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Head-enders as stationary bandits in asymmetric commons: Comparing irrigation experiments in the laboratory and the field

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ABSTRACT

The emergence of large-scale irrigation systems has puzzled generations of social scientists, since they are particularly vulnerable to selfish rational actors who might exploit inherent asymmetries in the system (e.g. simply being the head-ender) or who might free ride on the provision of public infrastructure. As part of two related research projects that focus on how subtle social and environmental contextual variables affect the evolution and performance of institutional rules, several sets of experiments have been performed in laboratory settings at Arizona State University and in field settings in rural villages in Thailand and Colombia. In these experiments, participants make both a decision about how much to invest in public infrastructure and how much to extract from the resources generated by that public infrastructure. With both studies we find that head-enders act as stationary bandits. They do take unequal shares of the common-pool resource but if their share is very large relative to downstream participants' shares, the latter will revolt. Therefore for groups to be successful, head-enders must restrain themselves in their use of their privileged access to the common-pool resource. The comparative approach shows that this result is robust across different social and ecological contexts.

1. Introduction

Experimental studies of collective action in commons dilemmas typically focus on scenarios in which actors all share symmetric (or similar) positions in relation to the common-pool resource (e.g. Ostrom et al., 1994; Janssen et al., 2010). Naturally occurring commons dilemmas, however, often involve asymmetric relationships among participants. For example, in irrigation systems farmers at the tail-end or head-end can, and often do, experience differences in their capacity to influence collective action problems related to the maintenance of the irrigation system and allocation of water (Ostrom and Gardner, 1993). Given these conditions, it is often assumed that irrigation systems require a central authority to solve coordination problems. Wittfogel (1957), for example, argued that such central control was indispensable for the functioning of larger irrigation systems and hypothesized that some state-level societies have emerged as a necessary side-effect of solving problems associated with the use of large-scale irrigation. However, many examples of complex irrigation systems exist that evolved without central coordination (Hunt, 1988; Lansing, 1991; Ostrom, 1992).

The fundamental problem facing irrigation systems is how to solve two related collective action problems: 1) the provisioning of the physical infrastructure necessary to utilize the resource (water), and 2) the asymmetric common-pool resource dilemma where the relative positions of "head-enders" and "tail-enders" generate asymmetric access to the resource itself (water) (Ostrom and Gardner, 1993). If actors behave as rational, selfish economic agents, it is difficult to imagine how irrigation infrastructure would ever be created in the first place. Even if the initial problem of providing the infrastructure were solved, conflict may emerge because head-enders may not necessarily share the water with the tail-enders. The vulnerability of irrigation system performance to such behavior leads to the question of why so many self-organized irrigation systems exist and persist for so long (Hunt, 1988; Lansing, 1991; Ostrom, 1992). Experiments in social dilemmas have demonstrated during the last 20 years that the selfish rational choice model is not a good representation of human behavior to explain observed behavior (Camerer and Fehr, 2006). That cooperation occurs in social dilemmas is not a surprise, but what determines differences in the level of cooperation need to be explained.

A possible solution to the dilemma is the interdependency between upstream and downstream participants. Lansing and Miller (2005) discuss a game theoretical framework between upstream and downstream communities in Bali where the communities must share water and cooperate on pest control. The upstream communities are

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more concerned about pest outbreaks, while the downstream communities are more concerned about water shortages. This interdependency explains the cooperation between upstream and downstream communities.

Weissing and Ostrom (1991) explain the existence of effective coordination among farmers who are dependent on the efficiency and costs of mutual monitoring. In their work, Weissing and Ostrom assumed that a coordination system existed since farmers were assumed to steal water with a certain probability when it was not their turn. In the experiments reported here, we assume that such institutional arrangements do not yet exist at the start of the experiment; we assume only the biophysical reality of upstream and downstream participants.

The problem of asymmetric commons dilemmas goes beyond irrigation systems. In many actual common-pool resource dilemmas, there are differences among appropriators in their ability to access common-pool resources or public infrastructure. For example, the countries that are the main emitters of substances that enhance the greenhouse effect are not the same as those who experience the most severe impacts. The asymmetric commons dilemmas we study in this paper allow downstream participants to respond to the decisions of upstream participants by withholding contributions to public infrastructure maintenance in future rounds. In this case, even-though there is an asymmetry in power, participants are dependent on each-other.

The stationary bandit metaphor of Mancur Olson (1993, 2000) describes the challenges faced by a ruler in managing asymmetric power relationships. Specifically, the ruler acts as a stationary bandit who steals from (taxes) his or her subjects. However, if he or she steals too much without providing sufficient public infrastructure in return, the subjects increase the cost of stealing (revolt, evade taxes, etc.). This metaphor can be applied to irrigation systems in the sense that head-enders have first choice to use the water (i.e. can steal at will), but also need the help of the tail-enders to maintain the irrigation infrastructure. If head-enders do not provide a fair share of water, tail-enders may revolt by reducing their contributions to maintenance of the public infrastructure. Inequality in resource appropriation due to power asymmetries might occur, but it is bounded by the amount of inequality the tail-enders will tolerate. Unlike the Bali case described above, in this case the interdependencies are social rather than biophysical.

In our field and laboratory experiments aimed at studying these dilemmas, we found that upstream participants needed to be fair to downstream participants in order to maintain the efficiency of the public infrastructure. With efficiency, we refer to the long-term outcomes in a social dilemma. Groups in which upstream participants take equal water shares are more efficient, produce more common resources, in the longer term (multiple rounds). The field experiments were performed with villagers who have day-to-day interactions with one another in natural resource management contexts. The laboratory experiments were performed with undergraduate students at a US university. Although designed for different purposes, the similarities in the relationship between efficiency and equity in these different experimental treatments are striking. This suggests that this relationship may transcend biophysical context and the characteristics of the subjects taking part in the experiment.

The special issue in which this paper appears focuses on experiments involving common-pool resources in different contexts. The comparative analysis of findings from multiple experiments conducted here is an example of how we might leverage experimental work to explore the impact of contextual variables on what we might call core common-pool resource dilemmas and point the direction for new experimental treatments. By contrasting two experiments which have the same underlying asymmetric commons dilemmas but have different framings, participant populations, and methods of experimentation we are able to highlight some key regularities regarding social interactions in such situations. We first present the findings for the field and laboratory experiments individually and then proceed with the comparative analysis.

2. Asymmetric Commons Dilemmas

The detailed analysis of the results of the individual lab and field experiments discussed in this paper can be found in Janssen et al. (submitted for publication-a) and Janssen et al. (submitted for publication-b), respectively. The basic setup of the experiments is similar although the execution and nature of the subject pools is quite different. In both treatments, participants first decide how much of their initial endowment to invest in creating shared infrastructure through which a common-pool resource is made available. Next, participants decide how much of the common-pool resource to appropriate using the shared infrastructure they have just created. Note that because of the nature of the shared infrastructure, participants have asymmetric access to the common-pool resource. During an experiment, a group of 5 participants share a commonly held stock of public infrastructure (e.g. 5 land holders commonly own an irrigation system). If they all invest a significant amount toward the creation of public infrastructure, participants can, if they distribute the resource equally, double the earnings for each group member as compared to the case in which they invest nothing.

A key feature of public infrastructure projects such as irrigation systems is the existence of minimum thresholds of input intensity that must be exceeded before they may be carried out on a reasonable time scale. Thus, until a minimum investment threshold is exceeded, very little public infrastructure is produced. We capture this feature in the experimental contexts by assuming a sigmoidal relationship between investment and production of public infrastructure (the function $g(\cdot)$ below). The choice of the production function is guided by including the interdependency of upstream and downstream participants. In our experimental treatments, at least two persons need to invest a significant amount before the potential returns on investment in the public infrastructure becomes positive.

When public infrastructure is generated, the "upstream" participants have easier access to the common-pool resource thus made available (water in an irrigation system, bandwidth in a telecommunications network) and may be tempted to take more than an equal share relative to downstream users. Since multiple rounds are played in each experiment treatment, participants downstream can "sanction" those upstream for taking too much by reducing their own investment in the public infrastructure in subsequent rounds. The next section details the laboratory and field experimental designs and findings.

3. Experimental Set Ups

3.1. General

In both the lab and field experiments, there are five participants A, B, C, D and E. In each round of the experimental game, participants first receive 10 tokens. They then decide how many to invest in a public fund that generates the infrastructure which determines the amount of common-pool resource available for the whole group to share. Finally, each player decides how much to extract from the common-pool resource. In the lab, the infrastructure is bandwidth and the common-pool resource is data that can be downloaded. In the field, the infrastructure is irrigation canals and the common-pool resource is water. In both cases, participants occupy positions A, B, C, D or E from upstream to downstream where A has the first choice to harvest the common-pool resource, B the second choice, etc. Although the experiments in the lab and field are very similar, they differ in several respects in terms of their execution.