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Analysis

Adding realism to the Agglomeration Bonus: How endogenous land returns affect habitat fragmentation

Thadchaigeni Panchalingam[a,1], Chian Jones Ritten[a,*], Jason F. Shogren[b], Mariah D. Ehmke[a], Christopher T. Bastian[a], Gregory M. Parkhurst[a]

[a] Department of Agricultural and Applied Economics, University of Wyoming, 1000 E. University Ave., Laramie, WY 82071, USA
[b] Department of Economics, University of Wyoming, 1000 E. University Ave., Laramie, WY 82071, USA

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ABSTRACT

The Agglomeration Bonus has been shown to be a potentially successful policy to reunite fragmented habitat and increase conservation enrollment in laboratory testbed experiments. Yet, one key criticism has been that land prices have been assumed exogenous and fixed in these experiments. In the field, voluntary conservation enrollment by landowners will likely affect the value of the surrounding land. This endogeneity of land values suggests a discrepancy between results from laboratory experiments and true landowner decisions under a given policy. We address this concern by using an experimental design that accounts for the endogenous effect on surrounding land values from habitat conservation based on estimated returns from an actual landscape in eastern Wyoming as a case study. We show that without incorporating endogenous land values, traditional laboratory experiments likely will underestimate the amount of habitat fragmentation resulting from basic conservation policies without Agglomeration Bonuses. We also find that a low-cost Agglomeration Bonus can work to reunite this fragmented habitat, even under endogenous land value conditions. Our research indicates that through voluntary conservation decisions by private landowners, a more cost effective Bonus scheme can create contiguous habitat across privately held land, even when incorporating realistic endogenous land values.

1. Introduction

Managing landscapes across multiple private landowners is a challenge to biodiversity conservation and management. Fragmented landscapes and ownership call for greater behavior coordination across individuals to improve biodiversity outcomes. Which policy alternatives are most successful at promoting cooperation across landowners when considering ecological spillovers of increased land parcel coordination is an open question. The Agglomeration Bonus (see Parkhurst et al., 2002) was introduced as an incentive system to encourage private landowners to reunite fragmented habitat across property boundaries. The Bonus is a coordinated payment designed to create spatially congruent conservation program enrollments, appropriate to needs of the species of interest (see Parkhurst and Shogren, 2007). Landowners are incentivized to meet targeted conservation through an additional conservation payment earned when voluntary conservation leads to the desired pattern.

Despite laboratory experiments showing that a properly designed Agglomeration Bonus may be an efficient and cost effective policy tool for reuniting fragmented habitat[2] (e.g. Banerjee et al., 2012, 2014, 2017; Drechsler et al., 2010; Parkhurst et al., 2002), questions remain about its ability to incorporate externalities resulting from congruent land parcel enrollment for conservation and biodiversity management. Observers have questioned the Agglomeration Bonus as a conservation policy tool since it has not been tested when possible conservation spillover effects on land values exist (e.g. Armsworth et al., 2006). In

* Corresponding author.
E-mail address: chian.jonesritten@uwyo.edu (C. Jones Ritten).
[1] Present address: Department of Agricultural, Environment, and Development Economics, Ohio State University, 2120 Fyffe Road, Columbus, OH 43210, USA.
[2] Conservation auctions are another mechanism studied regarding landowner decisions to conserve land. Unlike an Agglomeration Bonus, conservation auctions generally are not incentive compatible regarding spatial coordination of habitat since landowners are incentivized to conserve land with the lowest opportunity cost of forgone rents, which may not offer the highest environmental benefit. The government on the other hand, is incentivized to enroll land of the highest environmental quality at the least cost. To make conservation auctions incentive compatible in terms of spatial coordination, studies have shown the need for additional payments (either in the form of increased value for habitat contiguity (e.g. Banerjee et al., 2015) or through a connectivity bonus (Krawczyk et al., 2016)). These additional payments increase the cost to governmental agencies for conserved land, and ultimately reduce the quantity of conservation given a finite policy budget.

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laboratory economic experiments, researchers have assumed given and constant land prices and that conservation decisions on surrounding land do not influence the value of nearby land parcels. Yet, conservation of a parcel will likely affect the value of surrounding land (Drechsler and Watzold, 2009). This endogeneity of land values may lead to a divergence between conservation outcomes predicted from laboratory experiments when land values are assumed constant, and those realized.

The endogenous nature of land values suggests the influence of conservation decisions on surrounding land returns is dependent on the landscape in question. In urban or semi-rural landscapes, conservation may increase the amenities available to surrounding landowners (i.e. open space), which increases the value of the land. In agricultural landscapes, conserved land may offer ecosystem service spillovers that increase the productivity of surrounding agricultural land (i.e. pollination) and land values. Once a land parcel is conserved under existing policies (e.g. CRP), its value is based on the set payment it generates from the policy, and is not impacted by the conservation status of surrounding land. The endogenous influence of conservation only affects the surrounding land that is not conserved.

To model accurately the influence of an Agglomeration Bonus scheme and conservation policies, laboratory experiments must allow for the potential endogeneity of land values along with spatial heterogeneity in the landscape in question. Without increased understanding of the impact of endogenous values created by a proposed policy, prediction of conservation decisions and the resulting spatial outcomes will lack accuracy. Our research objective is to explore the potential impact of land value endogeneity on conservation outcomes where spatially explicit and realistic land returns are interacted with an Agglomeration Bonus policy compared to an existing policy.[3] We use pollinator habitat conservation policy as our motivating example, and we focus on Goshen County, Wyoming to parameterize our experimental design.

Pollinator populations in the U. S. are at risk, implying risks to the country's food system, ecosystem health, and economic welfare. Insect pollination is critical for healthy ecosystems and abundant food.[4] Across North America, insect pollinator populations are dwindling and out of step with agricultural pollinator demands. The gap between pollination supply and demand is expected to increase over the next decade (Aizen and Harder, 2009; Allen-Wardell et al., 1998; Goulson et al., 2015; Spivak et al., 2011). While numerous causes of pollinator decline have been identified, habitat loss and fragmentation are two of the biggest concerns (IPBES, 2016).[5] Fragmented pollinator habitat results in smaller patches that impair the metapopulation structures and recolonization of wild pollinators, particularly for bumble bees (Goulson, 2003). Additionally, there is an increase in domesticated bee colony losses with increased fragmentation of landscapes (Naug, 2009).[6]

Otto et al. (2016) find landowners currently receive greater financial gain from converting pollinator habitat to cropland, leading to habitat loss and fragmentation. As the conversion to cropland continues, the marginal productivity of pollination dependent croplands could decline due to a lack of pollination benefits from surrounding pollinators. Less productivity on one acre creates the incentive to increase cropland conversion to raise total revenues and spread costs over the land (Garibaldi et al., 2014). Policy must create the proper incentives for landowners, or this conversion cycle will continue, further eroding pollinator populations through decreased crop diversity (Kennedy et al., 2013).

The U. S. government offers policies that provide economic incentives to agricultural producers with the goal of mitigating pollinator habitat losses and thereby improving ecosystem support; a top policy objective for pollinator protection (Dicks et al., 2016). The Conservation Reserve Program (CRP) offers subprograms (e.g., CP-25 and CP-42) that pay landowner participants an extra annual payment ($150 per acre) to create pollinator habitat (signing bonuses and cost share are also available) (Farm Service Agency, 2017a,b) by planting specific seed mixes that are known to increase local pollinator numbers. While the CRP is an established tool to encourage biological conservation, the effectiveness of these new pollinator conservation subprograms is an open question. Jones Ritten et al. (2017) show current policy will likely lead to limited enrollment and create even more fragmented pollinator habitat. Through an experiment that mimicked existing CRP programs for pollinator habitat, the authors find that landowners are only incentivized to enroll lower-value land that is likely distributed across the landscape, creating low enrollment and high fragmentation. To address both of these concerns, they recommend investigating alternative policy schemes such as the Agglomeration Bonus to overcome pollinator habitat loss and fragmentation.

Analysis of an Agglomeration Bonus scheme assuming fixed and exogenous land returns is likely to provide a less relevant prediction of protection for pollinator habitat than might be the case for other species. Pollinators can increase yields for pollinator-dependent crops both in nesting and surrounding areas. This implies conserved pollinator habitat benefits pollinator-dependent crop production both in the direct habitat area and in surrounding areas (Garibaldi et al., 2016; Pywell et al., 2015). A neighbor bordering conserved pollinator habitat benefits as their non-conserved, pollinator-dependent crop productivity increases, ultimately increasing land returns.[7] Such a neighbor benefits from this positive externality and has less incentive to conserve habitat. This implies we need to understand how endogenous land returns impacts the efficacy of the Agglomeration Bonus as a policy tool.

Given the absence of actual land-use decision data under an Agglomeration Bonus policy, we use experimental methods to address our research question. Economists use experimental methods for three reasons – to test theory, to look for patterns, and to testbed new mechanisms designed for efficient resource allocation. In our case, we use the experimental method as a testbed (see Plott, 1994)—we want to examine the robustness of the Agglomeration Bonus given endogenous land prices. Since the Agglomeration Bonus has just begun to be implemented in the real world, we do not know how well the Bonus works given active land markets. The world is void of data to understand the potential limits of a Bonus in the field. The experimental method allows us to understand better the behavioral underpinnings and efficiency outcomes when using this novel mechanism under more realistic land

[3] We employ the Agglomeration Bonus to the existing uniform payment policy scheme currently used for pollinator habitat to make the experiment incentive compatible regarding spatial coordination. Due to the nature of existing policy, the use of an Agglomeration Bonus is more suitable than a conservation auction. To improve cost efficiency of the Agglomeration Bonus, we use a relatively low cost Bonus given an assumption of a limited government budget. The current Bonus is set at 10% of the average productive value of land. Previous studies have mainly used Bonuses that are multiple times the value of land (e.g. Parkhurst and Shogren, 2008). In conservation auctions, Krawczyk et al. (2016) includes a connectivity bonus of 50–100% of the value of land to achieve spatial coordination.

[4] Estimates of the global value of pollination services are between $235 and $577 billion annually (Gallai et al., 2009), and between $13.7 and $17.4 billion in the US (in 2017 USD), when adjusted for inflation (Federal Reserve Economic Data, 2017; Calderone, 2012; Marthinsen, 2015).

[5] Other causes of pollinator decline include threats from parasites and pathogens, floral resource decline due to herbicides, increased pesticide use (especially neonicotinoids), increased agricultural production, and climate change (Breeze et al., 2014; Calderone, 2012; Goulson et al., 2015; Kjøhl et al., 2011).

[6] Different insect species may have different habitat needs. For instance, a configuration of increased spatial connectivity is not optimal for insect pest management (e.g. see Zhang et al., 2010).

[7] Additional non-market benefits, such as existence value, may also create benefits but are not addressed in this research.

returns scenarios. The experimental results represent real evidence of decisions under a simulated economic environment (see Bohm, 2003; Shogren, 1993, 2005). This, in turn, may provide guidance (within reason) to understand the benefits and pitfalls of Bonus implementation in the field.

To achieve our research objective, our experimental design uses landscape level estimates of crop returns to simulate more realistic and spatially explicit incentives, including endogeneity of land returns from pollinator-dependent crops using Goshen County in Wyoming as a case study. Spatial heterogeneity associated with land characteristics, and the related returns from agricultural activity, impact landowner conservation decisions as they weigh added benefits from conservation and policy incentives versus potential reductions in returns (Rashford et al., 2010). This ultimately affects spatial patterns of conservation and related impacts on target species (Rashford et al., 2011).[8] Accurately accounting for spatial heterogeneity is critical to understand and predict landowner conservation decisions under current policy incentives and with the addition of an Agglomeration Bonus to create quality habitat. Following Fooks et al. (2016), we further address realism by testing a bonus scheme that assumes a constrained CRP budget.[9] We show that ignoring the endogenous nature of conservation on land values will likely underestimate the resulting fragmentation of habitats from traditional conservation policies. Our research indicates that through voluntary decisions by private landowners, a Bonus scheme that is modest in cost can create contiguous habitat across privately held land, even when incorporating land value endogeneity and spatial variation inherently impacting agricultural production and land use decisions.

2. Materials and methods

As data of enrollment under current pollinator policies and the inclusion of an Agglomeration Bonus are not available, we collected data from induced value experiments similarly structured to those conducted by Parkhurst and Shogren (2007, 2008). This methodology was chosen since it has been shown to capture expected landowner decisions under a landscape similar to that used in the current study.

2.1. Experimental procedures and treatments

Following standard experimental protocol and procedures (see e.g., Friedman and Sunder, 1994), the experiment was not context-loaded: participants were unaware of the specific context of land conservation for pollinator habitat. Participants were informed that they would be presented with a grid of cell values, and that they would be making decisions on which cells to cross out (see Appendix for experimental instructions).

[8] The spatial patterns of habitat may be of particular importance to pollinators. Insects such as the western honey bee (*Apis mellifera*) may forage over several miles of land, while other native pollinators, especially bumble bee species, require floral resources within a few hundred feet of their nest for adequate nutrition and fitness (Cusser and Goodell, 2013; Klein et al., 2012).

[9] Like many federal programs, CRP and its subprograms have limited budgets to fund landowner conservation programs. Many previous Agglomeration Bonus studies have incorporated this budget by limiting the amount of land that can be enrolled into conservation programs in the lab (e.g. Parkhurst and Shogren, 2008). With this upper bound set on conservation, these studies have included Agglomeration Bonus payments that range between 167% and 500% of the base conservation payment. This method does not represent current CRP subprogram policy, where the number of acres a landowner can enroll in CRP pollinator habitat conservation programs is not limited. A more realistic Agglomeration Bonus needs to be much smaller to account for CRP's limited budget, while still allowing a full range of habitat conservation. Further, a conservation auction is not utilized, as the CRP subprograms modeled here use a uniform payment scheme.

A total of 156 participants volunteered to participate. Upon starting their participation in the experiment, volunteer subject were randomly selected into one of four treatments. In all treatments, the timing of the experiment was as follows:

1. Participants volunteered to partake after a recruitment e-mail was sent to community members surrounding a Land Grant University. Participants from all demographic and socioeconomic statuses were included in the experiment. Research suggests this is appropriate for induced value experiments. A review of literature comparing various experiments testing differences across subject pools concludes that outcomes across different subject pools are generally consistent (Frechette, 2015). Further, Nagler et al. (2013) find similar behavior in induced value experiments between student and non-student samples. Different subjects were recruited for each experimental session reducing potential biases, such as order effects during analyses (Charness et al., 2012).[10]
2. At the beginning of each session, participants were given an information packet that included a copy of printed instructions, a sheet describing payments from crossing a cell out (to mimic conservation and any Agglomeration payments) specific to the treatment of interest, a record sheet to record earnings, and a receipt for payment. Participants were asked to read and sign a human subjects' consent form that followed standard experiment protocol. The University Institutional Review Board approved the experimental procedures. Upon completion of the consent form, the researcher presented experiment instructions while participants could follow along in the printed instructions provided. As part of the instructions, a hypothetical cell grid (to mimic land values), payoff structure, and specific incentives for the particular session treatment were discussed. Once the instructions were presented, participants were allowed to ask questions.
3. Three practice rounds were conducted on the computer before the actual rounds. Participants were informed that the cell and enrollment (described as a "cell you choose to cross out" in the instructions) values in the practice rounds were different from those of the actual experiment, preventing participants forming expectations based on practice rounds.
4. After the practice rounds, the rounds of the experiment began. Each session consisted of at least 10 rounds to achieve equilibrium behavior, with 4 participants per cell grid that were randomly assigned to a sub-grid. Participants were informed that the experimental session had a random number of rounds to avoid end-game-effects (Nagler et al., 2013).
5. Each participant made decisions about which cells to cross out (representing enrollment) from a spatially explicit grid of 100 cells (representing land units). Each participant (landowner) was randomly assigned one of 4 5×5 grids representing 25 cells during an experimental session. A participant saw his or her 5×5 sub-grid in a dark green color on the computer screen and was able to determine his or her position in relation to the other participants. Each cell had a number listed within it, which was known to the participant to be the value of that cell, prior to any additional treatment payments. The grid positions for all participants were constant for all rounds to allow for repeated interactions among the same participants. Participants had access to an on-screen calculator to select different configurations of cells and determine the estimated total payoffs before actual choices were submitted.
6. A chat window appeared at the bottom of the screen to allow

[10] Some have criticized the use of subjects such as students or any non-agricultural landowners. Nagler et al. (2013), for instance, conduct induced value laboratory market experiments with both college students and agricultural professionals and find no statistical difference in policy treatment effects or market outcomes between the two subject pools.

participants to communicate with one another to coordinate decisions. Communication was designed to recreate real-life situations in which landowners can communicate with each other regarding policy implementation. Previous studies have shown that communication facilitates coordination (e.g. Banerjee et al., 2014).
7. Each participant had 3 min to make a decision and submit his or her choice of which cells were to be crossed out per round. Participants could view the time remaining on their computer screen. If a participant ran out of time, the computer submitted the choices for him or her based on the configuration of cells crossed out on the computer at the moment time lapsed. In case a participant had not chosen any cells to cross out by the end of a round, the computer submitted the choice with no crossed-out cells. A history box appeared that displayed a record of the cells that each participant in the group crossed out in previous rounds.
8. Participants earned a currency called tokens based on the decisions made in the experiment. Each token earned was worth 1 cent (100 tokens = $1.00) and accumulated over the rounds. Participants were paid in cash at the end of the experiment based on their cumulative tokens earned.

We designed 4 treatments based on a 2 × 2 design: with endogenous or exogenous land values and without or with the Agglomeration Bonus. Each treatment had at least 8 replications (i.e. sessions), each with 4 participants, for a total of 156 participants. Participants were presented with a 10 × 10 block grid with each cell corresponding to a specific payout. In each round, participants could either choose to leave the cell active (leave in production) and earn the payout listed, or could cross out (conserve) that cell and earn a known conservation payment. Each replication lasted 10 rounds. We used a software program based on that from Parkhurst and Shogren (2008) to run the experiments.

The baseline treatment (*Endogenous Land Values – No Agglomeration Bonus*, referred to as *Endogenous – No AB*) captures the incentives faced by landowners considering enrollment in current CRP subprograms. When crossing out a cell, a participant forgoes that cell's listed value and earns the basic payment for crossing out a cell. The value received for crossing out a cell was based on the net present value of the actual CRP incentive program. Any non-crossed-out cell earned the payout listed for that given cell, which was based on the estimated crop returns for the land parcel represented by the cell, as described below. In addition, if a non-crossed-out cell (S) was next to (either shared a border or was directly diagonal) a crossed-out cell (C), then the non-crossed-out cell (S) received an additional payment (see Fig. 1). This increase in payment in the experiment represented the estimated increase in productive value that the non-conserved land would have from surrounding conserved land in the case study area of Wyoming (i.e. the increase in agricultural production returns due to nearby pollinators from pollinator habitat creation). This aspect mimicked the endogeneity of returns for non-conserved parcels to conservation decisions. As this baseline treatment includes endogenous land values, it is expected to generate results that mimic conservation outcomes in the real world.

The *Exogenous Land Value – No Agglomeration Bonus* (*Exogenous – No AB*) treatment was similar to the baseline treatment, yet participants only earned the basic payment that was given for each cell, independent of surrounding cell choices (to mimic exogenous land values, i.e., ignoring endogeneity). No additional payments were available. When crossing out a cell, a participant forgoes that cell's listed value and earns the basic payment for crossing out a cell (payment based on the net present value of the actual CRP incentive program).

The *Endogenous Land Value – Agglomeration Bonus* (*Endogenous – AB*) treatment introduces the Agglomeration Bonus to the *Endogenous – No AB* treatment. Following Fooks et al. (2016) we set the Agglomeration Bonus at a modest level of 10% of the average production value in the land grid. The Agglomeration Bonus rewarded participants whenever a

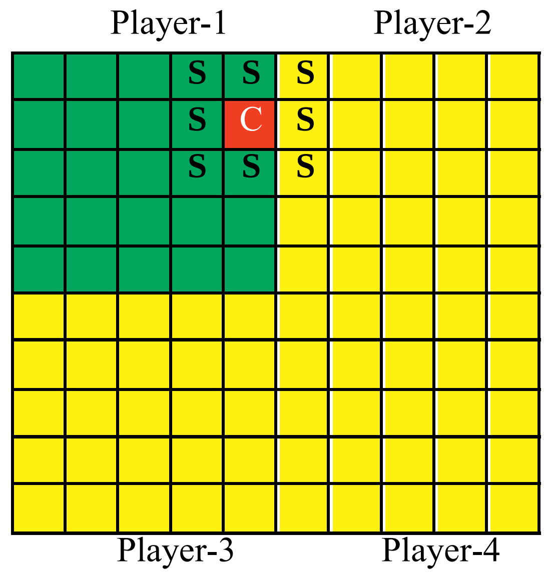

Fig. 1. Experimental representation of the endogenous land value effect on non-conserved land parcels (S) surrounding a conserved parcel (C).

crossed-out cell shared a row or column border with another of his or her crossed-out cells or another participant's crossed-out cells (Parkhurst and Shogren, 2007, 2008). Two adjacent crossed-out cells that are diagonal to each other do not receive the Agglomeration Bonus.

The *Exogenous Land Value – Agglomeration Bonus* (*Exogenous – AB*) added the Agglomeration Bonus to the *Exogenous – No AB* treatment. This treatment allows us to isolate the impact of the Agglomeration Bonus absent endogeneity to evaluate the Agglomeration Bonus's interaction and related performance with the presence of endogenous land values.

2.2. Land returns and grid cell values

The experimental grid is modeled after pollinator habitat conservation under CRP subprograms CP-25 and CP-42. Since landowner decisions in the real world should be based on land values and returns, the experimental land grid is based on a real landscape. We utilize cropping practices and rotations using aerial images of cropping patterns in Goshen County, Wyoming, in 2012 (in eastern Wyoming near the Nebraska-Wyoming state line: see Fig. 2). Although the vast majority of Goshen County is grass or pastureland, crop production is prevalent near the North Platte River. Fig. 2 details the cover and pattern of crops included in the study. The area is typical of Western Great Plains agriculture, a target landscape for pollinator conservation (Otto et al., 2016).

Goshen County has the highest total value of agricultural products sold in Wyoming, including both crops and livestock (U.S. Department of Agriculture, 2014). The County includes cultivation of a variety of crops in 536 farms consisting of 241,491 acres (U.S. Department of Agriculture, 2014). Each 5 × 5 sub-grid in the experiment is representative of 2000 acres of land, which is close to 1735 acres—the average size of a farm in the County (U.S. Department of Agriculture, 2014). Each cell in the experimental grid equates to 80 acres. Since the case study focuses on conservation decisions under CRP subprograms that have 10-year enrollment periods, the associated value listed in each cell represented the net present value of profits of representative crop production over a 10-year horizon for different crop rotations practiced in the County converted to 2012 dollars. These values were based on published statistics from the USDA regarding crops produced (U.S. Department of Agriculture, 2014), crop budgets representative of the area (University of Nebraska-Lincoln, 2013), and reported research

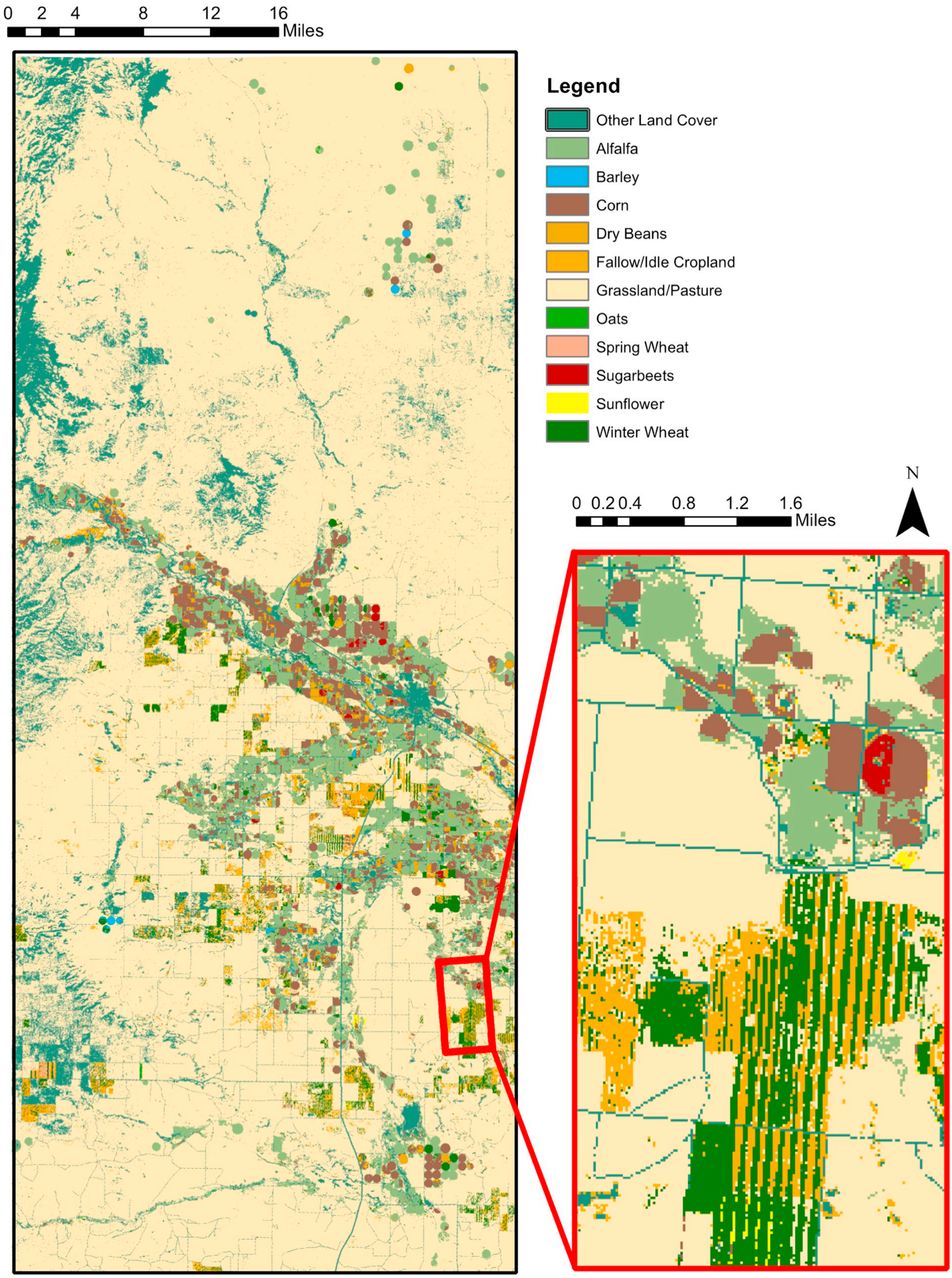

Fig. 2. 2012 Land cover map of Goshen County, WY (including detailed section).
Source: USDA NASS; Cropland Data Layer (https://nassgeodata.gmu.edu/CropScape/).

on practiced crop rotations for the area (Lee et al., 2014, 2015), while allowing for variations in crop productivity as described by Lee et al. (2015). The cell values given in the experiment are shown in Fig. 3.

The estimated net present values representing a 10-year horizon for each representative 80 acres were then divided by 1000 to give cell values reasonable scale during the experiment (Fig. 3). We assigned values to each cell in the experimental grid based on their associated crop rotation's calculated frequency in Goshen County. We assigned the

Player 1 Player 2

1	1	1	1	1	22	22	22	22	22
28	28	28	28	28	22	22	22	22	22
21	28	28	28	26	28	22	21	21	21
21	21	21	21	21	7	21	21	16	16
23	23	23	1	1	7	10	21	18	21
21	44	23	7	1	1	2	10	21	21
21	35	32	1	1	1	2	21	21	21
21	35	23	21	1	1	24	24	21	21
21	23	23	21	23	1	21	2	21	21
21	21	21	23	23	1	21	21	21	21

Player 3 Player 4

Fig. 3. Experimental grid with cell values.

cells with similar values clumped together while assuring that all four sub-grids got both high and low productive cell values. Within a sub-grid, we assigned some cells with low values along the common borders as we made the assumption that landowners would want to own the most profitable acres and that marginal lands would fall along the borders.[11]

Each non-crossed-out cell in the experiment earned the cell value representing the productive value of that land parcel. Each crossed-out cell earned a set value, which was based on the net present value of conservation in CRP pollinator subprograms. In the CRP pollinator programs, each acre of enrolled land receives a $150 enrollment payment in addition to CRP yearly payments (Farm Service Agency, 2013). Within the study region of Wyoming, the average yearly payment of enrolled CRP land was $26 per acre in 2013 (U.S. Department of Agriculture, 2014). The net present value of these payments over a 10-year frame was scaled down by the same factor as the productive values to create the base conservation payment in the experiment (4 tokens per crossed-out cell).

The presence of pollinators increases the productivity of many, but not all, crops within the study area. Given crop rotations in Goshen County, Wyoming, average yield levels would likely see reductions of 5% at the grid level without the presence of pollinators, and landowners may have to pay for commercial beekeepers to recoup this loss.[12] The crops that benefit from insect pollination within the County are alfalfa seed, sunflowers, and dry beans. On average, alfalfa seed production increases by 225–600 pounds per acre as a direct result of bees (Mueller, 1995). Dry beans show a 10% reduction in total production in the absence of insect pollinators, whereas sunflowers show 10 to 40% reduction in total production in the absence of pollinators (Klein et al., 2007). Wild pollinators have different habitat ranges; bumble bees have one of the shortest, with a foraging range of 50 to 100 m (Couvillon et al., 2014; Kluser and Peduzzi, 2007). A conservative estimate is an endogenous increase of 5% of discounted returns to productive land directly surrounding conserved land with quality pollinator habitat. In the experiment, this endogeneity was represented by a one token payment that was earned by each non-crossed-out cell (S) that was immediately adjacent to a crossed-out cell (C) (see Fig. 1) in the endogenous land value treatments.

2.3. Data analyses

Data include the cells crossed out, the payoffs earned, and the breakdown of payoffs into production payoffs (the discounted returns earned from not crossing cells out) and payoffs from conservation (that earned from crossing cells out). Based on these data, we focus on the number of cells crossed out by the group of four participants and the number of common borders of crossed-out cells in each round to gain an understanding of conservation and fragmentation of pollinator habitat in the real world. Since we are focusing on the efficacy in terms of amount and contiguity of conservation from CRP subprograms at the landscape level in equilibrium, we conducted all analyses by experimental session groups and not by individual participants. We examined the data via a convergence model. Following Ashenfelter et al. (1992) and Noussair et al. (1995), we estimated the general convergence model (1) to describe the data and allow for statistical comparison:

$$Z_{it} = B_0[(t-1)/t] + B_1(1/t) + \sum_{j=1}^{i-1} \alpha_j D_j[(t-1)/t] + \sum_{j=1}^{i-1} \beta_j D_j(1/t) + u_{it}, \tag{1}$$

where Z_{it} is the dependent variable of interest. We estimate Z_{it} for each of the following dependent variables: total number of cells crossed out by the group (to estimate amount of conservation), the total number of common borders between crossed-out cells by the group (to estimate fragmentation), and agency costs for conservation outcomes across replications for each of t rounds (1, …, 10) in cross section, j (where the number of treatments is equal to i); B_0 is the predicted asymptote and B_1 is the starting level of the dependent variable for the base treatment; α and β are adjustments to the asymptote and starting level for each treatment's relation to the base; D_j is a dummy variable separating j treatments; and u_{it} is an error term.

The convergence model analysis estimates converged values of equilibrium outcomes across treatments and has been used in similar research (see Parkhurst et al., 2004). The asymptote estimates weight the impact of later observations more heavily than early observations for the variable of interest. We can then use the asymptote parameter estimates, representing observed equilibrium values, to test for differences across treatments for the variables of interest.

We used the Parks method (Parks, 1967; SAS, 2008) to estimate the convergence model as it accounts for unique statistical issues of heteroscedasticity, contemporaneous correlation, and serial correlation found in econometric analyses of panel data sets. Since t-tests used to infer differences between convergence estimates assumes a normally distributed sample (Neter et al., 1985), the distribution of residuals for each analyzed outcome was tested using a Shapiro-Wilk test for normal distribution of residuals. When normality is rejected, we report the average outcome over the final five rounds of each treatment and a non-parametric Wilcoxon test to infer differences between treatments.

3. Results

The four treatments in this study are used to test the effectiveness (in terms of amount, contiguity, and fragmentation of conserved land) of adding the low cost Agglomeration Bonus to the existing policy payment and the implications of assuming exogenous instead of endogenous land values. Previous literature suggests a minimum of eight sessions or replications per treatment are necessary to measure the impact of an Agglomeration Bonus policy (e.g. Banerjee et al., 2012). In order to attain randomization, each experimental session was randomly assigned one of the four treatments until each treatment had at least eight sessions. As a result, the number of sessions per treatment varied based on this randomization. A total of 39 sessions were conducted with a total of 156 participants (see Table 1). The randomization of treatments led to the

[11] These assumptions are based off of land patterns in Goshen County and conversations with the County's Extension Crop Specialist.

[12] As noted by Rucker et al. (2012), honey bees are a substitute for wild pollinators that are coordinated by market prices.

Table 1
Number of sessions and participants per treatment.

Treatment	Number of session	Number of participants
Endogenous – No AB	11	44
Endogenous – AB	10	40
Exogenous – No AB	8	32
Exogenous – AB	10	40

Table 2
Convergence model estimates of the amount and contiguity of crossed-out cells across treatments (estimates reported in percentage terms).

Treatment	Percent of Cells Crossed Out	Percent of Full Contiguity
Endogenous – No AB	16.66[a]	7.38[a]
Endogenous – AB	20.06[b]	13.06[b]
Exogenous – No AB	16.00[a]	8.89[c]
Exogenous – AB	19.10[b]	12.01[b]

[a–c]Different superscript letters (a–c) assigned to reported values within a column indicate pairwise significant difference between treatments at the 1% significance level. If any two values in a column have the same letter, then these values are not statistically different from one another. If any two values in a column have different letters, then these two values are statistically different from each other at the 1% significance level.

baseline treatment (*Endogenous – No AB*) having 11 sessions, the *Exogenous – No AB* treatment having 8 sessions, and the *Endogenous – AB* and the *Exogenous – AB* treatments having 10 sessions each.

3.1. Result 1: in the absence of Agglomeration Bonuses, assuming exogenous land values is found to underestimate resulting habitat fragmentation

Under the *Endogenous – No AB* treatment, modeling the existing payments under CRP subprograms, and cell values are endogenous, 16.66% of the cells in the grid are crossed out by participants (*Endogenous – No AB*; Table 2). When the existing payments under CRP subprograms are the only policy available to landowners, and land values are assumed to be endogenous, 16.66% of CRP-eligible land is expected to be conserved. There is no statistically significant change in the total amount of crossed-out cells for the *Exogenous – No AB* treatment (16% of cells), suggesting that the land value assumption used in modeling does not influence the results in terms of the amount of land area conserved.

The assumption of land values is expected, however, to affect the estimated pattern of conservation. Between the *Endogenous – No AB* and the *Exogenous – No AB* treatments, there is a 12.5% change in the pattern of crossed-out cells (a change in 2 of the 16 crossed-out cells). Considering the endogenous increase in returns to non-conserved land directly surrounding conserved land, landowners are incentivized to fragment conserved parcels in order to maximize benefits to surrounding non-conserved parcels. As a result, there is significantly ($p < 0.01$) less contiguity between crossed-out cells in the *Endogenous – No AB* treatment than in the *Exogenous – No AB* treatment (7.38% and 8.89%, respectively: Table 2). These results are similar to those found by Drechsler and Watzold (2009) regarding spatial interaction incentives and conservation outcomes.

Results implicate that models estimating conservation decisions that ignore the endogenous nature of land values may accurately estimate the amount of conserved acreage but will likely underestimate the resulting fragmentation of that conservation.

3.2. Result 2: including an Agglomeration Bonus increases conservation and reduces habitat fragmentation and is robust over endogenous and exogenous land values

Previous research indicates that including an Agglomeration Bonus that rewards landowners when a conserved land parcel shares a row or column border with another conserved parcel increases the amount of conservation (Banerjee et al., 2012; Parkhurst et al., 2002; Parkhurst and Shogren, 2005, 2007). Our results support these findings when expanding the context to pollinator habitat conservation and the related issue of land value endogeneity.

Under the treatments that use endogenous land values, the amount of cells crossed out significantly ($p < 0.01$) increases by 20% when adding the Agglomeration Bonus (Table 2). In the *Endogenous – No AB* treatment, convergence model results indicate over 16% of cells were crossed out, suggesting that 16% of CRP-eligible land is expected to be conserved for pollinator habitat under CRP programs. The amount of crossed-out cells increases to over 20% in the *Endogenous – AB* treatment. A similar result is found in the treatments with exogenous values: the addition of the Agglomeration Bonus significantly ($p < 0.01$) increases the amount of cells crossed out by over 19% (Table 2). The addition of the Agglomeration Bonus to the existing CRP is expected to increase conservation by nearly 20%. In addition, the number of crossed-out cells is not statistically ($p < 0.10$) different across endogeneity assumptions, suggesting that our results are robust across endogenous and exogenous land values.

The amount of contiguity (as measured in the number of common borders between crossed-out cells in the experiment) is also expected to increase with the Agglomeration Bonus, and is likely robust over land value assumptions. In the endogenous treatments, adding the Agglomeration Bonus increased contiguity of crossed-out cells significantly by nearly 77%. The *Endogenous – No AB* treatment resulted in only 7.38% of full contiguity reached (i.e., only 13.28 common borders between crossed-out cells, compared to the 180 possible common borders) compared to 13.06% of full contiguity reached in the *Endogenous – AB* treatment (Table 2).

When land values are assumed exogenous, the inclusion of the Agglomeration Bonus is expected to increase conservation contiguity by over 35% (percent of contiguity increased from 8.89% in the *Exogenous – No AB* treatment to 12.01% in the *Exogenous – AB* treatment) (Table 2). Although there is a large percentage difference in the change of contiguity when adding the Agglomeration Bonus between the endogenous and exogenous treatments (77% compared to 35%), there is no significant difference found. The expected reduction in habitat fragmentation resulting from the Agglomeration Bonus is robust over land value assumptions.

3.3. Result 3: ignoring the endogenous nature of land values can lead to inaccurate estimates of policy costs

The cost of any conservation policy is important to governmental agencies. Under current pollinator habitat policy, the cost to the agency is estimated to average over $266 per acre (Table 3). If the endogenous nature of land values is ignored, the estimated cost to the agency will be underestimated by over $10 per acre (comparing the *Endogenous – No AB* and *Exogenous – No AB* treatments in Table 3). Not addressing endogenous land values is likely to underestimate the true cost of traditional conservation policies that use a uniform payment scheme.

The addition of an Agglomeration Bonus likely increases the cost to the agency. With our Bonus of 10% of the average productive value of the land, the Bonus increases costs by 185% and 172% to the basic conservation program with endogenous and exogenous land values, respectively (Table 3). This increase in cost is of a smaller magnitude to previous Agglomeration Bonuses employed in the literature,[13] suggesting that reduced fragmentation can be achieved even with more modest bonus levels.

When focusing on the additional cost of an Agglomeration Bonus to reduce habitat fragmentation, ignoring land value endogeneity will likely lead to an overestimate of the cost of adding an Agglomeration

[13] For comparison, the addition of the Agglomeration Bonus used by Parkhurst et al. (2002) increased costs by nearly 400% to get a coordinated habitat outcome.

Table 3
Convergence model estimates of average cost to agency per acre across and between treatments (over 10-year period).

Treatment	Cost ($)	Additional cost of Agglomeration Bonus (percent increase)
Endogenous – No AB	266.49	493.67 (185%)
Endogenous – AB	760.16	
Exogenous – No AB	255.91	440.24 (172%)
Exogenous – AB	696.15	

Table 4
Change in Cost to Agency of an additional common border from including an Agglomeration Bonus.

Treatment	Change in # of borders	Cost of additional border ($)
Endogenous - No AB v. Endogenous - AB	10.03	49.22
Exogenous - No AB v. Exogenous - AB	5.62	78.34

Bonus to the existing conservation policy. For each additional common border that an acre gains from an Agglomeration Bonus, an agency is expected to see an average increased cost of $49 (Table 4). When land values are assumed exogenous, the additional cost per common border gained from the Agglomeration Bonus is estimated to be over $78. As policy makers balance the costs and benefits of any conservation policy, incorporating the endogenous nature of land values is vital to accurate policy cost estimates, and effective policy implementation.

4. Discussion

These results suggest that conservation policies need to address land heterogeneity and value endogeneity realities to estimate their effectiveness at reducing habitat fragmentation. The addition of an Agglomeration Bonus can help reduce such fragmentation. The experimental setting in which the Agglomeration Bonus has been previously tested has not fully accounted for the endogeneity of land values to conservation decisions. These results inform the Agglomeration Bonus literature, encouraging analysts to account for landowner incentives from altered land values from surrounding conservation. We use pollinator habitat as a motivating example to test the influence of endogenous land values on habitat conservation and fragmentation.

The results reveal that in the case of pollinator habitat conservation under CRP subprograms, models assuming exogenous and fixed land values, may severely underestimate the contiguity of conserved land. Yet, the inclusion of a modest Agglomeration Bonus can significantly increase not only the amount of land conserved, but can also decrease the fragmentation of that land, regardless of the land value assumption. Given the biological needs of various wild pollinators, cross-boundary habitats with proximity to each other are preferred over fragmented habitats (Goldman et al., 2007; Vanbergen and The Insect Pollinators Initiative, 2013). A successful policy must increase the quantity and reduce the fragmentation of habitat to support a rebound of pollinator species (IPBES, 2016). Our results suggest that a policy void of an Agglomeration Bonus incentive will likely lead to lower acreage of habitat conservation—and these acres will likely be highly fragmented given endogenous benefits to landowners from such conservation. Adding the low cost Agglomeration Bonus will serve both purposes—increasing the amount of pollinator habitat while reducing the fragmentation of land conservation and maintain reduced costs.

Effective policy must also correctly incentivize landowners to voluntarily conserve private land (Dicks et al., 2016). The spatial heterogeneity of the landscape faced by landowners affects the resulting amount and fragmentation of habitat conservation under existing policies. Variations in the spatial value or returns to land will lead to divergent conservation practices (Rashford et al., 2011). Previous experimental studies have not examined more realistic spatial patterns, limiting the extrapolation of their laboratory results to the field. By using a land pattern modeled after a real landscape, our laboratory results offer the potential of increased accuracy in modeling landowner incentives and predicting conservation decisions in the field. Our results suggest ignoring such realism increases allocative inefficiencies of such policies.

Since different landscapes will have varying endogenous land value effects from surrounding conserved land, the relative magnitude of the Agglomeration Bonus to the endogenous effect will differ from that presented here. The relative value of the Agglomeration Bonus to the endogenous effect of conservation to surrounding non-conserved land has far reaching policy implications. When the endogenous effect is relatively small, a modest Agglomeration Bonus's incentive to create contiguous conservation likely will outweigh the endogenous benefit's incentive for fragmentation. But when the endogenous effect is large, only a relatively large Agglomeration Bonus will lead to reduced habitat fragmentation. Given the limited budget for most conservation programs, in landscapes with large conservation benefits to surrounding land, an affordable Agglomeration Bonus may be outweighed by endogenous land values, leading to significant conservation fragmentation. Successful programs should address the endogenous effect of conservation on surrounding land values and the specific spatial heterogeneity of landscapes in order to accurately predict conservation outcomes and to determine if an Agglomeration Bonus will achieve biodiversity and habitat goals.

5. Conclusions

The need for realistic models of land value endogeneity and land returns in laboratory experiments is vital when assessing the effectiveness of an Agglomeration Bonus incentive mechanism. Our results imply that in the absence of an Agglomeration Bonus, policies that do not account for the realistic endogenous nature of conservation and land returns will likely fail to achieve desired reduction in habitat fragmentation. Similar to Armsworth et al. (2006), our results suggest that if a model does not incorporate endogenous land value or returns, the results will overestimate the contiguity of conserved land.

Our results further show that adding an Agglomeration Bonus, even one that is relatively modest, will not only likely increase overall conservation, but will also decrease the fragmentation of that habitat. These positive changes to conservation under an Agglomeration Bonus scheme are found to be robust over endogenous and exogenous land value assumptions.

In the case study area used, the relative value of the Agglomeration Bonus is greater than the relative value of accounting for endogenous land values. In landscapes dominated by agricultural production (similar to the landscape in this experiment) the increase in land rents from surrounding conserved land is likely modest, and the Agglomeration Bonus dominates this endogenous effect. But in more urban landscapes where open space is a highly valued attribute, the effect of conservation on surrounding land value will most likely outweigh the influence of a modest Agglomeration Bonus. Evaluating the influence of an Agglomeration Bonus in these settings is necessary to further understand the robustness of our results across landscapes. Finally, we appreciate that additional factors can affect land values and influence landowner conservation decisions.

In conclusion, economists use laboratory experiments to predict how new and existing policies will affect landowners' decisions to enroll their land under voluntary conservation programs. Previous experimental explorations of the Agglomeration Bonus have been rightly criticized for assuming fixed land prices. Herein our research addresses this concern by modeling the endogeneity of conservation decisions on surrounding land values. Our results point to the importance of accounting for the incentives landowners realistically face when making conservation decisions when designing a robust Agglomeration Bonus scheme. Lack of attention to such details could easily reduce policy efficacy.

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Declaration of Competing Interest

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Appendix A. Supplementary data

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