VERTICAL COLLECTIVE ACTION:
ADDRESSING VERTICAL ASYMMETRIES IN WATERSHED MANAGEMENT[1]

This version: Sept, 2011

Juan Camilo Cardenas[a], Luz Angela Rodriguez[b], Nancy Johnson[c]

[a] Universidad de Los Andes, Carrera 1 No 18A-70. Bloque C, Bogotá (Colombia) email: jccarden@uniandes.edu.co
[b] Instituto de Investigaciones de Recursos Biológicos Alexander von Humboldt, Bogotá (Colombia)
[c] International Livestock Research Institute (ILRI), Nayrobi (Kenya)

Abstract: Watersheds have the characteristic of connecting people vertically by water flows. The location of people along a watershed or irrigation system defines their role in the provision and appropriation of water which makes cooperation among resource users more complex. Verticality 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 in the basin plays in affecting trust and cooperation, at the provision and appropriation decisions. Two field experiments were conducted: the "*Irrigation Game*" a new experimental design (Cardenas et al, forthcoming; and Janssen et.al 2011) that includes the provision and appropriation nature of the resource and where location is assigned randomly, and the *"Water Trust Game"*, an adaptation of the Trust Game (Berg et al, 1995), where we explicitly reveal the actual location upstream or downstream of the two players. The results from the two games show that reciprocity and trust are key motivations for upstream-downstream cooperation and that the role of upstream players has more important implications in water provision decisions. However, 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: Q0, Q2, C9

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

---

[1] Our thanks to seminar participants at Columbia University (May 2011), Michigan (may 2011), ASFEE-Martinique, May 2011, Universidad de los Andes-Bogotá, CBEES-East Anglia (2010). The work presented in the paper was conducted as part of the project "Sustaining Collective Action that Links Economical and Ecological Scales" (SCALES-PN20) of the CGIAR Challenge Program on Water and Food, led by the Centro Internacional de Agricultura Tropical (CIAT) and partners such as Universidad de Los Andes, World Wild Fund (WWF) Colombia, Corporación Semillas de Agua, Fundación Humedales and the World Agroforestry Centre (ICRAF).

1. Introduction

Watersheds are systems that have the characteristic to connect people vertically by water flows. The strong interdependency among users along social and biophysical scales makes their relationships complex and generates challenges to water and watersheds management. Watersheds, like other asymmetric systems such as irrigation systems, present both dimensions of common pool resources (CPR): provision and appropriation (Ostrom, Gardner and Walker, 1994). Provision refers to the actions done to create, maintain and improve the resource and avoid its destruction. Appropriation, on the other hand, refers to allocation of the resource among users (ibid). In these systems, the location of people along the system defines their role in water provision and appropriation decisions. Thus, verticality in watersheds and irrigation systems imposes additional challenges to collective action because location will impose key differential behavioral elements for decision making regarding intentions, beliefs, and outcomes.

Watersheds in particular are characterized by an important biophysical and socio-economic heterogeneity that generates a variety of actors. These actors face different economic and environmental conditions, like unequal 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). Indeed, watershed management requires coordination and cooperation in the management of natural resources across many different levels of social-spatial aggregation (Swallow et al, 2006) and involves handling upstream-downstream relationships.

Collective action for water management in watersheds require coordination among small communities to manage water points or develop water supply systems and intra-community cooperation on sharing stream flows or restricting practices that can increase water pollution (Swallow et al, 2006). However, cooperation in the provision and appropriation of water is 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 mechanisms are enhanced by the aware about dependence among participants (Ostrom, 1998; Ostrom and Gardner, 1993). Due to the nature of watersheds, trust and reciprocity in these contexts must be built at different scales and among appropriators of different levels. Upstream-downstream trust and reciprocity relationships can be a determinant the solution of CPR dilemmas in watersheds.

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, which means asymmetric access to better quantity or quality 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 and appropriation decisions on this context. Two field experiments were conducted: the *"Irrigation Game"*, a new experimental design (Cardenas et al, forthcoming; and Janssen et.al 2011) 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 which presents the dependence among players related to water and compensation flows.

Section 2 summarizes literature related to the effect of verticality in collective action. Section 3 describes the experimental context, design and implementation. Data analysis and graphic results are presented in Section 4 and regression results in Section 5. This paper concludes with an analysis of the results and a discussion of future research and policy implications.

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. Upstream people have the possibility to take better quantity and quality water, besides they generate flows of soil and pollutants that affect downstream people. Since the position of the individuals along the system determines their access to water -appropriation- and their possibilities to influence other actors, this condition will define their willingness to cooperate in the provision of the resource. This vertical provision and appropriation relationship among watershed actors is presented in other water systems like irrigation systems. *"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) The combined appropriation and provision problems of CPR implies that the nature of appropriation problem is affected by how well the provision problem is solved (Ostrom et al, 1994).

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. *The downward flows of water, soil, and pollutants, can be counterbalance by reverse flows of commodities, money, regulation or influence* (Swallow et al, 2006). However, the possibility for these exchanges and other cooperation agreements among players in different locations of the system depends on trust and reciprocity relationships among 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 (1972) 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.

Factors that affect collective action in CPR have been studied in different works. The physical characteristics of the resource as well as the attributes of its users and its local and external institutional context can determine collective action (Ostrom et al 1994; Araral, 2009). For that reason, institutional arrangements to be effective in resolving CPR problems must be compatible with the underling physical characteristics of the resource, facilitate appropriators' common understanding of the rule and have monitoring mechanisms as well as be adopted and enforced at different levels in large-scale contexts (Ostrom et al, 1994). Empirical evidence has demonstrated that self-governed CPR systems can outperform government management systems even in the presence of asymmetric access like irrigation systems (Ostrom and Gardner, 1993; Lam, 1998).

Some studies using field data have analyzed the factors that influence collective action in the commons and particularly in irrigation systems. Fujie et al (2005) examined local irrigation systems in Philippines and found that collective action is affected negatively by high differences in water supply between upstream and downstream farmers, group size, low population density – which reduces social interactions-, uniformity and relative abundance of water supply, nonfarm options availability for farmers and low experience in managing irrigation systems. Similarly, Araral (2009) analyzed a set of 1958 irrigation associations in the same country and found that collective action is positively related to water scarcity, proximity to markets, group size, wealth exit options – seem as farm size- and governance structure. Dayton-Johnson (2000) on the other hand, identified social heterogeneity and landholding inequality as factors associated negatively collective action in Mexican irrigation associations.

Experimental economics studies have also investigate the factors that affect cooperation and collective action in trust, public goods or CPR situations such as the role of heterogeneity among players (Hackett et al, 1994, Cardenas et al, 2002) and the effects of social distance which is associated with lower level of trust and cooperation (Cardenas 2003, Bohnet, 2008). The possibility to reach agreements through communication, which resembles self-government solutions in experimental settings, has proven to be the most effective way to increase cooperation levels, even in presence of heterogeneous actors (Ostrom, 2006; Cardenas, Ahn and Ostrom, 2004). In this regard, this paper is an aim to use field experiments to understand the effect that vertical asymmetries on water access have on trust and cooperation and the challenges that this fact imposes on collective action.

3. Experimental design

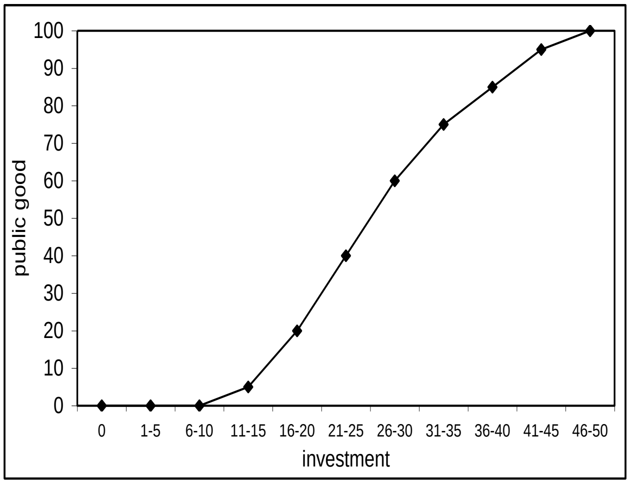
Water and watersheds management have some features that impose additional difficulties to collective action, like the rival nature of the resource and the asymmetries on its access that depend on the location of participants along the water system. In order to identify the effect that location in a context 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, we developed a framed field experiments strategy[2] in two real settings of water users in Colombia and Kenya. The provision and appropriation nature of water and the asymmetries in access due to location were included through a new experimental design called the *Irrigation Game,* while trust between actual upstream and downstream players is incorporated in an adaptation of the trust game framed around water and reverse flows represented as payments.

3.1.Design and implementation

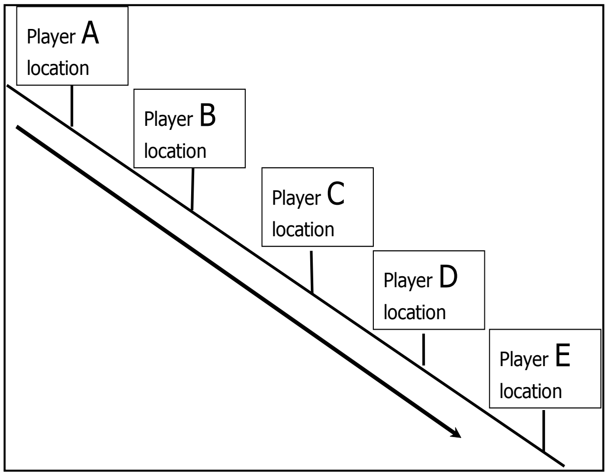
a. The Irrigation Game

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



---

[2] See Harrison G. and L. List (2004) for a taxonomy of field experiments. According to their classification framed field experiments are those developed with nonstandard subjects pool (no students), and that have a field context in either the commodity task, or information sets that the subjects can use.

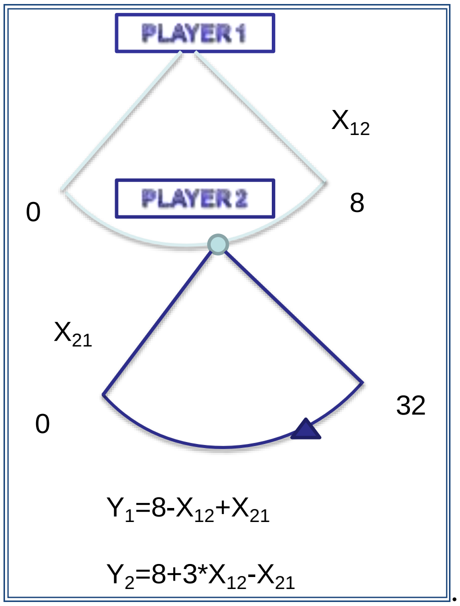
After the first ten rounds of baseline treatment, rules changed for some groups and this change is announced aloud to the players. Some groups were permitted to communicate; other face external regulation treatments and other groups continued playing with the baseline conditions.

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 were inspected, so the probability of being inspected was 1/6. In this case, 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 permited 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.

b. 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 were endowed with 8 tokens. Player 1 (proposer) could send a fraction of her initial endowment to player 2 (responder). The amount sent by player one was tripled before it reached player 2 who then decided 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 2.

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). The strategy method was used to get data of all conditional responses of second movers to all possible decisions of the first mover. During the session we also asked each of the players the amount they expected from the other player. By eliciting expected amounts, offers by the first player and responses by the second player for each amount sent by the first, we can test how trust and trustworthiness is affected by location in the watershed.

3.2. Sample of participants

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 in 142 pairs, from both countries distributed as shown in table 1.

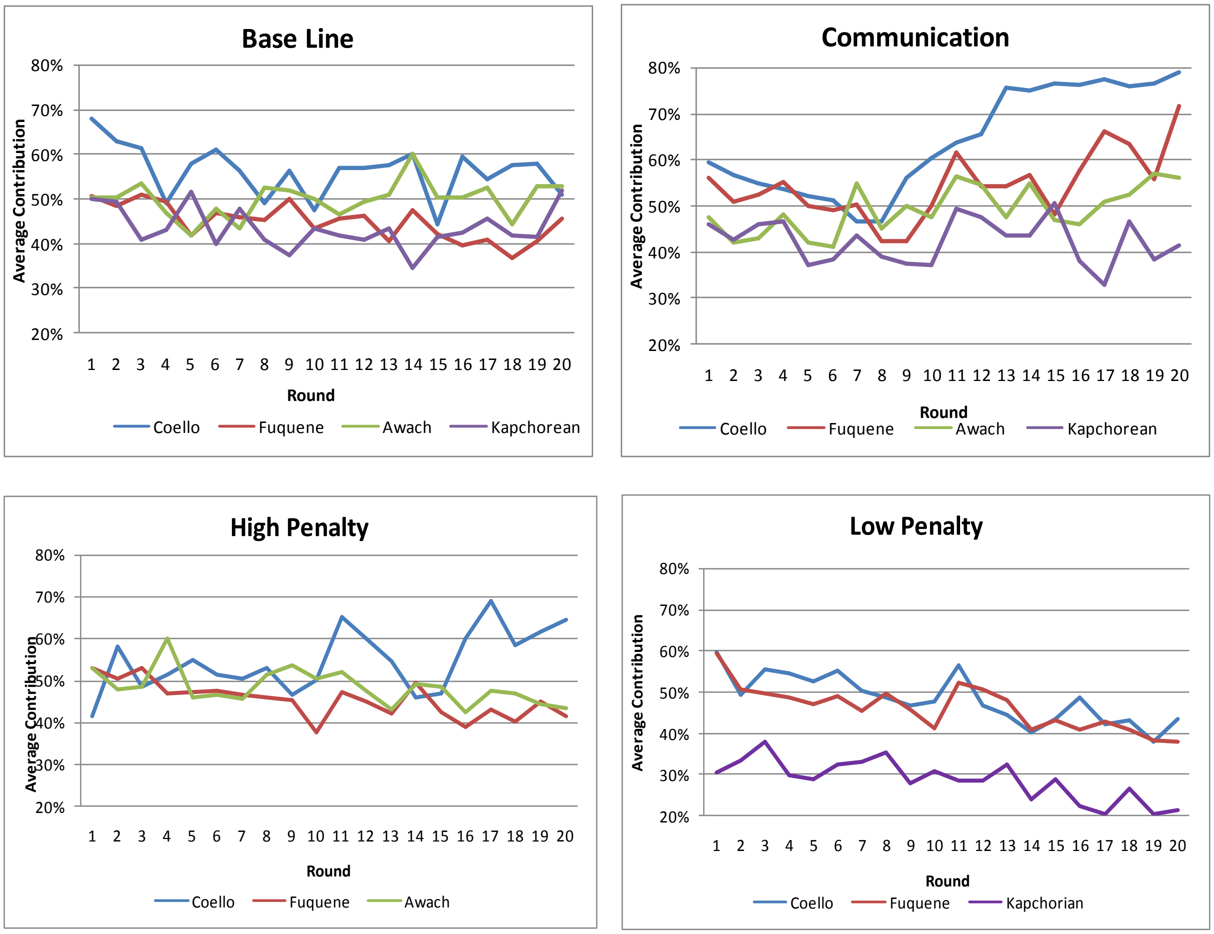
4. Data analysis and results

4.1.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 (See more on Cardenas, Rodriguez and Johnson, 2011). 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**

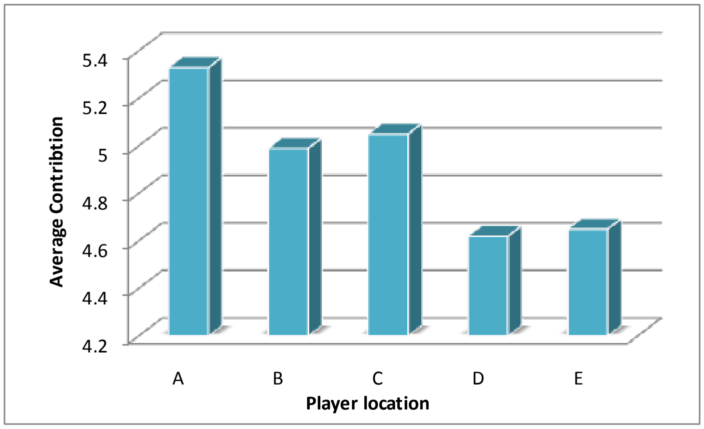


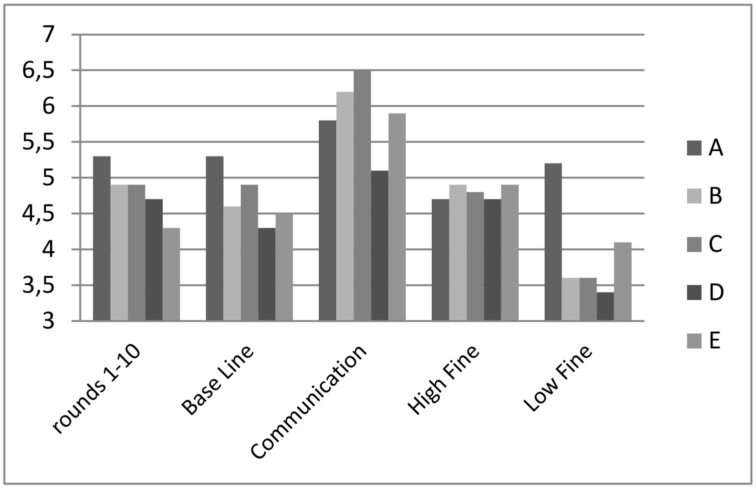
Table 2 contains the t-statistic comparing the average contributions. Except for comparisons between players D and E, and comparing players B and C, it is clear that downstream players contributed less tokens in average in the provision stage of the game, reducing the levels of social efficiency for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

Table 2. Contribution by location in the system

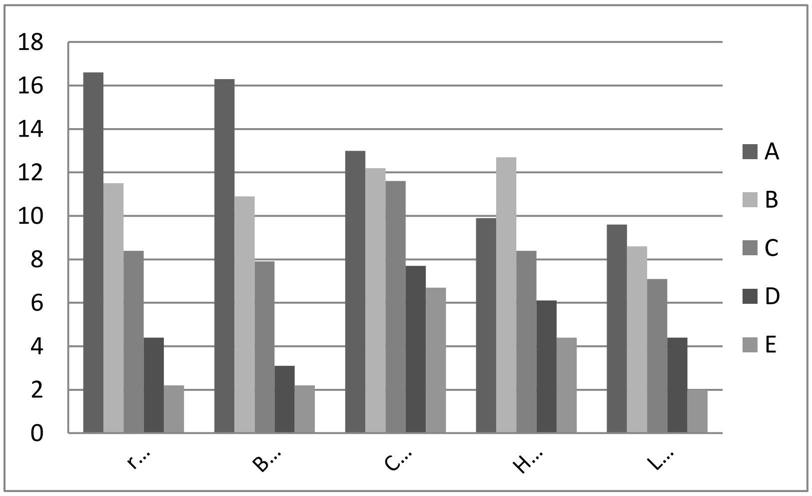
Player location	Contribution	T-statistic			
		B	**C**	**D**	**E**
A	5.33	3.37	2.72	6.88	6.61
B	4.99	----	0.57	3.69	3.42
C	5.05	----	----	4.15	3.88
D	4.62	----	----	----	0.26
E	4.65	----	----	----	----

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. However, the type of institution applied defines the persistence of the situation of remarked differences in contribution or a situation in which contribution –and maybe distribution – is more homogeneous among players. The comparisons of the behavior of the players about contribution and extraction by institution are in Graphs 6 and 7.

Graph 6. ***Irrigation Game*** **contribution by player location and institution**



Graph 7. ***Irrigation Game*** **irrigation by player location and institution**



While the external regulations – high and low fine – have some positive effect in the distribution of water, these regulations crowded-out the cooperation behavior. On the other hand, if the participants are allowed to communicate, they make higher contribution decisions that mean a higher amount of water available for all the players. Besides, the possibility of communication helps to improve the distribution of water among players, reducing the differences on access to water among players, especially among A and E players. Similar results have been found in common pool resources games, where external regulations crowded-out group-oriented behavior in favor of self-interest (see Cardenas et al, 2000)

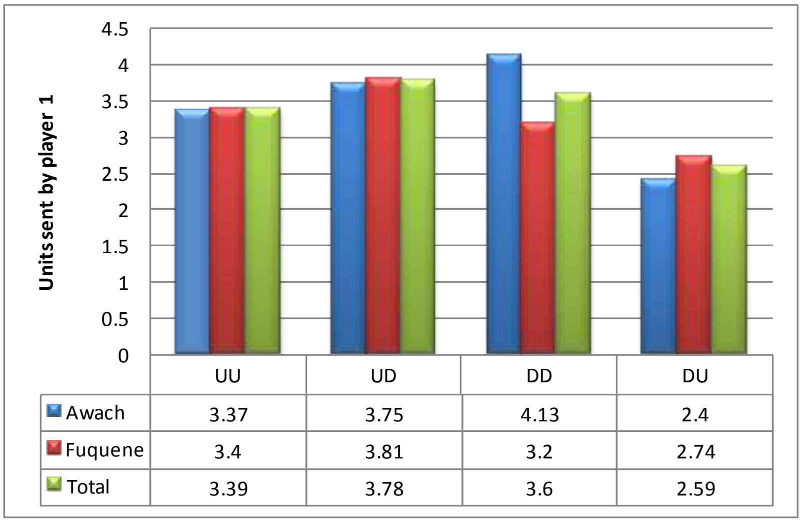
Let us now turn to the second game used, the *Water Trust Game*, where we study the role of the actual location of the players in the watershed and not the experimental location as studied in the irrigation game.

4.2. 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 8. Average amount of units sent by player 1 to player 2



Graph 8 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 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.

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.

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

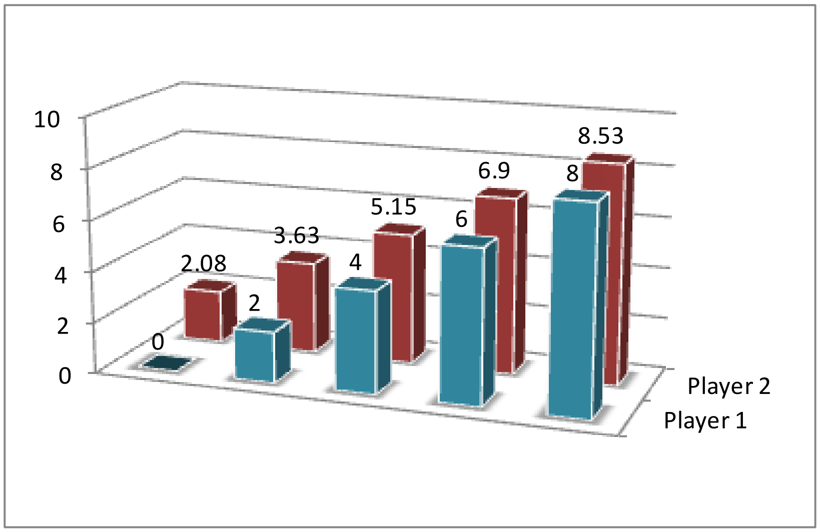


Table 3. T-test mean values of offers (p-value)

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. The description of the variables is shown below.

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.

Table 4. Summary statistics *Irrigation Game*

Variable	Obs	Mean	Std. Dev	Min	Max
Contribution	7100	4.87	2.87	0	10
Extraction as a percentage of the fair extraction	5787	1.52	0.96	0	5
Location	7100	3	1.41	1	5
Others contribution lagged	7100	19.61	6.82	0	40
Age	7060	39.28	15.27	14	88
Gender	7040	0.48	0.5	0	1
Education level	6860	5.97	3.6	0	19
Time in the community	6860	28.8	17.7	1	88
Household size	6760	5.53	2.84	1	20
Perception about autoregulation	6900	0.74	0.44	0	1
Perception about external regulation	6940	0.51	0.5	0	1
Participation in community activities	7060	0.62	0.48	0	1
Community cooperation	6920	5.42	2.72	0	10

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 24.2% 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 24.2% 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[3]. 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 (See Cardenas, 2004, 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. However, when we see the unspooled model, the significance of the negative effect remains only for the Kenyan watersheds (Awach and Kapchorean) (see Appendix 1)

With respect to demographic characteristics of the participants we find that older people, living in larger households seem to contribute more to the provision stage of the game. The effect of age can be related to users experience around natural resources management and expectations about reciprocation and group cooperative behavior. 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. With the coefficient size of "Others contributions lagged" 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.

---

[3] 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.

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

Dependent variable:	*Tokens contributed to the public fund*					
Independent variables	Pooled (1)	Dummies wtsdh (2)	Coello (3)	Fuquene (4)	Awach (5)	Kapchorean (6)
Round (learning)	-0.043	-0.043	-0.029	-0.06	0.005	-0.072
	(0.008)**	(0.008)**	(0.017)$^{+}$	(0.014)**	(0.018)	(0.020)**
Location along the water system	0.194	0.194	0.223	0.211	0.035	0.182
	(0.023)**	(0.023)**	(0.045)**	(0.037)**	(0.056)	(0.056)**
1 if treatment = communication	1.487	1.487	2.39	1.373	0.708	0.783
	(0.152)**	(0.152)**	(0.285)**	(0.251)**	(0.323)*	(0.319)*
1 if treatment = high fine	0.278	0.278	0.953	0.184	-0.497	
	(0.161)$^{+}$	(0.161)$^{+}$	(0.350)**	(0.229)	(0.315)	
1 if treatment = low fine	-0.281	-0.281	-0.52	0.192		-0.266
	(0.155)$^{+}$	(0.155)$^{+}$	(0.273)$^{+}$	(0.241)		(0.318)
Others contribution lagged	-0.04	-0.04	-0.009	-0.003	-0.07	-0.14
	(0.007)**	(0.007)**	(0.013)	(0.011)	(0.016)**	(0.017)**
Age	0.028	0.028	0.002	0.054	-0.031	0.078
	(0.004)**	(0.004)**	(0.007)	(0.006)**	(0.010)**	(0.012)**
Gender	-0.05	-0.05	0.289	0.389	0.47	-1.297
	(0.086)	(0.086)	(0.154)$^{+}$	(0.139)**	(0.205)*	(0.204)**
Education level	0.009	0.009	0.032	0.024	-0.132	0.096
	(0.012)	(0.012)	(0.02)	(0.018)	(0.034)**	(0.035)**
Time in the community	-0.002	-0.002	0.004	-0.011	0.018	-0.019
	(0.003)	(0.003)	(0.005)	(0.005)*	(0.007)**	(0.013)
Household size	0.064	0.064	0.018	0.14	0.131	-0.129
	(0.014)**	(0.014)**	(0.032)	(0.025)**	(0.034)**	(0.039)**
Perception about autoregulation	0.683	0.683	0.71	0.8	0.287	0.618
	(0.096)**	(0.096)**	(0.192)**	(0.152)**	(0.212)	(0.279)*
Perception about external regulation	-0.352	-0.352	-0.448	-0.585	0.778	-1.216
	(0.081)**	(0.081)**	(0.151)**	(0.135)**	(0.193)**	(0.251)**
Participation in community organizations	-0.062	-0.062	-0.318	0.4	0.686	-1.306
	(0.082)	(0.082)	(0.175)$^{+}$	(0.126)**	(0.192)**	(0.211)**
Community cooperation	0.004	0.004	0.041	0.062	-0.059	-0.096
	(0.015)	(0.015)	(0.027)	(0.026)*	(0.036)$^{+}$	(0.043)*
1 if watershed = Awach		2.107				
		(0.428)**				
1 if watershed= Coello		3.237				
		(0.466)**				
1 if watershed=Fuquene		2.027				
		(0.422)**				
Constant	3.03	0.923	3.537	1.394	6.657	1.565
	(0.394)**	(0.384)*	(0.712)**	(0.532)**	(0.692)**	(0.638)*
Fixed Effects (dummies)	71 groups	71 groups	20 groups	27 groups	12 groups	12 groups
Observations	6140	6140	1700	2220	1100	1120
R-squared	0.242	0.242	0.221	0.235	0.096	0.432

Robust standard errors in parenthesis

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

Finally, the variables that show the perception of the players about the kind of regulation they can get have both significant but inverse effects. While the p*erception about auto-regulation,* which takes a value of one if the person believes that group should get an agreement, has a positive effect on contribution decision; the p*erception about external regulation,* that takes a value of one if the person believes that they need external rules or regulations, has a negative effect. The perception of people about the possibilities of getting an agreement improves their willingness to contribute while the perception about the necessity of external regulation reduces the contribution.

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[4] 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 negative effect 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.

---

[4] 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)

Our watershed effects remain robust with the Colombian watersheds showing higher levels of contributions for all treatments. The effects of the perception about internal or external regulation also remain especially for communication and low penalty treatments.

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

Dependent variable:	*Tokens contributed to the public fund (rounds 11-20)*			
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)	-0.023	0.061	-0.014	-0.174
	(0.029)	(0.030)*	(0.034)	(0.030)**
Location along the water system	0.133	-0.068	-0.024	0.092
	(0.059)*	(0.063)	(0.076)	(0.071)
Others contribution lagged	-0.131	-0.045	-0.065	-0.139
	(0.020)**	(0.017)**	(0.023)**	(0.022)**
Age	0.009	0.033	0.025	0.037
	(0.01)	(0.012)**	(0.011)*	(0.012)**
Gender	0.159	-0.575	-0.126	0.581
	(0.27)	(0.230)*	(0.276)	(0.280)*
Education level	-0.004	0.006	0.007	0.08
	(0.033)	(0.039)	(0.034)	(0.030)**
Time in the community	0.013	-0.024	-0.011	0.047
	(0.007)$^{+}$	(0.008)**	(0.01)	(0.010)**
Household size	0.208	0.035	0.049	-0.084
	(0.035)**	(0.042)	(0.048)	(0.05)$^{+}$
Perception about autoregulation	0.897	1.669	-0.052	1.451
	(0.256)**	(0.269)**	(0.351)	(0.353)**
Perception about external regulation	-0.324	-0.527	0.123	-1.022
	(0.221)	(0.217)*	(0.284)	(0.260)**
Participation in community organizations	-0.52	0.41	-0.476	-0.448
	(0.211)*	(0.215)$^{+}$	(0.264)$^{+}$	(0.235)$^{+}$
Community cooperation	-0.084	0.101	0.117	-0.017
	(0.043)$^{+}$	(0.045)*	(0.045)*	(0.051)
1 if watershed = Awach	4.341	5.498		
	(0.565)**	(0.844)**		
1 if watershed=Fuquene	0.165	7.107	1.872	1.835
	(0.702)	(0.673)**	(0.594)**	(0.599)**
1 if watershed=Coello	3.604	2.705	1.075	1.65
	(0.636)**	(0.628)**	(0.634)$^{+}$	(0.667)*
Constant	4.095	0.365	4.554	5.299
	(0.957)**	(0.774)	(1.092)**	(1.354)**
Fixed Effects (dummies)	16 groups	18 groups	13 groups	14 groups
Observations	820	920	610	720
R-squared	0.353	0.373	0.222	0.413

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

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 for the Colombian basins whereas negative for the Kenyan ones. We had already mentioned the much stronger effect of communication for the Colombian cases, and in these cases, the communication disincentive the opportunistic behavior

Following the same regression strategy used to analyze the contribution decision, we study the extraction decision. The dependent variable used to estimate this decision is the water extraction decision as a percentage of the “fair extraction” for each player. The fair extraction corresponds to an equal share of the water for the remaining players. Table 8 presents the regression results for different models by watersheds and table 9 report the effect of different institutions on the fair extraction decision.

Table 8. Fixed-effects OLS estimation of extraction decisions *Irrigation Game*

Dependent variable:	*Water extracted as a percentage of the "fair extraction"*					
Independent variables	Pooled (1)	Dummies wtsdh (2)	Coello (3)	Fuquene (4)	Awach (5)	Kapchorean (6)
Round (learning)	0.007	0.007	0.006	0.008	-0.01	0.026
	(0.003)*	(0.003)*	(0.007)	(0.005^{+})	(0.006^{+})	(0.008)**
Location along the water system	0.184	0.184	0.231	0.156	0.182	0.228
	(0.008)**	(0.008)**	(0.016)**	(0.012)**	(0.018)**	(0.027)**
1 if treatment = communication	-0.285	-0.285	-0.123	-0.337	-0.169	-0.493
	(0.049)**	(0.049)**	(0.094)	(0.079)**	(0.108)	(0.127)**
1 if treatment = high fine	-0.291	-0.291	-0.397	-0.179	-0.206	
	(0.054)**	(0.054)**	(0.103)**	(0.088)*	(0.096)*	
1 if treatment = low fine	-0.179	-0.179	0.077	-0.339		-0.618
	(0.061)**	(0.061)**	(0.122)	(0.073)**		(0.149)**
Others contribution lagged	-0.007	-0.007	-0.016	-0.011	0.006	0.015
	(0.002)**	(0.002)**	(0.004)**	(0.003)**	(0.005)	(0.007)*
Age	-0.005	-0.005	-0.004	-0.002	-0.008	-0.025
	(0.001)**	(0.001)**	(0.002^{+})	(0.002)	(0.003)*	(0.006)**
Gender	0.039	0.039	0.098	0.042	-0.03	0.059
	(0.027)	(0.027)	(0.052^{+})	(0.049)	(0.064)	(0.086)
Education level	0.013	0.013	0.01	0.023	0.005	0.018
	(0.004)**	(0.004)**	(0.007)	(0.006)**	(0.01)	(0.02)
Time in the community	-0.001	-0.001	-0.005	0.001	0.001	0.005
	(0.001)	(0.001)	(0.002)**	(0.001)	(0.002)	(0.006)
Household size	0.008	0.008	0.034	0.007	-0.016	0.089
	(0.005^{+})	(0.005^{+})	(0.009)**	(0.008)	(0.012)	(0.018)**
Participation in community organizations	0.082	0.082	0.036	0.161	0.059	-0.249
	(0.027)**	(0.027)**	(0.052)	(0.044)**	(0.057)	(0.093)**
Community cooperation	-0.005	-0.005	-0.028	0.005	0.018	0.017
	(0.005)	(0.005)	(0.009)**	(0.008)	(0.011)	(0.022)
1 if watershed = Awach		-3.072				
		(0.087)**				
1 if watershed= Coello		-3.794				
		(0.097)**				
1 if watershed=Fuquene		-2.105				
		(0.199)**				
Constant	1.181	4.253	0.509	0.938	1.199	3.957
	(0.120)**	(0.084)**	(0.234)*	(0.183)**	(0.234)**	(0.217)**
Fixed Effects (dummies)	71 groups	71 groups	20 groups	27 groups	12 groups	12 groups
Observations	5077	5077	1460	2009	960	648
R-squared	0.376	0.376	0.415	0.3	0.403	0.484

Robust standard errors in parenthesis

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

Table 9. Fixed-effects OLS estimation of extraction decisions *Irrigation Game* by Institution

Dependent variable: *Water extracted as a percentage of the "fair extraction" (rounds 11-20)*

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)	0.035	-0.001	0.017	0.026
	(0.011)**	(0.008)	(0.008)*	(0.010)*
Location along the water system	0.198	0.117	0.129	0.111
	(0.022)**	(0.016)**	(0.018)**	(0.022)**
Others contribution lagged	0.009	-0.006	-0.004	0.022
	(0.008)	(0.004)	(0.005)	(0.007)**
Age	-0.009	-0.008	-0.002	-0.009
	(0.004)*	(0.003)**	(0.002)	(0.003)**
Gender	0.129	-0.097	-0.25	0.09
	(0.105)	(0.059)	(0.052)**	(0.09)
Education level	-0.048	-0.015	0.024	0.026
	(0.011)**	(0.009$^+$)	(0.010)*	(0.009)**
Time in the community	-0.007	0.002	0.001	-0.003
	(0.003)*	(0.002)	(0.002)	(0.003)
Household size	0.015	0.015	-0.028	-0.03
	(0.012)	(0.011)	(0.011)*	(0.017$^+$)
Participation in community organizations	0.484	-0.103	0.284	0.108
	(0.089)**	(0.049)*	(0.056)**	(0.07)
Community cooperation	-0.033	-0.017	0.01	0.006
	(0.015)*	(0.011)	(0.01)	(0.015)
1 if watershed= Coello	-2.099	-0.094	-0.507	2.626
	(0.275)**	(0.209)	(0.118)**	(0.229)**
1 if watershed=Fuquene	-1.069	0.743	0.724	-0.871
	(0.287)**	(0.248)**	(0.248)**	(0.232)**
1 if watershed = Awach	-3.933	-0.077		
	(0.230)**	(0.203)		
Constant	3.62	1.751	0.759	1.296
	(0.309)**	(0.264)**	(0.288)**	(0.373)**
Fixed Effects (dummies)	16 groups	18 groups	13 groups	14 groups
Observations	617	814	572	529
R-squared	0.532	0.55	0.363	0.51

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 10 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 10. 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
Trustworthiness	The location of the people that the player 1 believes that are the most trustworthy: 3 if upstream, 2 if midstream, 1 if downstream	141	2.35	0.83	1	3
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
Trustworthiness	The location of the people that the player 2 believes that are the most trustworthy: 3 if upstream, 2 if midstream, 1 if downstream	138	2,32	0.82	1	3
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 11 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.

Table 11. 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)	0.119	-0.011	-0.134	0.021
	(0.354)	(0.342)	(0.527)	(0.79)
Location of player 2 (1 if upstream)	-0.84	-0.903	-0.735	-0.972
	(0.333)*	(0.319)**	(0.471)	(0.439)*
Age	-0.039	-0.039	-0.046	-0.026
	(0.019)*	(0.02)$^{+}$	(0.026)	(0.041)
Gender	-0.137	-0.259	-0.139	-0.568
	(0.319)	(0.311)	(0.463)	(0.499)
Education level	-0.058	-0.046	-0.058	-0.06
	(0.057)$^{+}$	(0.054)	(0.082)	(0.105)
Time in the community	0.049	0.051	0.049	0.032
	(0.015)**	(0.016)**	(0.020)*	(0.034)
Participation in community organizations	-0.251	-0.026	-0.184	0.382
	(0.317)	(0.311)	(0.438)	(0.526)$^{+}$
Community cooperation	-0.022	0.075	0.035	0.213
	(0.067)	(0.074)	(0.102)	(0.118)
Trustworthiness	0.403	0.53	0.628	0.484
	(0.200)*	(0.200)**	(0.252)*	(0.348)
Expectation player 1	0.143	0.171	0.263	0.13
	(0.030)**	(0.032)**	(0.058)**	(0.041)**
1 if watershed=Fuquene		1.11		
		(0.371)**		
Constant	2.587	0.826	1.811	0.447
	(1.062)*	(1.194)	(1.561)	(1.977)
Observations	128	128	70	58
R-squared	0.348	0.389	0.449	0.406

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

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 5) 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. Besides, we found relationship among offers and the beliefs of people related to the trustworthiness of players located on different places of the watershed. If people believe that most trustworthy people is located upstream the offer is higher, which shows the importance of the perception about uplands players to build stable solutions to watersheds problems.

These results about the effect of verticality in trust are consistent with the results of the *Irrigation Game* where the position of players in the game affects their contribution decision, so the contribution is higher in the case of upstream players because they have more opportunities to benefit from better water quantity and quality. As a consequence, the behavior of upstream players generates a lack of trust in downstream players that imposes difficulties to collective action in watersheds or irrigation systems.

The lack of trust generates barriers to build more efficient relations around water access. The building of trust and the recognition of the interdependences among players are conditions to get players make decisions mutually beneficial for all the players engage in the relationship around water provision and appropriation.

Table 12. OLS estimation of reciprocity *Water Trust Game*

Dependent variable:	*Reciprocity rate*			
Independent variables	Pooled (1)	Dummies wtsh (2)	Fuquene (3)	Awach (4)
Expectation player 2	0.04	0.031	0.055	0
	(0.019)*	(0.019)	(0.025)*	(0.032)
Location of player 1(1 if upstream)	-0.064	-0.066	-0.058	-0.011
	(0.08)	(0.08)	(0.096)	(0.171)
Location of player 2 (1 if upstream)	-0.117	-0.103	-0.288	0.093
	(0.087)	(0.086)	(0.094)**	(0.17)
Age	-0.001	-0.001	0	-0.009
	(0.004)	(0.004)	(0.005)	(0.008)
Gender	-0.148	-0.141	-0.13	-0.012
	(0.095)	(0.095)	(0.105)	(0.193)
Education level	0.038	0.036	0.028	0.036
	(0.014)**	(0.014)*	(0.015)$^{+}$	(0.034)
Time in the community	0.006	0.006	0.001	0.016
	(0.003)	(0.003)	-0.004	(0.007)*
Participation in community organizations	0.217	0.219	0.15	0.348
	(0.091)*	(0.091)*	(0.099)	(0.164)*
Community cooperation	-0.017	-0.034	-0.036	-0.027
	(0.017)	(0.018)$^{+}$	(0.021)$^{+}$	(0.034)
Trustwirthiness	0.132	0.132	0.159	0.139
	(0.054)*	(0.054)*	(0.058)**	(0.101)
1 if watershed=Fuquene		-0.178		
		(0.101)$^{+}$		
Constant	0.569	0.838	0.744	0.641
	(0.253)*	(0.282)**	(0.250)**	-0.641
Observations	528	528	300	228
R-squared	0.07	0.075	0.129	0.071

6. Conclusions.

Based on a large sample of more than 600 villagers in four watersheds in rural Kenya and Colombia, we have explored the role that a vertical asymmetric relationship along a watershed where upstream players affect welfare of downstream players but all are affected by the collective action in terms of provision and appropriation of a resource. Other studies have explored similar problems using experiments conducted in the laboratory (Holt & Jonshon, 2010; Czap et.al, 2011). Our experimental design (Cardenas et.al, forthcoming) of the irrigation game (See also Janssen et.al 2011) of the irrigation game explores these asymmetries and allows us to test the role of trust and cooperation between the upstream and downstream players when we assign such locations randomly to players. Further, an adaptation of the trust game into a water trust game confirms that the actual location of the players seems to affect trust in a significant manner and particularly by reducing the trustworthiness of upstream players as seen by downstream ones. Some of the implications for the understanding of these problems and lessons for policy designers follow.

The challenge of vertical collective action emerges from the asymmetry in the location of players along the irrigation system. Headenders 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, tailenders 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 turn into more cooperative patterns, 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 difficulties to collective action 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.

References

Araral, E (2009) What explains collective action in the commons? Theory and evidence from the Philippines. *World Development,* 37(3): 687-697..

Berg, J., J. Dickhaut and K. McCabe (1995) Trust, reciprocity and social history. *Games and Economic Behavior*, 10: 122-142.

Bohnet, I (2008) Trust in experiments. In: Durlauf, S.N., Blume, L.E. (Eds.), New Palgrave Dictionary in Economics. Palgrave, Macmillan.

Bowles, S. (2008) Policies designed for self interested citizens may undermine "the moral sentiments": evidence from experiments. *Science*, 320:5883.

Cardenas, J.C (2004) Norms from outside and from inside: An experimental analysis on the governance of local ecosystems. *Forest Policy and Economics*, 6: 229-241. Elsevier Press

Cardenas, J.C. (2003) Real wealth and experimental cooperation: Evidence from field experiments. *Journal of Development Economics,* 70(2): 263-289.

Cardenas, J.C. and J. Carpenter (2008a) Behavioral development economics: lessons from field labs in the developing world. *Journal of Development Studies*, 44(3): 337-364.

Cardenas, J.C, M.A. Janssen, and F. Bousquet (forthcoming) Dynamics of rules and resources: Three new field experiments on water, forests and fisheries, forthcoming in *Handbook on Experimental Economics and the Environment*, John List and Michael Price (Eds.)

Cardenas, J.C., Luz Angela Rodriguez, & Nancy Johnson, 2011. "Collective action for watershed management: field experiments in Colombia and Kenya," *Environment and Development Economics*, Cambridge University Press, vol. 16(03), pages 275-303, June.

Cardenas, J.C., T.K. Ahn and E. Ostrom (2004) Communication and cooperation in a common pool resource dilemma: A field experiment, in Steffen Huck (Ed.) *Advances in* understanding *strategic behavior: Game theory, experiments and bounded rationality: Essays in honor of Werner Güth,* New York, Palgrave.

Cardenas, J.C., J.K. Stranlund and C.E. Willis (2002) Economic inequality and burden sharing in the provision of local environmental quality. *Ecological Economics,* 40: 379-395.

Cardenas, J.C., J.K. Stranlund and C.E. Willis (2000) Local environmental control and institutional crowding-out. *World Development,* 28 (10): 1719-1733.

Czap, Natalia V., Hans J. Czap, Marianna Khachaturyn, Gary D. Lynne, Mark E. Burbach (2011). Transcending the Limitations of Environmental Economic Framing: Toward a Metaeconomics of Environmental Choice. Poster at the Agricultural and Applied Economics Association 2011 Annual Meeting, July 24-26, 2011, Pittsburgh, Pennsylvania.

Dayton-Johnson, J (2000) Determinants of collective action on the local commons: a model with evidence from Mexico. *Journal of Development Economics,* 62: 181-208.

Fujie, M., Y. Hayami and M. Kikuchi (2005) The conditions of collective action for local commons management: the case of irrigation in the Philippines. *Agricultural economics,* 33: 179-189.

Hackett, S., E. Schlager, and J. Walker (1994) The role of communication in resolving common dilemmas: experimental evidence with heterogeneous appropriators. *Journal of Environmental Economics and Management,* 27: 99-126.

Harrison G., and J. Lee (2004) Field experiments. *Journal of Economic Literature,* 42(4): 1009-1055.

Holt, Charles A. & Johnson, Cathleen & Mallow, Courtney & Sullivan, Sean P., 2010. "Tragedy of the common canal," MPRA Paper 20838, University Library of Munich, Germany.

Janssen, Marco, John M. Anderies, Juan-Camilo Cardenas (2011) “Head-enders as stationary bandits in asymmetric commons: Comparing irrigation experiments in the laboratory and the field”. Ecological Economics. Volume 70, Issue 9: 1590-1598

Knox A., B. Swallow and N. Johnson (2001) Conceptual and methodological framework lessons for improving watershed management and research. *Policy Brief Number 3,* CGiAR SystemWide Program on Collective Action and Property Rights.

Lam W.F. (1998) *Governing irrigation systems in Nepal: Institutions, infrastructure and collective action.* Institute for Contemporary Studies (ICS) Press, Oakland.

Murra, J. (1985) El Archipiélago Vertical Revisited. In S. Masuda (Ed.) Andean Ecology and Civilization. Tokyo: University of Tokyo Press.

Murra, J. (1972) El control vertical de un máximo de pisos ecológicos en la economía de las sociedades andinas". Visita de la Provincia de León de Huánaco (1562). Iñigo Ortiz. Ed. Tomo II: 429-76.

Osborne, A. (1985). El vuelo de las tijeretas. Bogotá, Banco de la República.

Osborne, A. (1990) Comer y Ser Comido: Los Animales en la tradición oral U'Wa (Tunebo). Revista del Museo del Oro. Bogotá, Banco de la República.

Ostrom, E. (2006) The value-added of laboratory experiments for the study of institutions and common-pool resources. *Journal of Economic Behavior and Organization*, 61: 149-163.

Ostrom, E. (1998) A behavioral approach to the rational choice theory of collective action. *American Political Science Review*, 92: 1-22.

Ostrom, E. and R. Gardner, (1993) Coping with asymmetries in the commons: Self-governing irrigation systems can work. *The Journal of Economic Perspectives*, 7(4): 93-112.

Ostrom E., R. Gardner and J. Walker (1994) *Rules, games, and common pool resources.* The University of Michigan Press, Ann Arbor, Michigan.

Swallow, B., N. Johnson, R. Meinzen-Dick, and A. Knox (2006) The Challenges of Inclusive Cross-Scale Collective Action in Watersheds. *Water International*, 31(3): 361-375.

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

Dependent variable:	*Tokens contributed to the public fund (rounds 11-20)*							
	BaseLine				Communication			
Independent variables	Coello (1)	Fuquene (2)	Awach (3)	Kapchorean (4)	Coello (5)	Fuquene (6)	Awach (7)	Kapchorean (8)
Round (learning)	-0.018	-0.082	0.021	0.04	0.07	0.078	0.023	-0.123
	(0.058)	(0.046)$^+$	(0.055)	(0.056)	(0.037)$^+$	(0.051)	(0.059)	(0.062)*
Location along the water system	0.159	0.366	-0.023	0.336	-0.078	0.504	-0.622	0.216
	(0.255)	(0.102)**	(0.145)	(0.202)$^+$	(0.115)	(0.136)**	(0.213)**	(0.206)
Others contribution lagged	-0.091	-0.078	-0.008	-0.045	0.097	0.046	-0.11	-0.123
	(0.043)*	(0.030)*	(0.035)	(0.039)	(0.025)**	(0.023)*	(0.037)**	(0.041)**
Age	-0.021	0.051	-0.099	0.141	0.039	0.07	-0.002	0.189
	(0.03)	(0.016)**	(0.038)*	(0.045)**	(0.024)	(0.024)**	(0.025)	(0.029)**
Gender	3.648	-0.176	-1.421	-0.251	-0.425	-0.016	-0.777	-1.887
	(0.618)**	(0.403)	(0.472)**	(1.128)	(0.357)	(0.427)	(0.922)	(0.470)**
Education level	0.269	0.038	-0.713	-0.29	0.149	0.049	-0.15	0.457
	(0.194)	(0.048)	(0.229)**	(0.088)**	(0.063)*	(0.098)	(0.1)	(0.131)**
Time in the community	0.026	0.01	0.048	-0.304	-0.021	-0.018	-0.02	-0.131
	(0.024)	(0.017)	(0.014)**	(0.059)**	(0.013)	(0.013)	(0.033)	(0.041)**
Household size	-0.202	0.2	0.66	0.044	0.05	0.185	0.157	-0.355
	(0.201)	(0.087)*	(0.103)**	(0.114)	(0.068)	(0.093)*	(0.11)	(0.112)**
Perception about autoregulation	1.658	0.719	2.017	4.21	-1.803	0.735	2.287	1.625
	(0.461)**	(0.519)	(1.22)	(1.137)**	(0.534)**	(0.65)	(0.455)**	(0.957)$^+$
Perception about external regulation	-1.463	-1.331	2.028	0.988	0.383	-1.392	-0.182	-1.267
	(1.085)	(0.456)**	(0.686)**	(0.729)	(0.457)	(0.545)*	(0.448)	0.887
Participation in community organizations	-2.224	-0.805	2.237	0.794	-0.594	1.556	0.723	(2.598)
	(0.890)*	(0.354)*	(1.035)*	(0.583)	(0.451)	(0.360)**	(0.467)	(0.518)**
Community cooperation	-0.221	0.038	-0.7	-0.22	-0.013	0.211	0.616	-0.073
	(0.13)$^+$	(0.093)	(0.174)**	(0.177)	(0.092)	(0.078)**	(0.140)**	(0.156)
Constant	4.558	2.025	10.692	5.099	4.52	-2.436	3.54	4.112
	(2.561)$^+$	(1.425)	(2.836)**	(2.424)*	(1.619)**	(1.641)	(2.26)	(2.448)$^+$
Fixed Effects (dummies)	4 groups	7 groups	4 groups	4 groups	6 groups	7 groups	4 groups	4 groups
Observations	170	300	170	180	250	290	200	180
R-squared	0.399	0.356	0.501	0.615	0.471	0.436	0.381	0.555

Robust standard errors in parenthesis

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