cumulative Impact Incentive Bonus” (CIIB) wherever at least 50 percent of any 5 mile section of streambed is enrolled in the CREP (USDA, 1998). In a 1998 survey of potential CREP participants, approximately 76% indicated a willingness to work with neighbors toward enrolling contiguous stream miles (Kingsbury, 1999). One reason cited for landowners not wishing to take advantage of the bonus program was the perception that it would require a large investment in time. During the past decade CIIB awards have not been extensive. However, the incentive has proven successful in encouraging CREP participants to promote the program to neighbors (Sundseth, 2009).

Information limitations are a frequent impediment to the design of effective incentive mechanisms. Regarding the agglomeration bonus, its functionality is dependent on landowners’ knowledge of neighbors’ willingness to participate in conservation. For example, consider a farmer for whom the bonus level of compensation (paid to contiguous conservation) exceeds rents from agriculture, and suppose his agricultural rents are higher than some base-level compensation (paid to non-contiguous conservation). His payoff to enrolling in the conservation program may be positive or negative depending on whether his neighbors’ enrollment is sufficient to warrant bonus compensation. Hence, the farmer’s expected payoff is a function of each neighbor’s probability of enrolling. The farmer takes on risk by enrolling because his payoff could be negative. If information about neighbors’ willingness to participate is limited (as would be likely in a real-world application), he may forego participation even when he and his neighbors could mutually benefit from enrolling as a group.

The above example illustrates a significant limitation in the agglomeration bonus mechanism as it has been represented in the recent literature: the agreement to enroll is binding on both the landowner and regulator. The agglomeration bonus literature has not examined the potential for conditional agreements to overcome the informational requirements necessary to induce spatially coordinated land conservation. The real-world applicability of the
agglomeration bonus has likely been constrained by its strong information requirements. The modification to the agglomeration bonus mechanism proposed in this paper could enhance its applicability.

A Conditional Agglomeration Bonus

Predicting a landowner’s binary response to a voluntary conservation incentive such as a subsidy from the USDA’s Conservation Reserve Program is complex. Underlying the landowner’s decision to accept or reject such a subsidy is the quality (i.e. productivity) of his land, and by extension, the stream of rents he can earn from its highest and best use. Two factors that introduce complexity to a landowner’s response are: 1) the long term commitment inherent to most conservation programs (the minimum CRP contract is 10 years), and 2) the individual characteristics of the landowner. Under a long-term commitment, a landowner’s calculation of opportunity cost will incorporate his current rents as well as his expectations of future input and output prices. A landowner’s willingness to enroll in a conservation program will also depend on his personal preferences: for example, he may value the certainty of CRP payments, or he may be averse to being told what to do by the government. Due to such complexity, a fragmented response to a uniform incentive is possible even where current land rents exhibit a high degree of spatial correlation.

The agglomeration bonus attempts to overcome fragmented responses by creating a positive network externality among neighboring landowners (Parkhurst and Shogren, 2007), but relies on each landowner to perform what can be a very complex task: incorporate expectations of neighbors’ responses into his own enrollment decision. Each landowner’s expected payoff to
enrolling in a conservation program is a function of his expected opportunity cost and the probability of his neighbor(s) enrolling.

Asking landowners to perform such calculations is unnecessary if landowners’ commitments to enroll are binding if and only if a desired pattern of enrollment is achieved (e.g., \( n \) contiguous parcels). A conditional agglomeration bonus (CAB) program would pay compensation only where the desired pattern of enrollment occurs. Where the desired pattern of enrollment does not occur, the landowner and government are both released from their obligations. Assuming zero transaction costs, landowner \( i \) will conditionally enroll in the program whenever his opportunity cost is less than the CAB because his expected payoff \( \pi_i \) is always greater than or equal to zero:

\[
E(\pi_i) = p * (S_{CAB} - OC_i) + (1 - p) * 0 \geq 0
\]

\( S_{CAB} \) denotes the CAB bonus payment, landowner \( i \)'s opportunity cost of enrolling is \( OC_i \), and \( p \) is the probability that neighbors’ enrollment is sufficient to satisfy the regulator’s desired pattern of conservation. Under a CAB program the landowner’s expected payoff remains a function of his neighbors’ opportunity costs, but that information is no longer relevant to his conditional enrollment decision.

The following section develops a theoretical framework to analyze the application of a CAB.

**Theoretical Model and Analysis**

In the context of habitat creation where the benefits of habitat exhibit threshold effects, consider a square grid of \( N \) agricultural land parcels of heterogeneous quality, and of uniform shape (square) and area (1 acre). Suppose the afforestation of a parcel creates habitat \( h_i \) and that an
area of contiguously afforested parcels creates habitat \( H_j = \sum_f h_j \).\(^1\) To reflect the presence of threshold effects, the benefit per acre \( BPA_j \) is zero until some threshold acreage of contiguous habitat \( H_T \) is afforested (see figure 1):

\[
(2) \quad BPA_j(H_j) = \begin{cases} 
0, & H_j < H_T \\
> 0, & H_j \geq H_T 
\end{cases}
\]

The total benefit of afforestation on the grid is then \( TB = \sum_j H_j * BPA_j \).

The regulator’s goal is to maximize the net social benefits in equation (3), choosing \( SCAB \) and the minimum size \( H_j \) for which the CAB subsidy is awarded.

\[
(3) \quad \max_{SCAB,\min H_j} NSB = \left[ \sum_j \left( H_j(SCAB) * BPA_j(H_j(SCAB)) \right) - \sum_j OC_j(SCAB) \right] \\
\text{s.t. } \sum_j h_j * SCAB \leq B
\]

The opportunity cost of enrolling parcel \( j \) is \( OC_j \), and \( B \) is a budget constraint.\(^2\) The regulator cannot solve the maximization problem without perfect information about the spatial coordinates of \( OC_i \) \( \forall i \). The selection and size of each \( H_j \), and value of each \( BPA_j \), depend on the spatial pattern of parcels that satisfy \( OC_i < SCAB \). Without knowledge of each parcel’s spatial relationship to other parcels, the change in NSB with respect to a change in \( SCAB \) is unknown.

A more realistic informational assumption, adopted here, is that the regulator knows only the value distribution of \( OC_i \). Although the regulator does not have enough information to choose \( \min H_j \) and \( SCAB \) optimally, or even ensure the exact expenditure of his budget, his choices can be informed by his knowledge of \( BPA_j(H_j) \) and the distribution of \( OC_i \).

Regarding the choice of \( H_T \), the regulator will always choose \( \min H_j \) such that \( \min H_j \geq H_T \). Given the assumed functional form of \( BPA_j(H_j) \), subsidizing the afforestation of parcels

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\(^1\) For the purposes of this paper, two parcels are considered contiguous whenever they share a rook border.

\(^2\) \( OC_i \) essentially represents the reservation price of landowner \( i \), above which he is willing to engage in afforestation of his land.
where $H_j < H_T$ would result in a net social loss because $BPA_j(H_j < H_T) = 0$. The extent to which $\min H_j$ should exceed $H_T$ will depend on the shape of $BPA_j(H_j)$ and the distribution of $OC_i$. Where the change in $BPA_j(H_j)$ with respect to a change in $\min H_j$ is large, it may be advantageous to increase $\min H_j$. The magnitude of this advantage will depend in part on whether the recruitment of larger $H_j$'s requires the enrollment of parcels with substantially higher opportunity costs, and consequently a substantially higher $S^{CAB}$.

The level of enrollment induced by particular $S^{CAB}$ will be sensitive to the spatial distribution of low opportunity cost parcels. For example, if low opportunity cost parcels are clumped together a small $S^{CAB}$ will enroll a relatively large number of parcels, even with a large $\min H_j$. On the other hand, if low opportunity cost parcels are spatially fragmented the same $S^{CAB}$ may enroll a few as zero parcels when $\min H_j > 1$.

The net social benefits of choosing a particular pair $(S^{CAB}, \min H_j)$ are uncertain where the regulator knows only the distribution of $OC_i$ and the benefit function. However, given the model presented in this section, the CAB program will always perform at least as well as a standard uniform subsidy whenever the following conditions are met: 1) $\min H_j \geq H_T$, and 2) $S^{CAB} = S^{UNI}$. If $H_T \leq 1$, the uniform and CAB programs will enroll identical sets of parcels and generate equal NSB’s. If $H_T > 1$, the CAB program will enroll a subset of the parcels enrolled by the uniform program, generating NSB’s greater than or equal to those generated by the uniform program:

\[ (4) \quad NSB_{CAB} - NSB_{UNI} = \sum_i OC_i \forall i \in (H^{UNI} - H^{CAB}) \geq 0 \]

$H^{UNI}$ is the set of parcels enrolled by the standard uniform subsidy and $H^{CAB}$ is the set of parcels enrolled by the CAB program. Under the stated conditions, the CAB program drops any parcel from enrollment that does not produce positive benefits, while the uniform subsidy accepts all
enrollments regardless of each parcel’s production of benefits. Where the spatial distribution of low-opportunity cost parcels is fragmented and/or $H_T$ is large, the CAB program is likely to provide substantially larger benefits than a uniform subsidy.

In the following section I run a basic simulation on a hypothetical landscape to demonstrate the result in equation (4).

**Simulation**

The hypothetical landscape consists of 625 parcels arranged in 25 X 25 square grid. The parcels are of homogenous size (100 acres) and shape (square). Each simulation assumes the following benefit function:

$$BP_{Aj}(H_j) = \begin{cases} 0, & H_j < 300 \\ \frac{A_j}{P_j}, & H_j \geq 300 \end{cases}$$

$A_j$ denotes the total area, and $P_j$ the total area, of the contiguous set of parcels $H_j$. The threshold is $H_T = 300$, below which the afforestation of parcels produces zero benefits. The benefit function favors habitat configurations that minimize exposed perimeter relative to total area.

Parcel opportunity costs were randomly drawn from a normal distribution: $OC \sim N(100, 100)$.

I compare the NSB’s under a CAB program and a uniform subsidy for a series of subsidy levels where $S^{CAB} = S^{UNI}$. The randomly drawn opportunity costs have minimum and maximum values of 70.0 and 127.6, and a mean of 99.8. Figures 2a and 2b show the parcels enrolled by the uniform subsidy and the CAB program when $S^{CAB} = S^{UNI} = 92.0$.

The CAB program is demonstrated to have an advantage over the uniform program in the production of net benefits (see table 1) at each subsidy level. The low-opportunity cost parcels on the simulated landscape are highly fragmented and the uniform subsidy enrolls many parcels that produce zero benefits. The total benefits produced by the uniform subsidy and CAB
program are identical, but the uniform subsidy incurs additional opportunity costs whenever it enrolls more parcels that the CAB program.

**Conclusion**

The problem of motivating groups to take collective action is hardly unique to taking advantage of cumulative effects in land conservation. The difficulty inherent in many situations is that even when benefits are large under collection action, the payoff to an individual who deviates from the status quo (e.g., engaging in conservation) is often negative. For example, if I contribute $100 to establish a non-rival good such as a public radio station and not enough funds are collected from my community to get it off the ground, I lose $100. I, as well as my neighbors, will hesitate to contribute even though we may obtain substantial benefits (e.g., $200 each) if enough of us contribute. However, I will not hesitate to contribute if I am assured my check will not be cashed unless enough of my fellow citizens contribute to create the radio station. I will make the decision to contribute regardless of my knowledge of my neighbors’ preferences for a new radio station and their willingness to contribute. The worst case scenario is that I will incur the transaction cost of writing and mailing a check.

The agglomeration bonus literature has not recognized the potential of conditional agreements to overcome the informational requirements (particularly those of landowners), necessary to induce spatially coordinated land conservation. The model presented in this paper shows that the net social benefits produced by a CAB program are at least as large as those produced by a traditional uniform subsidy whenever the benefit function exhibits threshold effects and the uniform and CAB subsidies are equal. This result requires no assumptions about the information available to landowners. The regulator’s informational requirements are limited to the shape of the benefit function.
References


Sundseth, D. "County Director, USDA Farm Service Agency, Tangent, OR." (2009).

USDA (1998) Agreement between the USDA Commodity Credit Corporation and the State of Oregon Concerning the implementation of a conservation reserve enhancement program.


Table 1. Net Social Benefits under a CAB Program and a Uniform Subsidy

<table>
<thead>
<tr>
<th>Subsidy Level</th>
<th>Uniform Subsidy</th>
<th>CAB Program</th>
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<tbody>
<tr>
<td>92</td>
<td>127</td>
<td>10,977</td>
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<tr>
<td>94</td>
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<td>19,443</td>
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<tr>
<td>98</td>
<td>270</td>
<td>24,587</td>
</tr>
</tbody>
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Figure 1: Benefit per acre of contiguous afforestation
Figure 2a: Parcels enrolled by a uniform subsidy of $92

Figure 2b: Parcels enrolled by the CAB program when $S^{CAB} = $92