A Classroom Experiment about Common-Pool Resources and Local Environmental Control

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ABSTRACT

This article describes a hand-run classroom experiment that illustrates the basic principles behind common-pool resource management, including the "Tragedy of the Commons" and a comparison of strategies intended to facilitate cooperation in managing a shared environmental resource. The experiment can also be used to illustrate concepts such as Pareto efficiency and Nash equilibrium, public goods, factors which motivate self-interested and group-oriented behavior, and the potential for externally imposed regulations to crowd-out civic-minded behavior. The experiment has been run successfully in a variety of courses and disciplines at both the undergraduate and graduate levels, including introductory and intermediate microeconomics, a public finance course for Master's students in a public policy and administration program, and a natural resources conservation course. Other courses for which the experiment would be appropriate include environmental economics and game theory. The same experiment has also been used in the field where the participants are actual common-pool resource users with results similar to those in the classroom.

1. Introduction

Although active learning is on the rise in other disciplines (Sax 1996), engaging students with hands-on exercises is still lacking in economics (Becker 1997). The use of classroom experiments is a fun, tangible way to introduce new concepts to students. This article describes a classroom exercise that can be used to illustrate a number of economic concepts, including the basic elements of a common-pool resource (CPR) and the "Tragedy of the Commons," Pareto efficiency, Nash equilibrium, and public goods. In addition, the experiment challenges students to think critically about factors that might motivate self-interested versus group-oriented behavior, how these factors might affect the ability of externally-imposed regulations to improve cooperation in managing a local environmental resource, and the implications this has for designing public policies.

The experiment is a classroom adaptation of field experiments run by Cardenas, Stranlund and Willis (2000) with rural villagers in Colombia, and was motivated by real-world local common-pool resource dilemmas these people face in their daily lives. The experiment is framed as a resource extraction problem – how much time to spend in the forest collecting firewood. The problem is that water quality and firewood collection are inversely related – the more time each person spends collecting wood, the lower the water quality will be for everyone in the community due to soil erosion. Hardin (1968) postulated that rational self-interested behavior will result in over-exploitation of a CPR.[1] However, both experimental and field evidence consistently demonstrate that individuals do not always behave as if they were purely self-interested; instead they often make decisions that balance self and group interests (see Davis and Holt 1993, and Kagel and Roth 1995 for a survey). Ostrom (1990) identifies a number of

[1] In this context, self-interested means that an individual's utility function depends exclusively on her own gains and does not include the welfare of others.

long-enduring, successfully managed CPRs, and some key elements that these have in common. Moreover, research indicates that externally imposed regulations that theory predicts should improve social welfare may in fact be counter-productive by crowding-out civic-mindedness and encouraging more selfish behavior (Frey and Oberholzer-Gee 1997; Ostmann 1998; Cardenas, Stranlund and Willis 2000). On the other hand, communication and group involvement in organizing and governing a local resource may result in higher levels of cooperation (Ostrom and Walker 1991).

2. Experiment design for classroom use[2]

Experiment summary

The experiment consists of a series of rounds in which students must decide how many months to spend extracting firewood from the forest. Typical of CPR problems, individual payoffs are function of both the individual's decision about how many months to spend in the forest, $x_i \in [0,8]$, and the aggregate decision of all n group members, $\sum_{j=1}^{n} x_j$. The latter term captures the negative externality that generates the divergence of private and social interests. The function that defines individual payoffs is:

$$\Pi_i\left(x_i, \sum x_j\right) = \frac{2}{8405}\left[1372.8 - \left(\sum x_j\right)^2 + 97.2x_i - 3.2\left(x_i\right)^2 + 30\left(8 - x_i\right)\right]^2 \quad (1)$$

These payoffs are summarized in a Payoff Table (Figure 1 contains a condensed version) that is included with the instructions (Appendix A). The table given to students does not include the highlighted cells. This Payoff Table is identical for each student. The socially optimal solution is

[2] All materials useful for running the experiment are available from the author's web page, http://www.umass.edu/resec/fac+staff/murphy/teaching.html. For those with access to a computer lab, the authors have also created a computer-based version of this experiment that is freely available on the web page.

for each person to spend just one month in the forest, but this is not a Nash equilibrium. Students submit their decisions to the instructor, who tabulates the results and announces the total number of months spent in the forest by each group (individual decisions are not revealed, just the group total). The experiment consists of three different treatments that test three different policy options: (1) an unregulated CPR, (2) an imperfectly-enforced externally-imposed regulation, and (3) communication as a tool for managing the resource via self-governance. These treatments are discussed in more detail later. For a 75-minute class, we typically run about 15 to 20 periods divided into the three treatments. The exact number of periods is not announced to the class.

<< INSERT FIGURE 1 HERE >>

Getting started

To save class time, a few days before the experiment, hand out the instructions and ask students not to discuss the experiment amongst themselves because it only detracts from their experience. We have found that students usually honor this request. Encourage students not only to read and understand the instructions, but also to think about the types of decisions they might make in the experiment. Before the start of the experiment, answer any questions but avoid suggesting how a person should play the game.

At the beginning of class, randomly assign students into groups. All groups in both Cardenas, Stranlund and Willis (2000) and our class experiments consisted of $n = 8$ members, and in the remainder of this paper we assume groups of eight. If there are a few “extra” students, we usually have some students work together in pairs jointly making a single decision so that all groups have eight “participants.” It is possible to conduct this experiment with group sizes less than eight, and at the end of the paper, we provide some details on running the experiment with smaller group sizes. In larger classes, it might be useful to select one or two students to assist in running the experiments. To preserve anonymity, randomly assign each of the *n* group members a unique player number between one and *n*. Only the individual should know her player number. All decisions will be submitted using this number so that not even the instructor will be able to link individual students to their decisions.

Running the experiment

Participants need to decide how many months to spend extracting wood from the forest. This must be a whole number between zero and eight, inclusive. Students use an Experiment Card (Figure 2) to submit their decision to the instructor. If there are multiple groups, we have found it convenient to have each group's Experiment Cards on a different color paper. Note that the student does not report her name on the Experiment Card, only the player number, so there is no way of linking individual students to their decisions. The students also record their decisions on the Record Sheet (Figure 3) for their own record. The instructor collects the Experiment Cards and inputs each decision into an Excel spreadsheet. The spreadsheet tabulates the results and also plots the results for later discussion. The instructor announces the total for each group, and the students then calculate their earnings using the Payoff Table. The process is then repeated for the next period.

<< INSERT FIGURE 2 HERE >>

<< INSERT FIGURE 3 HERE >>

Treatments

The experiment consists of three treatments, usually run in the following sequence: (1) five to eight rounds of an unregulated CPR without communication among participants (referred to as the *NoReg-NoComm* treatment), (2) five to eight rounds of a CPR with exogenous regulation and random monitoring (*Reg-NoComm*), and (3) a few rounds of an unregulated CPR in which participants are given an opportunity to communicate before making a decision (*NoReg-Comm*). Clearly, the experiment could be run with any combination or sequence of treatments. The instructions given to students prior to the experiment are for the *NoReg-NoComm* treatment, and students are not aware of any upcoming changes.

NoReg-NoComm. This treatment presents students with a typical CPR dilemma, and could be used alone or in conjunction with the other treatments. Students are not allowed to speak with each other. The efficient solution is for each person to spend one month in the forest. In this situation, the group payoffs are maximized and each person earns E$645. This is not, however, a pure strategy Nash equilibrium. With a group size of eight, should an individual expect the other seven group members to choose one month, he could increase his own individual payoff by choosing eight months and earning E$891. (The highlighted cells in Table 1 indicate an individual's pure Nash strategy. These cells were not highlighted in the table given to students). The pure strategy Nash equilibrium is for each person to choose six months and earn E$155.[3] It is worth noting that at the Nash equilibrium, subjects earn about 24% of what they would at the efficient outcome.

Reg-NoComm. After about five to eight rounds of the *NoReg-NoComm* treatment, the experiment is paused and the students are given a piece of paper with the new monitoring rules (Appendix B). The instructor reads these new rules aloud while the students read along. The intent of the regulation is to reach the socially efficient outcome, therefore the regulation stipulates that each person may spend no more than one month in the forest. Communication among group members is still prohibited. In reality, monitoring and enforcing regulations is

[3] Since each group member has identical payoffs, the Nash equilibrium is symmetric.

often costly and difficult. The experiments, therefore, use an imperfect monitoring mechanism. After students have made their decisions and the Experiment Cards are collected, there is a 1/16 probability that one person in the group will be monitored. For each group, to determine whether someone is monitored, the instructor tosses a coin. If tails, then nobody will be monitored; if heads, then one person in the group will be monitored. If heads, to determine which person will be monitored, cards numbered one through eight are placed in a box. The instructor draws one card and the number on the card corresponds to the player monitored. Although the player number is announced to the class, no one except the individual monitored knows her identity. Once the player number is announced, the card is returned to the box. It is possible that the same individual may be monitored multiple times. It is also possible that no one is monitored. This monitoring sequence should be repeated separately for each group.

If the person monitored chose to spend zero or one month in the forest, then the person is in compliance and there is no penalty. However, if the person monitored spent more than one month in the forest, then the penalty is E$100 for every month that the person is out of compliance. For example, if the person chose five months, she is four months above the standard and receives a E$400 penalty. In this case, the person monitored should deduct the E$400 penalty from her earnings for that period. The instructor's Excel spreadsheet will automatically track the penalties.

Assuming risk neutrality, the Nash equilibrium is reached when each player chooses to spend five months in the forest (as opposed to six months in the unregulated case). The expected payoff is E$268, which is about 42% of the payoffs that could be attained if everyone fully complied with the regulation. However, since the regulation is intended to induce more efficient choices, each individual's expected payoff is about 73% higher than the Nash equilibrium in the *NoReg-NoComm* treatment.

NoReg-Comm treatment. After about five to eight rounds of the *Reg-NoComm* treatment, the remaining time is allocated to the *NoReg-Comm* treatment. In this treatment, the regulation is no longer in effect, but students are now given about five minutes to meet with their fellow group members. Students are permitted to discuss any aspect of the experiment, but they are not allowed to use threats, agree to transfer money, or show anyone their Record Sheet. Once students return to their desks, all decisions are private and the experiment proceeds like the first treatment (*NoReg-NoComm*). Because of time constraints, we usually run only two to four rounds of this treatment, but this is sufficient to generate meaningful discussion.

Paying students in cash

Earnings in the experiment are denoted in experimental dollars (E$). If desired, these experimental earnings could be converted to local currency at a pre-announced exchange rate. Although paying students is optional, to maintain some degree of saliency and fun, we usually announce that two names will be drawn at random at the end of the experiment. The winners will be paid their average earnings in cash. We prefer to use a random drawing, rather than paying those with the highest earnings, because all participants will always have a chance to be paid and therefore have an incentive to maximize earnings. With eight people in a group, average earnings usually range between E$350 and E$600 with an average of about E$450. We use average earnings, rather than cumulative earnings, so that payoffs are independent of the total number of rounds. We do not recommend that students grades be linked in anyway to the outcome of the experiment.

Keep in mind that the experiment is designed such that the instructor cannot identify a student's decisions, and therefore cannot verify how much a student earned. If students are randomly selected to be paid, the "winners" will have to provide their player number to the instructor, which removes a degree of anonymity. (The other students will still be unaware of their peers' individual decisions). Students should be made aware of this possibility.

Preparing for the experiment

The instructor should bring the following to class:

1. Laptop computer with a spreadsheet to tabulate results (or a calculator with some paper for manual record keeping).
2. Coin (for flipping to decide if anyone is monitored)
3. Empty box or hat (for drawing ID numbers if someone is monitored)
4. Payoff Table (Figure 1, one for each student)
5. Experiment Cards (Figure 2, about 15-25 for each student, depending upon number of rounds)
6. Record Sheets (Figure 3, one for each student)
7. Monitoring rules (Appendix B, one for each student)
8. Extra copies of instructions (Appendix A, in case some people forget to bring them)
9. Optional cash payoffs (if some students will be paid)

Running experiments – sequence of steps

Getting started

1. Answer any questions about the instructions.

2. Assign students to groups of eight.
3. Distribute Experiment Cards, Record Sheet and Payoff Table.

The experiment

4. Begin round.
5. If students are allowed to communicate (*NoReg-Comm* treatment), allow about five minutes to discuss experiment.
6. Students make decision and record on both Experiment Card and Record Sheet.
7. Instructor collects Experiment Cards, tabulates results, and announces total number of months spent in the forest by each group.
8. If regulation is in effect (*Reg-NoComm* treatment), flip coin to decide if someone will be monitored. If heads, randomly select one group member for monitoring. Repeat for each group.
9. Students calculate earnings for the round, including any penalties. The Excel spreadsheet automatically does this accounting for the instructor.
10. Begin next round. If changing to another treatment, announce new rules before students make decisions.

3. Running the experiment with smaller group sizes

It is possible to conduct this experiment with group sizes smaller than eight, but we would recommend no fewer than four students per group. The two key changes are a smaller payoff matrix and a new Nash equilibrium. For a group size of $n < 8$, delete the last $(8-n)\cdot 8$ rows of the Payoff Table (Figure 1).[4] For example, with a group size of six, delete the last 16 rows (*i.e.*, the rows corresponding to "their months" equals 41 through 56). The values in the Payoff Table

[4] The web page contains the payoff matrices for group sizes of 4 through 8.

are unchanged. Figure 5 contains the Nash equilibrium for groups of four to eight. With six students per group, for example, the symmetric Nash equilibrium is for each person to spend seven months in the forest with each person earning E$300, but the socially optimal choice is two months with each person earning E$663. The last row of Figure 5 shows that at the Nash equilibrium students earn 45% of what they would have at the social optimum.

When the external monitoring is in effect (*Reg-NoComm* treatment), the standard may have to be adjusted to reflect the new social optimum. With six per group, for example, the new regulation should penalize those choosing three or more months.

4. Discussing the results[5]

Students quickly recognize the common-pool resource dilemma they face: payoffs would be maximized if everyone chose to spend one month in the forest, but there are economic incentives for individuals to deviate from this. Use this as an opportunity to introduce common-pool resources and public goods, as well as the concepts of efficiency, private welfare and social welfare. For classes that discuss game theory, instructors can point out that for the *NoReg-NoComm* treatment, the pure strategy Nash equilibrium is for each person to spend six months in the forest (the Nash responses are highlighted in Figure 1). Emphasize that the payoff maximizing choice is not to always spend eight months in the forest. In some cases, a purely self-interested individual may earn more by spending fewer months in the forest. Note that if the individual expects all the other group members to average, say, seven months in the forest (*i.e.*, their months equals 49), her payoff maximizing decision is to choose four months and earn E$49. A slightly more advanced exercise would be to have students calculate the *expected*

[5] The Excel spreadsheet automatically plots the results as they are entered. This allows the instructor to present some results immediately after the experiment, or to make available for discussion in the next class.

payoffs and Nash responses under regulation. These expected payoffs are available for download from the web page. Using expected payoffs, the Nash equilibrium for the *Reg-NoComm* treatment is five months.

Once these concepts have been introduced, it is interesting to discuss the results for the first treatment (*NoReg-NoComm*) and identify the factors that may have led to the observed outcomes. Individual decisions in this treatment usually vary, with a mean and median typically between four and five months. However, the modal choice is consistently eight months. Figure 4 shows the mean decision for a typical group by period for the three treatments. If the group mean is around four or five, ask students why the "Tragedy of the Commons" did not occur. Were individuals consciously playing a Nash strategy? Is the distribution bi-modal, with the group divided between "free-riders" and "group-oriented" individuals, so that the mean is somewhere in the middle? The key is to understand and discuss why groups' outcomes are the result of a population of both types. More advanced courses or discussions could go to the literature on agent types, including Ostrom's paper (2000) on social norms and collective action.

The second treatment, *Reg-NoComm*, parallels a situation in which an external government agency imposes regulations on the group in an attempt to reach a more efficient solution. These regulations are sometimes imperfectly enforced, particularly in developing countries. Research indicates that individuals are sometimes made worse off when faced with a modestly enforced government-imposed regulation that standard theory predicts would be welfare enhancing (Frey and Oberholzer-Gee 1997; Ostmann 1998; Cardenas, Stranlund and Willis 2000). The rationale for this mystifying result appears to be that when individuals are confronted with a regulatory constraint, they tended on average towards more self-interested behavior (*i.e.*, towards pure Nash strategies), while in the absence of regulatory control their choices were significantly more group-oriented.

When the regulation is imposed, there is typically high compliance in the first few rounds. But this compliance usually deteriorates and decisions are often at the same levels that they were in the *NoReg-NoComm* treatment. This would be consistent with the notion that external regulation may "crowd-out" other-regarding behavior. Figure 4 contains the results from a single experiment that demonstrates this pattern. The mean and median of all periods combined is usually about one month lower than the *NoReg-NoComm* treatment; the modal decision is usually one month, although modes of eight months are not uncommon especially in the later rounds. For groups that do not display the early compliance pattern shown in Figure 4, it is still common to observe about a one month decrease in the mean.

The last treatment, *NoReg-Comm*, is a proxy for allowing a weak form of self-governance over the shared local resource. What is particularly interesting about this treatment is the high degree of compliance that communication fosters, even in the absence of any regulation. In over 75% of the experiments we have run, there is perfect or near-perfect compliance by all group members (see Figure 4). Prior to the last round, we announce that this will be the end, but rarely observe any significant end-game effects. A discussion can begin with why one might expect end-game effects, and then focus on the reasons why these effects were or were not observed in the classroom.[6]

The results of the last two treatments usually generate a lively debate about self-governance versus external regulation. In theory, even a modestly enforced regulation should improve social welfare, whereas non-binding communication should have no impact. Yet in the

[6] Alternatively, instructors could elect not to make the last round known, but it is likely that students will be able to anticipate when the end is near.

experiments, we consistently observe the opposite. Ask students why communication was so effective, and to discuss the appropriate level of government (national, state, local) for confronting various environmental and shared resource problems. To what extent did communication help to foster the development of social norms, and what role did these norms play in managing the resource?

Appendix A. Experiment Instructions

INSTRUCTIONS FOR CLASS EXPERIMENT

Please read through these instructions carefully **before class**. Be sure to bring these instructions along with you to class. PLEASE DO NOT DISCUSS THE EXPERIMENT WITH OTHERS IN THE CLASS. However, I encourage you to begin thinking about the types of decisions you might make in the experiment. If you have questions, feel free to call or email me before class. Before the experiment begins, everyone will be given an opportunity to ask questions. Once the experiment begins, you may raise your hand if you have questions. Talking with the others during the experiment is NOT permitted.

In each round of the experiment, you will have the opportunity to earn cash in experimental dollars (E$). After the experiment is over, we will compute your average earnings per round. Then, I will draw the names of two individuals who will be paid in cash the US$ equivalent of your experiment earnings. I would like to point out that, in terms of cash earnings, your incentives are <u>identical</u> in this setup with a random drawing for two names as they would be if everyone were paid his/her earnings. The more you make in E$, the more you will make in US$ if your name is called.

Introduction

This experiment attempts to recreate a situation in which a group of families must make decisions about how to use a shared resource, for example, a forest, a water source, or a fishery. In this experiment, the resource will be referred to as the forest. You will play for several rounds that are equivalent, for instance, to years or harvest seasons. Make no assumptions about the number of rounds.

The payoff table

At the start of the experiment, you will receive a PAYOFF TABLE identical to the one attached at the end of the instructions. This table contains all the information that you need to make your decision in each round of the experiment. The numbers that are inside the table correspond to the experimental dollars (E$) that you would earn in each round for a given set of decisions. Each of you must decide the number of MONTHS that you want to allocate to "*time extracting from the forest*" (in the columns from 0 to 8).

To play in each round you must write your player ID (which the instructor will give you), the current round number, and your decision (a number between 0 and 8) on an EXPERIMENT CARD that the instructor will give you. (There is an example attached to the end of the instructions).

It is very important that you keep in mind that your decisions are completely private and you may not show them to the rest of members of the group. Moreover, the instructor will not know what you decided and will not divulge your decisions to anyone.

After everyone has made his/her decision, the instructor will collect the EXPERIMENT CARDS from all 8 group members, and will calculate the total of months that the group decided to spend extracting from the forest. When the instructor announces the group total, each of you will be able to calculate the E$ that you earned in the round. Let us explain this with an example.

In this experiment, we assume that each player has available a maximum of 8 MONTHS to work each year extracting a resource like firewood or logs. In the PAYOFF TABLE this corresponds to the columns from 0 to 8. Each of you must decide from 0 to 8 in each round. But to be able to know how much money you earned, you need to know the decisions that the rest in the group made.

An example of how the payoff table works

		My Months In The Forest								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Their Months	**19**	488	520	550	578	603	625	645	661	674
	20	475	506	**535**	561	585	606	625	640	653
	21	461	491	519	544	567	587	605	619	630
	22	447	476	502	527	548	567	584	597	608

- You decide that "MY MONTHS IN THE FOREST" will be 2.
- The instructor collects all the Decision Cards and announces that a TOTAL of 22 months were spent in the forest.
- Therefore, you know that "Their months in the forest" was 20, and your earnings for the round are 535.

The Record Sheet

OK, let's look how the experiment works in each round. Each participant will receive a RECORD SHEET like the one attached to the end of these instructions.

Using Example 1 above, let us see how to use this RECORD SHEET. Suppose that you decided to spend 2 months in the forest this round. On the EXPERIMENT CARD, you should write 2 next to "*My months in the forest*." You must also write this number in the first column (A) of the RECORD SHEET. (You are writing your decision down in 2 places: the EXPERIMENT CARD you give to the instructor, and the RECORD SHEET you keep).

The instructor will collect the EXPERIMENT CARDS from everyone in your group and will calculate the total time spent in the forest by the group. The instructor will announce this total to the group. Suppose that the total was 22 months. Write 22 in column B of the RECORD SHEET. To calculate "Their months in the forest," subtract column A from column B, and record this in column C. In our example, "their months in the forest" is 20. To calculate your earnings, use the payoff table as described earlier. If "my months" equals 2, and "their months" equals 20, then your earnings would be 535. So in this example, you would have written the following on your RECORD SHEET:

NAME: ______________________________ PLAYER NUMBER: _______				
	Column A	**Column B**	**Column C**	**Column D**
Round No.	**MY MONTHS IN THE FOREST** (Your decision)	**TOTAL GROUP MONTHS IN THE FOREST** (Announced by the Instructor)	**THEIR MONTHS IN THE FOREST** (Column B minus Column A)	**MY EARNINGS IN THIS ROUND** (Use your PAYOFF TABLE)
1	2	22	20	535
2				

It is very important to clarify that nobody will know your decisions in each round or your earnings for the experiment. Only the **group total** is announced in public. No one, including the instructor, will know what each participant in your group decided.

If you have any questions about how to earn money in the experiment, please email me, or ask before the experiment begins.

Summary of steps for playing one round of the experiment

How is it played: In each round, you must decide how many months in a year between 0 and 8, you want to devote to extracting resources from a forest. Your earnings in each round depend on both your decision and the decisions by the rest of the group, according to the PAYOFF TABLE.

What you need: To play you need a PAYOFF TABLE, a RECORD SHEET, and several EXPERIMENT CARDS. You also need a player number. The instructor will provide all of this.

Steps for each round:

1. Using the **PAYOFF TABLE,** decide how many months you will spend in the forest.
2. On the **RECORD SHEET,** write your decision (MY MONTHS IN THE FOREST) in Column A for the current round.
3. On an **EXPERIMENT CARD,** write the round number, and your decision (MY MONTHS IN THE FOREST). Make sure it corresponds exactly to what you wrote on the RECORD SHEET. Hand the experiment card to the instructor.
4. The instructor will collect all the experiment cards and announce the **TOTAL GROUP MONTHS.**
5. On the **RECORD SHEET,** write this total in Column B (TOTAL GROUP MONTHS IN THE FOREST).
6. On the **RECORD SHEET,** calculate Column C (THEIR MONTHS IN THE FOREST). This equals Column B minus Column A.
7. On the **RECORD SHEET,** write in Column D the total amount you earned for this round. To know how much you earned, use the PAYOFF TABLE and columns A and C (MY MONTHS and THEIR MONTHS).
8. Play another round (Go back to step 1).

Appendix B. Monitoring rules for *Reg-NoComm* treatment

EXTERNAL REGULATION

In addition to the rules for the rounds we just completed, there is now an additional rule in effect. The goal of this new rule is to help obtain the maximum earnings possible for the group. We will try to guarantee that each player in your group chooses to spend no more than 1 MONTH IN THE FOREST.

However, it will be very difficult to inspect everyone's decision. Thus, we will select someone at random to be monitored. To determine who will be monitored: The instructor will flip a coin. If TAILS, then nobody will be monitored this round. If HEADS, then one person will be monitored this round. The monitor will draw one name from a box with all eight participant numbers. If that person spent more than one month in the forest, a penalty will be imposed.

The penalty is E$100 for each additional month. For example, if a player is selected randomly, and he had chosen to spend 3 MONTHS IN THE FOREST, the monitor will subtract E$200 from his total earnings in that round.

If someone is monitored in the round, no one will know who that person is. Moreover, only the individual and the monitor will know whether that person was in compliance. The card for the person who was monitored will be returned to the box. Thus, it is possible for someone to be monitored more than once during the experiment. It is also possible that someone may not be monitored at all.

PENALTY IF YOU ARE MONITORED									
My Months	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Penalty (E$)	0	0	100	200	300	400	500	600	700

Figure 1. Payoff matrix for eight persons in a group [a]

		MY MONTHS IN THE COMMONS								
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
THEIR MONTHS IN THE COMMONS	**0**	619	670	719	767	813	856	896	933	967
	7	600	645	688	729	767	803	836	865	891
	14	546	583	619	652	683	711	736	758	776
	21	461	491	519	544	567	587	605	619	630
	28	355	377	396	414	430	443	453	461	466
	35	238	253	266	277	286	293	297	300	300
	42	127	135	142	148	152	154	155	154	152
	49	40	44	46	48	49	48	47	45	43
	56	0	1	1	1	1	1	0	0	0

[a] To conserve journal space, this is a condensed version of the payoff matrix. This reduced matrix only contains the rows for which the seven "other" group members each choose the same number of months. The web page has the complete matrix that should be given to students. For those without web access, the complete matrix can be constructed in Excel using equation (1), and includes the 57 rows corresponding to "their months" equals 0 to 56, inclusive.

Figure 2. Experiment Card

EXPERIMENT CARD	
Player Number:	
Round Number:	
My months in the forest:	

Figure 3. Sample Record Sheet

NAME: ______________________________		PLAYER NUMBER: _______		
	Column A	**Column B**	**Column C**	**Column D**
Round No.	**MY MONTHS IN THE FOREST** (Your decision)	**TOTAL GROUP MONTHS IN THE FOREST** (Announced by the Monitor)	**THEIR MONTHS IN THE FOREST** (Column B minus Column A)	**MY EARNINGS IN THIS ROUND** (Use your PAYOFF TABLE)
1				
2				
…				
20				
			TOTAL	

Figure 4. Average individual decisions from one group

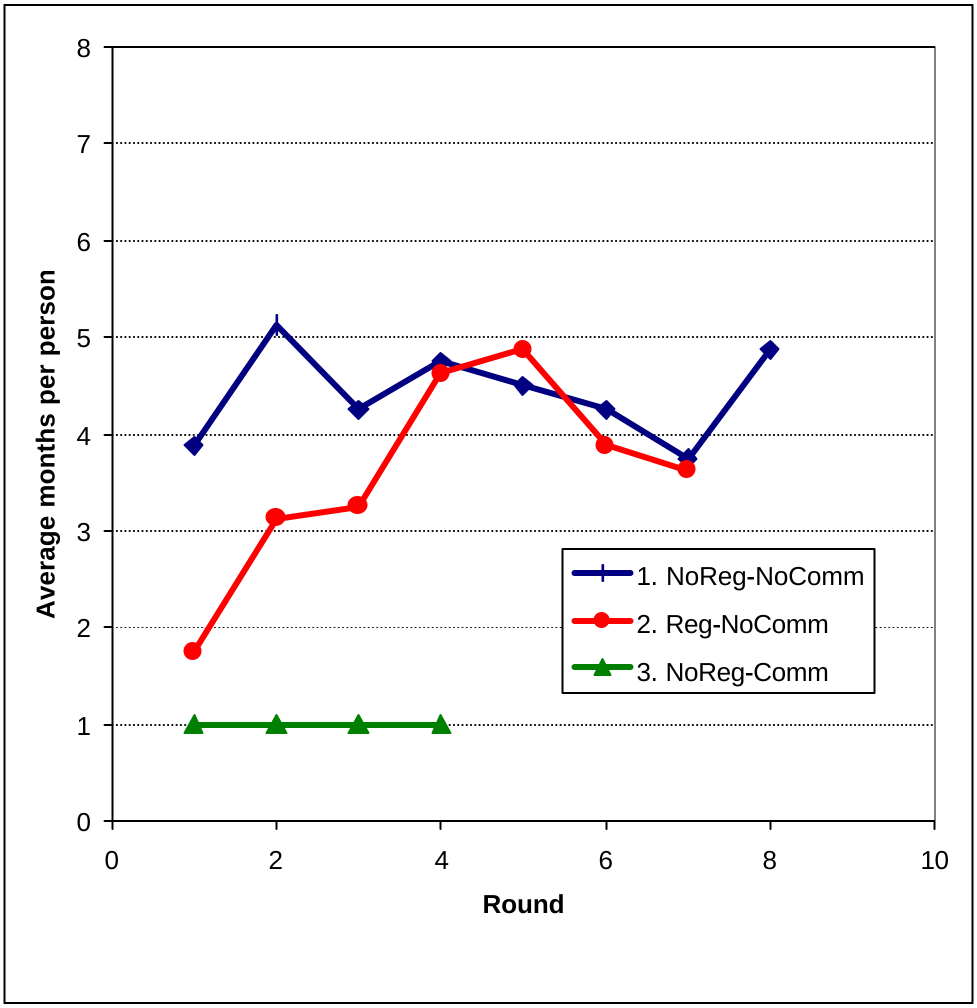

Figure 5. Benchmarks for different group sizes

		Group Size				
		8	**7**	**6**	**5**	**4**
Social Optimum	Months in forest - individual	1	1	2	2	3 or 4
	Months in forest - group	8	7	12	10	12 or 16
	Earnings - individual	645	651	663	680	711
	Earnings - group	5160	4557	3978	3400	2844
	Efficiency	100%	100%	100%	100%	100%
Symmetric Nash Equilibrium	Months in forest - individual	6	6 or 7	7	8	8
	Months in forest - group	48	42 or 49	42	40	32
	Earnings - individual	155	276	300	371	561
	Earnings - group	1240	1932	1800	1855	2244
	Efficiency	24%	42%	45%	55%	79%

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