Smart Subsidies for Habitat Conservation

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Brief Summary: *A* smart subsidy *can be design to induce neighboring landowners to create a contiguous habitat reserve voluntarily and cost-effectively.*

Abstract

Creating contiguous protected areas requires the voluntary cooperation of private landholders, who might be more likely to participate if they are compensated. We use experimental economic methods to testbed a *smart subsidy* proposal relative to two standard policy options, compulsion and a standard fixed-fee subsidy. A smart subsidy creates an explicit network externality between neighboring landowners by paying an additional agglomeration bonus when they retire land adjacent to other conserved parcels, both their own and their neighbors. In a lab setting, we find that the smart subsidy outperforms the alternative policies at creating the desired contiguous habitat reserve cost-effectively.

Introduction

Protecting threatened biodiversity hotspots in densely populated areas requires the creation of landscape-scale contiguous reserves and corridors to support viable species populations and ecological processes (e.g., Cincotta et al., 2000; Margules and Pressey, 2000). Creating contiguous protected areas cannot be accomplished, however, without the voluntary cooperation of private landholders. Their cooperation is more likely if they are compensated for financial losses, e.g., US Conservation Reserve Program (Innes et al., 1998; Farraro and Kiss, 2002). Herein we explore how a *smart subsidy* can be used to create contiguous habitat voluntarily.[1] The smart subsidy creates an explicit network externality between neighboring landowners by paying an additional *agglomeration* bonus when they retire land adjacent to other conserved parcels, both their own and their neighbors (Parkhurst et al., 2002). We use experimental economic methods to testbed the smart subsidy proposal relative to two standard policy options, compulsion and a standard fixed-fee subsidy.[2] The point of our exercise is to illustrate the potential for such an interlinked subsidy scheme for habitat conservation. Our results support the general notion—the smart subsidy outperformed both alternative policies at creating the desired contiguous habitat reserve.

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[1] The choice of the word "smart" is not meant as a pejorative term that implies other subsidies are somehow "dumb." Rather the choice follows the tradition set in the experimental economics literature on "smart" markets, in which the exchange institution is designed "smart" to explicit account for interdependencies between traders in water and electricity markets (see McCabe et al., 1991). These markets provide feedback on physical constraints (e.g., congestion) to buyers and sellers, which then allows them to increase efficiency of trades beyond that usually attainable by the market itself.

[2] See for example Vernon Smith's (1998) discussion on the role of experimental methods in economics as a tool in the study of alternative market mechanisms.

Experimental Design

The experimental design has six structural elements—landscape and landowners, policy treatments and subsidy design, players and rounds, game strategies, calculator and communication, and information and history. Consider each in turn.

Landscape and landowners. We represented the landscape with a 10x10 land grid (Figure 1), divided into four private 5x5 landholdings.[3] Each cell in the land grid was assigned an economic value ranging from $20 to $50 per cell, i.e., the land's opportunity cost if retired for conservation. Land values differed across landholdings. Each landowner knows their own land values and the three other owners' land values.

Policy treatments and subsidy design. We compared three land retirement policy tools—compulsion land retirement without a subsidy, a simple $93 flat-fee subsidy per retired parcel, and the smart subsidy with agglomeration bonus (see Table 1). The smart subsidy divides a landowner's payment into four distinct parts: (1) a $20 flat fee per cell retired; (2) a $50 own-border bonus for each common border shared between two of his own retired cells; (3) a $24 row-border bonus for each shared border with his row-neighbor (to the south in Figure 1); and (4) a $22 column-border bonus for each shared border with his column-neighbor (to the east). The amount of each bonus payment depends on the productive values and desired configuration and location of the habitat, and can be positive, negative, or zero.[4]

Number of players and rounds. We conducted two 20 rounds sessions for each policy option. Eight subjects from the University of Wyoming participated in each

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[3] With this land grid design, we extend and test the robustness of the work of Parkhurst et al. (2002) on conservation incentives that used a classic normal form 8x8 payoff matrix game in which the spatial element is implicit and embedded in the payoffs. To our knowledge, our land grid is the first spatially explicit design in the experimental economics literature.

[4] We kept the absolute value of the simple and smart subsidy the same by equating the $93 simple fixed fee subsidy based to the average per cell payoff generated in the smart subsidy treatment.

session, and were randomly assigned into two fixed groups of four. *Game strategies—Brown out cells.* In the compulsion session, each subject was required to retire, or "brown out," five cells; the remaining 20 cells were left in production (i.e., leave *green*) and earned the specified value for the cell. In the simple and smart subsidies, each subject could brown out up to five cells {0,1,2,3,4, or 5} to receive the policy subsidy; the remaining cells were left in production.[5] For the compulsion and simple subsidy policy, each subject has one clear dominant strategy—retire his or her five lowest valued cells.[6] In the smart subsidy policy, however, each player has at least two non-dominated strategies. Figure 2 illustrates how the players in the Northwest, Northeast, and Southeast sections of the land grid have two dominant strategies: both strategies retire land at the border line with the three neighbors, although only one of these strategies exactly creates one-quarter of the targeted habitat. The Southwest player has five dominant strategies, four at the borderline and one in the far corner with lowest land values.

Calculator and Communication. Each subject had a 10x10*grid calculator* on the computer screen to assist him or her in calculating profits. The subject could experiment with different *brown out* strategies—for him or herself and for the other three landowners—before having to make a binding decision. The subject's own potential profits based on the configuration of brown cells on the calculator, were calculated and displayed. Subjects could send one message per round to the group.

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[5] Note the large set of potential strategy permutations. By presenting subjects with the land grid and allowing voluntary participation the subjects have 68,406 strategies to choose from. To calculate strategy choices a combination was used. N was an element of the set {0, 1, 2, 3, 4, 5} and the number of cells to choose from was 25. The equation is (25!/5!20!) + (25!/4!21!) + (25!/3!22!) + (25!/2!23!) + (25!/1!24!) + (25!/0!25!) = 68,406. Since there are four subjects in each group, the possible group outcomes for the corridor treatment are $(68{,}406)^4$.

[6] A dominant strategy is any strategy that maximizes a player's payoffs irrespective of the strategy choices of the other players.

Communication was non-binding, unstructured with no restrictions on timing or content, and in which a common language was implemented by allowing subjects to send messages in their natural language (Crawford, 1998). Subjects had two minutes to send messages, use the calculator, and send their choices.

Information and History. After all four subject's brown out choices were submitted, the resulting land grid was shown to the group. The subjects' 5x5 grid of values, the maximum allowed number of brown cells, a message box, and the grid calculator came up on the computer screen and players chose the cells to brown out. Subjects had common knowledge regarding payoffs and strategies. Each subjects individual payoffs and accumulated payoffs were private information. The entire 10x10 grid showing the configuration of brown cells and the payoffs for each subject within the group then appeared in the history box. Subjects had record sheets and the history box to help him or her keep track of his own and the other group members' choice of strategies and associated payoffs in previous rounds.[7]

Results

First to set the stage, consider three illustrative examples on groups land retirement decisions and the resulting habitat configurations given each policy treatment. For the compulsion treatment, Figure 3 shows that a non-contiguous habitat retirement pattern emerges. Once all subjects learned to play their dominant

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[7] We followed standard economic experimental procedures. All experiments were run on computers. Subjects were not told the objective of the experiment and all wording in the instructions and on the computer screens were context free. Following standard protocol, subjects were recruited campus wide and were told to report at a computer lab at a given time. Experimental instructions were provided to each of the participants and the monitor read them out loud while the subjects followed along. The experimental instructions are available on request. Subjects had an opportunity to ask questions concerning the experimental procedures, which were answered by the monitor. The monitor also walked the subjects through two practice rounds to familiarize the subjects with the experimental design. The monitor handed out the agglomeration bonus specification page, which the subjects were allowed to review. The subjects then entered their name and student identification number into the computer, and the computer randomly assigned the subjects to groups of four.

strategies (by round 6), they retire their cheapest cells and created fragmented habitat. Figure 4 shows a similar non-contiguous pattern for the simple subsidy treatment. Here subjects played their dominant strategy in every round, and again created a fragmented reserve. In contrast, Figure 5 shows the smart subsidy induced the desired contiguous spatial pattern. Once all subjects realized the dominant strategy created by connectivity incentives of the agglomeration bonus (rounds 4 – 20), they voluntarily created a contiguous reserve. The smart subsidy provided the proper incentives for subjects to minimize the fragmentation of the conservation efforts.

Now consider all data from two perspective of efficiency—economic and biological. Economic efficiency (EE) measures the frequencies with which groups make land retirement choices that maximize personal wealth. Formally, EE is the percentage of available program rents captured by the group, in which EE = 100 percent means all rents are captured.[8] Biological efficiency (BE) measures the connectivity of the groups habitat. Formally, BE is the percentage of the shared borders between conserved parcels achieved by the group to the maximum number of shared borders.[9] BE = 100 percent implies the targeted contiguous habitat was created.

Figure 6 shows the measures of efficiency by round for each policy. For economic efficiency (panel a), we see all three policies induced approximately the same range of efficiency—between 80 and 99 percent. The distinction is small—most groups captured most of the rents most of the time. In contrast, biological efficiency (panel b)

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[8] To be precise, EE = [Group earnings – minimum earnings]/[maximum earnings – minimum earnings].

[9] For the agglomeration bonus treatment, in which the incentive mechanism is positively correlated with the conservation objective, if a group coordinates to the desired habitat, all efficiency measures equal unity (i.e., EE = BE = 100 percent). For the simple subsidy and compulsion treatment, no correlation, positive or negative exists between economic efficiency and biological efficiency. For expediency, the three efficiency measures are average group outcomes for 5 round intervals {1-5, 6-10, 11-15, 15-20}. The group outcome is the most precise measure of effectiveness since all four players must select the payoff dominant strategy for the outcome to be considered *first best*.

differed substantially by policy option. For compulsion, BE starts at 50 percent and drops to about 40 percent in rounds 6-20; for the simple subsidy, BE starts at about 60 percent and drops to about 52 percent in rounds 6-20. For the smart subsidy, however, BE increase with rounds, starting at 91 percent and increasing to about 99 percent. We summarize our findings thus far—the smart subsidy, which links earnings and the conservation objective, is more biologically efficient at creating contiguous conservation reserves than the current status quo policies of compulsion and a simple flat fee subsidy.

We formally confirm our observations using a conditional regression analysis with random effects that corrects for serial correlation (Brosetta, 2000; Crawford 1995). We consider how our three policies influence our bioeconomic indicators of success, EE and BE. We test two hypotheses: H1: the simple subsidy does not improve bioeconomic efficiency relative to the compulsion policy; H2: the smart subsidy does not improve bioeconomic efficiency relative to the compulsion policy. The following exponential equation is imbedded into a generalized least squares regression analysis.[10]

$$\beta' X_{i,t} = \alpha + \beta_{Simple} Simple_{i,t} + \beta_{Smart} Smart_{i,t} + u_t + \varepsilon_{i,t} \qquad (1)$$

where *i* indicates the group and *t* the period. u_t is a time specific random effect with zero mean and ε_{it} is normally distributed with mean zero and unit variance. Equation (1) accounts for the influence of the different compensation mechanisms. *Simple* is a dummy variable equaling 1 if the group was participating in the simple subsidy treatment; 0 otherwise. We expect the coefficient to not be statistically different from zero—the simple subsidy does not tie the subsidy payments to the contiguousness of the conservation objective. *Smart* is a dummy variable equaling 1 if the group was participating in the agglomeration bonus treatment; 0 otherwise. Here we expect the

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[10] A Hausman test supports the use of a random effects model over a fixed effects model.

coefficient on *Smart* to be positive and significantly different from zero for the regressions on BE. In the EE regression, we expect the coefficient on *Smart* to be non-positive. Coordination games with multiple equilibria create risk, which has a non-positive effect on earnings.

Table 2 presents our econometric results. We first consider *simple* (*H1*) by testing the coefficient β_{Simple}, in which $H_0 : \beta_{Simple} = 0$ and $H_A : \beta_{Simple} \neq 0$. We cannot reject the null hypothesis for the regression on BE or EE. This implies providing a group a simple subsidy to conserve land performs no better at achieving contiguous conservation objectives than does compulsion policy. People are, however, able to realize and extract the additional rents. Now consider *Smart* (*H2*) by testing the coefficient β_{Smart} in which $H_0 : \beta_{Smart} = 0$ and $H_A : \beta_{Smart} \neq 0$. Here we reject the null hypothesis for biological efficiency (see Table 2)—the estimated coefficient β_{Smart} is positive and statistically different from zero at better than the 1 percent significance level for BE. We cannot reject the null, however, for EE. These results indicate the smart subsidy with the agglomeration bonus successfully created a positive correlation between rent seeking behavior and the conterminous conservation objective.

Discussion

Creating contiguous protected areas requires the voluntary cooperation of private landholders, who are more likely to collaborate if they are compensated as noted by Aldo Leopold half a century ago (see Bean, 1998). In our laboratory testbed, we find the idea of a smart subsidy could work, albeit under stylized conditions. The scheme was more effective at inducing people to voluntarily coordinate their conservation decisions relative to current policy options of compulsion and a simple fixed-fee subsidy.

By formally creating a link between the payment and the conservation objective, the smart subsidy achieves both economic and biological goals without resorting to compulsion or land-specific compensation schemes. The landowners choose to retire the targeted land willingly; whereas with compulsion and fixed fees people still secured the economic rents but did not create the desired habitat. But can a smart subsidy be implemented in the field? This is an open question in which the answer, yea or nay, is likely to be site-specific and cannot be answered now without knowing more about specific conditions. What our lab results do suggest, however, is that policy makers might consider adding the smart subsidy idea to their list of policy options for cost-effectively conserving habitat across private landholdings.

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Table 1. Treatment Parameters

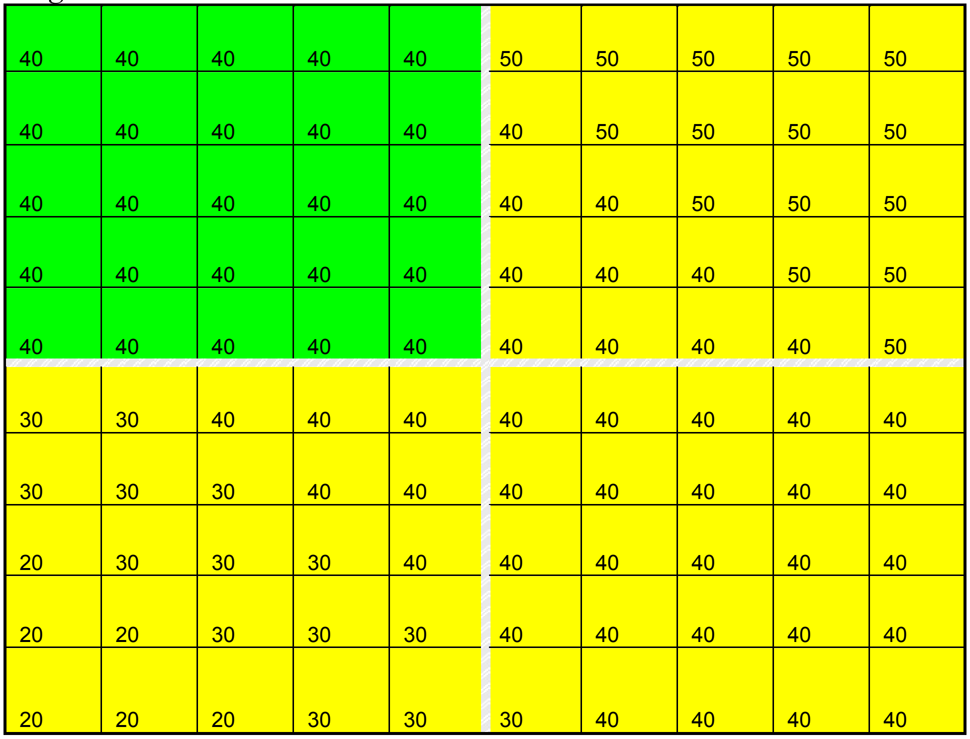
Treatment	Fixed Fee Per Cell Subsidy	Own-Border Bonus	Row-Border Bonus	Column-Border Bonus	Number of participants (Rounds)
Compulsion (No Subsidy)	$0	$0	$0	$0	16 (20)
Simple Subsidy	$93	$0	$0	$0	16 (20)
Smart Subsidy with Agglomeration Bonus	$20	$50	$24	$22	16 (20)

Table 2. Random Effects Regression Analysis—Rounds 5-20

Variable	Biological Efficiency BE	Economic Efficiency EE
α	0.411*	0.922*
	(0.046)	(0.052)
β_{Simple}	0.102	0.030
	(0.065)	(0.074)
β_{Smart}	0.573*	0.066
	(0.065)	(0.074)
Hausmann (p-value)	$\chi_1^2 = 169.50$ (< 0.01)	$\chi_1^2 = 272.84$ (< 0.01)

* significant at the 1 percent level
standard errors in parentheses
Behavior converged by round 6 and thereafter. Regression results on all rounds are available on request.

Figure 1. 10x10 Land Grid



40	40	40	40	40	50	50	50	50	50
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40	40	40	40	40	40	40	50	50	50
40	40	40	40	40	40	40	40	50	50
40	40	40	40	40	40	40	40	40	50
30	30	40	40	40	40	40	40	40	40
30	30	30	40	40	40	40	40	40	40
20	30	30	30	40	40	40	40	40	40
20	20	30	30	30	40	40	40	40	40
20	20	20	30	30	30	40	40	40	40

Figure 2. Dominant Strategies by Landowner Grid Location

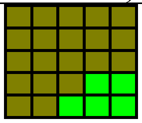
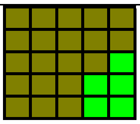
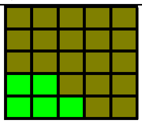
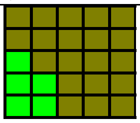
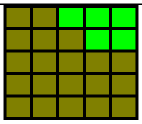
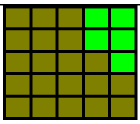
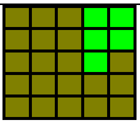
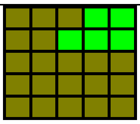
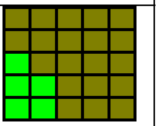
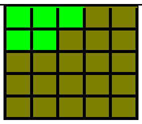
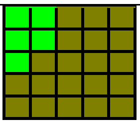
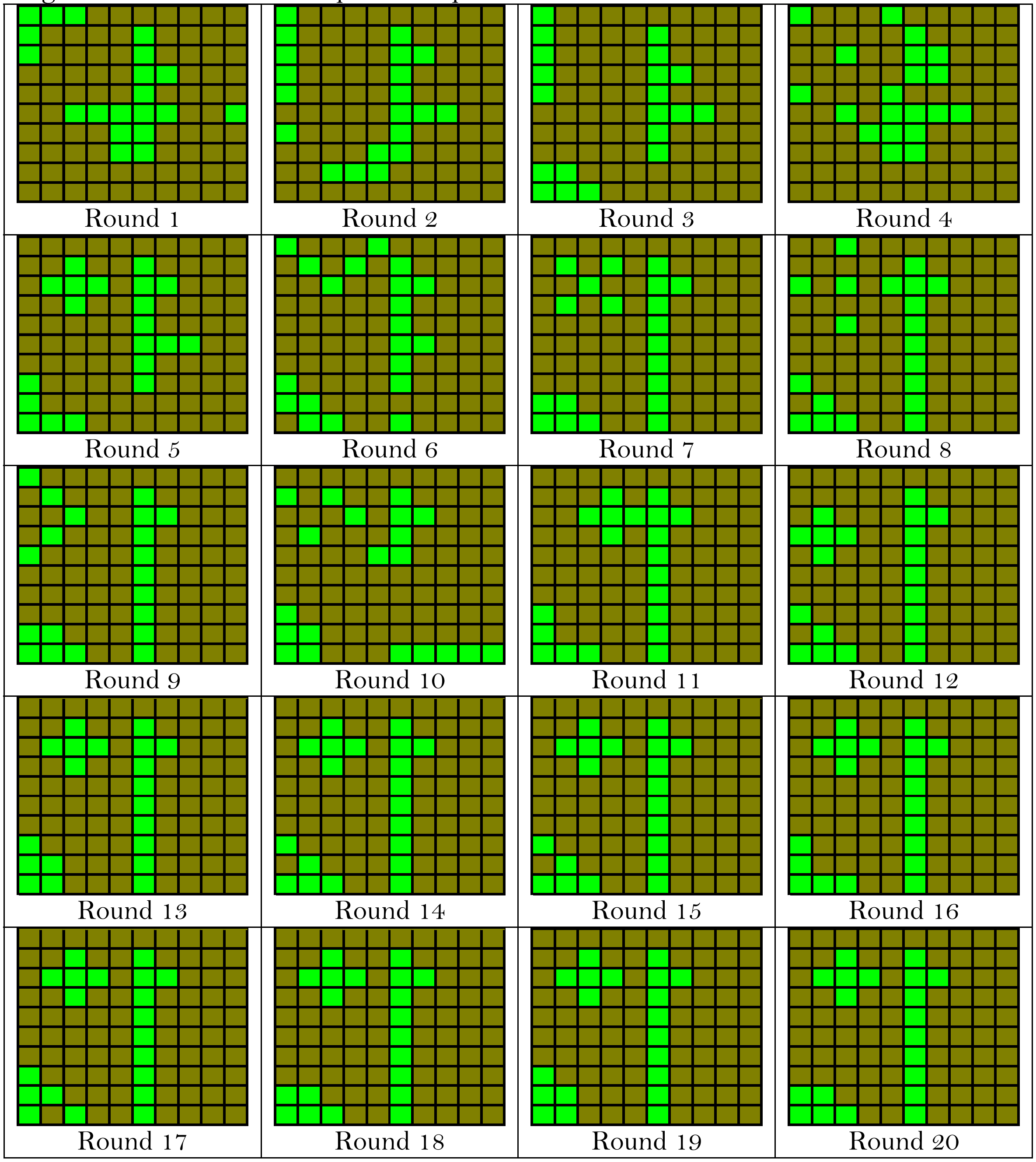
Landowner Location	Dominant Strategy {meets targeted habitat}	Dominant Strategy {does not meet targeted habitat}			Dominant Strategy {lowest value land}
Northwest 5x5 Earnings Max: Min:	 $1266 $1150		 $1264 $1150		
Northeast 5x5 Earnings Max: Min:	 $1416 $1300		 $1414 $1300		
Southwest 5x5 Earnings Max: Min:	 $1016 $900	 $1014 $900	 $1002 $910	 $1002 $910	 $1000 $1000
Southeast 5x5 Earnings Max: Min:	 $1256 $1140		 $1254 $1140		

Figure 3. Illustrative Example—Compulsion



Round 1 Round 2 Round 3 Round 4

Round 5 Round 6 Round 7 Round 8

Round 9 Round 10 Round 11 Round 12

Round 13 Round 14 Round 15 Round 16

Round 17 Round 18 Round 19 Round 20

Figure 4. Illustrative Example—Simple Subsidy

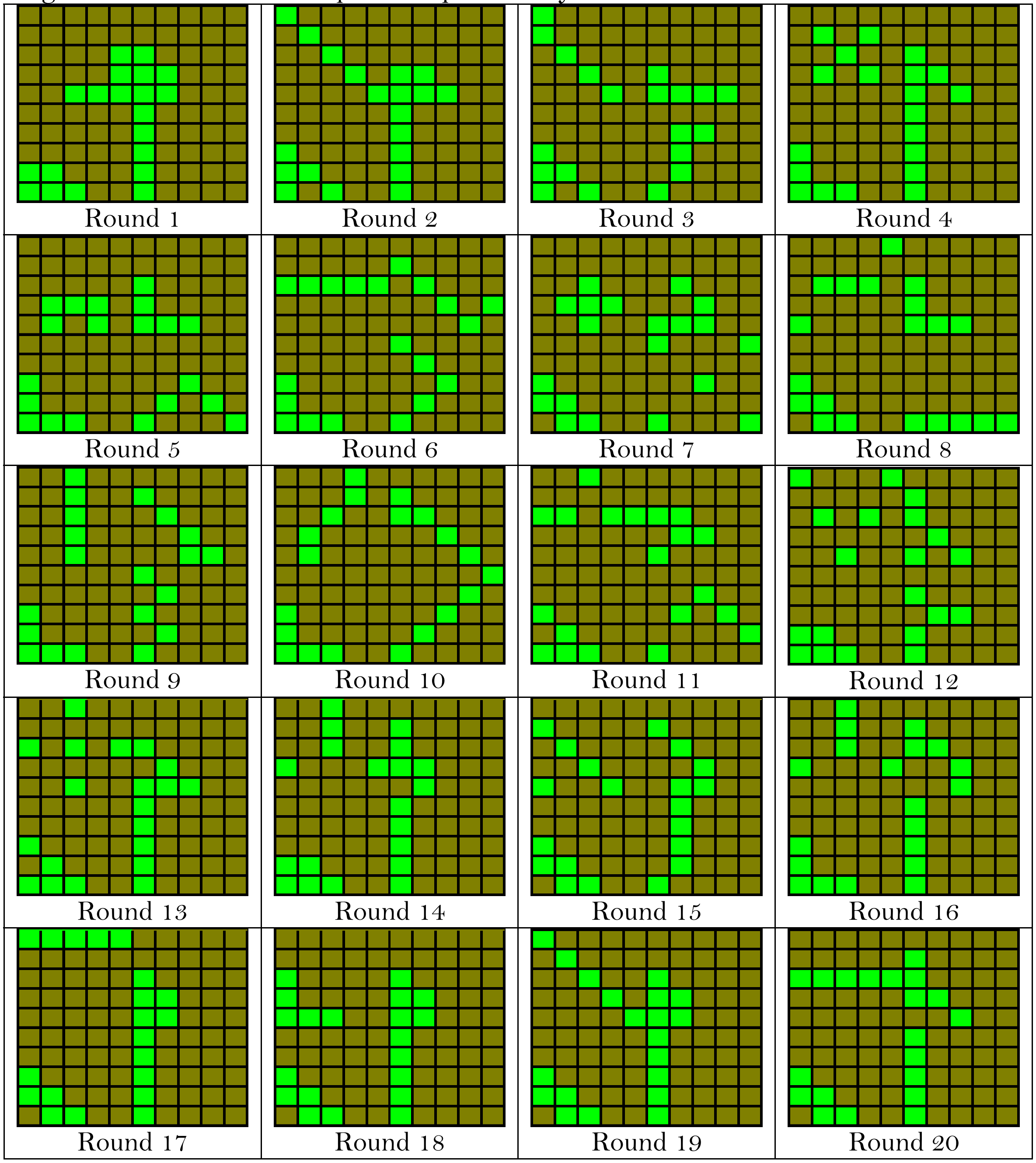


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Figure 5. Illustrative Example—Smart Subsidy with Agglomeration Bonus

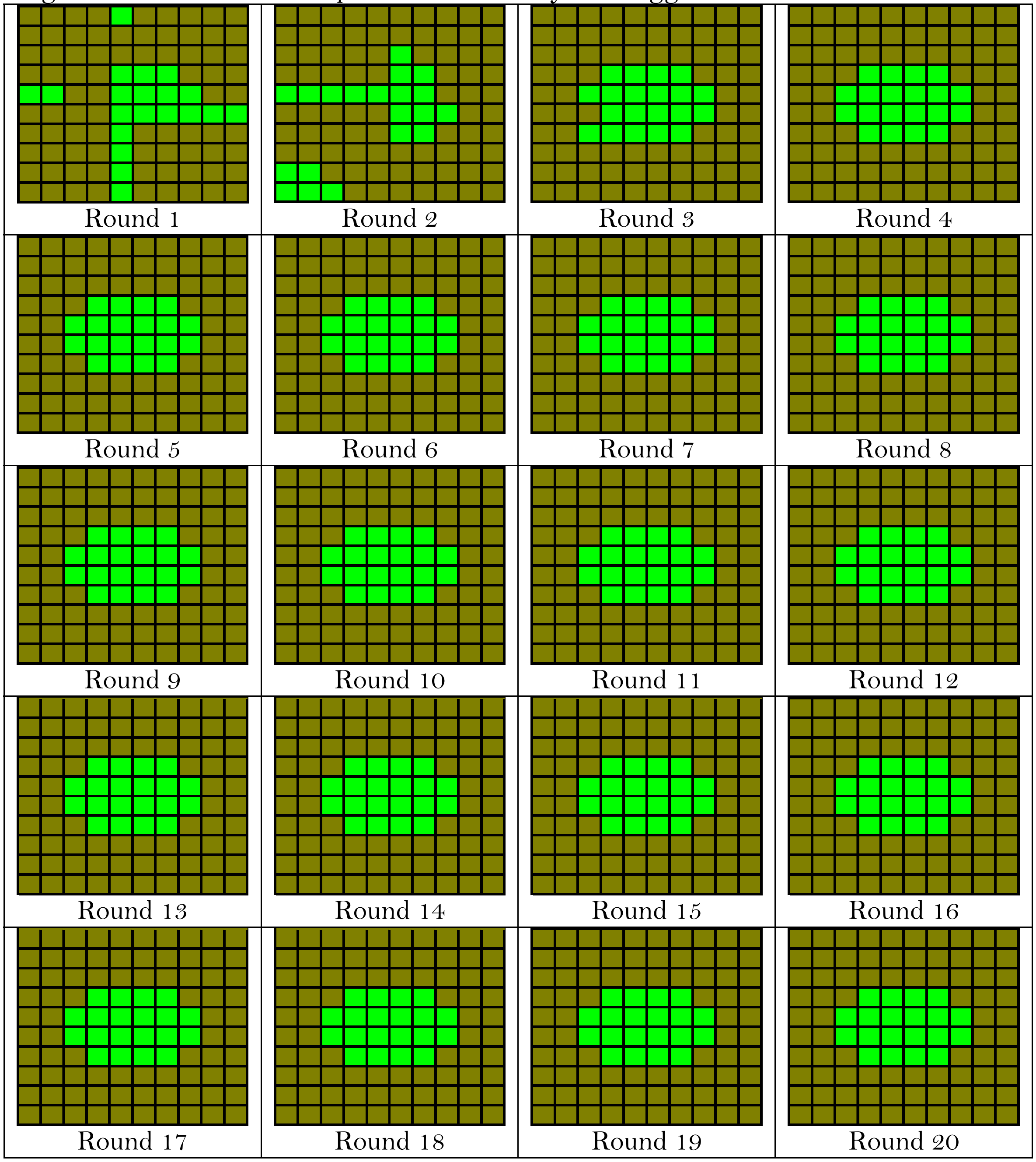

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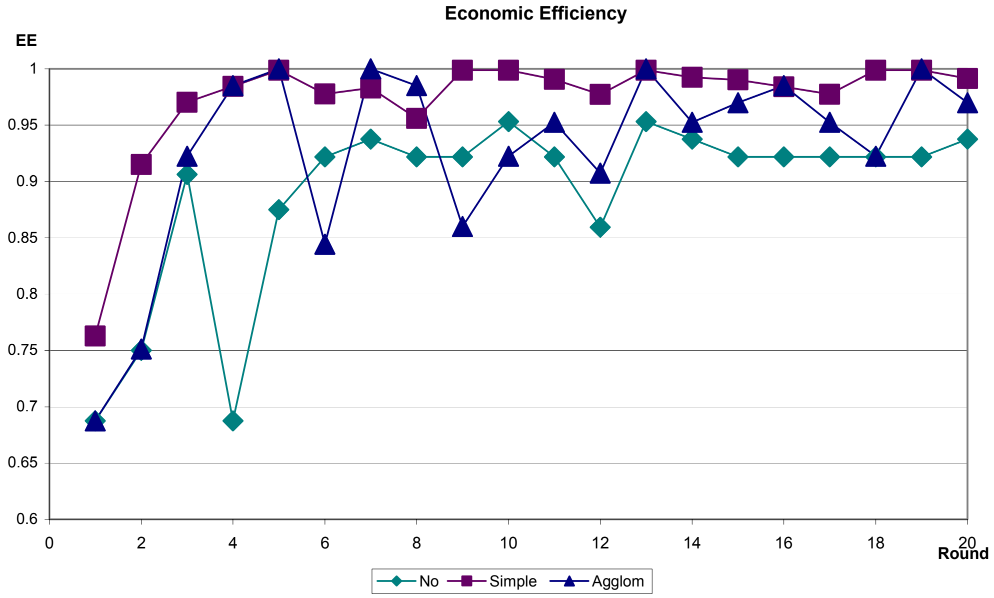
Figure 6. Economic and Biological Efficiency

(a)



(b)