Applying the stick to excessive water use: Does the group-size matters?

Evidence from a water fines program in Colombia

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Abstract

When in droughts, regulators use to apply monetary disincentives to promote collective action in water users. A vast part of the literature has agreed that the larger the size of a group the lower the cooperation. But, little is known about the effect of this kind of incentives on cooperation when group size is variable. In this paper, I analyzed the effect the application of monetary disincentive, the group-size and its crossed-effect on cooperation. Cooperation in this context, is related with reduction of water consumption when shortages affect the water system . Increasing the own consumption decrease water available for the other user. To estimate these effects, I used administrative data from a residential water fines program implemented in 2014 in Colombia. The aim was to punish overuse in regions that were facing drastic reduction on rainfall, affecting water availability. I exploit the spatiotemporal exogenous source of variation of its application, using a difference-in-difference specification in a one-year window before and after. I found, that the effect of the fines is positive on water use reduction. But, this effect is lower as the number of users in the water supply system grows. I exploit the its spatial and temporal exogenous source of variation , in a difference-in-difference specification in a window of one year . I found the effect of the fines is positive on water use reduction. But, this effect is lower as the number of users in the water supply system grows. This result depends on the type of organization that manages the system. When water is provided by a public utility the effects holds, also for those located in urban areas. My results depart from previous literature related to the effects of the group size on cooperation in contexts of resources with high rivalry degree. Here, the higher the number of users, the lower residential water consumption i.e., the greater the cooperation.

Keywords: *group size; cooperation; deterrent incentive; common pool resources; social dilemmas.* JEL Classification: D04; Q25; Q28; Q58

1 Introduction

Increasing water efficiency is one of the main goals of local governments and water utilities in Latin America. Factors such as climate variability and growth of urban areas have contributed to the imbalance between availability of water and its demand (WWAP, 2012). These situations pose challenges to policymakers to increase water savings. Water sector needs for actions that promote cooperation in its use. Besides other classical tools such as design water rates, awareness campaigns and infrastructure.

A vast part of literature states why some groups overexploit common resources and why others are more efficient. Mostly agreed in determinants as size of groups and heterogeneity within it. Olson (1965) claimed that it is difficult to sustain cooperation in larger groups. In this situations, selective incentives are required to punish defecting, e.g. monetary incentives. But, little is known about the effect of this incentives on cooperation when group size is variable.

In this paper, I analyzed the effect of a monetary incentive, the size of the group and the crossed-effect between it on cooperation. In this context, cooperation is related with reductions of residential water consumption when supply system is affected by shortages. The main interest is to study what occurs in presence of fines that punish water overuse. If it strengthens or weakens cooperation in small groups; or if it helps cooperation in larger groups. My contribution is in two aspects. 1) I establish evidence on the behavior of households facing a program of fines for water consumption in extreme droughts. 2) I provide causal evidence about crossed effect of a fine and group size on cooperation. For which, I used data from a fines program applied asymmetrically to households in Colombia.

Common pool resources (CPR) such as forest, fishing or water distribution systems; are permanently exposed to social dilemmas. It could derive in overexploitation or in efficient management schemes. These dilemmas can emerge when individual interest differs from collective and so, also the outcomes (Ostrom, 1990). Individual actions are not revealed to others, whom do not know the behavior and have little or none control over the payoffs (Kollock, 1998). Overcome this dilemmas requires cooperation (Hardin, 1971). Which is currently, a crucial behavior to ensure sustainability of water resources.

Cooperation depends inter alia, on the group-size and heterogeneity (Cardenas 2009). The group-size effect in literature have included different ways of estimation. Such as linear with a negative effect (Olson, 1965; Ostrom 2005; Nosenzo, Quercia \& Sefton, 2015); or linear with positive effect (McGuire, 1974; Agrawal \& Chhatre, 2006; Zhang \& Zhu, 2011; Szolnoky \& Perc, 2011). Other works include the group-size in a no-lineal form (Agrawal, 2000; Potete \& Ostrom, 2004; Yang \textit{et. al}, 2013; Caparo \& Barcelo, 2015). Some estimates found it ambiguous (Chamberlaine, 1974; Pecorino & Temimi, 2008; Esteban & Ray, 2001;) or even null (Tood, 1992; Rustagi et. al., 2010).

What is clear is that the effect depends on the degree of rivalry of the resource. (Chamberlin, 1974). A low rivalry degree is related with positive effects on cooperation. Although, a high degree produces a negative effect (Nosenzo et. al., 2015).

Another subset of studies have analyzed the use of incentives to promote cooperation on CPR, both lab and field experiments. Conditions and assumptions under which incentives fit better to promote cooperation are varied. (Travers et. al., 2011; Velez et. al., 2012; Fehr & Leibbrandt, 2011; Kerr et. al., 2012; Rodriguez et. al., 2008). Incentives to punish defection is a recurrent solution to overcome social dilemmas. They can be set up inside group or by an external authority, trough formal or informal social norms (Fehr & Gächter, 2000; Masclet et. al., 2003; Cárdenas, 2004). The effects are wide such as, displacement of intrinsic motivation (Kyriacou, 2011); difference under voluntary provision (Heckathorn, 1993); and asymmetries on punishment (Nikiforakis et. al., 2010).

In water resources, there is little literature about group size implications and even less when it comes to residential water sector. In this paper I analyze the crossed-effect between a fines application and group size on cooperation. Cooperation is reductions in residential water consumption when water supply systems face shortages. In particular, I study whether the effect is heterogeneous according to the group size.

The results show that the effect of the fines is better in larger water systems. Also, reduction decreasing as the number of users in the water supply system grows. This effect holds only when the water is provide by a public utility. The effect of group size found here, depart from the literature of resources with high rivalry degree. Here the higher the number of users was, the lower the residential water consumption i.e., the greater the cooperation. An explanation for this is that in Colombia the larger systems have access to technology, which allows them a better enforcement.

This paper is presented as follows: Section 2 described a background of the water sector in Colombia and how the fines program works; Section 3 include the identification strategy; Section 5 provide some results and interpretation; and Section 6 some conclusions.

2 Water sector

Latin America and the Caribbean is a region with abundant water resources, however the distribution is asymmetric. Some areas of Central America, Brazil and the Andean countries experience natural and seasonal shortages, that have accentuated in recent years by the effects of climate change.

The institutional arrangements for water management in the region, include different schemes between public organizations and private corporations who have made great achievements in urban coverages. Although in rural contexts situation is different where the water management is community based with low coverages and quality (Rojas, 2014).

Colombia is one of the countries with higher water availability in the world, but with increasing pressures. Climate variability with several droughts (El Niño) is becoming more frequent, setting drastic droughts[1]. The water demand in Colombia for different uses include: agricultural and livestock (55.1%), energy (21.5%) and residential (8.2%). Although, residential use reaches the higher losses with 31% of its extraction[2].

Utilities are organized by the law 142/1994, that set the regulatory framework for energy, water, communications and natural gas. Particularly, water sector is formed by: Superintendencia de Servicios Públicos-SUPERSERVICIOS, institution that exerts control and surveillance over the providers; and Comisión de Regulación de Agua y Saneamiento - CRA - that is in charge to regulate water rates and efficiency.

Access to water services is considered a human right for all the citizens[3]. For its provision there are 2749 registered water supply systems that are grouped into main four categories authorized by law: Community endeavors (58.4%), commercial organizations (21.6%), local governments directly (13.1%), and Public utilities (7%).

Water providers have differences in their characteristics and in their outcomes, although the sectoral policy is determined at national level. Major cities have public and/or private utilities with high efficient levels, less water losses, more coverage of metering and high return rates. However, 88% of the municipalities have less than 10.000 inhabitants with a variety of problems mainly related with access to capital and investments. About 70% of water utilities are ruled by governments or communities that manage their own systems, and approximately 85% of the population receive subsidies for almost half water consumption, which makes the service expensive in terms of social cost (SUPERSERVICIOS, 2016).

The diversity in institutional arrangements, infrastructure, technology and size of population seems to obtain different outcomes on coverage, quality and efficient use by the households. In this context, a centralized sector policy that does not consider these differences, may result in heterogeneous effects and diverted to those desired by the regulator.

In the last decade, sector policy has been consistent in the design of strategies that discriminate between two groups*: Small providers* that reach 83% of the total, and with up to 2,500 users; and *Large providers*,

[1]The Oceanic Niño Index (ONI) from National Oceanic and Amostpheric Administration -NOAA Oceanic Niño Index

[2]IDEAM (2014), National Water Study of Colombia

[3]The Corte Constitutional in its order T-740 from 2011, establishes: Water is considered as a fundamental right and is defined, in accordance with the provisions of the Committee on Economic, Social and Cultural Rights, as "the right of everyone to have sufficient, safe, acceptable, physically accessible and affordable water for personal or household use ". Corte Constitucional de Colombia

which are constituted for more than 2500 users.

The differences accounting by regulation are based on the performance, outcomes and capital investment. Small providers have in common characteristics such as high degree of local governments involved in operating capital, deficiencies in accounting, financial and management; scarce investment resources and a high dispersion of the users on the landscape that make more expensive the provision (SUPERSERVICIOS, 2015). Large suppliers include 222 providers located in 362 municipalities; 95% provide in addition sewerage and in some cases waste disposal services. The capital comes mainly from public utilities (66%). The providers are organized by companies with a structured incentive scheme and better performance in water quality, efficiency and financial results (SUPERSERVICIOS, 2016).

In terms of surveillances, sector is seen as a system of regulated freedom, where state exerts control in access, quality, continuity, rates and organizations. The residential water rates represents an increasing block price structure, with two kinks: below $20m^3/month/user$ called *Basic block*, between basic and $40m^3/month/user$ called *Complementary block;* and over $40m^3/month/user$ called *Luxury block*. The unitary price increases as long as user increases her consumption. It includes four parts, one is administrative average costs, return over capital (investment average cost), operative average cost and a conservation rate.

This price scheme is designed to respond to multiple objectives, such as: efficiency, equity and conservation. The first objective is related to an increasing structure, higher consumption higher pay. In terms of equity, national and local governments subsidizes part of consumption of low income groups, and also charge high income groups with overprice that provides additional resources to cover subsidy expenses. Conservation goal includes opportunity cost in terms of scarcity measured by environmental authorities, from that, a rate is imposed to households.

2.1 Water fines program to excessive water use

In 2009 regulator set a new policy, that included a fines program to excessive water use in regions where drastic variation in water availability took place[4]. The objective of this norm was to establish actions to promote an environmental conservation behavior in households. The activation depends on regulator, when environmental authorities recommends it. In August 2014 activation was carried out affecting some entire departments and the water supply systems within it.

The decision of in which departments activate fines correspond to level of precipitation that environmental authority observes and reports in previous months, calling attention about regions with a high probability of shortages. In a first administrative act regulator submitted to public a draft of the norm to obtain feedback through a process of direct discussion with users and agents of the sector. One month after final norm was published.

The mechanism established is as follows: The norm decreases the luxury standard, in principle same for all. Reduction is according with altitude where water supply system is located and imposes a fine equal to twice unit price on those households that consumes over the limit [5]. The strategy of the program is to increase the rates when the residential users increases the water consumption over the new standard. The decision of exclude some departments in every stage was made when the levels of precipitation returned to the normal conditions in those regions.

The activation process is summarized in three stages: i) At the beginning took place in 15 departments covering 488 municipalities in July 2014; ii) Three months later two departments were excluded (Bolivar and Atlantico), remaining active in 13 departments; and iii) Ten months later 10 departments were excluded, remaining only three departments with 70 municipalities. The spatiotemporal dynamic of the norm is shown in the Figure 1. In red, the municipalities affected by the norm in every stage described.

[4]CRA issued by Decreto 5051 in 2009 established actions to promote efficient water use

[5]The fines scheme is set for the excessive consumption level that varies according the altitude, such as: Systems over 2000 *m.a.s.l.* the block is reduce to $26m^3/month/user$; between 1000 - 2000 *m.a.s.l.* to $28m^3/month/user$; and up to 1000 *m.a.s.l.* to $32m^3/month/user$.

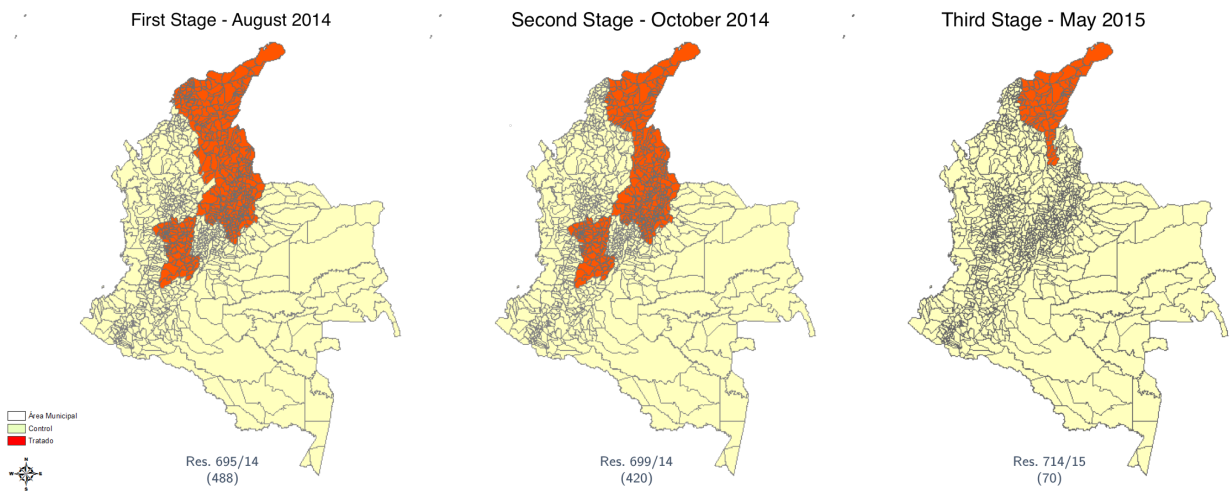


Figure 1: Spatiotemporal transition of water fines program

Note: Prepared with official data. Above the map the date of every stage of the intervention is indicated. The official resolution issued by the regulator is indicated at the bottom. In parenthesis the number of municipalities affected by fines.

3 Methodology

3.1 Data

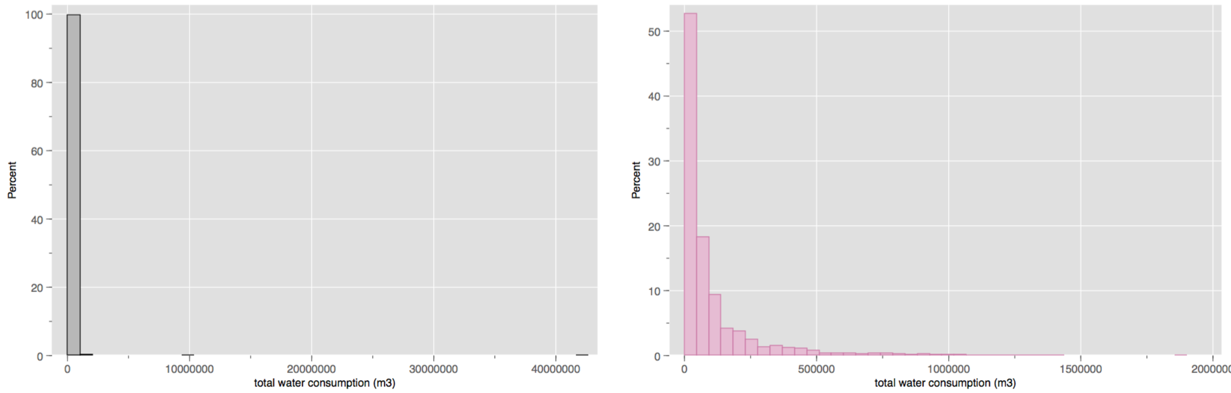
Data used for this research, comes from administrative sources. A monthly panel data for 1250 water supply systems in Colombia between January 2011 and December 2015 has been obtained from 'Sistema Único de Información de Servicios Públicos- SUI' (Unified information system for public utilities in english). The information set include aggregated variables at system level, including water consumption, total billing, number of users, users by incomes group, subsidies and overpricing.[6]

Since the information is self-reported (though is mandatory by Colombian law), problems as measurement error comes about in some periods of the sample. To deal with this, two strategies were used: First those system with high share of missing values were exclude, leaving 1101 systems. Second, the variables time series for each system were analyzed, and outliers were converted to missing values. Outliers were considered observation above percentile 99 or below percentile 1 within system. Histograms for total water consumption, number of users and total billing are showed in the figures 2 to 3. With this information two new variables were created: water consumption in cubic meters per user and water rate such as the ratio of total billing and total consumption (see Figure 4).

In the sample the number of users varies from 2 to 2.3 million, located in 999 municipalities (89% of the total) and total 33 subnational regions, 32 departments and capital district. Water consumption in total sample reach 15,517 $L/month/user$ on average (see table 1). The table also shows summary statistics divided by provider categories defined by the water sector policy. This is, *Small providers* (up to 2500 users) and *Large providers* (over 2500 users). In the data, small providers have an average water consumption of 16, 158$L/month/user$, 1,100 liters above the large providers. In terms of water rate, small systems pay 0.38 USD less than larger on average. Figure 6 shows the average water consumption per user for 5 years (2013 to 2015) split by the size of provider.

Table 2 presents the summary statistics by type of provider. This category include: and public utility (PU), community endeavors (CE), commercial organizations (CO) and local governments directly (LG). On average, water supply systems operated by PU consume the most, approximately 15,614 $L/month/user$,

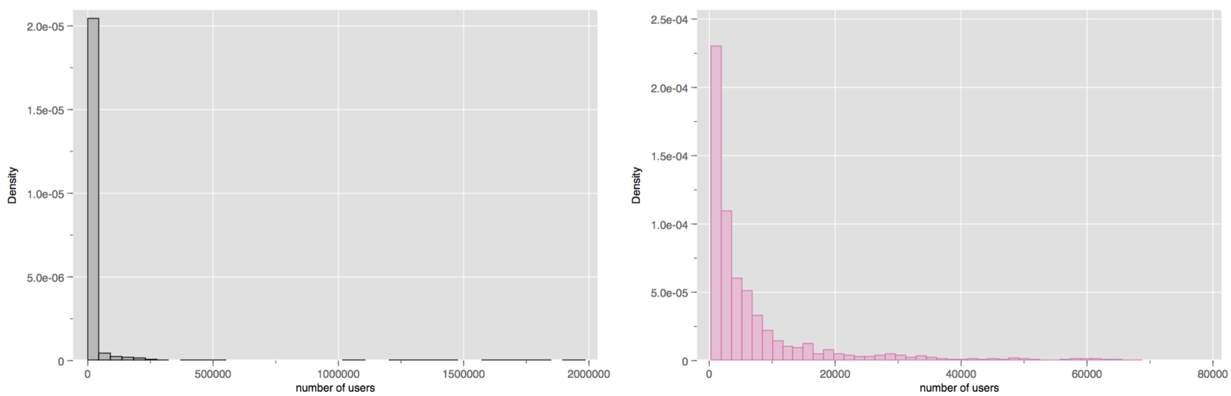
[6]Information available at: Sistema Único de Informacion de Servicios Públicos - SUI



(a) Original distribution

(b) Distribution after cut

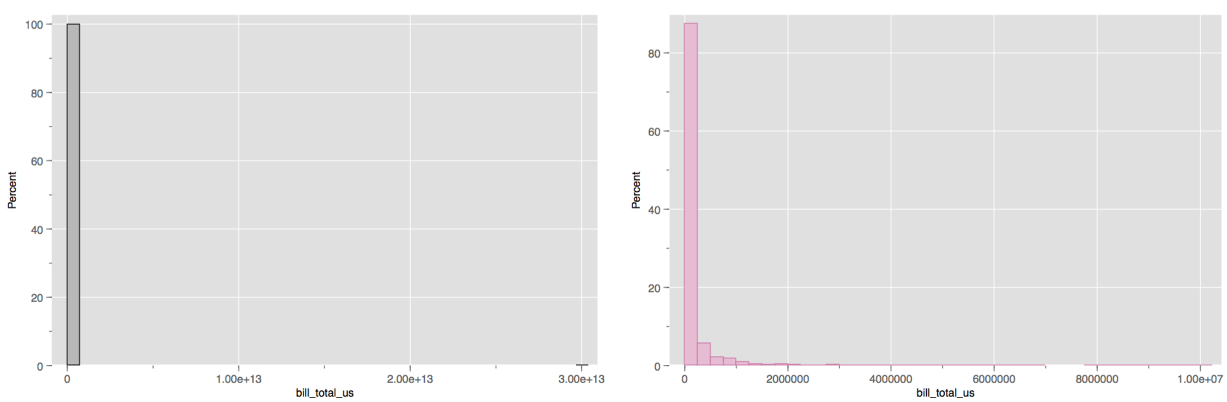
Figure 2: Distribution of the total water consumption in sample



(a) Original distribution of number of users

(b) Distribution after cut of number of users

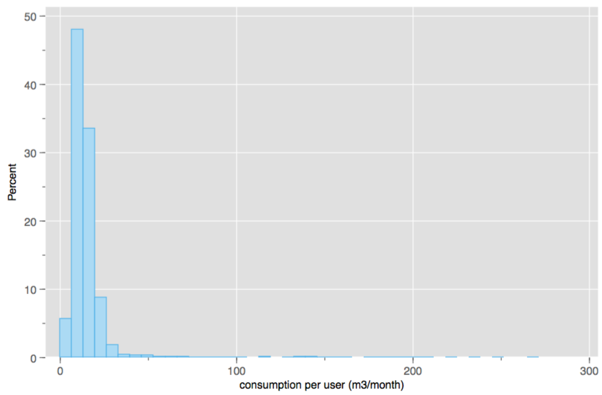
Figure 3: Histogram of number of users in sample



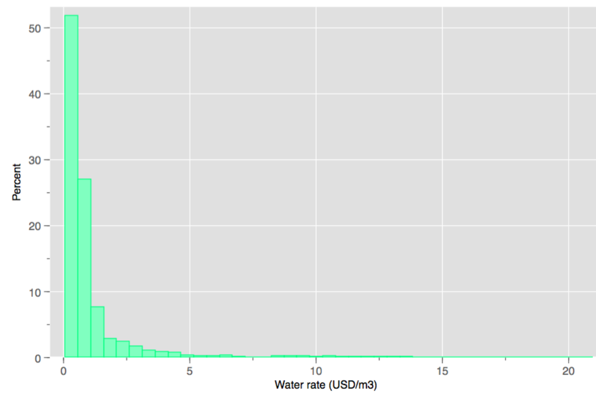
(a) Original distribution

(b) Distribution after cut

Figure 4: Distribution of the total turnover in the sample



(a) Histogram Water consumption per user



(b) Histogram of Water rate per system

Figure 5: Distribution of the created variables

Table 1: Summary statistics by type of provider

	mean	sd	min	max	n
Up to 2500 users					
Consumer per user (liters)	16158.95	14751.16	3.57	287541.66	
number of users	1605.91	1229.84	4.00	7514.00	
Water rate (USD/m3)	0.76	1.41	0.06	20.44	
users with subsidies (%)	0.91	0.22	0.00	1.00	
herfindahl index	0.58	0.22	0.17	1.00	
More than 2500 users					
Consumer per user (liters)	15051.18	11786.70	0.89	285713.78	
number of users	36503.49	132967.61	4.00	1947666.00	
Water rate (USD/m3)	1.24	2.20	0.06	21.10	
users with subsidies (%)	0.92	0.14	0.00	1.00	
herfindahl index	0.46	0.16	0.17	1.00	
Total					
Consumer per user (liters)	15517.00	13126.44	0.89	287541.66	
number of users	20754.57	100017.75	4.00	1947666.00	
Water rate (USD/m3)	1.04	1.92	0.06	21.10	
users with subsidies (%)	0.92	0.19	0.00	1.00	
herfindahl index	0.52	0.21	0.17	1.00	
Observations	82432				

Notes: Summary statistics for monthly residential water consumption levels at system for period of January 2013 to December 2015. Data sample includes 1089 water systems. Average water consumption and users levels are estimated from reported data from SUI.

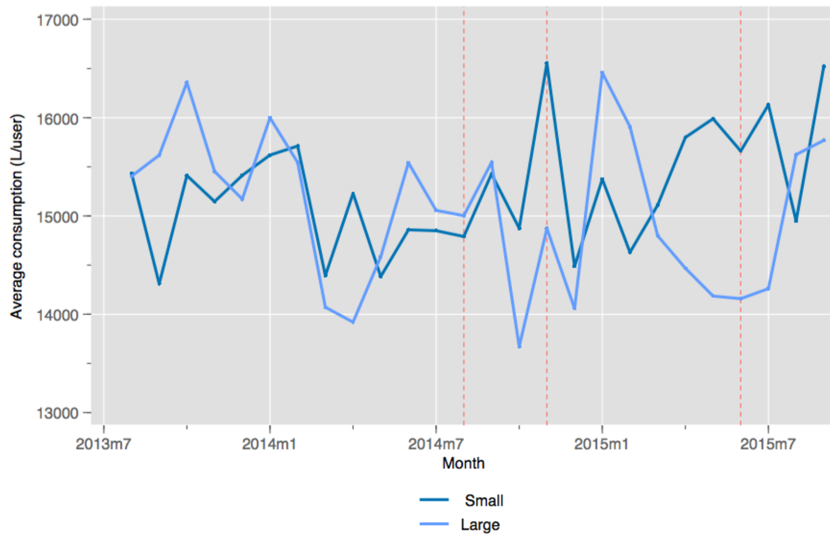


Figure 6: Average water consumption per user over time by size of provider

Notes: Data correspond to monthly average residential water consumption by classification provider for the period January 2013 to December 2015. Data sample includes 1089 water systems. Average water consumption and users levels are estimated from reported data from SUI.

with 64,000 users, this type of provider is located in the larger municipalities in Colombia. Followed by LG with 15,291 $L/month/user$. LG and CO have less than 2500 users on average, theses type of providers ar located mainly in small urban and rural areas. Figure 7 shows the average water consumption per user for 2 years, differentiating by the type of providers.

According to the data available, the systems affected by the water fines reaches 42.7% in the first stage, 36.6% at the second and 4.5% at the third, as explained in figure 1. Yet data is self-reported by systems, there is no reason to think that program activation in a specific department is related to the availability of information. The data shows that only 9% of observations with missing reports belongs to systems affected by the fines (see Table 3).

Information set also include climatic data with variables as temperature, rainfall, relative humidity, solar radiation, evaporation and evapotranspiration; provide by IDEAM[7]. This information correspond to multi-annual average for 30 years of monitoring; and is at station level. With support of GIS software, data was extrapolated to municipality location using the near distance approach. Additional administrative and location data at municipality level was taken from a panel data from CEDE-Universidad de los Andes[8], including altitude, official regions and distance to capital of the department and of the country.

3.2 Empirical strategy

I exploit the spatiotemporal exogenous source of variation generated by the program activation with a restricted sample of a panel data of water systems distributed among the country. To do so, I propose the following empirical model.

$$Cons_{ijt} = \beta_0 + \beta_1 U_{ijt} + \beta_2 Fines_{ijt} + \beta_3 U_{ijt} Fines_{ijt} + X'_{it}\alpha + \gamma_i + \vartheta_t + \varepsilon_{it} \tag{1}$$

[7]Official Institute of environmental studies IDEAM
[8]Banco de Datos CEDE-Uniandes

Table 2: Summary statistics by type of provider

	mean	sd	min	max	n
Public Utility					
Consumer per user (liters)	15613.73	14298.56	448.80	235969.20	
number of users	64066.99	234550.19	6.00	1947666.00	
Water rate (USD/m3)	0.81	0.96	0.07	10.00	
users with subsidies (%)	0.95	0.09	0.49	1.00	
herfindahl index	0.44	0.13	0.19	1.00	
Local governments directly					
Consumer per user (liters)	15290.44	18293.14	1018.05	273280.00	
number of users	1506.67	1407.26	10.00	10208.00	
Water rate (USD/m3)	0.87	1.71	0.07	19.79	
users with subsidies (%)	0.98	0.07	0.44	1.00	
herfindahl index	0.61	0.21	0.17	1.00	
Community based					
Consumer per user (liters)	14453.65	9397.13	26.45	198029.12	
number of users	2074.85	2537.81	4.00	19502.00	
Water rate (USD/m3)	0.99	1.46	0.06	16.40	
users with subsidies (%)	0.86	0.24	0.00	1.00	
herfindahl index	0.59	0.25	0.17	1.00	
Commercial organization					
Consumer per user (liters)	15112.13	15446.83	46.04	287541.66	
number of users	19783.37	52280.51	4.00	506110.00	
Water rate (USD/m3)	1.49	2.51	0.07	21.00	
users with subsidies (%)	0.91	0.20	0.00	1.00	
herfindahl index	0.49	0.18	0.17	1.00	
Total					
Consumer per user (liters)	15143.70	15264.58	26.45	287541.66	
number of users	20538.08	102949.38	4.00	1947666.00	
Water rate (USD/m3)	1.18	2.06	0.06	21.00	
users with subsidies (%)	0.93	0.18	0.00	1.00	
herfindahl index	0.53	0.21	0.17	1.00	
Observations	20654				

Notes: Summary statistics for monthly residential water consumption levels at system for period of January 2013 to December 2015. Data sample includes 1089 water systems. Average water consumption and users levels are estimated from reported data from SUI.

Table 3: Relation between missing reports and system affected by the program

	Missing report
1 if wss is in a deparment affected by water fines	-0.0932***
	(-11.68)
Constant	0.499***
	(355.61)
Observations	131104

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

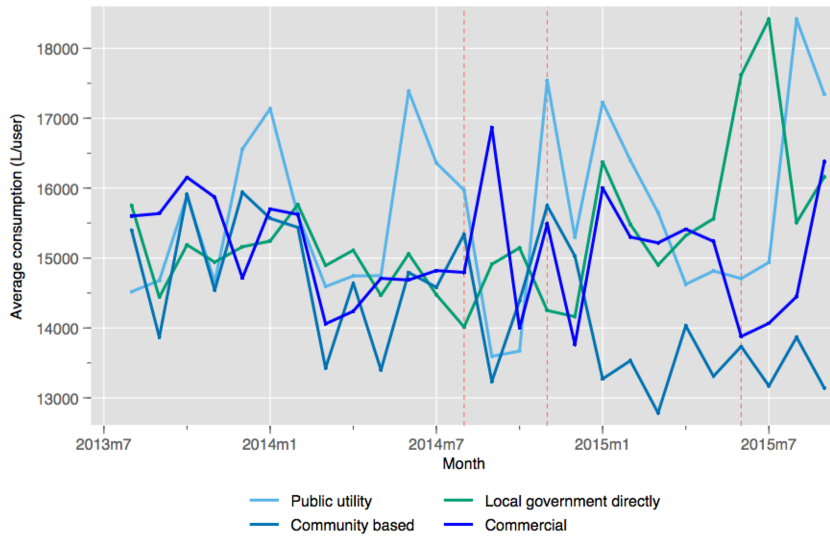


Figure 7: Average water consumption per user over time by type of provider

Notes: Data correspond to monthly average residential water consumption by type of provider, for the period January 2011 to December 2015. Data sample includes 1089 water systems. Average water consumption and users levels are estimated from reported data from SUI.

where subscript i represents the water system, j the department and t time in months period. $Cons_{it}$ is the residential water consumption per user, $Fines_{ijt}$ is equal to 1 if the water system i is in a department affected by the activation of the norm and 0 otherwise; U_{ijt} is the number of users that share the system; X_{it} is a matrix that includes information at water system level; γ_i are the system fixed effects, ϑ_t are the time fixed effects, and ε_{it} an unobservable term.

The parameters of interest are β_1, which represents the effect of the size group on water consumption. The hypothesis is that its sign is positive, i.e. as the number of users increases the water consumption per user increases, decreasing cooperation. The coefficient β_2 represents the effect of the fines on the water consumption. The hypothesis here is its sign is negative, i.e. those systems located in department that were affected by the fines activation decreasing the water consumption more than those who were not. Finally, β_3 represents the cross-effect between the fines and group size, we want to test if theres is an heterogenous effect on residential water consumption, if there was a decline, rise or no effect.

Covariates include water supply system fixed effects. This allows to control for information related to the systems and the users that are unobserved, such as service, technology or infrastructure used. Also time fixed effects are included to control for events like investments, changes in rates different from the fines, and climate variations, events that could affect the decisions of consumption. Since program implementation was established at departments levels and not at water supply system level, I estimate robust standard errors clustering by municipality and department.

3.3 Identification

In this research, the main interest is to analyze the effect of fines, group size and its cross-effect on cooperation, which is defined as a reductions in residential water consumption. A spatiotemporal exogenous source of variation generated by an activated water fines program in Colombia is explode. The intervention was, activate fines in water systems that belong to regions where precipitation reached a level lower than the average for a normal dry season.

The treatment group is composed by all water systems within a department affected by the program. The

Table 4: Differences in observables variables between treated and non-treated previous to program

	mean group 1	mean group 0	sd	Diff.	t
consumption per user (L)	448994.1	337497.4	1675.9	111496.7***	66.5
number of users	24005.6	19649.8	83.2	4355.8***	52.3
Water rate (COP/m3)	0.8	1.1	0.003	-0.31***	-120.7
User with subsidies (%)	0.9	0.9	0.0001	-0.019***	-144.9
average evaporation	1117.2	1482.9	4.0	-365.7***	-91.3
average evapotranspiration	1312.9	1503.9	2.5	-191.0***	-77.8
annual rainfall (mm/year)	1473.1	1769.6	9.2	-296.5***	-32.1
number of days with rain	146.8	117.5	0.6	29.2***	51.2
average annual temperature ¡C	22.0	25.8	0.06	-3.86***	-61.6
maximum average annual temperature ¡C	26.6	30.8	0.07	-4.21***	-60.1
minimum average annual temperature ¡C	17.5	21.0	0.05	-3.55***	-67.4

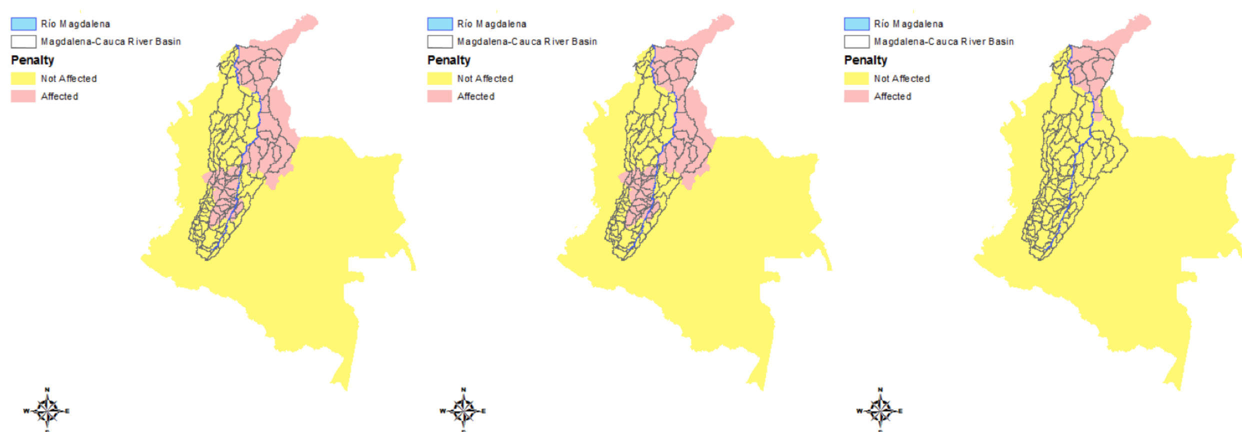


Figure 8: Magdalena-Caeca river basin location and affected areas

Note: Prepared with official data.

control group are those that have not been affected by the program or were exclude when rainfall back to normal conditions.

The decision about which areas are affected is related with climatic variables. This criteria may seem partially exogenous and estimate the effects by comparing treated and control groups. However, even in presence of a fully random assignment process, it is possible to observe differences on characteristics among groups prior to program. In terms of observable variables, there are significative differences between systems affected and those who do not, before the program. Water consumption per user and number of users is higher of the treated, and this differences are statistically significant (see table 4).

With this scenario, we explode a spatial pattern of treatment over the country to analyzed the wanted effects. In spatial terms, the 51% of treatment group observations belongs to water supply systems located in the Magdalena-Caeca river basin. Figure 8 shows the location of Magdalena river basin and municipalities affected by the water fines in every stage. Magdalena-Caeca represents the main river basin in Colombia. In this area near of 40% of the country's population are located, and 85% of total country's GDP is generated[9].

[9]Information available at: IDEAM: Diagnóstico ambiental cuenca Magdalena-Caeca

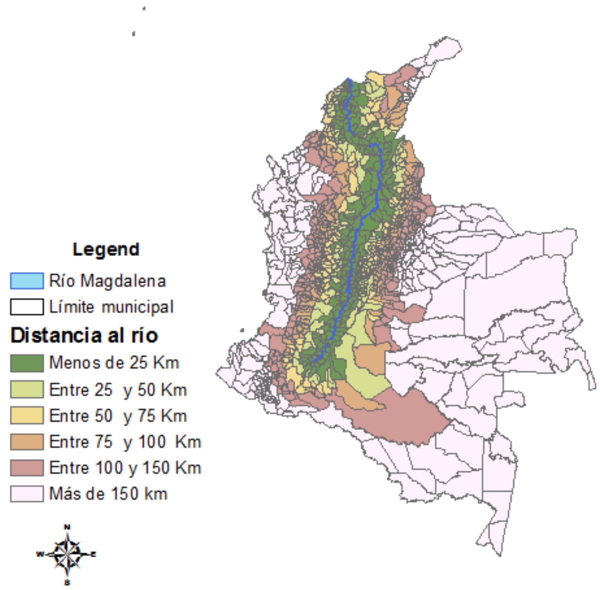


Figure 9: Buffer from distance of Magdalena river

Table 5: Differences in trends of consumption between groups before program

	All	<50	<100	<150	<200	<250	<300	<350	<400	<450	<500
p-value	0.07*	0.54	0.10	0.14	0.19	0.11	0.11	0.10	0.09*	0.08*	0.08*

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

This location pattern will be used as an identification strategy. The key assumption here is: The more the water supplies system approach to the main stream of the Magdalena River, water consumption are more homogeneous. To asses this assumption, differences between the trends on water consumption of the treated and control groups before program application were tested, for distance from 50 up to 400 kilometers, each 50. The distribution of municipalities in the river basin are shown in Figure 9.

The null hypothesis to test is: differences in water consumption trends before program between treated and control groups, at certain distance A from the Magdalena river, are statistically significant and equal zero:

$$E(Cons_i|time,\ Fine = 1,\ distance < A) = E(Cons_i|time,\ Fine = 0,\ distance < A) \tag{2}$$

Probability values of each test are showed in table 5. According to these, differences in trends as we move from the river, are statistically equal from zero up to 400 kilometers. This is, consumption among the groups was similar before fines program in this buffer. Under this results, the identification strategy used here is to compare residential water consumption before and after the program, of water supply systems in department affected and those who did not, both located in bandwidth up to 400 kilometers around the Magdalena river.

3.3.1 Differences in Differences

A diff-in-diff estimation is proposed to measure the effects, conditional on the exogenity on selection of the departments. The effect of the fine program is the Average Treatment on the Treated (ATT), this parameter is defined as $\tau(U_{it}, Fines_{it})$, which is the difference between the expected value of residential water consumption of system i in the affected department by fines at time t, $E(Cons_{ijt}|Fines_{ijt} = 1)$, minus the expected value of residential water consumption of systems located in departments not affected $E(Cons_{ijt}|Fines_{ijt} = 0)$. Such that:

$$E(Cons_{ijt}|Fines_{ijt} = 1) = \beta_0 + \beta_1 U_{ijt} + \beta_2 Fines_{ijt} + \beta_3 U_{ijt} Fines_{ijt} + X'_{it}\alpha + \gamma_i + \phi_t + \varepsilon_{ijt} \quad (3)$$

$$E(Cons_{ijt}|Fines_{ijt} = 0) = \beta_0 + \beta_1 U_{ijt} + X'_{ijt}\alpha + \gamma_i + \phi_t + \varepsilon_{ijt} \quad (4)$$

$$\tau = \beta_2 Fines_{ijt} + \beta_3 U_{ijt} Fines_{ijt} \quad (5)$$

The effect of the group-size is defined as the partial effect of the number of users on water consumption, this is: $\phi = \frac{\partial Cons_{ijt}}{\partial U_{ijt}} = \beta_1 + \beta_3 Fines_{it}$.

3.3.2 Common trends assumption

If the common trends assumption is not hold, the difference-in-difference estimator is biased. This assumption implies that treated and control groups, should have behaved similarly before the fines program was implemented. Table 5 show the differences between the trends on water consumption of the treated and control groups before fines application. Results that support this assumption.

4 Results

4.1 Baseline regressions

Table 6 shows the baseline results, including estimation for all the water supply system in the sample, and for those up to 400 kilometers from Magdalena river. Column 1 and 2 are estimation with controls including water rate, percentage of users with subsidies and a Herfindalh Index of income. Columns 3 and 4 include robust standard error clustering at municipality and department level. All the coefficients are statistically different from zero; and their sign correspond to initial hypothesis.

According with results, the program has a significant impact on water consumption. When fines are active, the reduction in consumption is approximately 697 and 706 liters monthly in average per user. This reduction is equal to use three times the washing machine. The group-size effect (ϕ) estimated in average is negative and accounting for reductions of 2.8 liters. The cross effect is significant and positive in a range of 0.13 liters per month. This effect can be seen as in presence of program, as the number of users increases the effect of the fines becomes increasingly low in terms of consumption. This effect as a function of number of users is shown in figure 10.

4.2 Heterogenous Effects

To analyze heterogeneous effects by system characteristics, first the sample was split into groups of type of providers. Results show that the coefficient of treatment variable is negative and statistically significant only for public utilities. The reductions on consumption in average for this type of provider reach 2,484 liters. The group size effect (ϕ) is negative and statistically significant in all cases (4.78 liters), while the cross-effect is positive and statistically significant (See table 7). The net effect of the program for all type of providers is shows in Figure 11. It can be observed that the partial effect in the panel (a), is negative when the number of users is below 10,000. However, as long as the number of users increase, the effects of program decrease consumption at lower rate. For commercial organizations, crossed effect is significant different from zero.

Second, estimations by location of providers was analyzed. This subgroups include provider in rural and urban areas, and those who are located in both. I found results are statistically significant for water supply

Table 6: Results of baseline regressions

	(1)	(2)	(3)	(4)
	All	<400km	All	<400km
fines	-705.5**	-696.8**	-705.5*	-696.8*
	(-3.13)	(-3.08)	(-2.28)	(-2.26)
number of users	-2.822***	-2.820***	-2.822***	-2.820***
	(-67.76)	(-67.56)	(-8.42)	(-8.41)
finesXgroup size	0.127***	0.127***	0.127***	0.127***
	(9.24)	(9.23)	(4.73)	(4.73)
Water rate (USD/m3)	-1694.5***	-1714.4***	-1694.5***	-1714.4***
	(-14.17)	(-14.15)	(-6.39)	(-6.29)
users with subsidies (%)	6383.6***	7344.3***	6383.6	7344.3
	(4.61)	(5.20)	(1.65)	(1.72)
herfindahl index	-15124.4***	-16977.1***	-15124.4*	-16977.1*
	(-9.84)	(-10.47)	(-2.03)	(-2.06)
Observations	11564	11504	11564	11504
Controls	Y	Y	Y	Y
TimeFE	Y	Y	Y	Y
SystemFE	Y	Y	Y	Y
Mpio_DeptoFE	N	N	Y	Y

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The dependent variable is Water consumption per user (*liters*). Column (1) and (3) include estimation for all systems in the sample, column (2) and (4) for those located at a distance from Magdalena river of 400 kilometers. I use the fixed effect estimator in all regressions, clustered standard errors by municipality and department only in column (2) and (4). All regressions include a non reported constant. Data for performance of water supply systems are provide by SUPERSERVICIOS. *** p<0.01, ** p<0.05, * p<0.1

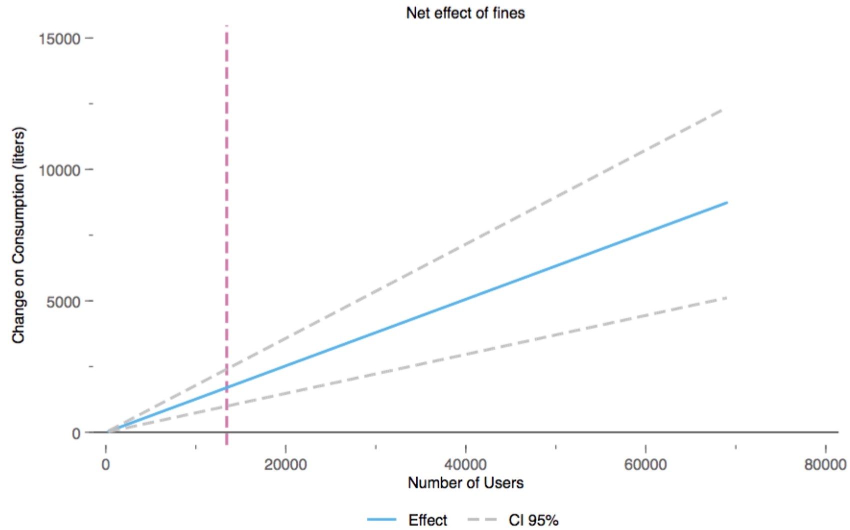


Figure 10: Net effect of the program as a function of number of users

Note: This is the partial effect of fines as a function of number of user. Dash line in x axis is the average users in the sample (13437). The distance from Magdalena river is 200 kilometers.

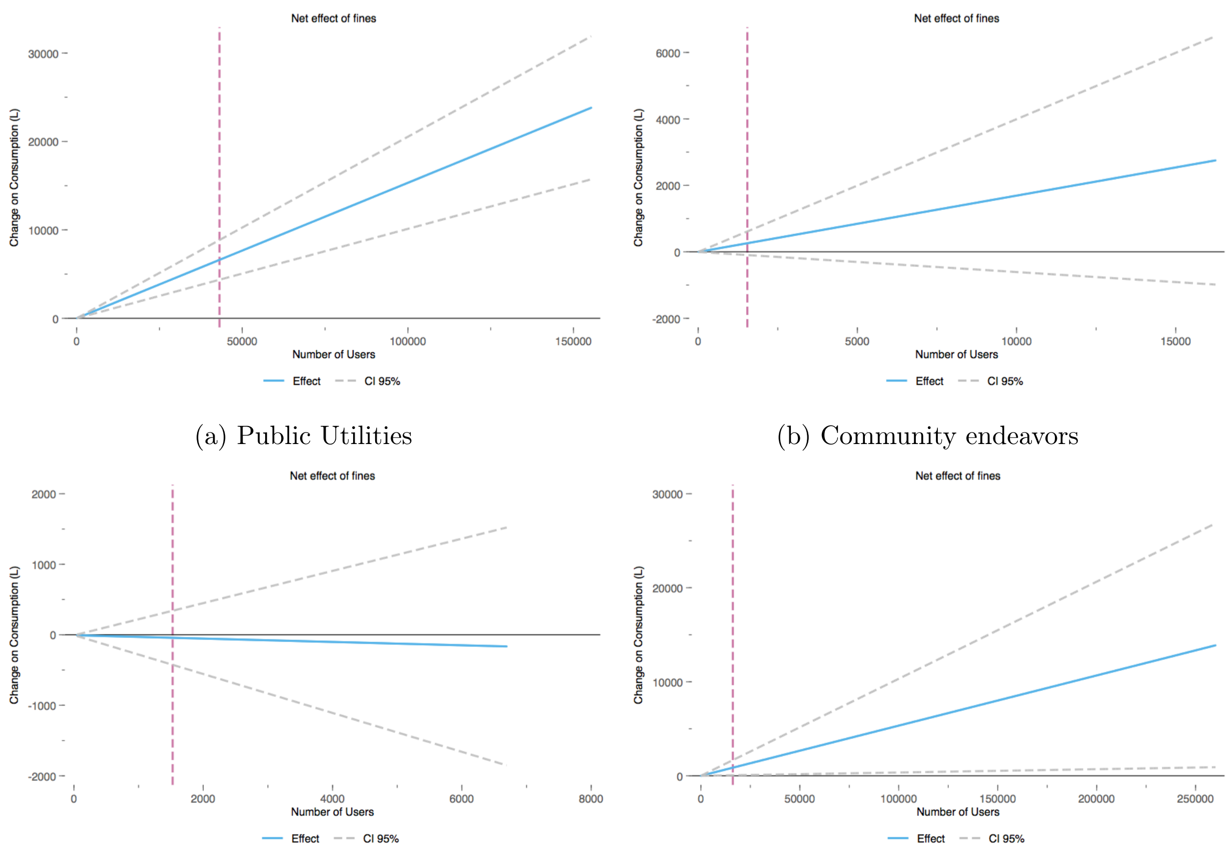
Table 7: Regressions by type of providers of system located at 200km from Magdalena river

	(1) Public Utilities	(2) Local Government	(3) Community	(4) Commercial org
fines	-2483.6***	-551.1	-615.9	251.8
	(-5.15)	(-1.84)	(-1.43)	(0.37)
number of users	-4.237***	-6.282**	-3.329***	-1.417***
	(-14.70)	(-2.63)	(-5.16)	(-5.50)
finesXgroup size	0.153***	-0.0237	0.169	0.0534*
	(5.77)	(-0.18)	(1.44)	(2.10)
Observations	1971	2427	1464	5642
Controls	Y	Y	Y	Y
TimeFE	Y	Y	Y	Y
SystemFE	Y	Y	Y	Y
Mpio_DeptoFE	Y	Y	Y	Y

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The dependent variable is Water consumption per user ($liters$). We use the fixed effect estimator in all regressions with clustered standard errors by municipality and department. The distance from Magdalena river is 400 kilometers. Column (1) include estimation for those systems considered public utilities providers (PU), column (2) for those directly provide by local governments (LG), column (3) for Community endeavors (CE), and column (4) for comercial organizations (CO). All regressions include a non reported constant. Data for performance of water supply systems are provide by SUPERSERVICIOS. *** p<0.01, ** p<0.05, * p<0.1



(a) Public Utilities

(b) Community endeavors

(c) Local Government directly

(d) Commercial Organizations

Figure 11: Net effect of the program as a function of users by type of provider

Notes:Figure presents net effects of the program as a funtion of users. for Public Utilities. Dash line in x axis is the average users in each case. The distance from Magdalena river is 400 kilometers.

Table 8: Regressions by location of providers

	(1) Urban	(2) Rural	(3) Both
fines	-830.2*	-1431.6	577.8**
	(-2.46)	(-1.19)	(2.95)
number of users	-3.375***	-1.354	-0.115**
	(-9.18)	(-1.76)	(-2.85)
finesXgroup size	0.0780***	0.253	-0.00111
	(3.67)	(0.67)	(-0.18)
Water rate (USD/m3)	-1676.0***	-1508.8*	-511.9***
	(-4.51)	(-2.40)	(-8.29)
users with subsidies (%)	9289.7	3200.1	4768.8**
	(1.37)	(1.38)	(2.93)
herfindahl index	-23938.3	210.2	-4950.2
	(-1.94)	(0.12)	(-1.92)
Observations	8323	882	2299
Controls	Y	Y	Y
TimeFE	Y	Y	Y
SystemFE	Y	Y	Y
Mpio_DeptoFE	Y	Y	Y

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The dependent variable is Water consumption per user (Lt). We use the fixed effect estimator in all regressions with clustered standard errors by municipality and department. The distance from Magdalena river is 400 kilometers. Column (1) include estimation for the water supply systems located in urban areas, column (2) for those systems located in rural areas, column (3) for those located in both. All regressions include a non reported constant. Data for performance of water supply systems are provide by SUPERSERVICIOS. *** p<0.01, ** p<0.05, * p<0.1

systems located in urban areas holding the signs of the baseline regression (See table 8). When an organization provide both areas, the program has a positive effect on consumption. If the sample is split in groups of size, according to the sector policy in the country. I found the program has a significant effect in water system below 2,500 users, but the crossed effect is only statistically significant in systems with more than 2,500 users.

In term of findings, it is clear that the water fines program has desirable results on excess water use, diminishing it. This result holds no matter the type of providers. A particular result is the sign of number of users' coefficient. A great part of literature coincides that effect of group size on cooperation is negative, when high degree of rivalry exists. Likewise, the case of water supply systems in presence of shortages. Nevertheless, I found an opposite direction in sign. This situation can may be thought as if the larger water supply systems are more efficient in management of water losses, better metering process, and higher investment in promoting environmental awareness in households.

A water fine program works, but its results are subject to the numbers of users that share the system and the type of providers. The kind of program that I analyzed here has achievements in promoting the reduction on water consumption in those systems with low numbers of users, and when a public utility or community is provider. This finding suggests that in this kind of systems the users are more in touch with environmental awareness than in those such as private capital or local governments.

Table 9: Regressions by subgroups of size

	(1) Up to 2500	(2) More than 2500
fines	-648.2*	-716.9
	(-2.31)	(-1.03)
number of users	-9.611***	-2.766***
	(-6.04)	(-8.12)
finesXgroup size	0.0770	0.117***
	(0.83)	(3.35)
Water rate (USD/m3)	-1529.7***	-1849.0***
	(-3.55)	(-5.38)
users with subsidies (%)	6571.4***	23945.5
	(5.96)	(1.41)
herfindahl index	-4326.5**	-55039.7
	(-2.97)	(-1.60)
Observations	5447	6057
Controls	Y	Y
TimeFE	Y	Y
SystemFE	Y	Y
Mpio_DeptoFE	Y	Y

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Notes: The dependent variable is Water consumption per user (Lt). We use the fixed effect estimator in all regressions with clustered standard errors by municipality and department. The distance from Magdalena river is 400 kilometers. Column (1) include estimation for the water supply systems with up to 2500 users, column (2) for systems with more than 2500 users. All regressions include a non reported constant. Data for performance of water supply systems are provide by SUPERSERVICIOS. *** p<0.01, ** p<0.05, * p<0.1

5 Conclusions

I analyzed the causal impact of a water fines program and its cross effect with the number of users on the residential water consumption. To do so, I benefit from a quasi-experiment that took place in Colombia. The regulator activated a fines program in some departments who faced drastic shortages.

I highlight two main findings:

First, there is a reduction on water consumption in those water supply systems affected by the fines program in contrast to those who were not affected. These reductions occur no matter the type of providers. However in presence of fines program the reduction on the residential water consumption becomes lower in the extent of numbers of users increase. This result holds only when the provider is a public utility. which are the main provider of larger systems.

Second, the sign of number of users on water consumption is different from expected. A vast part of literature coincides that effect of group size on cooperation is negative, when high degree of rivalry exists. Likewise, the case of water supply systems in presence of shortages. Nevertheless, I found opposite direction in sign. This situation can be thought as if the larger water supply systems are more efficient in management of water losses, better metering process, and higher investment in promote environmental awareness in households.

The effects predicted by the model and those found empirically confirm that the water supply systems who cooperated less or nothing initially, in the presence of the fines, reach higher levels of cooperation. The differences between the two predictions appear in terms of providers capacity, small systems consume more water compared to the larger and that is why the fine achieves the first cooperate to a higher level. This makes necessary to involve in a more complex way the monitoring levels in the model, so that allow capture the empirical results observed.

It is important in the design of this kind of incentives to reduce water overuse, discriminate in terms of the number of users. Given the heterogeneity of characteristics and the likely effects of the fine, a policy adjusted to these conditions is necessary. If the regulator observe the conditions related to the capacity of the providers, then he can formulate policies that fit better. It could include variations in fines that would achieve higher levels of cooperation in water supply systems.

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