DEPARTMENT OF ECONOMICS
WORKING PAPER SERIES

4239/2;

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Do the Number of Appropriators from the Commons Matter in Controlled Laboratory Environments?

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18 June 2017

Abstract

Many controlled laboratory experiments have shown non-binding communication among appropriators from a common pool to be an effective way to reduce over-appropriation from the commons. The controlled laboratory environments have tended to be environments with fewer than 10 participants. Recent work by Buckley et al. (2017) found that non-binding communication is not successful in reducing appropriation effort in a controlled laboratory environment with 12 participants. A conjecture was that there might be a difference between 12 participants and 8 participants (the typical number used by Ostrom et al. 1994 in their seminal work and used in many subsequent studies by others). This paper presents an environment that utilizes the CPR setting identical to that used by Buckley et al. (2017) reduces the number of appropriators from 12 to 8. Eight sessions (4 with and 4 without non-binding communication) are run using the Buckley et al. (2017) environment with 8 participants. The results suggest that the number of participants may not be an important factor in driving the differences between the impact that non-binding communication has on the Buckley et al. (2017) and Ostrom et al. (1994) environments. Alternate conjectures are presented to account for the differences.

JEL Classification: Q20, C72, C92

Do the Number of Appropriators from the Commons Matter in Controlled Laboratory Environments?

1. Introduction

Ostrom, Walker and Gardner (1994) summarize what are arguably the seminal controlled laboratory environments in which the management of common pool resources is studied and in which non-binding communication demonstrates success in reducing inefficient appropriation from the common pool. These environments were further developed by many social scientists who studied the management of the commons; the results presented in Ostrom et al. (1994) were generally confirmed. These results have supported arguments that policy-makers should have more confidence in the abilities of those individuals who appropriate from the commons to effectively manage their environments. It may not be necessary for external agents (governments beyond the local level) to inject themselves into the management of the commons, which is particularly relevant in situations related to indigenous populations.

This paper is the result of research initiated by Schott (2001) that proposed that output sharing among groups of appropriators from the commons could be an effective management tool. Schott, Buckley, Mestelman and Muller (2007) demonstrated the effectiveness of this partnership approach in a controlled laboratory environment when the correct size of the output-sharing groups was established. However, this mechanism was initially introduced into an environment in which appropriators could not communicate with one another. It was clear that once communication was possible, the countervailing free-riding externality that controlled the congestion externality would be weakened.

A study of the role of communication, both among members of output-sharing groups (local communication) and among the all appropriators regardless of their output-sharing group (global communication) is presented in Buckley, Mestelman, Muller, Schott and Zhang (2017) demonstrated both the strengths and weaknesses of the partnership approach to managing the commons. In the process of conducting this study, a baseline role of global communication among appropriators who are not in output-sharing groups was measured.

Unlike the results that are typically identified, Buckley et al. (2017) do not find that global communication leads to a significant reduction in effort devoted to appropriation from the common pool. The controlled laboratory environment introduced in Schott et al. (2007) differs from the environments used by Ostrom et al. (1994) and the work that followed in several ways, but one difference seemed to be a more likely contributor than the others for the failure of these groups of appropriators to coordinate on a more efficient outcome when they were able to engage in non-binding communication. The Schott et al. (2007) environment consisted of 12 participants. The Ostrom et al. (1994) environments and

many of those who built on this work consisted of 8 participants.¹ An obvious conjecture is that smaller groups are more able to coordinate than are larger groups. Perhaps Buckley et al. (2017) had passed the tipping point for effective group coordination with non-binding communication for this controlled laboratory environment?

If groups of 12 or more members are different from groups with fewer than 12 members, this may question the strength of the levels of efficiency that appropriators in the field may be able to achieve through the use of non-binding communication alone? Groups of more than a dozen appropriators in the field may not be exceptional.

In this paper we report the introduction of two new treatments to the treatments studied by Buckley et al. (2017). We conduct 4 controlled laboratory sessions using the same environment that is used in Buckley et al. (2017) for their baseline CPR treatment but rather than use 12 participants we use 8 participants. We then conduct 4 additional sessions using this new treatment with global non-binding communication. Finally, the results of these 8 sessions are compared to the results of Buckley et al. (2017) who use 12 participants with endowments of 28 effort units and to the results of Ostrom et al. (1994) whose treatments have 8 participants with endowments of either 10 or 25 effort units to allocate to appropriation.

We find that in the absence of global communication, the four treatments all converge to the predicted Nash equilibrium outcome by the last five rounds of fifteen rounds of appropriation from a commons. We further find that when global communication is introduced the treatments attributed to Ostrom et al. (1994) show a significant reduction in effort devoted to appropriation. For the Buckley et al. (2017) treatments, there are small reductions, but these are not statistically significantly different from zero. However, a further finding is that there is sufficient variation in the data that although in one Ostrom et al. (1994) treatment there is a very strong efficiency enhancing effect of non-binding communication, in the other three treatments, the average appropriations over periods 11 through 15 are not statistically significantly different from one another. This supports a conclusion that it is not the difference of group size that contributes to the poorer performance of non-binding communication in the Buckley et al. (2017) sessions than in the Ostrom et al. (1994) sessions.

2. The CPR Environments and the Data

The environments we consider are comparable in many ways. The Ostrom et al. (1994) and the Schott et al. (2007) yield functions are of the same form. The former is

¹ Examples include Hackett et al. (1994), Cardenas et al. (2000), Schmitt et al. (2000), Walker et al. (2000), Cardenas et al. (2004), Castillo and Saysel (2005), Moir (2008), Ahn et al. (2010), Janssen (2010), Janssen et al. (2010), Moreno-Sánchez and Maldonado (2010), Velez et al. (2010), Cardenas (2011), Velez et al. (2012), Janssen (2013) and Janssen et al. (2013).

$$Y = 23 E - 0.25 E^2 \quad (1)$$

and the latter is

$$Y = 32.5 E - 0.09375 E^2 \quad (2)$$

where Y is total lab dollar (L\$) yield and E is system effort devoted to appropriation. The environments (independent of whether or not there is non-binding communication) are identified as O10(8), O25(8), S28(12) and S28(8). The first two are the Ostrom et al. (1994) environments with individual effort endowments of either 10 units or 25 units and 8 participants. The latter two are the Schott et al. (2007) environments with individual effort endowments of 28 units and either 12 or 8 participants. For the O and S environments the opportunity costs of effort (if effort is not used to appropriate from the common pool) are L\$5 and L\$3.25. The effort benchmarks and endowments are summarized in Table 1.²

The effort data for the O sessions without communication are presented in Ostrom et al. (1994, Appendix 5.3). The effort data for the O sessions with communication are derived from Ostrom et al. (1994, Tables 7.2 and 7.3). These data are for mean system net rent over sets of five decision rounds for each session (rounds 1-5, 6-10, 11-15 and so on). Using the yield function (1) and the opportunity cost of effort we are able to determine the system effort that would generate the mean system net rent reported by Ostrom et al. (1994, Table 7.2 and 7.3). The data for the S sessions with 8 and 12 participants were collected at the McMaster Experimental Economics Laboratory.

Table 1. System Effort Benchmarks, Endowments and Benchmarks Relative to Endowments

	O10(8)	O25(8)	S28(12)	S28(8)
Nash Benchmark	64	64	288	224
Optimum Benchmark	36	36	156	156
Endowments	80	200	336	224
Nash/Endowment	0.800	0.320	0.857	1.000
Optimum/Endowment	0.450	0.180	0.464	0.696

Our focus is on the effect that non-binding communication has on the reduction of effort to appropriation from the commons. To make comparisons across the different environments we compute the differences between the predicted Nash equilibrium system effort for a treatment and the actual effort expended in a session for the treatment. We then normalize this difference by dividing it by the difference between the predicted Nash

² A detailed comparison of the treatments O10(8), O25(8) and S28(12) is presented in Buckley, Mestelman, Muller, Rogers, Schott and Zhang (2016).

equilibrium system effort for the treatment and the optimal system effort for the treatment. The mean values of these ratios by five-period blocks of decision periods are summarized in Figures 1 and 2. These mean values, and their standard deviations, are presented in Tables 2a and 2b for the four treatments with and without communication.

3. Results

The results from these eight treatments, representing four environments, with and without communication, are displayed in Figures 1 and 2. In Figures 1 and 2 the horizontal axes identify observations for which the actual mean system effort is equal to the Nash prediction for that treatment. An observation below the horizontal axis (a negative value) identifies mean system effort that exceeds the Nash prediction. Positive values indicate that effort is below the Nash prediction. A value of unity indicates that the members appropriating from the common pool are allocating the efficient amount of effort to appropriation from the common pool.

Figure 1 shows the results for the sessions without non-binding communication. The mean system effort for each of the four treatments is converging to their Nash equilibrium predictions.

Figure 2 shows the results for the session in which non-binding communication among appropriators is possible. The data are aligned so that all of the communication results are reported in periods 11-15, 16-20 and 21-25. The 0 communication sessions are run first with 10 rounds of no communication before non-binding communication is introduced.

The O10(8) sessions respond very well to the introduction on non-binding communication. Mean system effort is converging to the optimal effort for this treatment. The other three treatments begin their sessions with mean system effort nearly 40% below the Nash predictions for their treatments. However, over time they do not improve. All of the sessions ultimately experience increases in effort going to appropriation by the 11th through 15th communication periods of their sessions.

Table 2a. Relative system effort change for no-communication only sessions (standard deviations are in parentheses)

Rounds	1-5	6-10	11-15	16-20	21-25
No Communication					
O10(8), n = 3	0.121 (0.157)	- 0.026 (0.115)	- 0.024 (0.136)	- 0.021 (0.106)	
O25(8), n = 3	- 0.410 (0.184)	- 0.300 (0.136)	- 0.162 (0.194)	- 0.043 (0.099)	
S28(12), n = 4	0.078 (0.056)	0.013 (0.083)	- 0.005 (0.010)		
S28(8), n = 4	0.290 (0.110)	0.201 (0.102)	0.065 (0.047)		

Note: The means of the data used by treatment are in **bold** font.

Table 2b. Relative system effort change for sessions with 10 rounds of no communication followed by 15 rounds of communication (standard deviations are in parentheses)

Rounds	1-5	6-10	11-15	16-20	21-25
	No Communication		Communication		
O10(8), n = 3 (rounds 1-25)	- 0.054 (0.038)	- 0.092 (0.065)	0.823 (0.138)	0.848 (0.111)	1.000 (0.000)
O10(8), n=1 (rounds 1-20)					
O25(8), n = 6	- 0.200 (0.298)	- 0.303 (0.122)	0.345 (0.201)	0.421 (0.156)	0.304 (0.418)
S28(12), n = 4			0.338 (0.170)	0.146 (0.150)	0.091 (0.154)
S28(8), n = 4			0.377 (0.085)	0.229 (0.149)	0.185 (0.281)

Note: The values for S28(12) and S28(8) are for rounds 1-5, 6-10 and 11-15 in their 15 round sessions, but are reported here as in rounds 11-15, 16-20 and 21-25 so that they may be more easily compared with the three 5-round phases of the sessions with communication in environments O10(8) and O25(8); n = number of observations. The means of the data used by treatment are in **bold** font.

4. Analysis

The means and standard deviations presented in Tables 2a and 2b can be used to directly perform hypothesis tests with the data. However, in Table 3 we present an OLS regression that uses the mean relative proportion of reduction in effort to appropriate from the common pool (the relative system effort change) during periods 11 through 15 as the dependent variable and the seven treatments identified in Tables 2a and 2b as the independent variables. In this regression treatment S28(12) is the omitted treatment variable in the regression and its mean becomes the constant term. All coefficients are expressed as increases or reductions from the mean value of the “baseline” treatment S28(12). We use the result of this regression to describe hypothesis tests regarding the effect of non-binding communication to manage the over-appropriation from the commons that is anticipated in an otherwise unregulated commons. We focus on the last set of communication rounds as indicative of a value that may characterize convergence for a session with communication. We use the last set of rounds from the no-communication-only sessions to characterize convergence for the no-communication sessions. The means of the sets of values we use are in **bold** font in Tables 2a and 2b.

Table 3. OLS Regression: Treatment Effects on the Relative Proportion of Reduction in Effort to Appropriate from a Common Pool

Treatment	Coefficient	Standard Error	t-statistic	p-value
Constant	-0.0049	0.1189	-0.04	0.967
S28(8)	0.0696	0.1682	0.41	0.683
O10(8)	-0.0189	0.1817	-0.10	0.918
O25(8)	-0.1570	0.1817	-0.86	0.396
S28(12)G	0.0946	0.1682	0.57	0.576
S28(8)G	0.1895	0.1682	1.13	0.271
O10(8)G	1.0049	0.1817	5.53	0.000
O25(8)G	0.3086	0.1535	2.01	0.056
Observations	31			
F(7, 23)	7.09			
Prob > F	0.0001			
Adj. R-squared	0.5868			

Notes: The dependent variable is equal to the difference between the predicted Nash system effort and the actual system effort divided by the difference between the predicted Nash system effort and the optimal system effort. The constant term in the regression identifies the mean and standard error of the treatment S28(12).

There are some specific questions that are of interest for identifying whether or not the success of non-binding communication in the O environments is a result of the small number of participants in the laboratory commons. First, we should confirm that the results we have obtained using system effort are consistent with the results obtained by Ostrom et al. (1994) using net system rent as the efficiency measure.

In the absence of communication, after rounds 11-15 of trading (see Table 2a), the mean system effort is slightly above the Nash prediction for treatments O10(8) and for S28(12). Mean system effort is further above the Nash prediction for O25(8) than for the other treatments. However, mean system effort for S28(8) is below the Nash prediction. The variances on these mean values are such that the data will not support the rejection of the null hypotheses that none of the mean system efforts for these four treatments are statistically significantly different from one another ($p > 0.224$ for each pairwise comparison) in favour of the alternative that there is a difference.

When non-binding communication is introduced, treatment O10(8)G mean system effort falls to its optimal value by periods 21-25 (see Figure 2). However this is not the case for any of the other treatments. Comparing the relative proportion of reduction in effort from

the Nash prediction in rounds 21-25 (see Table 2b) with non-binding communication, the data support rejecting the null that mean system effort does not fall significantly for both O environments ($p = 0.000$ for O10(8)G and $p = 0.011$ for O25(8)G) in favour of the alternative that the reduction in system effort falls significantly. However, this is not the case for the S environments. The data cannot reject the null hypotheses that there is no statistically significant effect of non-binding communication for both S environments ($p = 0.271$ for S28(12)G and $p = 0.483$ for S28(8)G).

The variances of the mean system efforts for the three treatments other than O10(8)G are such that the data cannot reject the null hypothesis that none of these relative proportions of reduction in effort are significantly different from one another ($p > 0.177$ for each pairwise comparison; for the null that together all three relative proportions are equal to 0, $p = 0.241$). Table 4 presents a matrix of p-values associated with hypothesis tests making pairwise comparisons between treatments.

Table 4. p-values for Hypothesis Tests for Differences in Relative Proportion of Reduction in Effort by Pairs of Treatments

Treatments	S28(8)	S28(12)	O10(8)	O25(8)	S28(8)G	S28(12)G	O10(8)G	O25(8)G
S28(8)		0.683	0.631	0.225	0.483	0.879	0.000	0.133
S28(12)			0.918	0.396	0.271	0.576	0.000	0.056
O10(8)				0.484	0.263	0.535	0.000	0.064
O25(8)					0.069	0.178	0.000	0.011
S28(8)G						0.582	0.000	0.446
S28(12)G							0.000	0.173
O10(8)G								0.000
O25(8)G								

Note: Tests are based on statistics reported in Table 3.

5. Conclusions

Non-binding communication among appropriators from a common pool has been shown through many controlled laboratory experiments to be an effective way to manage a commons and reduce over-appropriation. The controlled laboratory environments have tended to be environments with fewer than 10 participants. Recent work by Buckley et al. (2017) found that non-binding communication is not successful in reducing appropriation effort in a controlled laboratory environment with 12 participants. A conjecture was that there may be difference between 12 participants and 8 participants (the typical number used by Ostrom et al. 1994 in their seminal work and the number used in many subsequent studies by others).

We have presented an environment that utilizes a common pool environment identical to that used by Buckley et al. (2017) other than the number of appropriators. These have been reduced from 12 to 8. The results of eight sessions (four with and four without non-

binding communication) using this environment with 8 participants suggests that the number of participants may not be an important factor in driving the differences between the impact that non-binding communication has on these environments.

Two additional conjectures arise. First, is there a difference between face-to-face communication in a laboratory setting and computer-mediated communication? Second, is there a cognitive difference between 8 or 12 people each deciding on how to allocate 28 effort units and 8 or 12 people each deciding on how to allocate 10 effort units. The first conjecture has been tested in other environments and there is support for the comparability of these ways of implementing communication (Janssen et al. 2010, Bochet et al. 2006). The second conjecture has been raised by Buckley et al. (2016), but has not yet been evaluated. We do believe, however, that the difference between 8 and 12 participants in a controlled laboratory setting is not the cause of the less effective non-binding communication treatments in Buckley et al. (2017) than in Ostrom et al. (1994) and subsequent studies (see earlier reference to the list of papers included in Buckley et al. 2016).

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