"VERTICAL COLLECTIVE ACTION: ADDRESSING VERTICAL ASYMMETRIES IN WATERSHED MANAGEMENT"

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Abstract

Watersheds have the characteristic of connecting people vertically by water flows, making relationships among users of water more complex. The location of the people along the watershed defines their role in the provision and appropriation of water. Verticality in watersheds thus imposes a challenge to collective action. This paper presents the results of field experiments conducted in four watersheds of two different countries: Colombia (South America) and Kenya (Africa). We recruited 639 watersheds inhabitants from upstream, midstream and downstream locations in these basins and conducted field experiments to study the role that location and verticality plays in affecting cooperation at the provision and appropriation decisions. Two field experiments were conducted using the "*Irrigation Game*" based on a new experimental design (Cardenas, et.al 2008a) that includes the provision and appropriation nature of the resource, and the *"Water Trust Game"* an adaptation of the Trust Game (Berg et.al 1995) where we explicitly announce the actual location upstream or downstream of the two players. The results show that reciprocity and trust are very important motivations for upstream-downstream cooperation and that the role of upstream players has important implications in water provision decisions. Results from both experiments suggest that the lack of trust from downstream players towards upstream players restricts the possibilities of cooperation among the watershed users.

JEL Classification:

Keywords: Collective Action, Verticality, Watersheds, Field Experiments, Irrigation game, Trust Game, Water Trust Game.

1. Introduction

Watersheds connect people vertically by water flows, making relationships among users of the resource complex. The interdependency among users along the social and biophysical scales of the watershed generates challenges to water and watersheds management. The location of the

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people along the watershed defines their role in the provision and appropriation of water, so verticality in watersheds imposes a challenge to collective action.

Watersheds are characterized by an important biophysical and socio-economic heterogeneity that generates a variety of actors. These actors face different economic and environmental possibilities, like the different access to the resources, especially water in terms of its quantity and quality. *"Watersheds may include grazing land, agricultural land, residential areas, forests, wetlands, common waterways, and water-storage structures, each of which may be used by a variety of resource users. Lateral flows of water, soil, and nutrients between source and destination areas may link those resource users to other stakeholders, some of whom live outside the watershed. Effective watershed management requires coordination in the way that various stakeholders use and invest in the resources"* (Knox et al, 2001)

The connection among actors in a watershed involves the requirements for coordination and cooperation in the management of natural resources that means a necessity to improve their collective action possibilities. The cooperation in the provision and appropriation of water can be affected by the rival nature of the resource and the asymmetries on their access. Trust and reciprocity are important mechanisms in a relationship that involves externalities and coordination failures and these factors are enhanced by the aware about dependence among participants (Ostrom, 1998; Ostrom and Gardner, 1993).

In this study we conducted new experimental designs in the field with the participation of rural communities' inhabitants of four watersheds of two countries: Colombia and Kenya. Through these experiments we expected to observe the factors that can enhance trust and collective action in a context of dependence among people in different locations along a watershed that means asymmetric access to better quantity or quality of water.

We recruited around 639 watersheds inhabitants from upstream, midstream and downstream locations. The field experiment approach was used in order to achieve a better understanding of the effect of participants' location on water systems and the factors that influence provision decisions on this context. Two field experiments were conducted: the *"Irrigation Game"* a new experimental design (Cardenas, et.al 2008a) that includes the provision and appropriation nature of the resource and the *"Water Trust Game"* an adapted version of the Trust Game (Berg et.al 1995)framed around water that presents the dependence among players related to water and compensation (reverse) flows.

2. Verticality in Collective Action

Actions of people living in the upstream areas will affect those downstream far more than those downstream can directly affect those upstream. The downward flows of water, soil, and pollutants, can be counterbalance by reverse flows of commodities, money, regulation or influence (Swallow, et al,). This relationship among watershed actors is presented in other water systems like irrigation systems where the position of the individuals along the system determines their access to water. Besides, this condition will determine their willingness to cooperate in the provision of the resource.

"In large-scales, centrally constructed irrigation systems, the headenders and the tailenders are in very different positions. Narrowly selfish headenders would ignore the scarcity that they generate for those lower in the system. But if the headenders get most of the water, those at the tail end have even less reason to want to contribute to the continual maintenance of their system. All common-pool resources generate both appropriation and provision problems. In an irrigation common-pool resource, the appropriation problem concerns the allocation of water to agricultural production; the provision problem concerns the maintenance of the irrigation system. In addition, irrigation common-pool resources also have an asymmetry between headenders and tailenders, which increases the difficulty of providing irrigation systems over time." (Ostrom and Gardner, 1993).

Following Ostrom and Gardner (1993) the incentives faced by the players along the water canal are very different. The higher the position of the players, the bigger the incentives to contribute to the water canals maintenance. So we expect to observe a pattern over time in which the headenders contribute more labor and get more water than tailenders. *'The game equilibrium with headenders contributing more than tailenders has undesirables properties, in the sense that production will be less than optimal and the system will be undermaintained* (Ostrom and Gardner, 1993)

In watershed and irrigation system contexts, where vertical relationship among participants and asymmetries in appropriation are presented, there is a real mutual dependence among players and can arise incentives to change the distribution of water in order to improve the provision of water by those located at the end of the system (Ostrom and Gardner, 1993). This could happen by a water-for-labor exchange or water-for-money exchange that can be seen as reverse flows. However, the possibility for these exchanges and other cooperation agreements among players in different locations of the system depends on trust and reciprocity relationships them

Anthropologists studying the pre-columbian Andean cultures have identified the important role that these vertical relations played, through myths, in the understanding of the relationships between high mountains and the regions downstream (Murra, 1972, 1985; Osborne, 1985, 1990). The combination of a tropical location along with the Andean geography created certain conditions where the interdependence between actions upstream and well-being downstream for social groups became a major concern in the management of land, agriculture and trade. Murra in particular developed the model of verticality or ecological complementarity to explain the complexity with which the Andean cultures developed a system of natural resource management based on the complementarities of the high lands and the low lands. For such system to work, it is very important to coordinate the actions upstream and downstream with the basin as a whole management unit. However, much of the agricultural land in mountainous regions around the world is managed through systems of private property rights and eventually some higher level management based on institutional arrangements by regional or local governments attempting, rather weakly, to regulate land uses along the watershed.

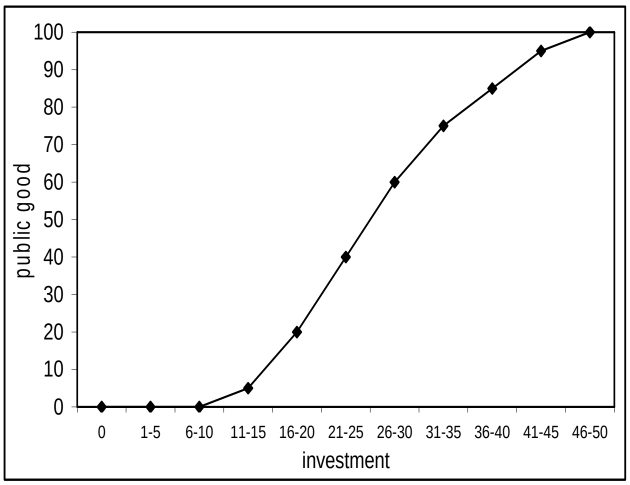
3. Experimental Design

Water and watersheds management have some features that impose additional difficulties to collective action, like the rival nature of the resource and the asymmetries on its access that depend on the location of participants along the water system. The objectives of the experimental games were to identify the effect that location in a context of vertical relationship around water can generate to collective action, and the factors that are more likely than others to increase levels of cooperation in this context. In order to include the provision and appropriation nature of water, a new experimental design called the *Irrigation Game* was used in the field experiments run in Colombia and Kenya watersheds. The other experiment was an adaptation of the trust game that presents the dependence among players as a relationship around water.

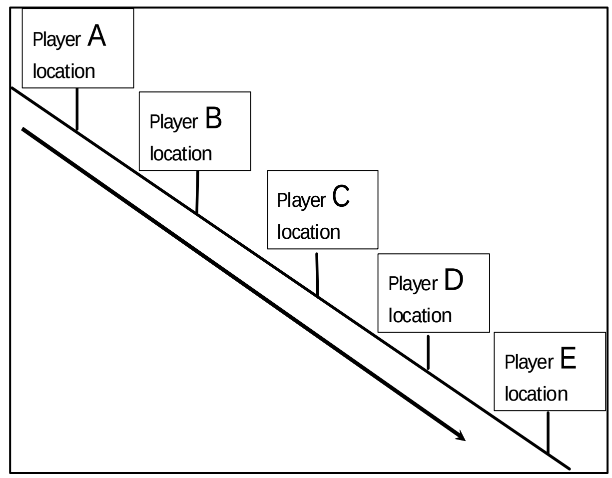
3.1. The Irrigation Game

This game introduces the asymmetries in the access to the resource among players. In the first part of the game players make the decision of how many tokens of their endowment of ten, they want to contribute to a project to maintain water canals, so the amount of available water depends on the total contributions according to a monotonic function of water production (Graph 1). Non contributed tokens are kept in a private account which yields private returns as well. The second decision of the players is the individual water extraction from the total water produced. This decision is taken according to the location of the players along the water canal, which is defined randomly and is represented by a letter: A for the player in the first position and E for the player in the last position (Graph 2).

Graph 1. Water Production Function



Graph 2. Players Location



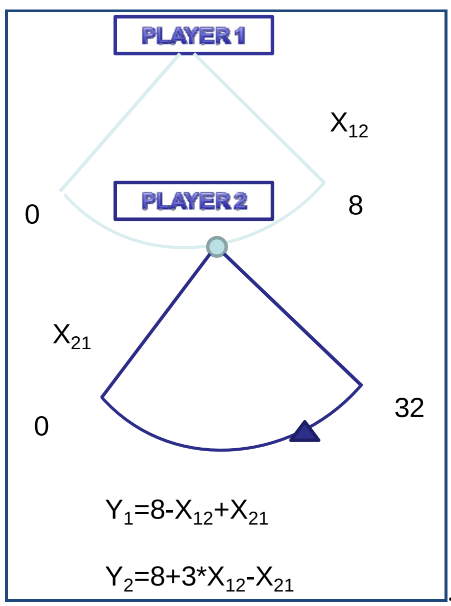
After the first ten rounds of baseline treatment, rules changed for some groups and this change is announced aloud to the players. Some groups were permitted to communicate; other face external regulation treatments and other groups continued playing with the baseline conditions.

In the **face-to-face communication** treatment, players were allowed to communicate with the other players in the group before returning to their places to make their own private decisions. Likewise in the baseline, they know the aggregate decision but not the individual decisions after each decision round. In the **external regulation** or **penalty treatments** players were told that there would be a chance of being monitored each round. The experimenter rolled a dice in front of the participants each round and if the number obtained is 6, all the participants are inspected, so the probability of being inspected was 1/6. The monitor checked the decision of the players and the players that had taken more water than the permit level, they had to pay a fine. The permit level for each participant of a group was the fifth part of the water produced. In the high penalty treatment, the fine was the extra amount taken plus six units of the cumulate earnings; in the low penalty treatment the fine was just the extra amount taken.

3.2. The Water Trust Game

Based on the standard trust game (Berg et al 1995), we constructed our *Water Trust Game (WTG)* framed around water access and distribution between two people located in different positions of a watershed. At the beginning of the game both players are endowed with 8 tokens. Player 1 (proposer) can send a fraction of her initial endowment to player 2 (responder). The amount sent by player one is tripled before it reaches player 2 who then decides how to split the tripled amount plus her initial endowment between herself and player 1 (Graph 3). In our framing, however, we explicitly framed the decision of player 1, if upstream, as the quantity of clean water sent to player 2 downstream, and player 2's decision as an economic compensation for the water provided by player 1. If the game started with a downstream player, also such decision was framed as an economic compensation for the water provided by player 1.

Graph 3. The extensive form of trust game



We implemented the trust game using the strategy method, that is, players 2 were asked the complete strategy of responses to each possible offer by player 1. Therefore player 2 had to respond, without knowing yet the amount offered by player 1, how many tokens she would return to player 1 for each possible offer by player 1 (0, 2, 4, 6, 8 units). During the session we also asked each of the players the amount the expected from the other player.

4. Data Analysis

We recruited around 639 watersheds inhabitants from upstream, midstream and downstream locations of Coello River and Fuquene lake watersheds in Colombia and Awach and Kapchorean rivers in Kenya. The distribution of the players between the games and the total number of observations are shown in table 1.

Table 1. Summary of the sessions

Game	WATER TRUST GAME		IRRIGATION GAME			
Country	**Kenya**	**Colombia**	**Kenya**		**Colombia**	
Watershed	Awach River	Fuquene Lake	Awach River	Kapchorean River	Fuquene Lake	Coello River
Session	62	80	12	12	27	20
Total players in sessions	124	160	60	60	135	100
Upstream players	62	80	50	50	29.63	35
Midstream players	0	0	0	50	37.04	30
Downstream players	62	80	50	0	33.33	35
Total Observations	62	80	1200	1200	2700	2000

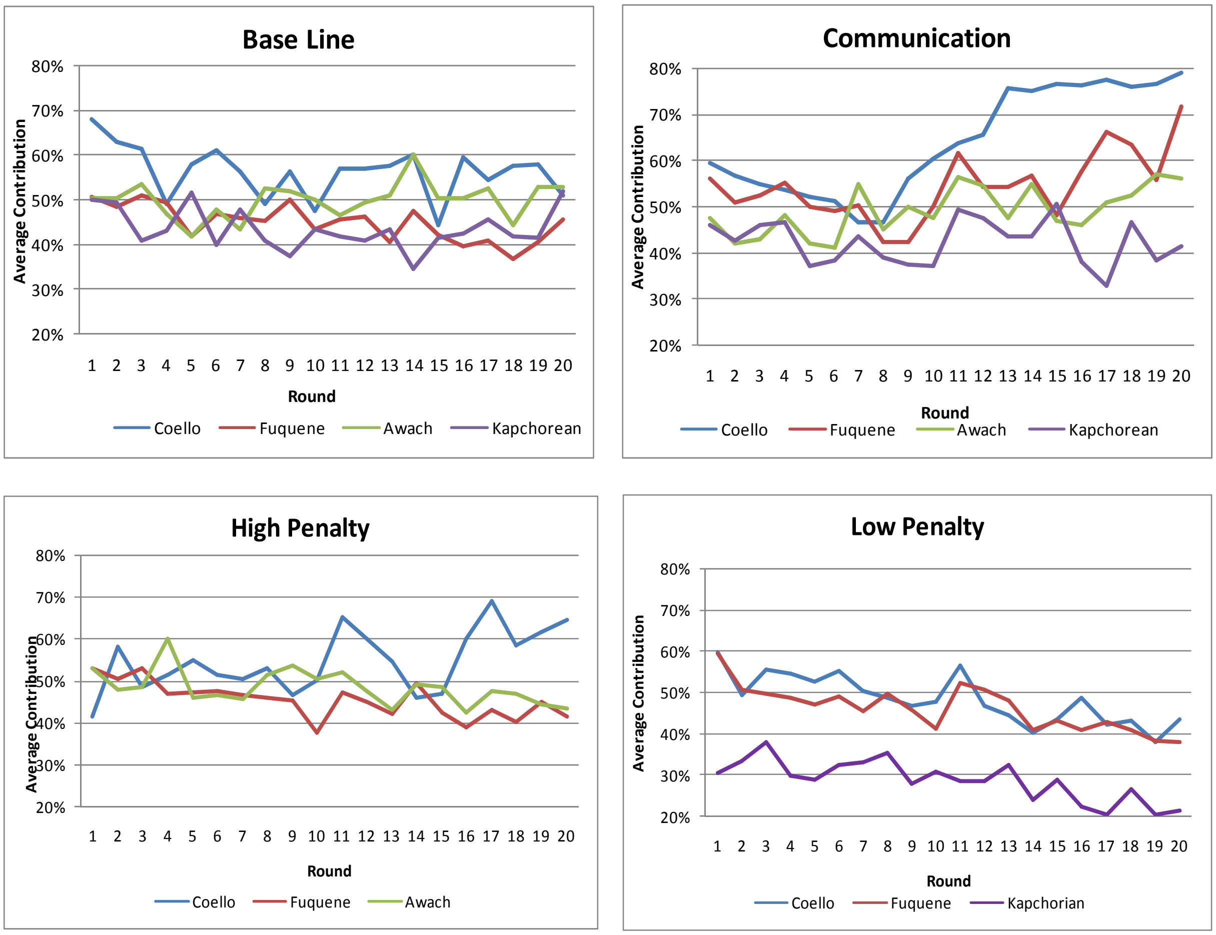
The *Irrigation Game* was conducted with a sample of 355 participants and the *Water Trust Game* with a sample of 284 participants from both countries distributed as shown in table 1.

4.1.1. Irrigation Game

The Social Optimum or Maximum Social Efficiency is an availability of 100 units of water that means a total contribution of 45-50 tokens. Nash Equilibrium is zero-contribution obtaining a suboptimal result of 50% of the maximum social efficiency possible. The overall results replicated the patterns of previous public goods or CPR games where predictions of non-cooperative game theory were not a common result and communication permitted to improve cooperation.

The contribution was on average 4.82 tokens, 48.2% of players' endowment, for the ten initial rounds. For the second stage of the game, the groups that continued playing with baseline institution got an average contribution of 4.71 tokens (47.1% of their endowment), the groups that could communicate reached a contribution of 5.9 tokens on average, and the penalty treatments groups obtained an average contribution of 4.83 for high penalty and 3.96 for the low penalty groups.

Graph 4. *Irrigation Game* contribution by treatment



However, the average contributions shown in the four panels in Graph 4 hide an important piece of information for our analysis. These are averages of five players who are located asymmetrically along the watershed, with contributions being monotonically greater the higher is the location of the player in the irrigation system. As we go downstream, the average contribution by the players reduces substantially as shown in the average contributions by player type, with A players being those assigned to the head end of the system and the E player as being the last player in the sequence of appropriation stage of the game.

Graph 5. *Irrigation Game* contribution by player location

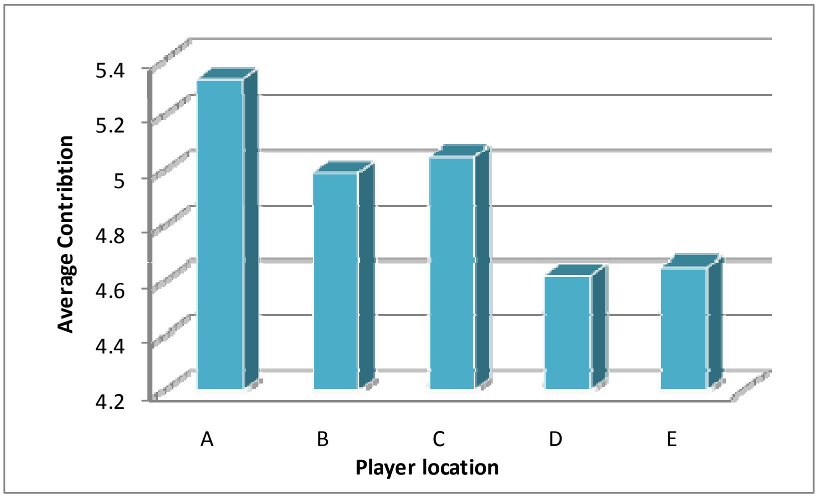


Table 2 contains the t-statistic comparing the average contributions. Except for comparisons between players D and E, and comparing players B and C, it is clear that downstream players contributed less tokens in average in the provision stage of the game, reducing the levels of social efficiency for the whole group.

Table 2. Contribution by location in the system

Player location	Contribution	T-statistic			
		B	**C**	**D**	**E**
A	5.33	3.37	2.72	6.88	6.61
B	4.99	----	0.57	3.69	3.42
C	5.05	----	----	4.15	3.88
D	4.62	----	----	----	0.26
E	4.65	----	----	----	----

Recall that these locations are assigned randomly at the start of each session and remain constant throughout the game. The results suggest that as one individual is assigned a unit further down in the irrigation system, her willingness to contribute to the public fund that provides water for all players decreases, eroding the possibilities of building collective action along the watershed.

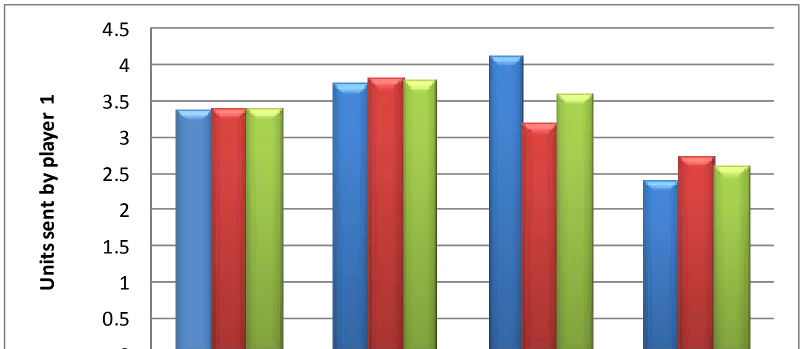
Let us now turn to the second game used, the *Water Trust Game*, where we study the role of the actual location of the players in the watershed and not the experimental location as studied in the irrigation game.

4.1.2. Water Trust Game

Regardless of the location, the Nash prediction in the trust game is for player one to send zero and player two to return zero. The Maximum Social Efficiency is for the first mover to send all her endowment what means 32 units to be distributed among both players. Like the results in other studies where replications of trust game were done, both player one and player two contributed an amount above Nash prediction and below Maximum Social Efficiency quantity.

The following graphs compare the results of average amount offered by player 1 to player 2 by treatment (UU=player 1 and player 2 are both located upstream; UD=Player 1 is upstream and player 2 downstream; DD= player 1 and player 2 are both located downstream; DU=Player 1 is downstream and player 2 upstream). Players 1 sent on average 41.8% of their endowment to player 2. We can highlight the consistency for the two watersheds where the games were conducted, with the treatment DU (downstream participants being player 1 and upstream participants as players 2) showing a systematically lower levels of offers, that is, lower trust in their counter-parts. Recall that in all treatments both players were informed of the actual location of the other player in the watershed.

Graph 6. Average amount of units sent by player 1 to player 2

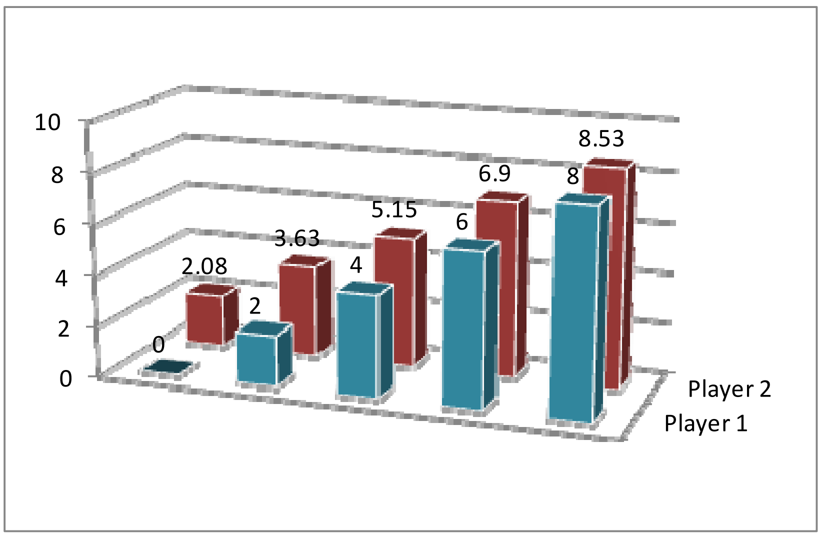


	UU	UD	DD	DU
Awach	3.37	3.75	4.13	2.4
Fuquene	3.4	3.81	3.2	2.74
Total	3.39	3.78	3.6	2.59

Graph 7 shows the amount sent by player 1 and the amount retuned by player 2 as a response to the different options that player 1 could offer to player 2. We are able to build this graph because we used the strategy method where players 2 had to respond the amount returned to player 1 for each possible offer. The results show that trust is followed by reciprocity with higher amounts returned from player 2 to player 1. People being trusted showed higher levels of reciprocity by returning with positive returns the initial investment, consistent with much of the literature using the trust game (See Cardenas and Carpenter (2008) for a survey of field and lab experiments using the canonical version of trust game).

Players 2 returned on average 26.2% from their initial endowment including the amount received, which is very common in the trust game where players 2 usually capture more of the social pie produced in the game, but with reciprocity present in the way players 2 return higher amounts to players 1 who send higher offers.

Graph 7. Amount sent by player 1 and returned by player 2



When we compare the amounts offered by players 1 across the four possible permutations between upstream (U) and downstream (D) players (See Table 3) only one level of offers seems to be statistically different from the others is when the water trust game starts downstream, that is, when players 1 are located downstream and send their offers to players upstream.

Table 3. T-test mean values of offers (p-value)

Treatment	UU	UD	DD	DU
UU	----	0.3958	0.6795	0.0567
UD	----	----	0.7309	0.0091
DD	----	----	----	0.0447

This phenomenon could explain in part why we observed in the irrigation game such lower contributions by players downstream; players downstream suffer more explicitly the effects of water extraction by players upstream and therefore are more sensible to such unidirectional externalities. Experience with such externalities can drive a reduction of trust among downstream inhabitants towards the rest of watershed users, and it is well reflected with both the experimental and actual location of the players in both games.

5. Regression Results

5.1. Irrigation Game

There are several types of variables at the individual, experimental session, and regional level that can also help explain the variation of the behavioral variables by our participants in the two games, beyond the experimental design and treatments. Therefore we conduct a regression analysis to explain the contributions by players in the provision stage of the irrigation game, and the offers levels by players 1 in the water trust game, to confirm our hypothesis of a downstream erosion of cooperation in the vertical collective action problem because of decreased trust by the downstream players in the game.

Our econometric strategy is as follows. First, we explain the individual contributions in the irrigation game as a function of the experimental conditions, including the round, the location in the irrigation system and the institutional treatment (baseline, communication, high fines and low fines); we then continue with the individual characteristics and given the richness of the demographics we were able to sample in the field. We include several context controls such as dummy variables for the watersheds and also for the particular five players' context. We chose therefore to run a robust standard errors fixed effects model where the fixed effects were captured by each of the particular 71 sessions conducted in the four watersheds. We test several formulations of the estimator including a pooled data model, a semi-pooled model with dummies for the watersheds, and an unspooled model where we estimate one separate regression for each of the watersheds. We also tested different institutional changes in round 11 for these sessions and compared them to the baseline treatment where players continued after round 11 under the same rules and incentives.

In table 4 we summarize the descriptive statistics of the irrigation game data set. We have about 7,000 observations since each of the 71 sessions was conducted for 20 rounds and for 5 players. The standard deviations of the variables used give us enough variation to conduct a regression analysis and derive some conclusions about the average behavior already analyzed in previous sections.

Table 4. Summary statistics *Irrigation Game*

Variable	Description	Obs	Mean	Std. Dev	Min	Max
Contribution	Tokens contributed to the fund	7100	4.87	2.87	0	10
Round	Round number (Learning)	7100	10.5	5.77	1	20
Others contribution	Other four players contribution in the previous round	7100	19.61	6.82	0	40
Age	Age of the player (years)	7060	39.28	15.27	14	88
Gender	A dummy that takes a value of one if woman	7040	0.48	0.5	0	1
Education level	Level of education of the participants (years)	6860	5.97	3.6	0	19
Time in the community	Time living in the community (years)	6860	28.8	17.7	1	88
Household size	Number of people that live together in the same house	6760	5.53	2.84	1	20
Watershed Location	Location of the player farm/house along the watershed (1=downstream, 2=midstream, 3=upstream)	7100	2.04	0.81	1	3
Participation in community organizations	A dummy for participation in voluntary community groups or organizations	7060	0.62	0.48	0	1
Community cooperation	Community cooperation in water conservation (Number of neigbors that cooperate from each 10 neighbors)	6920	5.42	2.72	0	10

Tables 5 and 6 show the regression results of two complementary estimation strategies for the same datasets. In Table 5 we report the regression results for different models broken down by watersheds. In table 6 we explore the effect of different regulations or institutions and the possibility of pooling or not the data set with respect to the regulatory environment in the second stage of the experiment.

Let us first analyze Table 5. We have first a pooled model (1) where we regress the contribution level by player 1 as a function of the variables already mentioned. This model yields an R-squared of about 23.5% of the variation. When we add (2) the dummy effects for each of the watersheds (the omitted dummy corresponds to the Kapchorean basin) we find that they are statistically significant although the overall estimation power remains the same at 23.5% for the R-squared value. We then estimate the same regression for each of the watershed subsamples (models (3), (4), (5) and (6)). As we will show, there are particularities to each of the watersheds that deserve attention as well as universal patterns that seem to remain across countries and watersheds.

Regarding our experimental design, we confirm that the location in the irrigation system (A,B,C,D,E) does play a significant role in the level of contributions; in the unspooled model for each of the watersheds we find that only for the case of Awach such effect is not significant[4]. Also, we observe the powerful effect of the communication treatment in increasing contributions for all estimated models. However, the introduction of high and low fines seem to have a poorer effect in the contributions; if anything, some of the estimated models show a positive effect of the high fine, and for the case of low fines all coefficients are negative and not significant (See Cardenas, 2004; 2005 for similar results comparing these type of regulations with a face-to-face communication treatments in common-pool resource experiments conducted in the field).

We also find that the contributions by the other people in the group in the previous round help explain contributions with a negative effect. That is, the higher the contribution by the other four players the smaller the contribution by the average player in the next round. This contradicts the reciprocity effect but the size of the coefficient is rather small. As we will discuss in the next stage of the econometric analysis (Table 6) this effect changes substantially if we study separately the institutional context of the regulation in the second stage.

With respect to demographic characteristics of the participants we find that more educated, older people, living in larger households seem to contribute more to the provision stage of the game. Other factors do not seem to present a robust effect across the 6 models. For instance, the context of cooperation and community activities seems to have a significant effect for Fuquene and the two Kenyan watersheds but with contradicting signs for the case of Kapchorean; however, it was in this watershed that we observed very low levels of contributions (notice the dummy positive effects that need to be added to the constant and the omitted dummy); also notice the low value of the constant for the Kapchorean (6) model.

[4] We do not think it is a country effect or an experimenter effect because the Kapchorean watershed did show statistically significant effects for the location of the players in the game, and the experimenters were the same in both locations.

With the coefficient size of "Others contributions lag" substantially larger, and a shifter downwards for the evaluation of community participation of others and participation in organization by the player, these combined would explain quite consistently the much lower levels of cooperation in this watershed. Recall Graph 4 where we clearly observe how this watershed showed distinct patterns for the communication and low penalty treatments.

Table 5. Fixed-effects OLS estimation of contribution decisions *Irrigation Game*

Dependent variable:	*Percentage of tokens contributed to the public fund*					
Independent variables	Pooled (1)	Dummies wtsdh (2)	Coello (3)	Fuquene (4)	Awach (5)	Kapchorean (6)
Round (learning)	-0.045	-0.045	-0.029	-0.062	0.005	-0.076
	(0.008)**	(0.008)**	(0.016)$^+$	(0.013)**	(0.018)	(0.020)**
Player located in position **A** (dummy)	0.807	0.807	1.269	0.73	-0.026	0.944
	(0.099)**	(0.099)**	(0.196)**	(0.155)**	(0.251)	(0.241)**
Player located in position **B** (dummy)	0.415	0.415	0.199	0.355	0.057	0.839
	(0.103)**	(0.103)**	(0.2)	(0.166)*	(0.25)	(0.247)**
Player located in position **C** (dummy)	0.367	0.367	0.571	-0.127	0.182	0.918
	(0.102)**	(0.102)**	(0.200)**	(0.159)	(0.259)	(0.252)**
Player located in position **D** (dummy)	0.084	0.084	0.39	-0.251	-0.248	0.683
	(0.103)	(0.103)	(0.194)*	(0.17)	(0.25)	(0.246)**
1 if treatment = communication	1.568	1.568	2.433	1.571	0.711	0.871
	(0.152)**	(0.152)**	(0.281)**	(0.245)**	(0.327)*	(0.335)**
1 if treatment = high fine	0.283	0.283	0.939	0.227	-0.528	
	(0.157)$^+$	(0.157)$^+$	(0.350)**	(0.22)	(0.312)$^+$	
1 if treatment = low fine	-0.315	-0.315	-0.514	0.08		-0.266
	(0.153)*	(0.153)*	(0.27)$^+$	(0.239)		(0.316)
Others contribution lag	-0.042	-0.042	-0.008	-0.006	-0.074	-0.156
	(0.007)**	(0.007)**	(0.012)	(0.011)	(0.016)**	(0.017)**
Age	0.031	0.031	0.011	0.051	-0.028	0.088
	(0.003)**	(0.003)**	(0.006)$^+$	(0.005)**	(0.011)**	(0.012)**
Gender	-0.14	-0.14	0.169	0.301	0.421	-1.473
	(0.086)	(0.086)	(0.154)	(0.141)*	(0.21)*	(0.219)**
Education level	0.025	0.025	0.028	0.051	-0.085	0.123
	(0.012)*	(0.012)*	(0.022)	(0.018)**	(0.034)*	(0.037)**
Time in the community	-0.004	-0.004	-0.003	-0.008	0.017	-0.017
	(0.003)$^+$	(0.003)$^+$	(0.005)	(0.004)$^+$	(0.007)**	(0.013)
Household size	0.066	0.066	0.012	0.155	0.094	-0.142
	(0.014)**	(0.014)**	(0.032)	(0.025)**	(0.034)**	(0.038)**
Participation in community organizations	-0.074	-0.074	-0.228	0.482	0.374	-0.781
	(0.079)	(0.079)	(0.167)	(0.123)**	(0.185)*	(0.183)**
Community cooperation	0.003	0.003	0.048	0.067	-0.051	-0.068
	(0.015)	(0.015)	(0.027)$^+$	(0.024)**	(0.041)	(0.044)
1 if watershed= Coello		2.455				
		(0.439)**				
1 if watershed=Fuquene		3.82				
		(0.565)**				
1 if watershed = Awach		2.775				
		(0.486)**				
Constant	3.792	1.337	4.561	1.583	7.254	0.816
	(0.375)**	(0.406)**	(0.769)**	(0.543)**	(0.748)**	-0.542
Fixed Effects (dummies)	71 groups	71 groups	20 groups	27 groups	12 groups	12 groups
Observations	6320	6320	1720	2380	1100	1120
R-squared	0.235	0.235	0.221	0.229	0.079	0.409

Robust standard errors in parenthesis

$^+$ significant at 10%; * significant at 5% level; ** significant at 1% level

In table 6 we address the role that the different regulatory treatments had on behavior. Models (1) through (4) estimate the level of contributions for each of the subsamples under each of the treatments, Base Line, Communication, High Fine and Low Fine respectively. Several lessons emerge from this analysis and that are related to our analysis of the vertical collective action problem.

The negative effect of time (learning effects) is reversed for the communication treatment whereas the negative effect observed in the base line is pushed further by the low fine regulation and maintained by the high fine. Elsewhere[5] it has been discussed the complementary or substitute effects of material incentives with intrinsic motivations; in this case it seems that these external fines do not contribute to crowd-in the cooperation levels, and the negative effect of the regulation in the size of the "round" variable as well as the effect of "Others contribution lag" specially for the low fine confirm such negative effect.

But let us concentrate on the problem of verticality for a moment. Notice that the asymmetry in the coefficients for the player location is decreased for the case of the communication treatment. One of the major effects we observed of the self-governed solutions generated in the face-to-face communication within the groups is that players begin to contribute in a more homogenous manner as well as distributing better the water along the sequence with substantial impact over equity across players.

The context of cooperation and community activities reported by the participants has rather interesting effect on contributions (See table 6). For the communication treatment, it has a positive effect on contributions but a zero or negative effect on the baseline and regulated treatments.

Our watershed effects remain robust with the Colombian watersheds showing higher levels of contributions for all treatments and with the Coello watershed showing a substantially higher level of contributions in all treatments.

[5] For a survey of experimental evidence see Bowles (2008), and for field evidence on the crowding-out of group-oriented behavior because of externally imposed by weakly monitored sanctions see Cardenas, et.al. (2000)

Table 6. Fixed-effects OLS estimation of contribution decisions *Irrigation Game* by Institution

Dependent variable:	*Percentage of tokens contributed to the public fund*			
Independent variables	BaseLine Wtshd=C,F,A,K (1)	Communication Wtshd=C,F,A,K (2)	High Fine Wtshd=C,F,A (3)	Low Fine Wtshd=C,F,K (4)
Round (learning)	-0.029	0.059	-0.017	-0.18
	(0.029)	(0.029)*	(0.033)	(0.029)**
Player located in position **A** (dummy)	0.768	-0.787	-0.098	0.898
	(0.258)**	(0.277)**	(0.326)	(0.302)**
Player located in position **B** (dummy)	-0.164	-0.022	0.277	-0.275
	(0.263)	(0.262)	(0.382)	(0.263)
Player located in position **C** (dummy)	0.012	0.523	-0.061	-0.471
	(0.31)	(0.259)*	(0.28)	(0.28)$^{+}$
Player located in position **D** (dummy)	-0.117	-1.087	0.284	-0.798
	(0.251)	(0.269)**	(0.276)	(0.313)*
Others contribution lag	-0.128	-0.047	-0.071	-0.134
	(0.019)**	(0.017)**	(0.022)**	(0.022)**
Age	0.01	0.051	0.024	0.052
	(0.01)	(0.012)**	(0.007)**	(0.011)**
Gender	-0.112	-0.975	-0.108	0.507
	(0.246)	(0.239)**	(0.278)	(0.275)$^{+}$
Education level	0.025	0.088	0.004	0.093
	(0.03)	(0.040)*	(0.034)	(0.031)**
Time in the community	0.014	-0.041	-0.009	0.018
	(0.008)	(0.008)**	(0.007)	(0.009)$^{+}$
Household size	0.185	0.076	0.04	-0.109
	(0.033)**	(0.039)$^{+}$	(0.046)	(0.048)*
Participation in community organizations	-0.598	0.711	-0.694	-0.22
	(0.206)**	(0.214)**	(0.252)**	(0.234)
Community cooperation	-0.133	0.055	0.125	-0.033
	(0.042)**	(0.042)	(0.044)**	(0.049)
1 if watershed= Coello	2.986	2.678	2.787	7.078
	(0.722)**	(0.655)**	(0.640)**	(0.666)**
1 if watershed=Fuquene	-1.422	4.137	1.336	6.82
	(0.554)*	(0.686)**	(0.582)*	(0.566)**
1 if watershed = Awach	3.579	3.601		
	(0.641)**	(0.677)**		
Constant	5.33	0.574	4.597	1.799
	(0.968)**	(0.787)	(1.052)**	-0.923
Fixed Effects (dummies)	18 groups	21 groups	15 groups	17 groups
Observations	840	940	640	740
R-squared	0.352	0.383	0.216	0.41

Robust standard errors in parenthesis
$^{+}$ significant at 10%; * significant at 5% level; ** significant at 1%

The next remaining exercise with the irrigation game is to separate the samples by watershed and treatment, and compare in particular the powerful effect of communication in each of the basins. This table allows us to study in further detail the observed lower levels of contributions for the two Kenyan watersheds. Notice for instance that the effect of the "others contributions lagged" turns out to be positive and significant for the Colombian basins whereas negative for the Kenyan ones. We had already mentioned the much stronger effect of communication for the Colombian cases.

Table 7. Fixed-effects OLS estimation of contribution decisions *Irrigation Game* by Institution and Watershed

Dependent variable:	*Percentage of tokens contributed to the public fund*							
	BaseLine				Communication			
	Coello	Fuquene	Awach	Kapchorean	Coello	Fuquene	Awach	Kapchorean
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Round (learning)	-0.015	-0.09	0.021	0.041	0.074	0.067	0.022	-0.112
	(0.06)	(0.044)*	(0.054)	(0.058)	(0.038)$^+$	(0.047)	(0.06)	(0.055)*
Player located in position **A** (dummy)	1.822	1.123	-1.67	0.654	-1.087	1.453	-6.38	-6.054
	(0.941)$^+$	(0.433)**	(0.632)**	(0.695)	(0.527)*	(0.597)*	(1.298)**	(1.170)**
Player located in position **B** (dummy)	0.948	0.015	1.521	1.525	-1.092	-0.124	-1.369	0.005
	(1.182)	(0.41)	(0.725)*	(1.056)	(0.507)*	(0.54)	(0.617)*	(0.805)
Player located in position **C** (dummy)	0.999	-0.975	-1.779	-0.357	-0.377	-0.438	0.323	0.774
	(0.96)	(0.563)$^+$	(0.731)*	(0.603)	(0.514)	(0.625)	(1.06)	(0.491)
Player located in position **D** (dummy)	1.379	-0.61	-1.796	1.096	-0.107	-0.685	-2.85	-2.529
	(0.586)*	(0.541)	(0.682)**	(1.583)	(0.504)	(0.614)	(0.720)**	(0.874)**
Others contribution lag	-0.111	-0.076	0.003	-0.066	0.091	0.041	-0.105	-0.071
	(0.045)*	(0.028)**	(0.036)	(0.039)$^+$	(0.025)**	(0.023)$^+$	(0.039)**	(0.04)$^+$
Age	0.009	0.013	-0.145	0.261	0.025	0.075	0.09	0.246
	(0.031)	(0.014)	(0.039)**	(0.080)**	(0.025)	(0.017)**	(0.039)*	(0.022)**
Gender	3.144	-0.71	-2.85	-2.746	-0.751	0.488	-3.002	-4.814
	(0.718)**	(0.391)$^+$	(0.905)**	(1.497)$^+$	(0.392)$^+$	(0.434)	(1.447)*	(0.497)**
Education level	0.089	0.071	-0.21	0.127	0.086	0.099	0.491	0.73
	(0.085)	(0.046)	(0.108)	(0.113)	(0.068)	(0.093)	(0.143)**	(0.143)**
Time in the community	-0.019	0.039	0.099	-0.201	-0.023	-0.028	-0.071	0.008
	(0.016)	(0.016)*	(0.013)**	(0.045)**	(0.012)$^+$	(0.015)$^+$	(0.041)$^+$	(0.051)
Household size	-0.386	0.31	0.377	-0.43	0.024	0.196	-0.039	0.025
	(0.219)$^+$	(0.072)**	(0.109)**	(0.215)*	(0.098)	(0.089)*	(0.165)	(0.118)
Participation in community organizations	-0.454	-0.471	-2.289	0.517	0.149	1.947	1.647	1.029
	(0.633)	(0.312)	(0.815)**	(1.266)	(0.513)	(0.309)**	(0.559)**	(0.711)
Community cooperation	-0.142	-0.207	0.036	0.227	0.044	0.129	0.681	0.503
	(0.121)	(0.081)*	(0.145)	(0.418)	(0.118)	(0.084)	(0.167)**	(0.150)**
Constant	6.465	7.669	6.417	-0.499	1.692	-2.012	1.361	-2.741
	(2.894)*	(1.729)**	(2.181)**	(3.974)	(1.69)$^+$	(1.862)	(3.471)	-2.201
Fixed Effects (dummies)	15 groups	35 groups	20 groups	20 groups	30 groups	35 groups	20 groups	20 groups
Observations	170	320	170	180	250	310	200	180
R-squared	0.364	0.365	0.524	0.593	0.443	0.483	0.372	0.637

Robust standard errors in parenthesis
$^+$ significant at 10%; * significant at 5% level; ** significant at 1

5.2 The Water Trust Game.

The rest of our statistical analysis of the verticality phenomenon focuses on the *Water Trust Game*. In this case we have 142 observations (pairs) for 284 participants in this game, and sampled from different locations in two of the watersheds (Fuquene for the case of Colombia and Awach for the case of Kenya). Table 8 shows the summary statistics for the data available for both our players 1 and players 2 in the game. Notice that we have recruited about half of players at upstream location (See "location player 1") and another half at downstream locations. Recall we conducted all possible permutations of pairs for upstream and downstream locations of the players with the purpose of studying if there is in fact an effect of the actual location of the people in the watershed on the level of trust, a key element of collective action.

Table 8. Summary statistics *Water Trust Game*

Variable	Description	Obs	Mean	Std. Dev	Min	Max
PLAYER 1						
Offer player 1	Amount sent by player 1	142	3.352	2.048	0	8
Location player 1	1=upstream; 0=downstream	142	0.514	0.501	0	1
Expectation player 1	Amount expected by player 1	142	6.599	5.687	0	32
Age	Age of the player (years)	141	35.13	13.53	13	80
Gender	A dummy that takes a value of one if woman	142	0.591	0.493	0	1
Education level	Level of education of the participants (years)	141	7.113	3.416	0	16
Time in the community	Time living in the community (years)	132	27.91	16.26	1	80
Participation in community organizations	A dummy for participation in voluntary community groups or organizations	141	0.511	0.511	0	1
Community cooperation	Community cooperation in water conservation (Number of neigbors that cooperate from each 10 neighbors)	142	5.887	2.543	0	10
PLAYER 2						
Response player 2	Amount returned by player 2	142	4.211	4.259	0	20
Location player 2	1=upstream; 0=downstream	142	0.493	0.502	0	1
Expectation player 2	Amount expected by player 2	142	4.521	2.33	0	8
Age	Age of the player (years)	142	37.03	16.18	13	85
Gender	A dummy that takes a value of one if woman	142	0.514	0.502	0	1
Education level	Level of education of the participants (years)	142	7.253	3.718	0	16
Time in the community	Time living in the community (years)	137	29.04	16.89	1	80
Participation in community organizations	A dummy for participation in voluntary community groups or organizations	140	0.564	0.498	0	1
Community cooperation	Community cooperation in water conservation (Number of neigbors that cooperate from each 10 neighbors)	141	5.759	2.715	0	10

In table 9 we estimate the amount offered by player 1 to player 2 as a function of the same kind of explanatory variables used in the previous analysis. Model (1) considers the pooled data set, whereas model (2) includes a dummy for the Fuquene watershed which turned out to be significant (also consistent with the higher levels of contributions in the irrigation game for the Colombian samples). Models (3) and (4) consider the separate samples for each of the watersheds.

Some robust results are worth mentioning. Reciprocal behavior drives trust by players 1. Those expecting more are sending more amounts to players 2. This is consistent across the estimated models. Older and more educated people and females have a slight but not significant tendency to offer less. However, the more time the player has lived in the community the higher the offers with a significant effect.

Let us now turn to the verticality effect. We had already in our descriptive analysis of offers (See Graph 3) that the actual location of the player in the watershed might be playing a role. We do find that the variable "Location of player 2" is significant and negative for all estimated models meaning that when the offers come from downstream players and player 2 is upstream, such offers decrease. That is, downstream players trust less upstream players and that has a significant effect on trust and social efficiency since each token not sent represents three less tokens not generated for the social efficiency of the pair of players.

Table 9. OLS estimation of offers *Water Trust Game*

Dependent variable:	*Player 1 offer*			
Independent variables	Pooled (1)	Dummies wtsh (2)	Fuquene (3)	Awach (4)
Location of player 1(1 if upstream)	0.21	0.129	-0.023	0.186
	(0.333)	(0.327)	(0.513)	(0.661)
Location of player 2 (1 if upstream)	-0.765	-0.797	-0.562	-0.925
	(0.319)*	(0.312)*	(0.467)	(0.422)*
Expectation player 1	0.151	0.176	0.281	0.126
	(0.031)**	(0.035)**	(0.058)**	(0.043)**
Age	-0.033	-0.031	-0.027	-0.028
	(0.018)$^{+}$	(0.02)	(0.025)	(0.042)
Gender	-0.292	-0.431	-0.213	-0.786
	(0.328)	(0.323)	(0.498)	(0.503)
Education level	-0.058	-0.048	-0.035	-0.086
	(0.057)	(0.054)	(0.084)	(0.091)
Time in the community	0.047	0.049	0.045	0.033
	(0.015)**	(0.016)**	(0.020)*	(0.033)
Participation in community organizations	-0.416	-0.277	-0.366	-0.002
	(0.309)	(0.302)	(0.442)	(0.444)
Community cooperation	-0.034	0.041	0.031	0.14
	(0.066)	(0.072)	(0.101)	(0.103)
1 if watershed=Fuquene		0.897		
		(0.368)*		
Constant	3.474	2.276	2.407	2.658
	(1.003)**	(1.15)	(1.601)	(1.474)
Observations	129	129	70	59
R-squared	0.328	0.357	0.405	0.385

Robust standard errors in parenthesis.$^{+}$ significant at 10%; * significant at 5% level; ** significant at 1

6. **Conclusions.**

The challenge of vertical collective action emerges from the asymmetry in the location of players along the irrigation system. Head enders or upstream players have better opportunities to capture the benefits of a public project that maintains or produces water because they have an earlier access to the resource. On the other hand their actions cause direct externalities to those downstream. Therefore, tail enders or downstream players notice two effects on their well-being: those upstream have better chances to benefit from the resource, and their appropriation actions affect them directly. Further, the appropriation by those downstream has no direct effect on players upstream and therefore the possibility of signaling through reciprocal responses is less available for downstream players. In our irrigation game this mechanism seems to operate through the contribution stage. Players downstream are willing to contribute less than upstream players to the public project; it seems that the effect is if anything of negative reciprocity which triggers even more the vicious cycle of reciprocity, trust and reputation well described by Ostrom (1998).

These effects can create a similar negative effect to that of heterogeneity in collective action in this case because of location. The distance created by these asymmetries i.e. better resource availability and unidirectional externalities from those upstream seems to reduce the level of trust and cooperativeness of downstream players. However, when players have the opportunity to communicate, the contribution patterns shift to more cooperative behavior, a result that has been reported in other studies with heterogeneous individuals, *"even in an environment of extreme heterogeneity in subject endowments, communication was a powerful mechanism for promoting coordination, resulting in rents very close to those observed in the homogeneous set*" (Ostrom, 2006).

It seems that one major challenge to solve the vertical challenge is to address the asymmetries in a manner that players perceive a more fair allocation of the resource and of the effort contributed to provide the resource. The proportionality between contributions and appropriation is part of the challenge. *"When rules are based on a clear principle of proportionality and all participants recognized that the rules enable them to reach better outcomes than feasible in the "state of* *nature" game, and all are prepared to punish rule breakers, more productive equilibria are reached and sustained over time"* (Ostrom and Gardner, 1993).

The challenge is to bring downstream players to the group oriented outcome of the game by creating better allocations of effort and resource extraction along the watershed. This is what the face-to-face communication treatment achieved in our results. It balanced the effort between upstream and downstream contributions and therefore increased substantially the water produced by the irrigation system, providing better chances for the downstream players (D and E) to obtain water in each round. *"Asymmetries among participants facing common-pool resource provision and appropriation problems can present substantial barriers to overcoming the disincentives of the "state of nature" game between head-end and tail-end farmers. However, these asymmetries are frequently overcome in settings where farmers are made aware of their mutual dependencies; after all, head-enders and tail-enders may need the resources provides by tailenders when it comes to maintaining the system over time"* (Ostrom and Gardner, 1993).

The lack of trust among the two ends of the watershed, and in particular of players downstream who suffer the most the effects of the decisions and better location of those upstream, is a major challenge here. Further research is needed to explore the impacts of simply informing better about the expectations and intentions of both players upstream and downstream and how different government and non-government actors can play in decreasing this lack of trust that we observe both because of the experimental location or the actual locations of our hundreds of participants in Colombia and Kenya.

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