Asymmetric commons games in the laboratory and the field

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Abstract

The emergence of large-scale irrigation systems has puzzled generations of social scientists. Given the challenges of both coordinating activities in a complex network of social interactions and providing public infrastructure, the number of irrigation systems that have evolved without central coordination and have persisted so long is astonishing. Specifically, irrigation systems seem to be vulnerable to selfish rational

actors that exploit inherent asymmetries such as simply being the headender or who free ride on the public infrastructure. In this paper we will discuss laboratory and field experiments that address the problem of self-governance in an asymmetric commons dilemma.

Laboratory experiments have been performed at Arizona State University, and field experiments have been performed in rural villages in Thailand and Colombia. We formulate an abstract dilemma where participants make both a decision about investment in public infrastructure and how much to extract from the resources generated by that public infrastructure. The impact of inherent asymmetry in irrigation systems on the provision of a public common resource the importance of fairness to generate long term efficiency will be discussed.

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Introduction

Studies of collective action in commons dilemmas typically focus on scenarios where actors all share similar positions in relation to the resource commons. However, naturally occurring dilemma situations often consist of asymmetric relationships. For example in irrigation systems, farmers at the tail-end or head-end can experience differences in influence on the collective action problems related to the maintenance of the irrigation system and allocation of water (Ostrom and Gardner, 1993.) It is often assumed that irrigation systems require a central authority to solve coordination problems (Hunt, 1988). Wittfogel (1957) 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 (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 act 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, if water is available to the head-ender it may not necessarily be shared with the tail-ender. The vulnerability of irrigation system performance to the behavior of selfish, rational actors leads to the question of why so many self-organized irrigation systems exist and persist for so long (Hunt, 1988; Lansing, 1991; Ostrom, 1992).

The problem of asymmetric commons dilemmas goes beyond irrigation systems. In many actual common resource dilemmas, there are differences among appropriators in their ability to access common resources. Such asymmetries might be the consequence of geography, social hierarchy, skills, knowledge, and other attributes of the action arena.

In field and laboratory experiments studying such dilemmas in irrigation systems, we found that participants balance efficiency and equity. With efficiency, we refer to the long-term outcomes in a social dilemma. Groups who allocate water more equally derive a higher efficiency in the longer term (multiple rounds). These field experiments have been performed with villagers who have day-to-day interaction in natural resource management. The laboratory experiments are performed with undergraduate students at a US university.

In recent years, various studies on asymmetry in social dilemmas have been performed, and most studies find common relations between efficiency and equity. If positions are more equal, participants contribute more to the public good or collect less from the common resource (Wilke, 1991).

Within asymmetric social dilemmas, lower levels of cooperation are found compared to symmetric situations (Ahn et al. 2007; Beckenkamp et al. 2007; Tan, 2008). Van Dijk and Wilke (1995) performed a series of asymmetric public good games and common pool resource dilemma games. Asymmetry was included in these games by differences in endowments (public good) or by the amount of maximum allowable extraction (common resource) by the participants. Participants in asymmetric public good games tend to contribute in proportion to their endowment, while participants in common pool resource games tend to equalize their earnings (Van Dijk and Wilke, 1995). Budescu et al. (1990) also found that participants in asymmetric common pool resource games tend to balance the appropriation in order to achieve equity in earnings.

Various studies have been performed where fairness and efficiency are considered to be competing motivation (Güth et al., 2003; Levati et al. 2007). In these studies fairness is found to dominate efficiency motivations, which is in contrast to the findings of our studies.

In this paper we present results from field and laboratory experiments which illustrate that in asymmetric commons participants need to be fair to create social efficiency of the resource they generated. Although the experiments were designed for different purposes the similarities in the trade-offs between efficiency and equity are striking and will be discussed in more detail. We discuss first the findings for the field and laboratory experiments separate, before we do a comparative analysis.

Asymmetric commons dilemmas

In this section we discuss the general design of the experiments. The detailed analysis of results presented in this paper can be found in Janssen et al. (2009a, 2009b). The basic setup of the experiments is to first have participants decide how much from their endowment to invest in creating a common resource, and second how much to collect using asymmetric access to the resource. There are 5 participants in each experiment.

If they all invest a significant amount into the resource they can double the earnings for each group member, if the resource is equally distributed.

The function of the public infrastructure, g() is assumed to be a sigmoidal function. When a small amount is invested in the public infrastructure, no resource is generated. At least two persons need to invest a significant amount before the returns on investment in the public infrastructure becomes potentially be positive.

When a common resource is generated the upstream participants have easier access to the resource and may be tempted to take more than an equal share they leave for those downstream. Since we play the experiment for a number of rounds, we can imagine that participants downstream can “sanction” those agents upstream for taking too much by reducing their investment in the public infrastructure in the next round.

We now discuss in detail the laboratory and field experimental designs and findings.

Laboratory experiments

The five participants A, B, C, D and E have to make two decisions. First they have to make a decision concerning how much to invest in public infrastructure. In each round they receive 10 tokens that can be used for investment. Each token is worth $0.1. The production function for public infrastructure g(y) depends on the total level of investment, y. In the experiment, the function g(y) is rounded to integer values. The function is:

$$g(y) = \frac{\omega y^{\gamma}}{y^{\gamma} + \eta^{\gamma}}, \tag{1}$$

where ω = 40 and defines the maximum level of the public good. The parameter η = 30 is the inflection point which defines the investment level for which 50% of the common resource is created. The parameter γ=10 defines the steepness of the function near the threshold. If both players invest their 10 tokens, the common resource reaches a level of 40 units. There is an inflection point at y=30. For investments from 0-30, the production function exhibits increasing returns and for investments over 30

In order to avoid biasing participants for a particular context, we do not present the experiment as an irrigation experiment but, rather, as a more abstract game. To explain the game to the participants we describe it as a game of downloading digital files, where participant A has priority access to the available bandwidth over participants B, C, D and E. Before downloading they make a decision how many tokens to invest in creating bandwidth. During a period of 100 seconds in each round, participants can click on images of files to start downloading the files. They see the animation of downloading and how much bandwidth is available for each participant.

After they have made their investment decisions, they are informed how much each of the participants invested, and how much bandwidth is available during the 100 seconds (Figure 1). The time left till the end of the round is projected on the screen.

Figure 1: Screenshot of the experimental software for N=5. Participants can click on button with 100. A green button is the file which is downloading, a red button is a file downloaded. The source of the information flow is the box at the left. The bandwidth in this example is 40 kbs

The public infrastructure that results from the total investment is bandwidth (kbs) that the players can use in the second part of the round. Each player can download a maximum of 10 files of 250 kb each during a period of 100 seconds. Player A has first access (i.e. is upstream) to the bandwidth generated B_T. The maximum downloading speed of each player is 25 kbs. The amount of bandwidth which is not used is available for player B. Thus if 40 kbs is available, and player A is downloading, 15 kbs is available for player B. The monetary returns depend on the production function f(x)

$$f(x) = \upsilon \cdot \frac{x^{\beta}}{x^{\beta} + \alpha^{\beta}} \quad (2)$$

where x represents the number of files downloaded and υ = 20 is the maximum number of tokens possible. When α=5 files are downloaded 50% of υ is derived. The parameter β defines the steepness of the function. Again, we have used a sigmoidal function in order to capture key aspects of the relationship between water and agricultural production. With too little water, yields drop off rapidly. Beyond a certain level, in this case 5, additional water generates decreasing marginal returns. If ten files are downloaded 20 tokens are earned. The total earnings of a player is the amount of tokens not invested in the common resource plus the number of tokens earned by downloading files.

$$h(x,y) = 10 - y + \upsilon \cdot \frac{x^{\beta}}{x^{\beta} + \alpha^{\beta}} \qquad (3)$$

If players download immediately if bandwidth is available, an opportunistic strategy, players A, B, C and D will invest 10 tokens and E 0 tokens. Players A, B and C will download 10 files, D 6 files, and E 0 files. This leads to 20 tokens earned by players A, B and C, 12 for player D and 10 for player E.

The cooperative solution is more sophisticated and in Figure 2 we see the group returns from different levels of investment in the common resource and optimal allocation of files downloaded. A total investment of 37 or 38 tokens by all five players in the common infrastructure can lead them to a total earnings of 104 tokens. The opportunistic strategy earns 82 tokens for the two players together. The irregular shape of Figure 2 is caused by the discrete units of the files and the bandwidth lost when a player is not downloading.

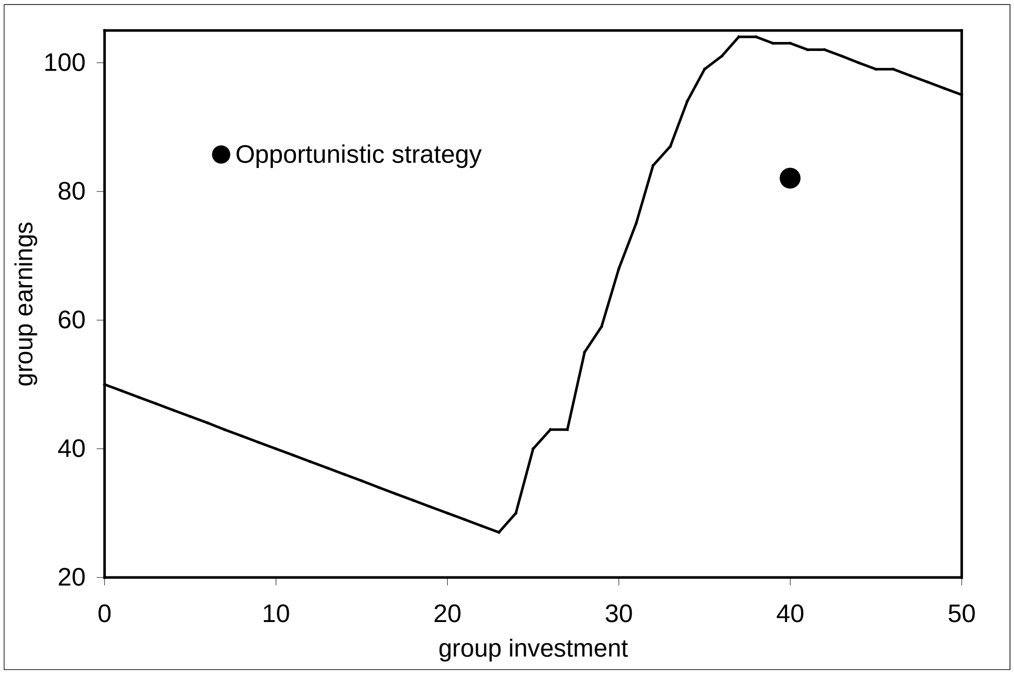

Figure 2: Maximum earnings (in tokens) for the five players if they cooperate and coordinate as a function of total investment. The dot refers to the opportunistic strategy.

Before the participants can start the experiment, they go through a number of instructions and can only start when all quiz questions are answered correctly. The experiment starts with 2 practice rounds which do not count for their earnings followed by 10 rounds for monetary returns. Before each round the players are allowed 60 seconds to exchange text messages among those within their group.

We used two treatments in this study. We included a treatment where partly downloaded files were lost if an upstream participant utilized all available bandwidth, completely disrupting the downloading of downstream players. The different treatments reflect the increasing complexity of coordinating allocation of the access to bandwidth and roughly correspond to biophysical realities in irrigation systems.

Table 1: Experimental design

Label:	5 person	5 person (B)
Number of participants	6 groups = 30 participants	5 groups = 25 participants
Positions	A, B, C, D, and E	A, B, C, D and E
Length of time to download file	Depends on available bandwidth	Depends on available uninterrupted positive bandwidth

Laboratory Experimental Results

The experiments were performed between November 2007 and February 2008 at Arizona State University. The participants were recruited from a database of undergraduate students willing to participate in experiments. This database consists of students from all majors and invitations were sent out to a random sample of the whole population when an experiment was scheduled.

Tables 2 and 3 present the basic statistics of the experiments. Participants invest considerable amounts in the shared infrastructure, although those who are ‘downstream’ invest somewhat less than those upstream. The number of files downloaded is quite unequally distributed. Position A downloads about twice the amount compared to position E. These differences are significant ($p<0.01$) between person A and C, D and E, and between B and E, while it is only significant between person A and E for experiments 5 person (b).

These investment-patterns and downloads lead to a considerable inequality in earnings between the upstream and downstream participants. Participants in position E received even less than the Nash equilibrium of 10 tokens when no investment was made.

Table 2: Average numbers per round for the default experiments (standard deviation).

	Tokens invested	Files downloaded	Tokens earned
A	8.75 (0.83)	6.95 (2.31)	16.48 (3.94)
B	8.48 (1.09)	6.80 (1.72)	16.85 (2.61)
C	8.48 (1.11)	5.42 (1.36)	13.35 (4.21)
D	7.78 (2.06	5.42 (2.38)	14.40 (3.77)
E	6.72 (3.51)	3.22 (2.20)	9.4 (3.70)

Table 3: Average numbers per round for the experiments where downloads can be disrupted by upstream participants (standard deviation).

	Tokens invested	Files downloaded	Tokens earned
A	9.08 (0.95)	5.44 (1.23)	13.68 (3.18)
B	9.04 (1.56)	5.78 (1.74)	14.22 (3.15)
C	7.22 (2.56)	4.32 (1.95)	11.94 (2.99)
D	8.60 (1.74)	4.62 (1.76)	11.30 (2.38)
E	7.24 (2.90)	3.42 (1.63)	7.96 (2.49)

The level of public infrastructure generated increases, but irregularly, over time. Figure 3 confirms that investments in the shared infrastructure are substantial and remain so over time.

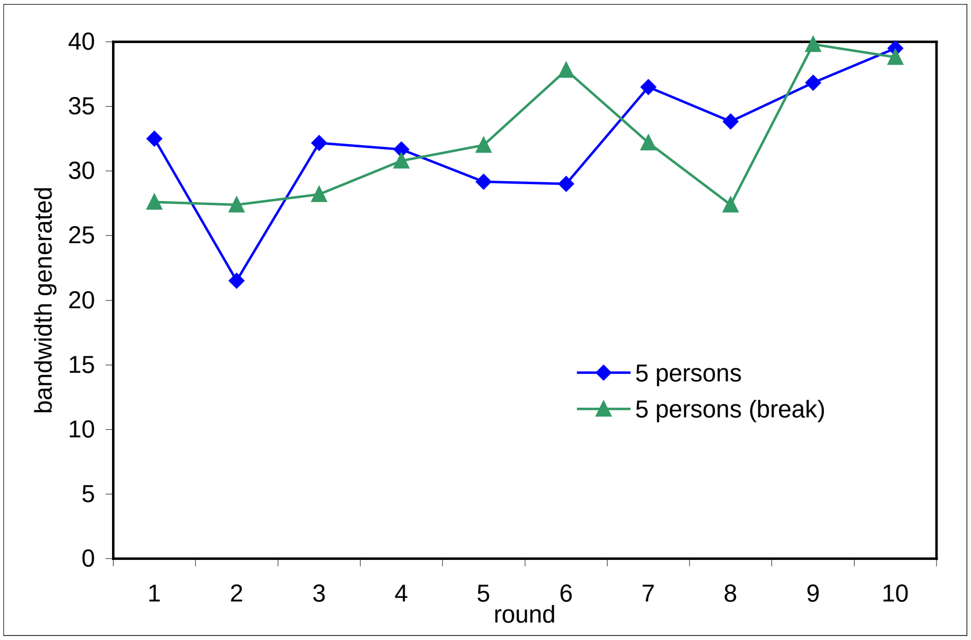

Figure 3: Average level of bandwidth for the two treatments.

The level of earnings per person is also increasing over time. Initially, about 12 tokens per round was earned, and over time this increased up to 15 tokens. Note that the level of the 5-person (b) experiment has considerable lower earnings (due to lost files and more complex coordination).

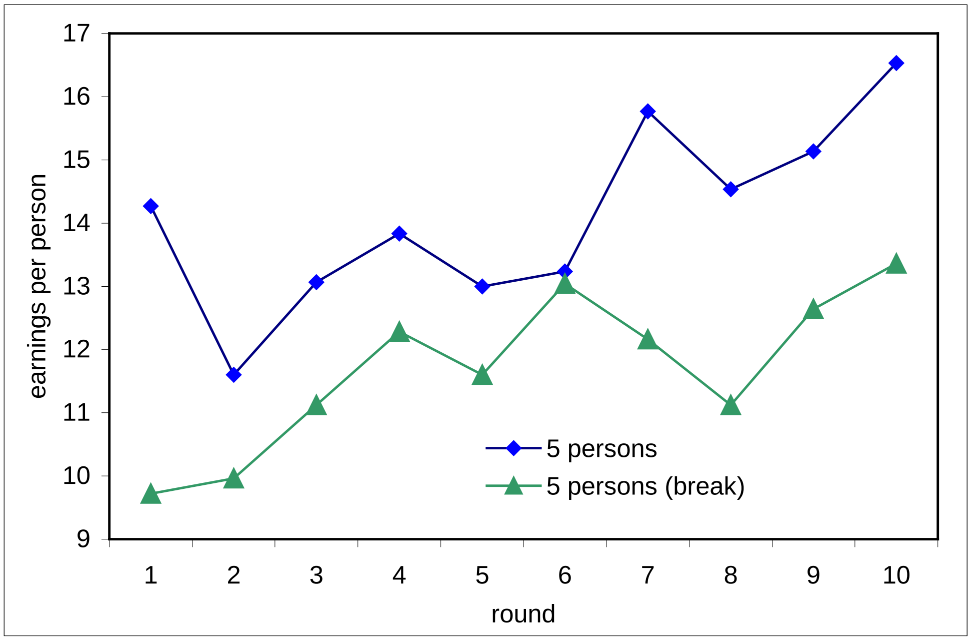

Figure 4: Average level of earnings for the two treatments

On average the upstream participants receive much higher earnings than participants downstream. This is especially at the beginning of the experiment where the inequality of the number of files downloaded is substantial as reflected in the gini coefficient in Figure 5. But over the rounds we see that the level of inequality is reduced. The inequality of contributions is lower and stays at the same level over the experiments. The 5 person (b) experiment leads to a lower gini coefficient to the less challenging 5 person experiment. Later in this paper we will show that the 5 person (b) experiment lead to more need for coordination and fair distribution of the files in order to keep up the investments in the common resource.

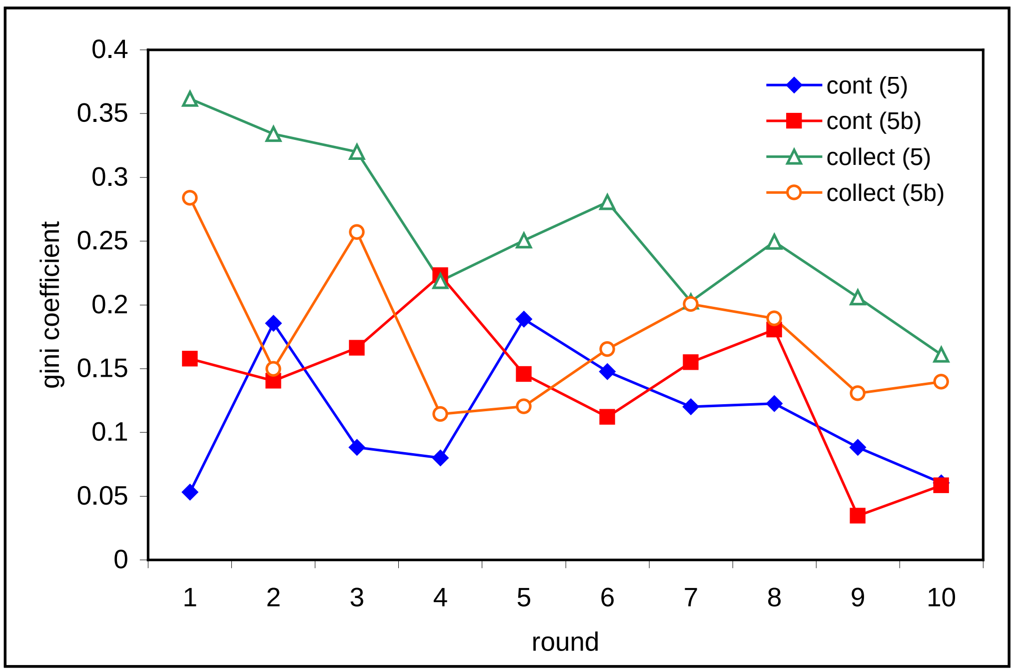

Figure 5: Average Gini coefficient of number of files downloaded.

Figures 6-7 show the actual level of group investment and earnings in relation to the optimal cooperative solutions. We see that it is more difficult for the participants to coordinate when a partly downloaded file can be lost. We see also that a typical strategy is to invest the maximum in the common resource but this does not lead to the maximum output for the group. In the second treatment (Figure 7) we see that only rarely the earnings of the group reach the level of the opportunistic strategy. Positive reaction times and lost files due to losing connection, leads to low amount of files downloaded downstream.

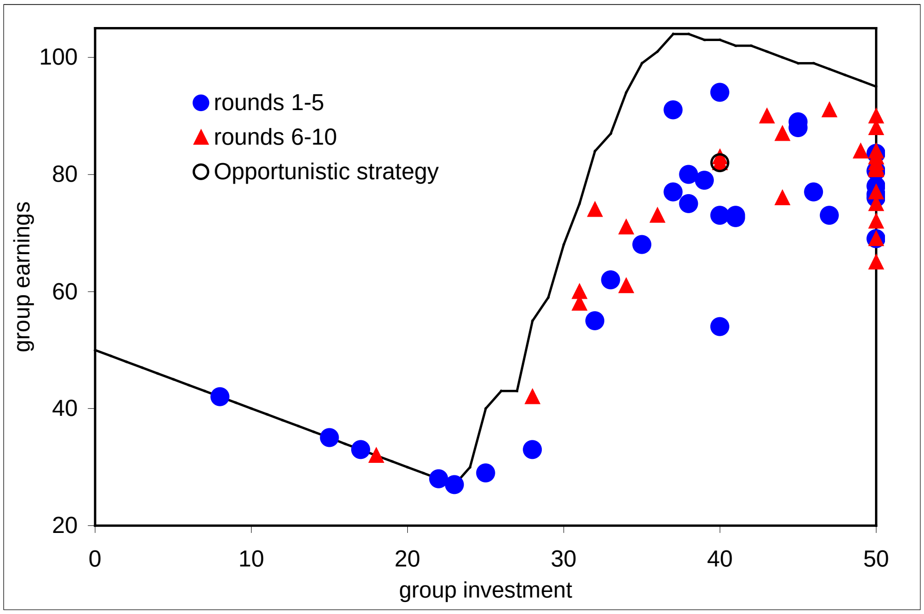

Figure 6: The relation between the group investment and group earnings for each round of the five person experiments. Distinction is made between data from first half and second half of the experiment.

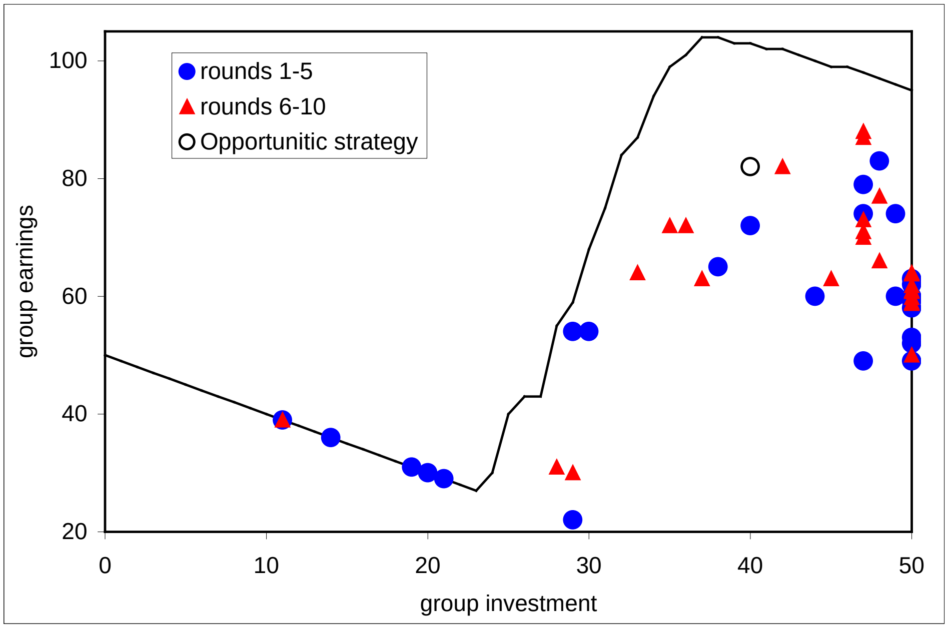

Figure 7: The relation between the group investment and group earnings for each round of the five person (b) experiments. Distinction is made between data from first half and second half of the experiment.

We used linear multilevel analysis to estimate the effect of inequalities in the amount of tokens contributed to the group total and the number of files downloaded from the previous round on the level of group contribution in this round. As we see in Table 4 there is a negative relationship between inequality and the level of contributions, especially for the treatment where file downloads can be cut off. The lower the equality in contributions and files downloaded, the lower the amount of contributions.

Table 4: Regression results of number of tokens invested in bandwidth by groups. Between brackets are the standard deviations.

	5 persons	5 persons (break)
constant	35.223 *** (3.558)	48.895 *** (3.346)
round	1.444 *** (0.393)	0.456 (0.436)
Gini contribution (t-1)	-14.666 *(7.827)	-35.863 *** (5.774)
Gini collection (t-1)	-8.573 (6.060)	-32.916 *** (7.818)
- Log likelihood	188.761	154.454
N	54	45
Variance components		
Group component	4.440 (2.221)	0.0000
Individual component	7.359 (0.784)	7.489 (0.789)
X^2	2.36 (p=0.0621)	0.0000 (p=1.0000)

Field experiments

The importance of the micro-situational variables and the nature of the community is often stressed in the study of institutions (Poteet et al. in press). This raises obvious questions regarding how these considerations affect the outcomes in the lab experiments described above. To explore these issues, we compare the lab results with outcomes from the irrigation games as performed in six rural villages in Thailand and Colombia, three villages in each country, where villagers participate in natural resource appropriation on a daily. More details can be found in Cardenas et al. (2009).

For all these locations permission to perform experiments was given, if needed, by the heads of villages. The experiments were conducted during the first 6 months of 2007. Typically four days of experiments in each location were followed by in depth interviews with a sample of relevant stakeholders of the village.

In each village each of the three resource games was conducted with 4 groups of 5 people. As a result 360 individuals participated in the experiments. Thus for the irrigation experiments, 20 persons participated in each of the six villages, leading to a total of 120 individuals.

The general outline of the experiment is as follows. In each experiment 5 individuals participate. They may know each other, but they do not know the decisions of the other individuals during the experiment. Only the aggregate outcomes of the decisions are presented to the group. They are not allowed to communicate with others during the experiment. Assistants are available during the experiments for those participants who have difficulty with reading and/or arithmetic. After instructions and practice rounds, the participants will play 10 rounds. They are not told the number of rounds in advance. Then a second stage is played of 10 more rounds, but under a different set of rules which they can vote for. However, our analysis here focuses on these first 10 rounds of the baseline game, given our interest in studying the intrinsic asymmetries of the incentives and functioning of the game in the absence of added institutional complexities. More information about the analysis of the later rounds can be found in Janssen et al. (2009b).

The participants were recruited via word of mouth and flyers posted throughout the village, and participants of 18 years and older could participate. Special emphasis was done to recruit adults from households engaged in the resource extraction of that particular village. Only one member of a family was allowed during the same session. At the end of the series of experiments a handful of people were identified for in depth interviews. Those individuals were selected among the participants to receive a representative sample of the community. At the end of the week, a session was organized to discuss the experiments and their situation in relation to natural resources.

In the irrigation game, participants get 10 tokens each round and have to first make a decision as to how much to invest in a public fund that generates the infrastructure and limited the amount of water for the whole group to share; then each player, in sequential turns from upstream to downstream players decide how much to extract from the generated water. Each token kept (not invested) has a monetary value for the player, and is equal to the value of each unit of water extracted.

Participants occupy positions A, B, C, D or E from upstream to downstream locations, where A has the first choice to harvest water from the generated resource. In Table 5, the water provision generated is defined as a function of the total investments of the five participants. There are many possible Nash equilibria, depending on the assumptions of players how the generated water resource will be allocated. If each participant is selfish and rational and expects other to be this too, the Nash equilibrium is that nobody invests in the water provision, and all receive 10 tokens for a group earnings of 50 tokens. Another equilibrium can emerge if the beliefs of player A are that at least 6 more tokens will be invested by the rest of the players. If so, player A should invest all her 10 tokens thus generating a total of 20 water units and then extract them all for a net profit of 10 units from her initial investment. These beliefs could be based on player A's assumptions about the prosocial preferences of the other players. However, in the same manner, all other players should not invest any token if they believe that player A has such selfish preferences[1]. More equilibria can emerge if the expectations increase in the sum of contributions by players B to E.

In the cooperative (social optimum) solution, everybody invests her 10 tokens in the public good, producing 100 units of income for the group in each round. Therefore, for a sequence of 10 rounds, the group earnings would sum up to 1000 tokens for all 10 rounds. This should be compared to the Nash equilibrium discussed before where all players keep their tokens producing a social efficiency of only 50%.

Table 5. Water production as a function of units invested in public fund.

Total units invested by all 5 players	Water available
0-10	0
11-15	5
16-20	20
21-25	40
26-30	60
31-35	75
36-40	85
41-45	95
46-50	100

[1] The reason we can speculate on these scenarios relies on the fact that all five players know each other from a previous history in the village, and can observe the exact location of each of the players in the game.

Results of field experiments

The average age of our participants was 37 years (Std.Dev 13.8), and 39 percent of them were females. About two thirds of them reported living in that village for their entire life. Their households were in average of 5 members (also the modal household size), with 5 percent of the households having 2 or less members and 10 percent of the households with 9 or more members. The education level of the participants varied as well. 5 percent of them had no formal education, and about 28 percent of them with some or complete primary education. 53 percent of the players had secondary education and only some 15 percent received technical or university training. About 81 percent of them reported owning some land.

At the end each participant was paid in cash and in private according to the tokens earned in the game, plus an additional show up fee. In average each player earned the equivalent to 1-2 days wage for her participation in a 2-3 hours session.

We will conduct the analysis in the following manner. We will describe the patterns of individual and group behavior and study how it affected the individual and group earnings over time. Recall that every session included 10 periods or rounds under a baseline treatment where players could not communicate with each other.

Figure 8 shows the average and 95 percent confidence interval for the levels of contributions by all players in each round. From the start of the first stage the Thailand sessions show lower higher levels of contributions for the production of resources for the group. The decrease over time of such contributions, consistent with baseline voluntary contributions or public goods experiments seems to be present, especially for the Colombian sessions.

Figure 9 shows the group earnings in relation to group investments. Compared to the laboratory experiments (Figures 6 and 7), there was no significant loss of the resource. About 2 percent of the resource was not collected by the group.

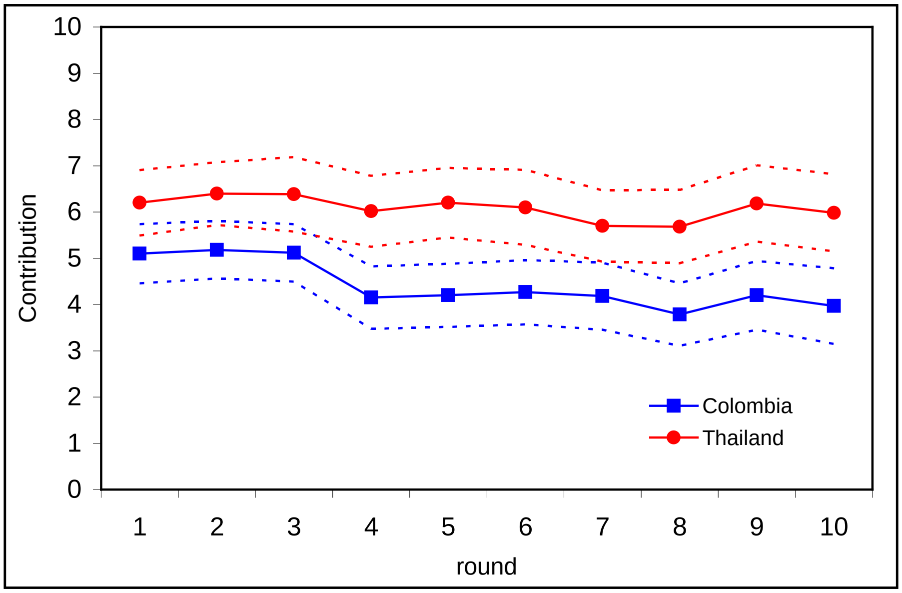

Figure 8: Contributions of group to public infrastructure.

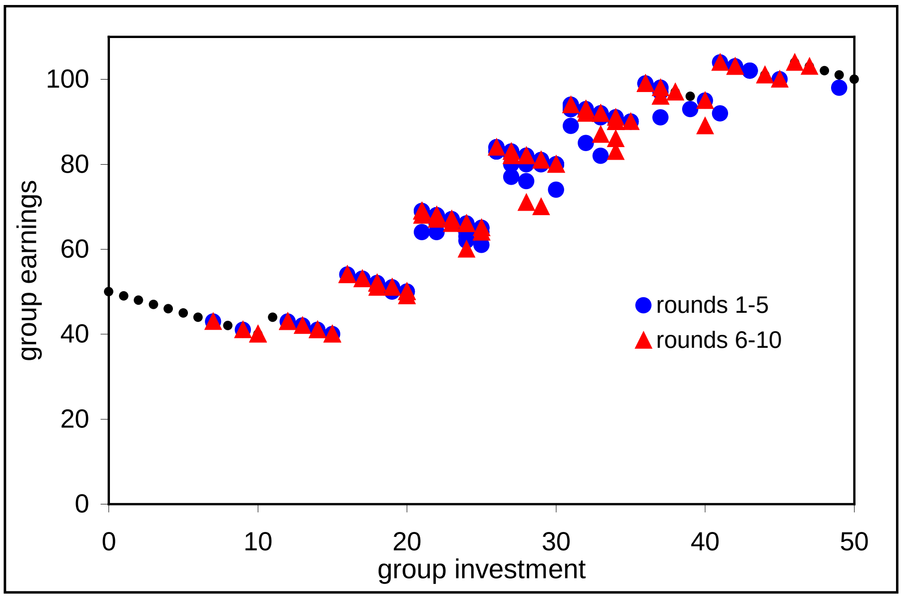

Figure 9: The relation between the group investment and group earnings for each round of the five person (b) experiments. Distinction is made between data from first half and second half of the experiment.

In Figure 10 we report the average earnings in each of the locations in the watershed and compare both countries. In both countries we see a clear inequality of earnings between those upstream and those downstream. In both countries the participants at position E receive less than 10 units per round, which would be the level of returns if they do not invest anything in the public infrastructure. Clearly, under this baseline condition, downstream players E are subsidizing those upstream, by contributing about half of their endowment (See Fig. 8 and Fig. 12) and obtaining a very small return from it. Meanwhile, those upstream are obtaining a large return on their initial contributions which is not substantially larger than the contributions made by those downstream as seen in Figure 12. The econometric analysis below will explore in more detail these findings and discuss the implications of such asymmetries in the problem of these types of commons.

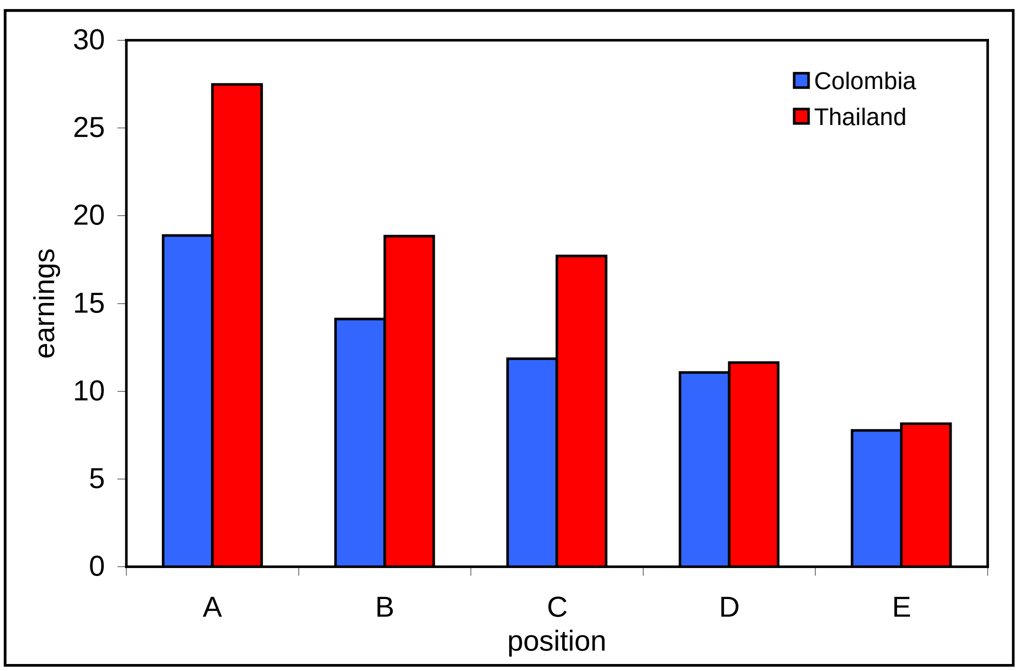

Figure 10: Average earnings per round for the different positions.

We performed a linear multi-level analysis to test, like the laboratory experiments, how inequality affects contributions to the group. We find the inequality in contributions and extraction in the previous rounds reduces the contributions to the current round. Including various demographic and survey data, we also find that Thai participants invest 2 tokens per round more than Colombian participants. We also found that more women in a group lead to higher contributions, and surprisingly a higher response to questions that enable us to estimate a trust level indicates that there is a negative relation between trust and contribution.

When we look at what contributes to inequality of contributions and collection at the group levels we find that there is a strong “learning” effect. Over the rounds, ceteris paribus, groups will increase their inequality. This inequality will increase even more for the collection of the resource, if the average age is higher, and more married persons are in the group.

Table 6: Regression results of number of tokens invested in water resource by groups. Between brackets are the standard deviations.

	Contribution	Gini contributions	Gini collection
Constant	55.837*** (6.272)	0.420 *** (0.079)	-0.200 (0.173)
Country (Colombia = 0)	10.155 *** (3.249)	0.001 (0.030)	-0.209 *** (0.073)
Round	-0.084 (0.151)	0.006 *** (0.002)	0.012 *** (0.003)
Irrigation village	-5.388 * (2.917)	-0.012 (0.020)	0.048 (0.061)
Gini contributions (t-1)	-26.077*** (4.378)		
Gini extractions (t-1)	-5.948 ** (2.632)		
Contribution		-0.009 *** (0.001)	-0.008 *** (0.002)

Avg age	-0.106 (0.091)	0.002 * (0.001)	0.015 *** (0.002)
Avg fraction women	7.074 *** (1.989)	0.004 (0.025)	-0.023 (0.052)
Avg education	-0.051 (0.980)	0.005 (0.012)	0.093 *** (0.024)
Avg married	-1.567 (2.567)	0.002 (0.032)	0.188 *** (0.066)
Avg trust[2]	-34.773 *** (9.837)	-0.067 (0.097)	-0.091 (0.240)
- Log likelihood	663.554	280.647	112.369
N	212	240	233
Variance contributions			
Session	5.345 (0.267)	0.0742 (0.0037)	0.1457 (0.0070)
Village	2.960 (1.312)	0.0150 (0.0078)	0.0574 (0.0293)
Country	0.005 (0.036)	0.0000 (0.0002)	0.0000 (0.0107)
χ^2	9.59 (0.0083)	2.64 (p=0.2665)	5.62 (p=0.0603)

Comparative analysis

Both the laboratory experiments and field experiments used asymmetric commons dilemmas where 5 participants first needed to decide how much of their endowment to invest in the public infrastructure, and then in order of access can collect from the generated resource. The circumstances and designs of the experiments where quite different from each other. The laboratory experiments used undergraduate students of Arizona State University, the experiments were computer based, the participants did not know the other persons in the group but could exchange text messages, the problem was translated into a real-time downloading game. The field experiments were

[2] Trust is a composed value between 0 and 1 based on a series of survey questions. More information can be found in Janssen et al. (2009b).

performed with villagers in rural areas in Colombia and Thailand, using paper and pencil. The participants knew each other but could not talk with each other during the experiment, which was framed as an irrigation game.

If we look at the level of the generated resource over time (Figure 11), we see that initially the levels were similarly, but the level of the laboratory experiments increased over time, while the level of the field experiments declined a bit. This is not surprising since participants in the laboratory experiments could chat with each other and this has been found to increase the level of cooperation (Hackett et al., 1994).

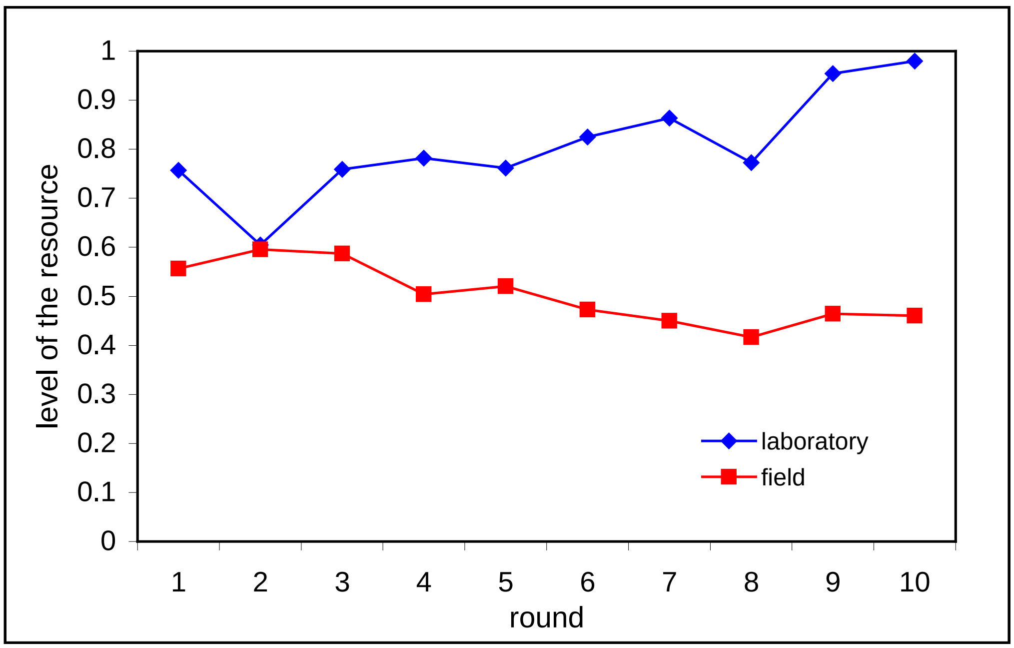

Figure 11: Scaled average level of resource per round for laboratory and field experiments.

We see that the downstream participants in the laboratory experiments invest less than the upstream participants (Figure 12). This can also be found in the communication where downstream participants are allowed to invest a bit less to make up for the lost earnings in previous rounds when they did not got sufficient opportunity to download files. In some cases downstream participants do not invest a significant amount in the generation of the common resource as a protest against lack of downloading opportunities in the earlier rounds. The average contribution among the villagers is insensitive to the position of the participant.

The earnings from collecting from the resource is much more skewed in the field compared to the laboratory. In the laboratory there is an initial inequality but over the rounds participants develop rotation systems to reduce the inequality of earnings.

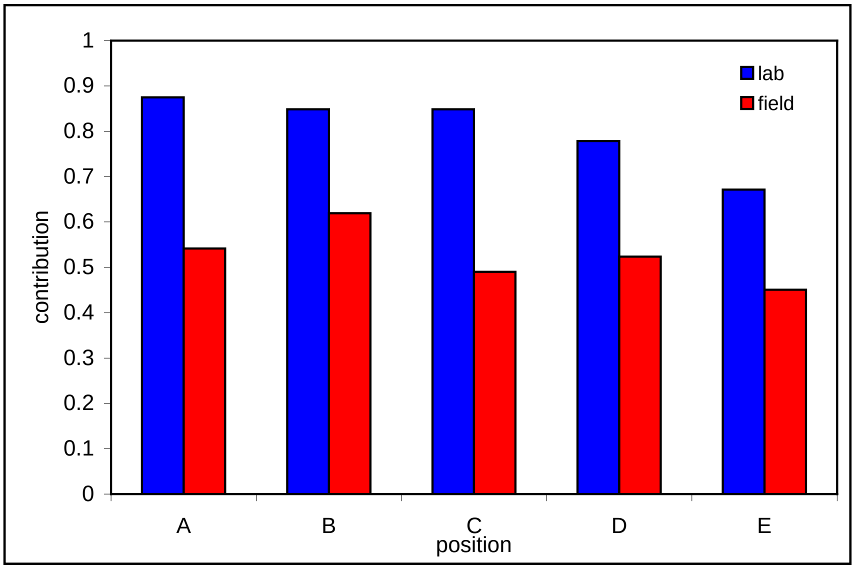

Figure 12: Scaled level of contribution for the different positions.

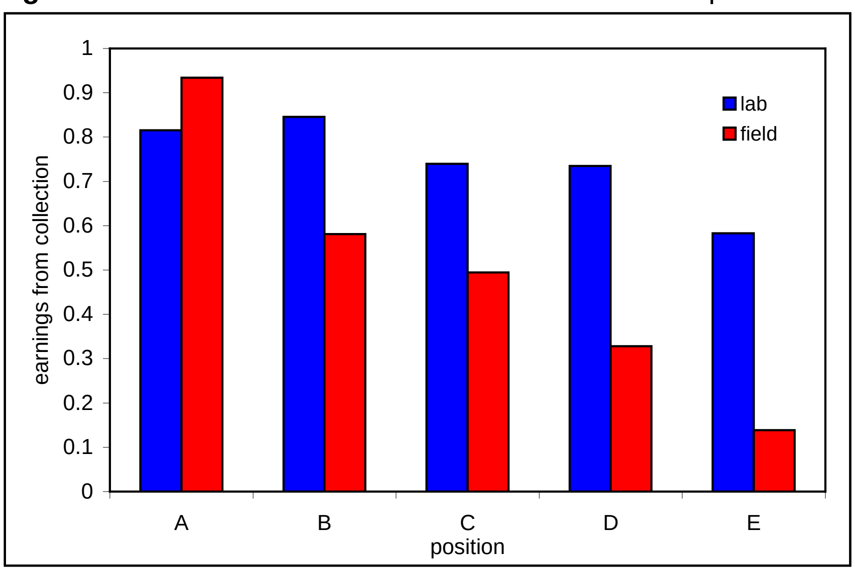

Figure 13: Scaled level of earning from collecting from the common resource for the different positions.

From the statistical analysis we learned that contributions to the public infrastructure are in both types of experiments significantly related to the inequality of contributions and earnings from collection in the previous round. Inequality leads to lower contributions, and hence a reduction of the earnings for the whole group in the longer term.

Discussion

We report and compare two experiments performed with asymmetric commons dilemmas in the lab and the field. Despite the very different participant pools and experimental context, we derive in both experiments that upstream take more than downstream participants, but there is a negative relation between inequality of resources collected from the previous round and investments into the public infrastructure. This indicates that there is a fundamental balance between inequality and efficiency. In asymmetric situations, how much inequality do the less privileged accept before reducing their investments in the common infrastructure?

Common pool resource experiments have not yet paid much attention to asymmetry of power, while this is an important attribute to investigate. The concept of roving and stationary bandits would be a helpful framework to investigate such asymmetries (Olson, 2000). The stationary bandits in our experiments were randomly assigned, and there was a considerable attention to equality of the extraction of the resources. Such equality considerations might be reduced when asymmetrical positions are not randomly allocated, but endogenously derived.

In sum, the concept of asymmetric commons dilemma provides interesting initial results that need to be examined in more contexts of resource and social dynamics.

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