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Conserving Spatially Explicit Benefits in Ecosystem Service Markets:

Lab and Artefactual Field Tests of Network Bonuses and Spatial Targeting

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Abstract

Conserving contiguous areas often enhances environmental benefits. However, most conservation efforts are voluntary, incentive-based, do not reward landowners for contiguity, or select based on contiguity. Thus, achieving optimal contiguity of conserved parcels is unlikely especially with limited budgets. Using laboratory and artefactual field experiments, this paper evaluates two mechanisms in the context of reverse auctions for achieving optimal contiguity: network bonuses and spatial targeting. Results suggest that spatial targeting alone improves the aggregate environmental and social welfare outcomes while network bonuses alone result in worse outcomes. The interaction of the bonus-effect and the targeting-effect is positive, suggesting that in a competitive auction environment that already includes bonuses, adding spatial targeting minimizes the damage.

Conserving Spatially Explicit Benefits in Ecosystem Service Markets: Lab and Artefactual Field Tests of Network Bonuses and Spatial Targeting

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Introduction

The environmental benefits obtained by conservation programs often depend on the spatial pattern of enrollment. For example, enrolling an agglomerated block of land parcels may yield better wildlife habitat than the same acreage in a scattershot spread across the landscape; or more riparian buffers along one stream may reduce nutrients entering the watershed more than the same number of acres on four streams. Contiguity and hotspots (areas with high marginal conservation benefits) are two spatial configurations that are highly valued in the literature on conservation.[1] While contiguity may be desirable from a conservation perspective, achieving it can be difficult without optimal contiguity incentives and given the voluntary nature of most conservation programs and ecosystem markets.[2] With an increasing emphasis on using markets to improve cost effectiveness, it is possible that protected areas may become even more spatially scattered if markets are designed without the proper incentives (Wu and Skelton 2002, Wu and Boggess 1999).

This paper is rationalized by a failure in the literature to provide definitive guidance on how best to achieve contiguity in a reverse auction for ecosystem services. We argue that the failure arises from confounding two subtlety different approaches: network bonuses and spatial targeting. We disentangle the two approaches and then reframe contiguity policy as an experiment with four

[1] Hotspots are areas with endangered, threatened and/or diversified flora or fauna. There are many hotspots at the local level. Critical habitat or habitat of special concern is an example of such hotspots. A hotspot can also be area around a watershed that is critical to the quality of water but vulnerable to human activities.

[2] Examples include the Conservation Reserve Program and the Environmental Quality Incentives Program in the U.S., the Eco-Tender and Auction for Landscape Recover program in Australia, and the Challenge Fund Scheme in the U.K.

possible combinations (see Table 1): (1) policy with or without network bonus-induced coordination; and (2) policy with or without spatial targeting through mathematical programming. A network bonus is a side-payment—a payment offered in addition to the baseline contract payment—which is only paid when contiguous land is enrolled. Spatial targeting provides the government a means to select contiguous parcels over non-contiguous parcels when enrollment is budget-constrained. Bonuses reward landowners for the additional marginal benefits contiguity provides, thus avoiding under-provision. Targeting strategies, on the other hand, ensure that the program administrators appropriately represent society's preferences in their purchase decisions—without taking these preferences into account, the demand for the spatial externality is underrepresented.

Habitat fragmentation has been widely discussed by scientists and is considered to be the key pressure on biodiversity loss (Opdam and Wascher 2004). Targeting land that would deliver more cumulative benefit significantly improves the efficiency level of conservation efforts in the presence of threshold effects. For instance, Lamberson, McKelvey, Noon, and Voss (1992) found that the spatial pattern of habitat mattered for the Northern Spotted Owl's viability, while Wu, Adams, and Boggess (2000) found temperature threshold effects were important to consider when designing stream-shading programs to preserve steelhead trout. The literature on conservation-practice complementarities is vast and arises from several disciplines (Saunders et al. (1991) offers a seminal paper in the conservation biology literature). This literature includes economists, who have contributed to policy analysis (e.g. Wu and Skelton 2001, Parkhurst and Shogren 2008, Lewis, et al. 2009). Lynch and Carpenter 2003 address the economics of contiguity/fragmentation in the case of land preservation. Economic studies largely examine the cost effectiveness of policies in light of contiguity. For instance, Drechsler et al. 2007 conduct a case study for which they estimate that environmental benefits are increased by 50% simply by altering spatial configurations of a practice.

Despite substantial literature citing large potential benefits to contiguity, the goal of conserving large contiguous tracts of land has not been prioritized or realized (Lynch and Musser 2001, Stoms, et al, 2009, Lynch 2009). Generally, land conservation programs have conserved land in a scattered pattern rather than in targeted geographic regions, due in part to the voluntary nature of the programs, the lack of sufficient funds to enroll all eligible land, and political equity concerns. Margules and Pressey (2000) suggest that more strategic planning of where to locate reserves is needed to achieve conservation goals.

The importance of contiguity, thresholds and/or hotspots introduces a spatial externality in the selection of parcels for conservation purposes. Therefore, governmental intervention that focuses solely on enrolling parcels without considering these spatial externalities will under-provide valuable ecosystem services. The existence of these spatial externalities thus presents a mechanism design challenge. Economists have long suggested that competitive institutions, such as markets, be used to enroll participants in voluntary conservation programs to reduce costs and increase efficiency (Ribaudo et al. 2008, Latacz-Lohmann and Van der Hamsvoort 1997, Stoneham et al. 2003). A difficult policy question motivates this research: How can a competitive enrollment institution simultaneously encourage competition among enrollees and encourage the coordination necessary to enroll contiguous land? The first goal involves fiscal cost-effectiveness[3], while the second goal concerns a broader understanding of benefits in a social cost-effectiveness analysis.

[3] Fiscal cost-effectiveness is social-welfare-relevant (and not simply about transfers) because government expenditures involve the deadweight loss associated with collecting tax dollars.

Literature and policy suggest that targeting schemes are often implemented through the designation of specific geographic areas that are eligible for payments and, if these areas are small enough, contiguity is achieved with sufficient budget. The Conservation Reserve Enhancement Program (CREP) allows states to set priority areas for specific conservation objectives. Yang et al (2005) found that the Illinois CREP program's use of geographic targeting and first-come, first-served ranking mechanism increased the cost by four times over the least cost solution and resulted in environmental outcomes below the stated goals. Lynch and Liu (2007) found little evidence that such designated areas result in higher degrees of contiguity. Lewis and Knaap (2012) also conclude that designated areas have not resulted in a high degree of contiguity due to inadequate budgets and lack of coordination between land conservation and urban containment strategies.

Bonus payments (also referred to as "smart subsidies") for contiguity are a more recent innovation, and have received considerably less research attention than targeting mechanisms. Bonuses are appealing because they are simple and transparent. They are relatively easy to explain to potential enrollees, they are easy to administer, and they are "fair" in the sense that a uniform bonus is paid (per parcel, or potentially per acre) out to all who qualify. This can be thought of as a fixed payment specifically for the spatial externality in that it is independent of parcel costs or qualities. However, the payment or amount is conditional on others' enrollment decisions, so does present a degree of uncertainty. Coordination may be fostered by landowners who recruit their neighbors to the program in the hopes of receiving additional payments. Yet, bonuses are also crude. Bonuses could pay individual landowners more than their reservation price, creating rents which a competitive enrollment mechanism is designed to minimize. Further, by encouraging coordination, bonuses could result in rent seeking by a group of landowners, resulting in payments to the group considerably higher than the combined willingness to accept.

Empirical studies of bonus payments are limited, as the strategy has been used so infrequently in actual conservation programs. Bucholtz, Higgins, and Lynch (2010) compared the CREP programs in Oregon and Illinois. Oregon used a bonus-payment scheme to encourage dense enrollment of parcels; Illinois had similar conservation goals under their CREP program, but did not offer contiguity bonuses. The authors found that bonuses have thus far not resulted in increased contiguity of parcels in Oregon. In part, Illinois has enrolled many more acres (40,509 acres compared to Oregon's 27,625 acres from 1998 to 2008) and thus has achieved a degree of contiguity due to the high level of enrollment.

Most of the evidence supporting the use of bonus payments comes from experimental studies (Parkhurst and Shogren 2007, 2008, and Parkhurst et al. 2002). These studies found that a bonus payment was an effective mechanism for fostering coordination. These studies, however, did not examine the use of bonuses as a part of a competitive mechanism. Given that economists traditionally advocate for the efficiency benefits of competitive mechanisms and the largest conservation program in the U.S. (Conservation Reserve Program) and many smaller conservation programs use this type of mechanism, determining how bonuses function in this environment is essential. This paper provides insight into the development of an institution that encourages contiguity while maintaining an efficient enrollment structure.

In this paper we report the results from experiments in both the laboratory using student participants as well as using agricultural landowners. The latter constitutes an 'artefactual field experiment,' a term coined by Harrison and List (2004) to describe experiments with laboratory like control, but using non-student participants from the population of interest. Experiments were used to evaluate the effectiveness of four possible mechanisms: (i) a basic reverse auction where sellers are selected by lowest cost, (ii) a reverse auction where the buyer selects for spatial targeting using mathematical programming, (iii) a reverse auction with network bonus, and (iv) a reverse auction with both spatial targeting and network bonuses (Table 1). To our knowledge, this is the first paper to look at both of these mechanisms and test for the relative performance of these mechanisms in isolation and in combination. The results suggest that spatial targeting increases the total environmental and social benefits achieved. In contrast, network bonuses alone decreases the achieved benefits as the extra costs of bonuses can quickly extinguish the available budget. The two mechanisms do have a complementary effect, however. Analysis of individual behavior shows that when combined the networks bonuses encourage landowners of highly valued parcels to place offers more often and spatial targeting permits the best selection from among these highly valued parcels. Taken together, these results suggest that if marginally smaller bonuses remain effective at attracting landowners, a hybrid bonus-targeting scheme might be effective.

Model of Reverse Auction Behavior

This section outlines a basic model for seller behavior in both the spatial targeting and network bonus settings. Suppose there are no network bonuses and no spatial targeting (Treatment 1 in Table 1). We assume that, absent the additional spatial externality, parcels have homogeneous environmental values. Therefore, if the buyer does not explicitly account for network size in selection they will treat each parcel as having equal conservation value to the program. Potential enrollees submit offers (“bids”) to join the program. The administrator orders the offers from lowest to highest, selecting parcels until the budget is expended. A landowner who is accepted into the program is paid her offer, b, but must in exchange implement conservation practices, or otherwise forego profitable land uses, at a cost of c. Total profit from enrolling is thus

$$\Pi = b - c.$$

When formulating her offer, however, a potential enrollee is unsure whether her offer will be accepted. Assuming risk aversion[4], a landowner will maximize expected profit

(1) $$E(\Pi) = c + (b - c)\,\Pr(win|b),$$

where $\Pr(win|b)$ is the probability that an offer of b is accepted.[5]

From the seller's perspective, increasing b increases profit all else equal, conditional on acceptance. Because offers are accepted by the program administrator from lowest to highest and because a potential enrollee does not know the offers being made by other sellers, increasing b will decrease the probability of acceptance, all else equal. The seller therefore must balance a desire for more profits with the uncertainty of acceptance. Taking the derivative of expected profit with respect to b, we get the usual marginal condition

(2) $$\Pr(win|b) + (b - c)\frac{dPr(win|b)}{db} = 0$$

An optimal offer balances the increase in payout (b - c) from increasing b against the associated decrease in the probability of winning. Call the offer that satisfies (2) b^*.

In contrast, suppose that the program administrator introduces spatial targeting and network bonuses (Treatment IV in Table 1). Consider a fairly simple selection mechanism that maximizes

[4] Since risk is not of primary interest in this research we will take the fairly common approach when considering the results of the experiment of assuming that since stakes in the experiment are moderate, behavior will be approximately risk averse (Rabin, 2000; Cassar and Friedman, 2004). If landowners are risk averse the standard result of an incremental decrease in offer to increase the probability of acceptance would be applicable.

[5] Note that in general, the probability of winning will also be conditional on other bids, spatial configurations, and the buyer's budget. In our notation we focus on the offer amount as being the landowners' decision variable. Also, in the design we include a submission fee. This is omitted here for clarity.

a grading function over the set of all possible network configurations. This grading function, *G(X)*, represents the conservation value that the buyer places on a given configuration of parcels, *X*. A parcel configuration is made up of disjoint sets of contiguous parcels, with each parcel n belonging to a set having length x_n. This could represent any number of different measures including perimeter, compactness, or some specific ecological function. In our case we use length, as defined as a number of connected contiguous homogenous parcels. *G(X)* sums over a function of the x_ns. If there is a positive value for spatial agglomeration we would expect this function to be increasing faster than linearly in x_n. For simplicity we use a quadratic form as shown below. A concrete case of this on a rectangular grid is described in the experimental design, with examples of calculated values of G shown in Figure 2. The mechanism maximizes this given the set of parcels on which offers were submitted, *B**, and given the cost of enrolling the parcels (including both the offer amounts and the potential bonus payments) and available funds. In this case, the buyer selects a configuration of purchased parcels, *X* to maximize *G*:

(3)
$$max_{X \epsilon B^*} G = \sum\nolimits_{x_n \in X} (x_n + \beta x_n^2)$$
$$s.t \sum\nolimits_{n} b_n + \gamma x_n \leq C$$

where *X* is a set of parcels configuration of networks (drawn from a subset of offers in B*); x_n is the length of network which parcel *n* belongs to; b_n is the offer submitted for parcel *n* by the landowners; *C* is the total available funds for the conservation program in the current round; β is a contiguity preference parameter; and γ is a bonus payment rate parameter.

From the seller's perspective, introducing spatial targeting (Treatment II in Table 1) is akin to increasing the probability of acceptance *for a given offer* when a parcel is contiguous to enrolled land. Consider the problem from the perspective of a single parcel that will join an existing network if the seller's offer is accepted. Assume all other sellers are not part of a network. For this seller, given her geographic location near a network, targeting represents an increase in the probability of acceptance at all values of b. Since the same optimality condition Equation (2) will hold for an optimal offer, a rational seller whose conditional probability of acceptance has increased due to its spatial desirability will increase her asking price above b^*. The possibility of being contiguous to a network is akin to additional information that increases one's estimate of acceptance probability for a fixed b. Another way of looking at this is that spatial targeting induces heterogeneity over otherwise homogenous parcels, and we would expect the usual result of sellers' with high value items seeking to extract additional rent. The difference here is that the heterogeneity is not constant, and endogenous to the current and past decisions of all players.

A different process is at work when a network bonus is introduced instead of spatial targeting (Treatment III in Table 1). Without targeting, the probability of winning with a given offer is fixed (i.e. it is identical to $\Pr(win|b)$ in (1)). However, network bonuses represent an extra potential payment. That is, the total payment, z, for a winning seller is now z=b+P, where P represents the expected bonus payment. Note that since the bonus payment also comes out of the buyer's budget, it is essentially a fixed inflation of the offer. Also, since the size of the payment depends on others' enrollment, this payment will be stochastic, and possibly grow over time. The seller's problem then becomes

(4) $$Max_b E(\Pi) = c + (z - c)\Pr(win|z).$$

Consider the problem from the perspective of a single parcel, which will join an existing network if the offer from the landowner of this parcel is accepted. First, assume all the remaining sellers are single sellers, and as of yet not part of a network. The difference between the decision to place an offer with a bonus can be seen in the marginal condition:

(5) $$\Pr(win|z) + (b + P - c)\frac{dPr(win|z)}{db} = 0.$$

The condition (5) is identical to the condition (2)—the total payment that satisfies (5), z^*, is identical to b^*. Because the seller receives the bonus payment P if her offer is accepted, the offer b should be adjusted down so that the total payment z is equal to what b would be if there were no bonuses (the original case, laid out above). That is, the landowner should decrease the offer to compensate for the bonus while improving her probability of being accepted. These basic facts—that (1) targeting increases the probability of contiguous parcels winning, which should cause sellers with contiguous parcels to increase their offers and receive higher payments and (2) bonuses should induce sellers to adjust their offers downward to increase their probability of acceptance—are clearest when one considers a simple scenario with a single potential contiguous enrollee making offers in a one-shot auction against non-contiguous competitors. Reality is, of course, considerably more complicated. To the extent that other parcels have similar contiguity possibilities, the probability of acceptance will be lower across the board; hence, increases in offer prices should be lessened. Incentives may additionally be altered by dynamics, such as in the experiment that follows. In this case, participants have the opportunity to forgo a stream of returns on a land in return for a contract for conservation payments that is binding over time. These contracts are offered by a repeated reverse auction, so the participants' problem involves entry timing decisions and information feedback. While the incentives embedded in a bonus payment are clear in a one-shot auction, the ability to wait to enter the auction after observing competitors' behavior may change behavior, for example.

Experimental Design

To test the effect of the different mechanism options outlined in Table 1 within a reverse auction, we conducted economic experiments. Each session was composed of 12 participants. Eight laboratory sessions were conducted using undergraduate economics students at a large university in the Northeast of the United States and two artefactual field sessions were conducted using agricultural landowners in Wye Mills, Maryland. Each session lasted about two and a half hours. Student participants received an average of $30, while landowner received an average of $75. Both groups contained the same parameterization, but the exchange rate from experimental to real dollars was higher for the landowners. Table 2 contains the detailed experimental design. Upon arrival to the experiment sessions, participants were randomly assigned a computer that was equipped with a privacy screen and the experiment software. The software consisted of an Excel spreadsheet programmed with Visual Basic for Applications. Participants were provided written instructions (see Review Appendix) and the experiment protocols were explained orally using a Powerpoint presentation.

For each session, participants were divided into three groups of four participants each. Each group represented a geographic region of farms and participants in these groups were located in separate rooms to prohibit communication across groups. Each participant was assigned three non-adjacent parcels within her room. For instance, a participant might be assigned parcels 1, 9, and 11 as shown in black borders in Figure 1. Non-adjacency prevented participants from unilaterally building contiguous groups of parcels, which would confound the study of multilateral behavior. By providing three parcels, however, participants could be engaged in an interesting, nontrivial decision problem over multiple rounds.

Sessions were divided up into multiple "enrollment eras" which were further divided into "rounds." Each experiment session began with a practice era and then had eight eras during which participant choices resulted in cash earnings. Each era had a random number of rounds between three and five; to avoid potential end-of-era effects, participants were only informed that each era would consist of “at least three rounds.” The number of rounds in each era was predetermined so that there would be consistency across experimental sessions.

In each round, participants made separate decisions for each of their three parcels. Participants could choose to “Retain” some or all of their parcels in a privately known, constant revenue producing use, or they could make an “Offer” on some or all of their parcels for enrollment into a conservation program. If a parcel was accepted, the participant would forgo the existing revenue stream on that parcel for the remainder of the era in exchange for a contract payment schedule from the conservation agency, as described below.

Parcels were defined by their geographic relationship to other parcels and an ownership return. In relation to any other parcels, a parcel may be adjacent or non-adjacent. Adjacency means that two parcels share a border, i.e., a “rook” spatial relationship. Corner to corner, or “queen” spatial relationships are not considered adjacent. For example, Figure 2 shows that parcel 1 is adjacent to parcels 2 and 4, but not to 5. Adjacencies are only defined within a room, so parcel 10 in room 1 is not adjacent to parcel 1 in room 2. A group of parcels that are enrolled into the conservation program and are connected by a path of adjacency will form a network. Figure 2 illustrates three possible scenarios of preserved parcels over two different rooms in different network configurations and also shows the calculated “Buyer Environmental Benefit Value” (denoted by *G; see equation (3)*) for each of the networks. We used a value of β (the contiguity strength parameter in the buyer’s objective function) of 0.05, and γ (the bonus payment rate) of 50,000. Note that the decision variables for the problem were sets of parcels forming networks. Algorithms to find an exact solution to this problem had prohibitively long runtimes to implement live during an experiment, so we used an evolutionary algorithm during the sessions. This would generally converge to an optimal or near optimal solution in 30 seconds to a minute.

Scenario A has a network of four, a network of three, and a singleton. The marginal contribution to G of a single parcel belonging to a network of four would be $(4+0.05*4^2) = 4.8$,, three would be $(3 + 0.05*3^2) = 3.45$, and one would be $(1+ 0.05*1^2) = 1.05$, so $G = 4*4.8 + 3*3.45 + 1.05 = 30.6$). Scenario B has a network of five and a network of three, so $G = 6.25 + 3*3.45 = 41.6$), while Scenario C has a network of seven and a singleton so $G = 7*9.45 + 1*1.05 = 67.2$).

In our experimental sessions, participants were not given the mathematical representation of the buyer's problem (3), but were told that individual parcels all had the same value, but that the buyer was trying to purchase parcels to form networks, and that the same number of parcels in long networks would be much more valuable to the buyer than in shorter networks. They were also provided examples of networks and buyer's environmental benefit value (such as in Figure 2) in the instructions and in the oral presentation of how this would be calculated for different example networks. Additionally, all participants were provided an Excel worksheet that they could use to calculate the buyer's value score for a given configuration of preserved parcels. Participants were permitted to use this worksheet at any time during the experiment.

The ownership return represents the return available from a single parcel in a single round if the participant were to "Retain" that parcel for that round. Ownership returns are constant within an era. Returns are uniformly distributed between \$200,000 and \$800,000 across all rooms; the distribution within room is defined such that there will be one room that tends to have low values, one room that tends to have medium values, and one room that tends to have high values.[6] This is constructed so that there is some overlap between values for each room. This distribution, as well as values for all of the other parameters, are summarized in Table 2. Participants knew the overall distribution of values, and were told that the values could be

[6] Three rooms with different average ownership returns are an analog to areas with different soil quality, for instance, resulting in different returns to agriculture. For example, Iowa farms per acre yields are more than Maryland farms which yield more than North Dakota.

unevenly distributed between rooms, but were not told what room (Low, Medium, or High) they were assigned during a given era. At the start of each enrollment era, participants were assigned different parcels with different value distributions.

In each round, participants could attempt to sell some or all of their parcels to a conservation agency by making offers in a “reverse” auction. The buyer had a total budget for each era that was drawn from a symmetric triangular distribution between $5.2 million and $23.0 million. This range, at the maximum, was chosen so that the buyer could purchase all the parcels in each room if that buyer had full information and were able to perfectly price discriminate so that they could purchase from any participant at the value of the participant’s ownership return. The total budget for the era was divided randomly into available new funds for each round. In each round, there was a 20% probability that there would be no new funds available[7], with the total budget being uniformly distributed as new funds available across the remaining rounds. The total funds available in a round were calculated as the new funds available plus any unspent funds from the prior round.

Parcel owners may attempt to enroll in the conservation program by placing an offer in the auction. If they place an offer, they must pay a $40,000 submission fee, regardless of whether their parcel is selected. The submission fee was included to mimic the transactions costs of enrolling in a conservation program.[8] If their offer was not accepted (not selected by the program), then they continue to receive their ownership return and may choose to pay the submission fee and place another offer in future rounds. If the offer is accepted then that parcel is

[7] The possibility of having zero new funding was included to mimic the funding uncertainty common in conservation programs.

[8] At $40,000, the submission fee is 8% of the average (constant) ownership return of a parcel in the Medium room, as drawn from the distribution described in Table 2. Groth (2008) suggests that these types of costs represent 1.7% to 9.1% of the amount of submitted offers for participants in a European Agricultural Fund for Rural Development biodiversity conservation program.

enrolled. If the owner's parcel was adjacent to another enrolled parcel(s), the owner received a one-time network bonus payment(s), as well as the amount of her offer. For the remainder of the era, they continued to receive their offer amount. They also will receive a "top-off" bonus payment if any additional parcel enrolls into their network. In other words, when a parcel enters a network and receives a bonus payment, the previously enrolled parcel also received a payment of the marginal bonus over their prior bonus payments so that over the course of the era all parcels enrolled in the same network receive the same total bonuses. Bonus payments were made to all owners of parcels enrolled in a network size of two or more. They were made one time in the amount of $50,000 per parcel in the network to all members of the network. So, for example, if two adjacent parcels were to enroll at the same time they would each get a bonus payment of $50,000*2 = $100,000. If, in the next round, a third parcel adjacent to one of the first two parcels were to enroll the network would now be of size 3, so the new enrollee would receive a bonus of 3*$50,000 = $150,000, and the two previously enrolled parcels would get a top-off payment of $50,000. In total all members of the network will have received $150,000 in bonus payments. This $50,000 payment represents about 10% of the average ownership return, which is relatively small as compared to amounts proposed in the literature. Parkhurst et al (2002) had land opportunity costs of high ($6), middle ($4), and low ($2) with bonuses set at $10.[9] Parkhurst and Shogren (2008) had opportunity costs ranging from $20 to $50 per parcel while the average per parcel bonus (smart subsidy) was $93.

The buyer's goal for the conservation program was to secure the highest level of benefit (in the form of the value of the objective function G, from (3)) from preserving parcels. These benefits were assumed to be increasing in both the number of parcels and the size of networks that those

[9] Parkhurst et al (2002) argued that the bonus payment is so high because they want to cover the subjects' transaction cost of making that calculation of coordinating within the experiment.

parcels form, and to be realized annually every year that the parcel was enrolled. To test the effectiveness of program structures in achieving that goal, the reverse auctions were varied in two different aspects. Auctions varied based on 1) whether enrolled parcels received a bonus based on their spatial configuration and 2) whether a spatial targeting rule was used to explicitly account for the network sizes formed by preserving parcels. With different combination of these, we have four possible auction formats (Table 1). Bonuses were altered within sessions, with bonuses being offered in some eras but not in others. Spatial weighting was varied between sessions with the buyer using spatial targeting for all eras in some sessions, and just trying to maximize the number of parcels enrolled during an era (or, equivalently, setting $\beta = 0$) in others. Spatial weighting was specifically varied between sessions as it is relatively more cognitively difficult than bonuses, and varying within the session likely would have been overly confusing. The opportunity of participants to communicate within their group (room) was also varied between sessions. Since the agglomeration bonus scheme could induce cooperation, payments could be more effective when participants are given the opportunity to communicate. Participants in communication sessions were given one minute between each round to talk openly. This period was after results from the prior round were revealed, but before decisions for the following round were made. A timer was used to strictly enforce the one minute limit. Administrators were instructed to keep track of the topics discussed; however this data ended up having little variation.

This design tends to produce several outcomes. For instance, the frequency of parcels being selected by the conservation program changes over time and by treatment. Figure 3 offers a pattern of “ideal” enrollment. This is a theoretical enrollment pattern based on the case where the buyer can perfectly discriminate. Parcels are enrolled at their opportunity cost based on the buyer's budget according to the treatments. The ideal enrollment pattern calculates the frequency that a parcel is enrolled over the the parameterizations used in the experiment. This is calculated with each mechanism using the parameters used in the sessions. The shading indicated the frequency of selection at or before a given round, with darker parcels being enrolled more often. Across all treatments, more parcels are selected as one enters the last few rounds compared to the first round simply because more money is spent as the rounds progress. Another common feature across the treatments was that the program selected parcels in the lowest cost room (the top block of 12 parcels) with more frequency than those in the higher cost parcels (the bottom block of 12 parcels). Parcels with the lowest opportunity costs (ownership returns) were most cost effective all else equal. Interestingly, a program providing network bonuses (Treatment III) selects fewer parcels. The budget is spent on bonuses rather than enrolling more parcels. Buyer spatial targeting (BST, Treatment IV) on the other hand leads the program to select with more frequency a cluster of contiguous parcels. Finally, a program using both network bonus and BST more frequently selects contiguous parcels in the lowest cost room.

Empirical models and results

To test the effectiveness of network bonuses and spatial targeting we estimate models of direct effects and interactions between treatments on both conservation outcomes, i.e. total environmental benefits, and the total social welfare effects of the program. Then, we investigate the behavioral pathway by which these treatments affect these outcomes. We estimate models to explore behavior with seller decisions as the unit of observation. The seller's strategy has two components: the decision to enter into the auction, and the amount to offer if they do enter. We use two separate models to examine the decision to enter the auction, as well as the rent premium, or amount offered above cost, conditional on entering. *Conservation Outcomes*

The reason for the existence of conservations auctions is to secure environmental benefits. Schilizzi and Latacz-Lohmann (2007) propose three separate criteria to evaluate their performance: budgetary cost-effectiveness (in this case, level of G obtained per dollar spent), information rents, and economic efficiency. In this case, since the selection is optimized conditional on the budget, our evaluation effectiveness evaluation will focus primarily on how the aggregate behavior of all potential enrollees combines to secure aggregate conservation benefits. Following this we will also look at total economic welfare. We will consider rents from the perspective of premium charged in the offers instead of total rent extracted. Let $n = 1, \ldots, 36$ index the experiment's parcels, $r = 1, \ldots, R$ index rounds, and $j = 1, \ldots J$ index enrollment eras. Let $G_{r,j}$ be the total benefits accrued from all enrolled parcels in round r of era j, and $G_j = \Sigma_r G_{r,j}$ be the total benefits secured by the program during era j. This is modeled as:

$$G_j = \beta_0 + \beta_1 C_j + \beta_2 F_j + \beta_3 E_j + \alpha T_j + u_j$$

where:

C_j: Total available budget over the era in experimental dollars

F_j: Dummy variable indicating the session was an artefactual field experiment

E_j: Length of the era, between 3 to 6 rounds

T_j,: Vector of treatment dummy variables, including targeting, bonuses, communication, and possibly interaction

u_j: Standard error term

For the both of the era level models, we clustered standard errors by session to account for correlation of errors within sessions, and included era ordering fixed effects to control for learning.

The welfare effects of the program are measured in terms of the net impact of the program on both conservation and productive outcomes. Define $R_{r,j}$ as the total lost agricultural productivity, or forgone ownership returns, from all enrolled parcels in round r of era j, and $R_j = \Sigma_r R_{r,j}$ be the total lost productivity caused by the program during era j. Then the net welfare effect of the program will be the secured conservation benefit minus the forgone agricultural productivity: $W_j = G_j - R_j$. This is modeled as:

$$W_j = \beta_0 + \beta_1 C_j + \beta_2 F_j + \beta_3 E_j + \alpha T_j + u_j$$

with all variables as defined above, era order fixed effects, and standard errors clustered by session.

The estimated parameters for these models are displayed in Table 4. Note that the average values of G_j and W_j are \$23,784,455, and \$12,118,866, respectively (all figures that follow are in experimental dollars), and that the magnitudes of the treatment effects (in the range of negative thirteen to eight million) are fairly substantial relative to this. Model 1 estimates how the experimental design attributes affect total environment outcomes. Overall, we find the variables explain 64% of the variance in total environmental outcomes (R^2=.6357). The regression controls for auction attributes that will be beyond the control of the auction designer. For instance, higher budget and longer eras (more time to enroll parcels) cause higher environmental benefits. The type of participant was also shown to affect benefits. Experiments with the agricultural landowners resulted in higher environmental benefits (by almost \$9 million, or nearly a 40% increase relative to the mean) than those with students. Several variations on this model were considered with interactions with the field session variable, but these were all found to be insignificant.

In terms of policy treatments, the results show that providing network bonuses alone has a negative, statically significant effect on environmental benefits. A conservation program using network bonus would have a total environmental benefit measure \$11.74 million less than one that did not employ network bonuses, all else equal. In contrast, the coefficient on spatial targeting was positive and significant. A program using spatial targeting to select parcels has an almost $7.47 million increase in environmental benefits, all else equal. The two treatments have similar estimated magnitudes, though in opposite directions. Allowing communication between participants within the same room did not impact the environmental benefits in this model.

To examine how interactions among the independent factors affect outcomes, Model 2 was estimated (see Table 4). As with Model 1, higher budgets, more rounds, and the agricultural-landowner participants cause higher environmental benefits. The coefficient on bonuses again also remains negative and significant. However, with interactions buyer spatial targeting becomes insignificant, while the new interacted term of buyer spatial targeting and bonuses has a positive, significant coefficient estimate. All else equal, programs offering network bonuses have a $14.3 million lower environmental benefit than those that do not. The interesting aspect is the interaction between spatial targeting and bonuses. While bonuses alone negatively affect the outcome, bonuses with spatial targeting offset that by $10.2 million, though this is not enough to have a positive net effect.

Models 3 and 4 show parallel results for the net welfare effects of the program. These results are very similar to Models 1 and 2 in terms of both magnitude and significance. As expected, the predicted total welfare effect is much lower, since we are backing out a strictly positive variable; however the program resulted in a net improvement in social welfare 92% of the time. Otherwise, our conclusions hold for both conservation and social welfare outcomes.

One interpretation of this result is that it appears that with bonuses a greater number of contiguous parcels to enter the auction. This means that there will be fewer constraints, and hence a larger feasible set to the buyer's problem, or in other words, BST will have a larger pool of highly valuable parcels from which to select. The bonuses provide the landowners an additional incentive to coordinate and provide high quality parcels (from the buyer's perspective), i.e., low-cost contiguous parcels. However this improved offer pool only benefits the program if it is targeting for spatial attributes. When the program uses a bonus without targeting, contiguous parcels will enter offers but the program does not favor these parcels in the ranking of who is accepted. This interpretation constitutes a testable hypothesis, which requires analysis of the decision making at an individual level.

Auction Entry Process

The hypothesis to be examined is that bonuses alter the composition of the offer pool. The total environmental benefits will depend on the tradeoff between selecting a "better" set of parcels versus selecting more parcels. A possible approach is to model how landowners enter the auction based on the number of offers in a round as a function of the independent variables. There are, however, drawbacks to this approach. First, the data is stretched by this approach due to a number of highly collinear heterogeneous parcel attributes (i.e., opportunity costs or location within a geographic area). Second, the number of sellers submitting offers over multiple parcels in a given round within an era is not independent. The number of offers depends on the number of un-enrolled parcels, which in turn depends on past entry behavior. Thus, an implicit sample selection issue exists—the availability of a parcel to offer in a given round is a function of the same attributes affecting the offering behavior in that round.

Therefore, we estimate the probability of placing an offer in a given round using a Heckman probit model to correct for endogenous selection. Model 5 has the probability specified as a function of the treatment, the era attributes, parcel attributes, and position variables that proxy for the spatial desirability of the parcel:

$$\Pr(\text{Offer}_{n,r,j} = 1 | \text{ Enrolled}_{n,r,j} = 0) = \beta_0 + \beta_1 B_{r,j} + \beta_2 F_j + \beta_3 c_{n,j} + \ \alpha T_j + \gamma Q_p + u_j$$

where:

$B_{r,j}$: Available budget in round *r* of era *j* in experimental dollars

F_j, T_j: Field variable and treatment variables as in the previous models

$c_{n,j}$: Opportunity cost for parcel *n* in era *j* in experimental dollars (the induced value given in the experiment for the ownership return minus the cost to the landowner of enrolling in the program)

Q_p Vector of dummy variables indicating parcel *n*'s geographical position within its block. This could be:

Interior: Surrounded by four parcels (#5 and 8 from Figure 1)

Edge: Three connected parcels (#2, 4, 6, 7, 9, and 11 from Figure 1)

Corner: Two connections (#1, 3, 10, 12 in Figure 1)

The geographic location of corner, edge, and interior parcels mean that they have potential adjacencies (or "contiguity valences") of 2, 3, and 4 respectively. If we take the view that the probability of another parcel enrolling as roughly uniform, then the probability of one of these parcels entering into a network would be increasing in the number of potential adjacencies. So from the point of view of the land owner, interior parcels will have a higher probability of yielding bonus payments. From the point of view of the buyer interior will have a higher probability of joining into contiguous networks, so can be thought of as having a higher value in expectation. Corner parcels are the reference group omitted from the regression. The average marginal effects as estimated for Model 5 are reported in Table 5.For both the probit and heckman models we clustered standard errors by eras to account for correlation of errors within eras, and included subject fixed effects to control for individual specific heterogeneity.

The results show an important result for auction design. Bonuses not only induce entry of more parcels into the auction, they specifically induce entry of parcels that are higher value in term of the spatially explicit conservation objective. To see this result consider that Model 5 in the context of the number of offers such as. On average, out of 36 parcels 67% (or 24 of these parcels) are not enrolled. A 0.10 change in the probability of making an offer would represent an increase to the offer pool of 2.4 parcels.   The network bonus treatment is significant with a marginal effect of 0.044. When bonuses were offered, participants were more likely to enter into the auction. The results also show that participants with different parcel "quality" responded differentially to the bonuses. Interior parcels are considered the highest quality because they are the most likely to be contiguous to already conserved parcels. The average marginal effect of the bonus and interior parcel interaction variable proved to be significant, with an average marginal effect of 0.053. In terms of the model posed earlier in this paper, this shows that at least participants are aware of the effect of spatial targeting on their probability of acceptance, and respond by entering the auction more frequently, as we would expect from a higher expected payoff in an endogenous entry setting.

Another result is that edge and interior parcels are more likely to enter in general as compared to corner parcels. This may not be surprising in light of the experimental design, but the extensions to the real world are direct.[10] In addition, we also find that a higher opportunity cost decreases a parcel's probability of entering. Parcels having higher ownership returns stay in their current use rather than enter a conservation use, all else equal. A larger budget which is known to the participants during a round also increases the probability of entry. These results are what one intuitively expects.

In sum, Models 2 and 4 found that the interactive effect between targeting and bonus was significant and of a large positive magnitude. Model 5 confirms our hypothesis that bonuses

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[10] Although not explored in this experiment, future work could include designing a test of edge-parcel incentives in a agglomeration setting. If conversion of the parcel to developed uses is possible, then the dynamics of edge parcels becomes relevant to auction performance. Simply, there is always an edge parcel, though the edge may be moving.

affect entry and thus create a more desirable offer pool for the conservation program. The large positive effect is, however, not enough to outweigh the negative effect of the bonus. The marginal dollars spent by the auctioneer on bonus payments tended to crowd out expenditure on other parcels, for a net negative effect. Perhaps a smaller bonus payment could still induce participation while leaving more of the budget available for enrollment. This is a question for future research.

Rent Seeking Behavior

Another important question is how landowners' behavior may change given the treatment once the decision to enter the auction has been made. Economic theory would suggest that the bonuses might be capitalized by participants' offers. For example, in response to spatial targeting, a participant may wait to submit her offer until a large group of adjacent conserved land was formed. At which point, the landowner could use her position as a high benefit parcel to extract large rents from the buyer. Contiguity via her geographic position adjacent to a cluster creates market power. We investigate the rent premium implicit in landowners offers.

The rent premium is defined as the offer amount minus opportunity cost. We analyze the rent premium using a linear model with a Heckman adjustment for selection bias with standard errors again clustered by era. Like the entry decision, we expect the offer amount to be affected by the budget, the field status, the treatment status, era length and geographic position of the parcel. The targeting treatment is interacted with the geographic variable as a proxy for market power derived from geographic position. We hypothesize that the coefficients on the interacted variable will confirm evidence of "market power" driven rent premiums. This represents the increased offer amount associated with a higher conditional probability in the model described earlier.

The estimated marginal effects for Model 6 are reported in Table 5. Some evidence that landowners capitalized the bonuses into the offer decision exists. However, the average discount was only $14,807 which is small compared to the $50,000 per contiguous parcel bonus payment in the network. Interestingly, communication has the largest effect. Being able to communicate likely made collusion easier and enabled participants to increase the amount of rent extraction. When interacted with BST however, this effect was offset. Possibly, BST allowed programs to more explicitly trade-off the environmental benefit of contiguity against the potential cost of conservation from landowners' offers. Additionally, participants with high value (contiguous) parcels increased their offers when targeting is used. This would suggest that participants may be aware that their parcels are more valuable to the agency, and exploit that value to extract additional rents.

Conclusion

Research on spatially explicit conservation has two main veins: bonus induced coordination and mathematical targeting mechanisms. These are designed to address two different failures in the conservation process. Because voluntary incentive based conservation programs do not explicitly compensate landowners for spatial attributes, landowners have no extra incentive to provide them. Thus, from an environmental perspective, contiguity is an underprovided positive externality. The second failure results from the conservation program not explicitly selecting parcels based on contiguity. By not including this attribute in the selection function, programs under select parcels for this attribute even if the environmental benefit of enrolling the parcel is greater than the cost of participation.

Using both laboratory and artefactual field experiments with agricultural landowners, we test how bonuses and spatial targeting will impact environmental and social welfare outcomes within a conservation program using a reverse auction. We find advantages and challenges to both approaches. Agricultural landowners in the field experiment generally performed better than students, consistent with faster learning, but were not otherwise behaviorally different.

Bonus payment schemes internalize the spatial externality for the individual landowner by directly paying her for the additional benefit generated by large networks of contiguous conservation. Thus, both coordinated landowner efforts are rewarded and parcels of high probability of contiguity are induced to enter the auction because they are positioned to form or enlarge networks. While landowners do seem to partially capitalize the bonuses into their offer amount, the average amount of capitalization is less than the average bonus payment; average discounting was on average 32% of the bonus payment. There could be a few factors contributing to this. First, participants could be slow to internalize the tradeoff between the amount of the bonus payments and their probability of winning into their offer function. This effect would be expected to decrease as subjects learn. Secondly, the bonus the actual amount of bonus paid is a function of future development which is unknown at the time of bidding. Participants could be underestimating the amount of future development which will yield bonus payments. This would be an interesting avenue for further research. Also, we find a traditional price discriminative reverse auction will fail to select the "best" parcels for purchase under just a bonus scheme. In other words, the results indicate that participants do not fully and consistently incorporate capitalization the bonuses into their decisions.

A selection mechanism can be used which properly targets the buyer's objective function, specifically purchasing parcels that lead to higher quality portfolios of conservation networks, instead of trying to purchase as a large quantity of parcels without regard to the total conservation value of their efforts. This approach does offer substantial gain in the total social and conservation benefits achieved. However, it can decrease the auction efficiency as it gives owners of advantageously situated parcels the market power to extract surplus rents from the conservation program.

Finally, we considered the case where both network bonuses and spatial targeting are utilized. The joint application of the two approaches offers a natural synergy. Bonuses increase the size and quality of the pool of offers submitted; targeting enables the program to select the best parcels from the improved offer pool. Because of insufficient “capitalization”, a traditional offer-selection mechanism is less likely to select high valued parcels (those who will get high bonuses) that would improve environmental outcomes. Thus, incorporating contiguity into the selection mechanism can lead to better selection of parcels and higher environmental and social benefits.

Figure 1. Spatial Lay-out of Parcels by Room

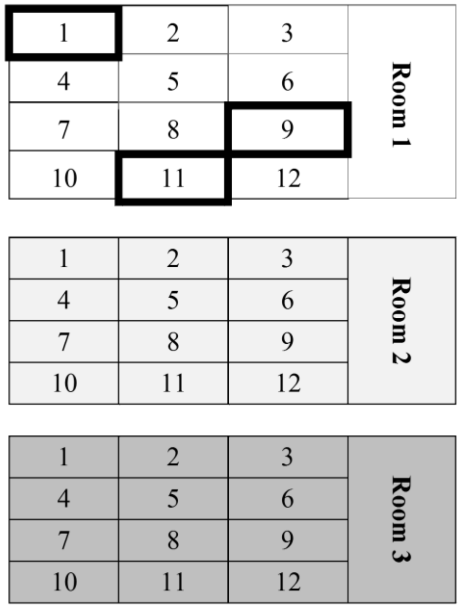

Figure 2. Three Possible Conservation Scenarios with Network Sizes and Buyer Environmental Benefits

Scenario A	**Scenario B**	**Scenario C**
Network Sizes: 4, 3, 1	Network Sizes: 5, 3	Network Sizes: 7, 1
Buyer Environmental Benefits: 30.6	Buyer Environmental Benefits : 41.6	Buyer Environmental Benefits : 67.2

Scenario A

1	2	3
4	5	**6**
7	8	9
10	**11**	12

1	**2**	**3**
4	5	6
7	8	9
10	11	12

Scenario B

1	**2**	3
4	**5**	6
7	8	9
10	11	12

1	**2**	**3**
4	5	6
7	8	9
10	11	12

Scenario C

1	**2**	3
4	**5**	6
7	**8**	**9**
10	11	**12**

1	**2**	3
4	5	6
7	8	9
10	11	12

Figure 3. Average observed selection frequency by round and by treatment based. Rooms are differentiated by high, medium, and low "cost" in terms of ownership returns.

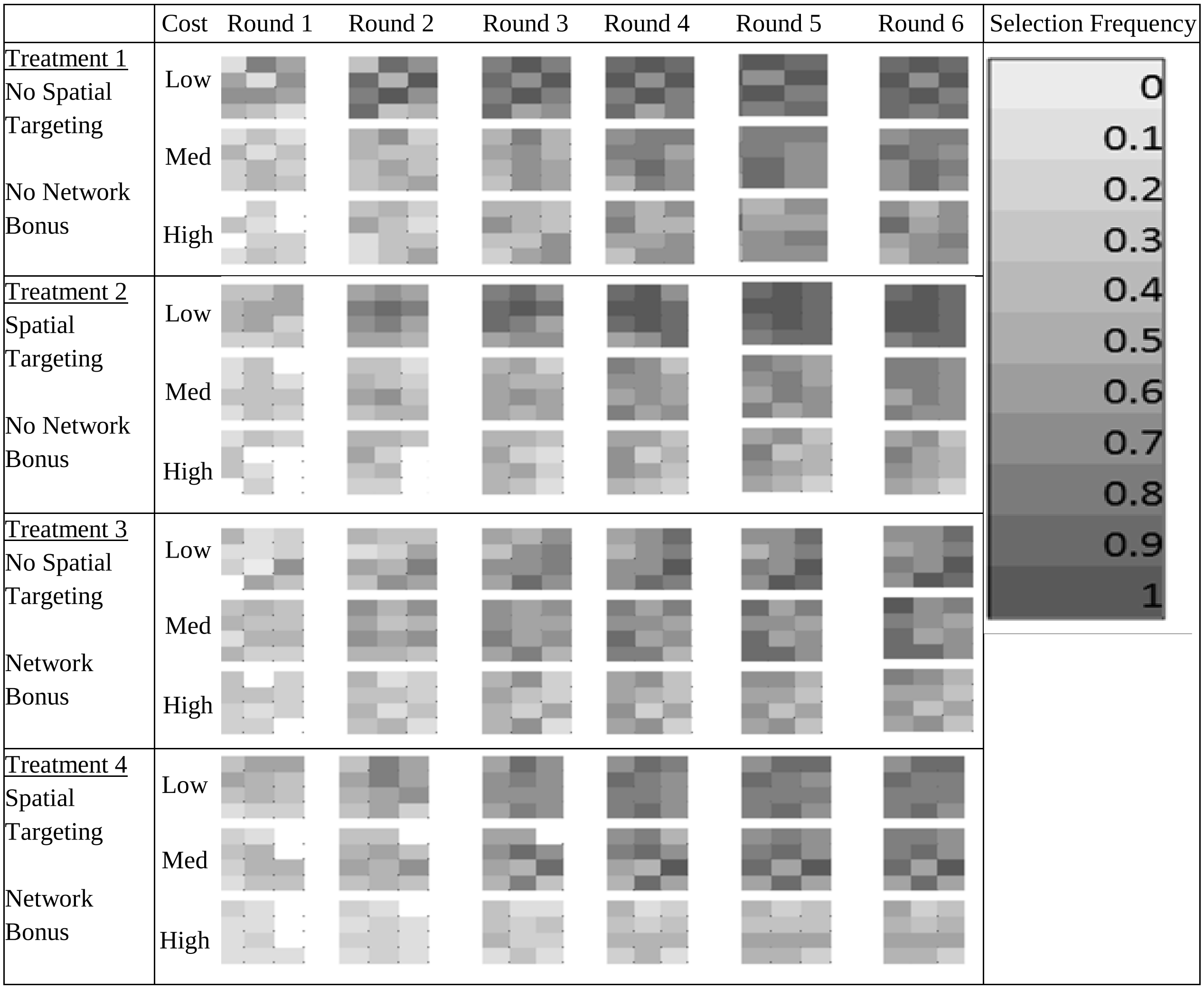

Table 1. A Reconciliation of Two Possible Solutions to Achieve Spatially Explicit Conservation Discussed in the Literature: Spatial Targeting and Network Bonuses

		Demand **Buyer's Preference for Spatial Targeting in Selection**	
		No	**Yes**
Supply **Sellers Receive Network Bonuses**	**No**	*(Treatment I)* Most programs in real world	*(Treatment II)* Targeting literature
	Yes	*(Treatment III)* Agglomeration literature	*(Treatment IV)* Socially Optimal Conservation?

Table 2. Experiment design to determine the impact of network bonuses and spatial targeting for achieving contiguity in conservation selections

Participants	120 participants (96 undergraduates, 24 landowners)
Session Setup	3 rooms; 12 participants, 4 per room
Time Structure	9 enrollment eras, 3-6 rounds in each era
Parcel Distribution	3 per participant, grouped by room
Individual Values	Induced ownership returns received for each parcel in each round, known Uniform distribution ($200K, $800K) differentiated by room. The probability of the range of uniform distribution by room is below:

	Probability of Value from Uniform Distributions (in thousands of dollars)				
Rooms	*200-320*	*320-440*	*440- 560*	*560-680*	*680-800*
Low value	60%	40%			
Medium value		20%	60%	20%	
High value				40%	60%

Buyer Values	Nonlinear, increasing in number of parcels and lengths of networks ($\beta = 0.05$, $\gamma = 50{,}000$)
Buyer Budget	Randomly drawn from Triangular distribution ($5.2M, $23.0M)
Contract Structure	Forgo ownership returns in exchange for payments equal to their offer amount
Network Bonuses	Cumulative, based on network size, $50,000 per parcel for each parcel in the network.
Average Earnings	$30 for undergraduates, $75 for landowners
Average Time	2.5 hours

Table 3. Summary Statistics

	Number of Bids	Parcels Enrolled	Average Bid	Total Conservation	Total Welfare
Overall Summary					
Min	4	3	14,000	7,169,730	18,900,000
Max	36	36	7,123,000	46,751,736	154,000,000
Mean	22.8	17.4	688,587	11,849,559	90,731,111
St Dev	6.78	7.13	388,220	13,651,815	31,174,565
Mean By Program Treatment					
No Targeting, No Bonuses	22.6	18.5	734,869	13,903,435	92,330,769
Targeting, No Bonuses	21.3	17.3	702,889	19,350,007	102,050,000
No Targeting, Bonuses	24.5	16.9	645,238	847,907	76,780,769
Targeting, Bonuses	22.5	16.7	688,628	16,731,264	96,600,000
Mean By Communication					
Communication	22.8	16.8	664,479	10,202,154	90,022,500
No Communication	23	17.7	701,082	13,167,483	91,298,000

Table 4. Total Environmental Benefits (*G)*

	Environmental Benefits		Net Welfare Effect	
	Model 1	**Model 2**	**Model 3**	**Model 4**
Intercept	3,762,797 (635574)	3,667,604 (6,941,930)	2,230,005 (6,438,212)	2,133,756 (7,196,103)
Budget	0.0134*** (0.0019)	0.0117*** (0.0015)	0.0115*** (0.0017)	0.00988*** (0.0015)
Field Session	8,422,212* (4,654,660)	8,317,315 (4,676,801)	8,259,768* (4,219,787)	8,154,257* (4,251,728)
Length	58,474 (1,491,839)	488,640 (1,391,653)	- 36,180*** (1,470,711)	387,682 (1,387,014)
Buyer Spatial Targeting (BST)	7,468,305** (3,256,543)	913,353 (5,669,785)	8,129,092** (2,837,698)	1,748,755 (4,800,696)
Bonuses	-11,742,253*** (2,606,422)	-14,264,095*** (2,367,377)	- 10,783,144*** (2,697,587)	-12,947, 217*** (2,572,582)
Communication	-690,153 (2,715,909)	-369,210 (2,316,030)	-109,222 (2,476,765)	225,953 (2,396,632)
BST*Bonuses		10,200,749*** (5,187,910)		9,627,649** (3,255,312)
BST*Communication		3,704,071 (6,025,535)		3,913,067 (5,348,975)
Bonuses*Communication		-3,032,798 (4,163,297)		-3,228,869 (3,947,608)
R^2	0.6357	0.6684	0.6106	0.6485
N	88	88	88	88

Notes: Standard Errors clustered by session are in parenthesis, *, **, *** indicate significance at the 0.1, 0.05, and 0.01 levels. Era ordering fixed effects were included in the estimate. Analysis similar to Models 2 and 4 were conducted with three-way interactions of the treatments. The coefficient for three-way interaction variable was not statistically significant and did not change the primary results of the models. This analysis is available from the authors upon request.

Table 5. Individual Entry Decisions and Rent Premiums

	Model 5 **Auction Entry Probability**	**Model 6** **Offer Inflation**
Opportunity Cost (In $100,000)	-0.0755***	1,437
	(0.0027)	(1,038)
Buyer Spatial Targeting (BST)	-0.0163	-15,848**
	(0.0369)	(7,273)
Bonuses	0.0438**	-14,807**
	(0.0238)	(6,731)
Communication	-0.0256	29,661***
	(0.0549)	(10,371)
BST*Bonuses	-0.0281	18,498***
	(0.0331)	(6,667)
BST*Communication	-0.0371	-21,272**
	(0.0564)	(9,265)
Bonuses*Communication	0.0159	-11,387*
	(0.0493)	(6,123)
Edge	0.0417***	-12,239***
	(0.0082)	(3,763)
Interior	0.0531***	-6,762*
	(0.0153)	(5,016)
Bonuses*Interior	0.0320**	-3,166
	(0.0165)	(4,426)
Available Budget (in $100,000)	0.0004***	-12.76***
	(0.0000)	(1.58)
BST*Edge		8,699**
		(4,131)
BST*Interior		11,855***
		(4,555)
Inverse Mills Ratio (λ)		131,972***
		(18,820)
Log-likelihood	-12,470	-117,085
N	12,602	12,602

Notes: Reported parameters are marginal effects.Subject fixed effects are included. Standard Errors clustered by era are in parenthesis, *, **, *** indicate significance at the 0.1, 0.05, and 0.01 levels.

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