Transboundary Pollution and Municipal Investments into Wastewater Management

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Abstract: This study examines the effect of location on municipal investment into wastewater management. Specifically, it explores whether location, relative to regional and international borders, plays a role in these investment decisions. Intuitively, transboundary aspects of pollution undermine a jurisdictional government's desire to curtail the amount of pollution generated from a source. As the distance between the source and a border falls, the transboundary aspects grow since a greater proportion of the detrimental effects of the pollution are born by neighboring downstream jurisdictions. Empirical studies consider the problem of transboundary pollution by examining various relevant outcomes. Some studies examine pollution levels on two sides of an intra-national border. Other studies assess environmental quality at intra-national or international borders. Additional studies examine the stringency of regulations imposed on and enforcement actions taken against facilities located at or near borders. Our study contributes to this literature in two ways by (1) developing a rich conceptual framework to explain governmental use of policy tools to induce better environmental management by polluters, and (2) exploring the problem of transboundary pollution in the context of a developing economy. Using data for municipalities in the country of Colombia between 2000 and 2013, we find that municipalities located further from an intra-national border invest more into wastewater management than municipalities located closer to an intra-national border, consistent with the hypothesis that regional governments employ policy tools more strongly against the former set of municipalities. However, distance to international borders does not affect municipal wastewater investment.

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1. Introduction

This study explores the effect of transboundary pollution on municipal investment into wastewater treatment in the context of a developing country, namely Columbia. Pollution transcends both domestic and international borders separating jurisdictions. Water pollution flows downstream across borders along riverways and streambeds, while air pollution blows across borders based on wind direction. This transboundary dimension of pollution generates negative externalities. In a sub-national setting, a polluting "upstream" jurisdiction imposes some of the detrimental effects of its pollution on its neighboring "downstream" jurisdiction. For example, some of the water pollution from one U.S. state flows into another U.S. state. When authority over environmental protection is decentralized to some extent within a single country, individual regional jurisdictions hold much autonomy over their own governance of pollution control. Thus, the negative externality generally remains unresolved. As important, the presence of a transboundary externality extends to the international setting. In this setting, a polluting upstream country imposes some of the generated detrimental effects on its neighboring downstream pollution. Since no supra-national authority fully controls pollution control, the international externality remains unresolved.

Of course, multiple entities generate pollution within a given jurisdiction or country. Excepting highly centralized economies, the national government and regional governments do not directly control pollution control or environmental management decisions made by the many polluting entities. Instead, the national and regional governments merely influence the polluters' management choices using various policy tools. Our study explores environmental management effort expended by municipal governments to treat household-based wastewater. As in most countries, the national government and regional governments do not directly control even these local government management decisions, relying instead on various policy levers.

Environmental management expended by polluting entities, including local government wastewater treatment plants, helps to reduce pollution. The difference between who bears the cost of the environmental management and who enjoys the benefits in the form of reduced environmental harm leads to inefficiently low environmental management, which implies excessive pollution. As argued, the inefficiently low level of environmental management reflects inefficiently weak use of policy tools on the part of national and regional governments.

Assessing whether the environmental management level is too low or the policy tool use is too weak is quite challenging. The more straightforward analysis is to exploit variation across space within a given jurisdiction or country. The regional government should employ its policy tools less strongly when the polluting entity lies relatively closer to the regional border and employ its tools more strongly when the polluting entity lies relatively far from the regional border because the transboundary effect grows as distance to the regional border falls. Consequently, the polluting entity expends greater management effort when located further from the regional border. Similarly, the national government should employ its policy tools less strongly when the polluting entity lies relatively closer to the international border and employ its tools more strongly when the polluting entity lies relatively far from the international border. Consequently, the polluting entity expends greater management effort when located further from the international border.

In Colombia, wastewater management decisions regarding household-based wastewater lie with municipal governments. However, the central government offers direct transfers for wastewater management and applies regulatory pressure, while regional governments offer both direct transfers and technical assistance, because concerns about water pollution are prominent in Colombia. Our study gathers data on an array of rivers, municipalities, and departments and defines their position within the country relative to rivers' directional flow. Then our study exploits these data to examine the effect of location on a city's investment into wastewater management. Specifically, it explores whether location, relative to regional and international borders, plays a role in these investment decisions.

Several studies consider the problem of pollution in transboundary settings. Some studies examine the level of emissions generated by polluting sources as the dependent variable. Of these, some studies examine location relative to intra-national borders. These studies mostly capture location by measuring the distance to an intra-national border. The remaining studies contrast pollution levels on two sides of an intra-national border, distinguishing between upstream and downstream regions. All of these studies reveal the expected effect: the closer is a polluting source to an intra-national border, the higher is the pollution level (Cai et al., 2016; Helland and Whitford, 2003). Other studies assess ambient water quality as the dependent variable. These studies find evidence of a transboundary effect, at both intra-national and international borders, by observing lower quality on the upstream side of a border but higher quality on the downstream side of a border (Sigman, 2002; Sigman, 2005). The last set of studies examines regulatory actions as the dependent variable. These studies reveal that environmental regulation and enforcement are less stringent against facilities located at or near borders.

Our study contributes to this literature by exploring the problem of transboundary pollution in the context of a developing economy. Our study also contributes by developing a rich conceptual framework to explain governmental use of policy tools to induce better environmental management by polluters.

To generate these contributions, we first theoretically analyze the problem by developing a conceptual framework that captures the institutional setting of water quality protection in Colombia. We consider a situation of one country with three different levels of government: central, departmental, and municipal. Departments represent regional government entities. The country includes one central government, multiple departments, and multiple municipalities. Some departments lie within the interior of the country, while other departments lie on the country's border. Similarly, some municipalities lie within the interior of a given department, while other municipalities lie on a given department's border. Municipalities discharge wastewater into rivers that flow from one municipality to the next and from one department to the next until the river crosses an international border or empties into an ocean. The central government employs two policy tools: financial transfers for environmental management and regulatory pressure (e.g., fines for violating pollution limits). The departmental government employs its own policy tools: financial transfers and technical assistance. From our theoretical framework, we derive the following hypotheses: (1) the level of environmental management investment is greater for those municipalities located upstream within a department because the departmental government employs its policy tools more strongly against these interior municipalities, and (2) the level of environmental management investment is greater for those municipalities located in departments that lie upstream within a country because the central government employs its policy tools more strongly against these interior departments.

Second, we use data on municipalities in the country of Colombia between 2000 and 2013. We employ regression analysis to link a municipality's location, relative to domestic and international borders, to the level of municipal wastewater treatment investment. We measure location in two ways: (1) two binary indicators, one contrasting interior and border municipalities within a department and a second contrasting interior and border departments within the country of Colombia; (2) two distance measures: one capturing the distance to a departmental border and a second capturing the distance to an international border. We further manipulate the distance measures to construct non-linear specifications: (1) quadratic polynomial in distance, and (2) distance splines. Our results reveal that interior municipalities invest more than border municipalities and that the distance to a department border positively affects municipal wastewater management investments, both consistent with our first hypothesis. Results from the quadratic specification demonstrate that the impact of regional border distance falls as this distance grows, consistent with a convex relationship between transboundary pollution and distance, i.e., transboundary pollution becomes disproportionately more important as distance falls.

We do not reach a similar conclusion for the international setting. The binary indicator does not prove significant. The distance measure is significant only in the parsimonious model, which includes no control factors. And the quadratic effect is insignificant.

Collectively, we conclude that intra-national transboundary pollution influences regional governments' policy efforts but international transboundary pollution does not affect the central government's policy efforts.

The rest of the study elaborates on these points. Section 2 reviews the relevant literature. Section 3 describes the context of the empirical analysis. Section 4 constructs a conceptual framework. Section 5 describes the empirical strategy. Section 6 interprets the empirical results. Section 7 concludes.

2.. Literature Review

The aim of political decentralization is to give citizens or their locally elected representatives more power in public decision-making and autonomy to determine investments including those to protect the natural resources. However, situations in which different political jurisdictions share natural resources generate negative externalities, which affect the investment decision-making process. According to Olmstead (2014), these negative externalities are particularly common for shared water resources. When two or more political jurisdictions share a natural resource, location relative to jurisdictional borders affects investment into environmental management on the part of polluting entities by influencing the use of policy tools on the part of jurisdictional governments. The same logic applies to the sharing of a natural resource by multiple countries.

Various studies consider this problem of transboundary pollution. Some studies examine pollution levels (air, water, land) from regulated sources as the dependent variable. Of these, some examine intra-national borders and most examine the internal distance to an intra-national border. All previous studies reveal the expected effect: the closer is a regulated source to an intra-national border, the higher is the pollution level (Cai et al., 2016; Gray and Shadbegian, 2004; Helland and Whitford, 2003). Other study contrasts pollution levels on two sides of the intra-national borders comparing upstream and downstream provinces in China, finding that upstream provinces generate higher levels of pollution (Cai et al., 2016). Other study examines a border effect, assessing the effect of the proximity to intra-national borders, it finds that the pollution levels are lower the closer to an intra-national border (Gray and Shadbegian, 2004).

Another set of studies examines international borders. One study examines the effect of proximity to an international border on pollution levels. This study finds different results for different pollutants when assessing proximity to the Canadian border. The results reveal more biochemical oxygen demand (BOD) pollution discharged into water but less sulfur dioxide (SO_2) pollution emitted into the air (Gray and Shadbegian, 2004).

Similarly, a set of studies examines environmental water quality. Most of these studies examine pollution levels using measurement stations as units of observation (Limpscomb and Mobarak, 2015; Kahn et al., 2015; Sigman, 2002). Some studies examine intra-national borders comparing water quality on two sides of the intra-national border. In particular, Sigman (2005) focuses in the relationship between states in the US with authorization to enforce the Clean Water Act and its neighboring states. To do so, the author tries to identify the impact of an upstream authorized state on the water quality in a downstream state. The study reveals that being downstream of an authorized state has a negative impact on water quality, which is consistent with the hypothesis of free-riding; however, other result reveals zero effects on water quality for those authorized states (Sigman, 2005). Other studies comparing two-sides of intra-national borders describe expected results, and confirm higher levels of water pollution in upstream jurisdictions closer to an intra-national border than the water pollution in downstream jurisdictions (Limpscomb and Mobarak, 2015; Kahn et al., 2015).

Of these studies, some also examine the internal distance to an intra-national border. Sigman (2005) includes three different location variables indicating whether the measurement stations are located upstream of a state border, downstream of a state border, or located on river when it forms a border between two states. Under the assumption that far downstream of a border, the pollution endowment from upstream free riding diminishes with natural attenuation and far upstream the polluting state experiences almost all the damage, Sigman (2005) also considers the proximity to an intra-national border to measure the effect of upstream state's authorization on downstream state's water quality. The result of this continuous measure confirms the initial findings with a discrete approach: upstream state's authorization has a negative impact on the water quality measured at downstream stations within 50 miles of the border. The remaining studies reveal similar results examining internal distance to an intra-national border (Limpscomb and Mobarak, 2015, Kahn et al., 2015). Other study examines international borders and compares environmental water quality on two sides of international borders. This study finds that the level of pollution discharged into a waterbody upstream of an international border is higher than other comparable stations (Sigman, 2002).

The last set of studies examines regulatory actions as the dependent variable (e.g. inspections, enforcement, and location permit). Of these, one study examines intra-national borders, comparing regulatory actions on two sides of the intra-national border. This study finds that regulation agencies are more lenient against regulated sources located upstream of a border (Cai et al., 2016). Some other studies examine regulatory actions using the internal distance to an intra-national border as the regressor. These studies find that, within a particular region, the regulation is less stringent at bordering counties, particularly when it comes to the enforcement of pollutant industries or the decision on the location of pollutant industries (Cai et al., 2016; Duvivier and Xiong, 2013). Other study examines the effect of proximity to an intra-national border on regulation actions. The results for plants located nearby to the border of states with a strong environmental regulation show to fewer inspections and more enforcement in the water pollution side, more inspections and enforcement in the air pollution side (Gray and Shadbegian, 2004). Similarly, this study examine the impact international borders on the regulation finding different results for different pollutants; plants located near to the Canadian border face the fewer inspections for water pollution (and more BOD pollution), but more enforcement actions for air pollution (and lower SO_2 emissions) (Gray and Shadbegian, 2004).

3.. Context

3.1. Political and Administrative Division

Colombia is a unitary republic with autonomous regional entities or sub-national governments identified as departments (equivalent to U.S. states) and municipalities. Departments are defined as territorial entities with autonomy to manage, to plan and to promote socio-economic development within their own territory. Similarly, the departments are responsible for (1) coordinating and complementing municipal action and (2) intermediating between the central government and municipalities in able to provide the services determined by the constitution (DANE, 2007). A municipality is the basic territorial entity unit with political, fiscal, and administrative autonomies within its boundaries.

3.1.1.. Decentralization

In the last three decades of the 20th century, Colombia decentralized its government functions. As one of the first steps, the 1968 constitutional reform transferred responsibilities from the central government to the departments, allowing departmental governors to design and implement development plans and programs, as well as to fulfill other functions that lie below the ministerial capacities at the national level. Colombia reinforced this transfer of competencies in 1971 with the “Situado fiscal”, which dedicated a proportion of the national income to local administration for the provision of municipal services. During the same year, the national government crafted a system for sharing sales tax revenues with departments and municipalities, defining these revenues available for all purposes (Moncayo Jimenez, 2005).

Decentralization can be horizontal or vertical (Steiner and Correa, 1994). In Colombia, this process was vertical because it transferred decision-making and resources to sub-national levels – departments and municipalities. In particular, the central government delegated a multiplicity of functions to municipalities, including water systems, sewer systems, and environmental management (Valencia-Tello and Karam De Chueiri, 2014; Moncayo Jimenez, 2005).[1] This process not only included an increase in delegation of functions and resource decentralization, but also attempted to change access to and the provision of basic services in all the regions of the country. According to González (1994), the decentralized model implemented in Colombia was a copy of the fiscal federalism model, which main objective is to achieve local efficiency and a reduction in the central government expenditure. However, at the beginning of the process, some levels of centralization remained, due to institutional weaknesses at the municipal level (Valencia-Tello and Karam De Chueiri, 2014), Afterwards, the central government tried to correct the negative effects of the institutional design and to strength its regulatory capacity in two ways: (1) defining clearly departmental and municipal competencies regarding the provision of public services, and (2) conditioning municipal resources to a certification awarded by each department based on criteria established at the national level (Zapata-Cortés, 2016). Despite this decentralization, the central government designed a set of rules applicable to the budgetary process at the national and sub-national levels of government (DDT-DNP 2012) that allowed the central government to maintain some control.[2]

By 2000, Colombia had completed its decentralization process. Due to this decentralization, municipal governments have the autonomy to govern their own environmental management constrained by the central government's retained authority and authority delegated to departmental governments.

3.1.2.. Geographical and Population Division

Colombia is a reasonably large country at 1.2 million square kilometers (Murad Rivera et al., 2003). Located in the northern extreme of South America, Colombia shares hydrological basins

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[1] Act 715, 2001. Art. 76.5.4 identifies these activities: execute decontamination projects of water streams and water deposits affected by wastewater discharges, as well as disposition programs, elimination, and recycling of liquid and solid residuals, and controlling air pollutant emissions.

[2] The central government created the Statue of Budget (Estuto Único de Presupuesto) – EUP, defining the budgetary process in Colombia and its different steps. Two main agents operate at the local level: major and municipal council. The major is responsible for local economic development, including allocating the municipal expenditure and investments according to the approved budget (DDT-DNP, 2012). The municipal council approves and authorizes budgetary revenues and expenditures. Similarly, two agents operate at the department level: governor and department assembly. Governors are responsible for regional economic development, designing plans and programs, and defining revenues and expenditures (DDT-DNP, 2012). The department assembly approves the plans, projects, and budgets proposed by the governor.

with five bordering countries -- Ecuador and Peru in the south and Venezuela and Brazil in the east -- and meets the Pacific Ocean in the west and the Caribbean Sea in the north (IDEAM, 2015). Colombia governs coasts along the Pacific Ocean and Caribbean Sea, which has implied a constant process of negotiation with the neighbors to protect shared water resources and marine areas.

Currently, the country has 1,120 municipalities, each embedded within one of the 32 department (DANE, 2007). Some municipalities are located along departmental borders (hereafter "border municipalities"). Other municipalities are located within the interior of a department (hereafter "interior municipalities"). Similarly, some departments are located along an international border or coast (hereafter "border departments". Other departments are located within the Colombian interior (hereafter "interior departments").

Based on physical features, regional identity, history, and economic characteristics, the National Geographic Institute of Colombia divides the country into four main natural regions: (1) Atlantic, formed by coast plains and the Santa Marta Sierra; (2) Pacific, formed by the Pacific Ocean coast and the western cordillera; (3) Andean, formed by the central and west cordilleras and the valleys of Cauca and Magdalena; and (4) Eastern, formed by plains, the Orinoco basin, and the Amazonas basin. Most of the country's population resides in the Atlantic region. In contrast, the Eastern region houses only 2% of the population yet represents 42 % of the total territory (Murad Rivera et al., 2003). During the second half of the 20th century, Colombia transformed into a mostly urban country as people migrated to the main four cities. More recent violent conditions in the rural areas has prompted the migration and forced displacement toward big cities, increasing the pressure on environmental resources.

3.2. Municipal Wastewater Treatment and Water Quality in Colombia

3.2.1. Water Quality Issues

Colombia faces increasing environmental issues related to pollution of water sources. According to the Ministry of Environment, Housing, and Territorial Development (MAVDT) (2004), growing urban areas generate pressure over natural resources, housing and provision of public services due to the constant migration of population toward these areas. So there is an increased pollution discharged on water resources coming from municipal sewers, with deficient or no treatment. Although Central and local authorities have tried to adopt wastewater treatment programs and projects, following international patterns, these have difficulties.

Besides the pressure over water resources generated by the increase in urban population, Colombia faced other issues. The central Government identifies three major issues: First, there are environmental and health impacts associated with a decrease in water quality availability and restrictions in use. On one hand, ecosystems are affected by the increasing pollution discharged, specially by big urban areas (Bogota, Medellin and Cali), according to the National Inventory of Water, since 1998 around 1300 waterbodies received pollution from municipal wastewater reducing the quality of water sources; on the other hand, there are also effects on public health, the increase in the levels of pollution on water bodies, added to low economic levels, lack of education, and poor sanitation in some communities, configures a high risk setting for diseases with a high economic cost. Along with the pollution generated by domestic agricultural and industrial activities, the inexistent or inefficient wastewater treatment also contributes to generate environmental and health problems.

A second issue relates to the wastewater systems build in Colombia and the institutional capacity to generate programs toward wastewater treatment. By 2004, the MAVDT reported 237 wastewater systems build in 235 municipalities, representing only 21.7% of the municipalities in the country; including Bogotá, capital of the country; the proportion of population covered reached the 64%, and only the 44% excluding Bogotá. Regional environmental authorities - AAR and local authorities (municipalities) did not have enough instruments to develop programs and projects for wastewater treatment (MADS 2004). By 2013, the proportion of municipalities with wastewater systems in place increased to 43.5% (SSPD 2013), but there is still a deficit in the proportion of pollution treated that follows the trends for the Latin American (SSPD, 2013; Tiempo, 2017) region where around 31% of water is treated before discharge into waterbodies.

A third problem identified is the institutional framework. The level of centralization in the country added to the different number of public institutions involved in the problem of wastewater treatment made difficult the coordination of goals and tasks. At the national level, there was not a definition of a state policy in this regard (MADS 2004). At the regional level (AAR and Departments) struggled with financial and technical restrictions to provide support to the municipalities and to implement the confusing decontamination national policies. Finally at the local level there were not enough efforts planning toward the development of local systems for environmental recovery and wastewater treatment.

In terms of water quality, two of the major rivers in Colombia show different quality levels across the country. On one hand, the Magdalena stream shows low water quality levels in the municipality of Girardot, department of Cundinamarca, where the Magdalena receives waters coming from the Bogotá stream. In this segment, known as the "High" Magdalena, the low water quality is explained by the high levels of Total Solid Suspended coming from bordering municipalities in Cundinamarca; the "mid" Magdalena also reveals a low water quality condition due to the economic activities in neighboring departments (Santander and Boyacá) that affects multiple tributaries to the Magdalena stream. Finally, the "low" Magdalena is affected due to cattle raising, municipal discharges and gold mining activities (IDEAM**,** 2014). On the other hand, the Cauca stream shows a low water quality index due to the affectation of some of its tributaries at different station points.

3.2.2. Pollutant Discharges and Wastewater Treatment

The Colombian Hydrology and Meteorology Institute (IDEAM) estimates the pollutant net load by discharge points that are discharged into the hydrologic systems coming from industrial, domestic, and agricultural sources (IDEAM, 2014). The highest contribution of pollution discharge into the water bodies in Colombia is made by the domestic sector (80% on average), followed by the industry (19% on average). The urban areas are the major contributors to the pollutant discharge being responsible for about 70% on average for the discharges of pollutants such as Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Solid Suspended (TSS), Nitrogen (N), and Phosphorus (P). Similarly, the IDEAM identifies the hydrographic sub-zones under higher pressure due to loads of BOD and COD, being the Magdalena has the highest pressure; the "high" Magdalena (interior departments) receives 180.781 ton per year from the Bogotá River, being the highest load of BOD in the country.

Table 1 summarizes the amount of pollution removed by the wastewater treatment system in placed in the municipalities. The IDEAM estimates that around a third of BOD and COD is removed, and that around half of the pollutants discharged by the industry is removed while less than 20% of the pollutants discharge by the domestic sector is removed.

Table 1

Parameter	Domestic and Industry load (kg)	Domestic and Industry discharges (kg)	Quantity removed (kg)	% removed
BOD	1,085,127,286	736,296,107	348,831,179	32.1%
COD	2,411,886,881	1,648,621,034	763,265,847	31.6%
TSS	1,517,405,973	1,119,062,421	398,343,552	26.3%
N	128,890,983	126,345,302	2,545,681	2.0%
P	32,465,812	31,915,345	550,467	1.7%

Source: National Water Study (IDEAM, 2014)

1.1.1. Regulatory framework

Due to this context, the country developed an institutional framework to achieve a reduction in the amount of pollution generated and discharged into water sources. First, the central government designed policies guiding the coordination of environmental management among national, regional and local entities, and defined common objectives (SSPD 2013). Second, the central government also made efforts implementing a regulatory framework related to the wastewater treatment including acts to regulate wastewater discharges, and defining instruments (economic, management and institutional) to execute the policies for this sector.

Regarding the institutional framework, the country defined a structure to design, implement and regulate the domestic wastewater treatment. At the national level, there are three entities coordinating efforts. The first institution at the central level is the Ministry of Environment and Sustainable Development – MADS (by its Spanish name), which has traditionally coordinated the environmental policy in Colombia. The MADS dictates the general framework for the preservation and restauration of natural resources through the Natural Resources National Code (Executive order 2811, 1974)[3] that defines wastewater treatment plants as instrumental in order to preserve the water resources in Colombia; implements a national system to deal with environmental issues, and defines its own functions, as well as other decentralized entities functions such as Environmental Regional Authorities (Act 99, 1993).

Within its functions, this ministry defined the parameters required for wastewater treatment management plans – PSVM (by its Spanish name) and included these plans as a part of the licensing process for those entities in charge of the wastewater treatment management (Res. 1433, 2004). Similarly, it delegates the approval of the PSVM, and licensing process into the Environmental Regional Authorities, and environmental units within the municipalities[4]. Moreover, the MADS established technical guidelines for wastewater treatment management in Colombia (Res. 1096, 2000), where it describes the minimum requirements that the process of design, construction, technical supervision, operation, and maintenance of wastewater treatment systems in Colombia must follow (MADS 2000).

The MADS also defines the retributive rate for direct and indirect use of water to discharge pollution. In 2011, the central government established: 1.) that retributive rates and compensations apply too for pollution levels above the limits permitted without exclusion of any other preventive or sanction measure, and that the payment of such retributive rates do not legalize the discharges object of sanction; and 2.) that the resources collected by the charge of the retributive rates and compensations will be allocated to wastewater treatment projects, decontamination projects, and water quality monitoring projects (Act 1450, 2011). In this way, the MADS defines the guidelines to establish load pollution limits, the process of control of such limits, and defines the parameters to calculate the retributive rate for discharge points (Executive order 2667, 2012).

[3] Part III, Title VI. Water uses, conservation, and preservation of water bodies. Chapter II Prevention of pollution and pollution control. Art. 134-148.
[4] Municipalities with population greater or equal to 1 million.

Finally, according to the National Social and Economic Policy Council (Conpes 3177, 2002), the MADS prioritizes the municipalities to invest in a two-step process. First, the MADS prioritizes investments in wastewater treatment plants using a set of minimum conditions:

1. Municipalities where the discharges produce a substantial negative impact, considering the receptor water body assimilation capacity and its effects on public health;
2. Municipalities with sewer coverage above 80% and that have built, or have resources guaranteed to build interceptors, collectors and final emissaries of their systems;
3. Municipalities with water supply systems that include potabilization plants;
4. Municipalities that, by Act 142, 1994, guarantee the financial, operational and institutional strength of their systems.

Second, the MADS prioritizes municipalities based on additional criteria:

1. Municipalities where the receptor water body is the water source for water supply systems downstream from the discharge point(s)
2. Municipalities, that from a basin perspective, represent major benefits on the recovery and use of the water resource;
3. Projects with a higher reduction of pollutant load by Peso ($) invested
4. Projects that formulate the re-use of wastewater

The MADS dictates technical norms and regulations in coordination with other ministries. The second entity at the central level is the Ministry of Health and Social Protection – MSPS; this ministry dictates public health and sanitary norms and regulation as well as controls water quality for different uses. The MSPS is responsible to establish what uses, that produce or could produce water pollution, will require its authorization before asking for authorization from the local environmental authority for the use of the resource. Similarly, the MSPS defines the desirable and admissible characteristics for water bodies as a measure of sanitary control, this is, the discharge of pollutants to the water bodies must be adjusted to the rules defined by this ministry (Act 9, 1979). The MSPS defines the water quality criteria, uses and destinations for water bodies, and the rules regarding pollutant discharges into water bodies, establishes minimal requirements for discharge points and gives guidelines for discharge permits, discharge plans, and the record of the discharges (Executive order 1594, 1984).

Finally, the third institution at the central level is the National Planning Department – DNP, which supports the assessment and formulation of policies, plans and projects within multiple sectors including the wastewater treatment sector. Through the Social and Economic Policy Council – Conpes, the DNP contributes to the design of the National Plan for Wastewater treatment management looking to make viable the policies within this sector (DNP, MADS, and MDE 2002), defining funding sources for these projects as well as addressing the financial resources from the General National Budget to investments in wastewater management according to the priorities defined by the MADS.

Similarly, at the regional level there are two entities. The Department (state) participates in the planning process, and gives technical and financial assistance to municipalities and entities in charge of the wastewater treatment (MADS 2004). The environmental regional authority executes the national decontamination policies. As we have mentioned, the MADS delegates into the environmental regional authorities the approval of PVMS, and the designation of licenses for wastewater treatment plants, define regional discharge limits, in its region (Act 99, 1993). At the local level, the municipality must assure provision of efficient sewer systems (directly or through private agent), and invest own resources in water related including wastewater treatment projects.

These entities coordinate actions to achieve the objective of reducing pollution levels on water bodies. The central government, through the three entities described above, has designed and enforced regulations related to environmental protection, national sanitary code, water quality and dumping; it has also provide technical norms for the wastewater treatment management sector, has implemented retributive rates for direct and indirect use of water to discharge pollution, and has delegated into the environmental regional authorities and municipalities functions including approving PSMV plans and licensing for wastewater management, while still keeping some controls.

4.. Conceptual Framework

This section constructs a conceptual framework assessing the effects of transboundary spillovers on environmental abatement effort. We consider the situation of one country with three different levels of government: central, departmental, and municipal. Departments represent regional government entities. The country includes one central government, multiple departments, and multiple municipalities. Some departments lie within the interior of the country, while other departments lie on the country's border. Similarly, some municipalities lie within the interior of a given department, while other municipalities lie on a given department's border.

Municipalities discharge wastewater into rivers that flow from one municipality to the next and from one department to the next until the river crosses an international border or empties into an ocean (or sea). Given this directional flow, we label certain municipalities as upstream or downstream from others and certain departments as upstream or downstream from others. For simplicity, we consider a single river that flows across the entire country. Moreover, we consider two categories of departments: (1) upstream, interior department and (2) downstream, border department. Similarly, within each department, we consider two categories of municipalities: (1)

upstream, interior municipality, and (2) downstream, border municipality. Combining these two sets of categories, we consider four types of municipalities:

(1) upstream, interior municipality within an upstream, interior department;

(2) downstream, border municipality within an upstream, interior department;

(3) upstream, interior municipality within an upstream, border department; and

(4) downstream, border municipality within an upstream, border department.

Our conclusions generalize to consideration of an array of rivers and arrays of municipalities and departments as defined by their position within the country relative to the rivers' directional flows.

Municipalities are able to engage in abatement to lower their discharges, denoted as a. Each government entity plays its role in promoting these efforts. The municipal government invests its own resources into abatement, denoted as a_m. The central government transfers resources to municipal governments, denoted as a_g. The central government also expends regulatory efforts, denoted as q, to induce greater abatement from municipalities. These regulatory efforts include the provision of permits, imposition of discharge limits, conducting of inspections, and application of fines. Departmental governments also transfer resources to municipalities for wastewater abatement, denoted as a_d. Departmental governments also offer technical assistance to municipalities, denoted as η.

The amount of resources allocated to abatement comes from three sources: municipal government's own investment (a_m), departmental transfers (a_d), and central government transfers (a_g). Total abatement effort is as follows: $a = a_m + a_d + a_g$.

This conceptual framework explores how the central government and departmental governments decide how many resources to transfer, how much regulatory effort to expend, and how much technical assistance to offer.

4.1.. Central Government and Municipal Government

For expositional purposes, we first consider the case of two government levels: central government and municipal. Thus, we remove the departmental level. The central government objective is to maximize central net benefits of abatement, denoted Π_c. The benefits of abatement divide into three categories: internal to both the municipality and the central government, denoted $v(a)$ ("internal-internal"), external to the municipality but internal to the central government in certain cases, denoted $w(a)$ ("external-internal"), and external to both the municipality and the central government, denoted $z(a)$ ("external-external"). The internal-internal benefits differ between the interior municipalities i and the border municipality b, as described below. The cost of abatement is denoted $k(a)$. We assume that the internal-internal benefits and the abatement costs do not differ between the interior and border municipalities: $v_i(a) = v_b(a)$ and $k_i(a) = k_b(a)$. Based on these definitions, social net benefits are shown in equation (1):

$$\Pi = v(a) + w(a) + z(a) - k(a) \quad (1)$$

Municipalities seek to maximize municipal net benefits, denoted Π_m, which exclude external benefits. Consider interior municipality i. The municipality enjoys only one internal benefit, $v(a)$; the other benefits, $w(a)$ and $z(a)$, are external to the municipality. In this case, independent of transfers, the interior municipality identifies its optimal level of abatement effort denoted $a_{mi}*$, where municipal net benefits are maximized:

$$\frac{d\Pi m}{da} = 0 ==> \quad \frac{dv}{da} = \frac{dk}{da} \quad (2)$$

However, the central government's net benefits, Π_c, are broader for the interior municipality because the central government cares about the benefits enjoyed by the downstream border municipality. Thus, central net benefits for the interior municipality are shown as follows:

$$\Pi ci = v(a) + w(a) - k(a) \quad (3)$$

Given this broader set of net benefits, the centrally optimal level of abatement for the interior municipality, denoted $a_{ci}*$, is based on this condition:

$$\frac{dv}{da} + \frac{dw}{da} = \frac{dk}{da} \quad (4)$$

Now consider border municipality b. Again the municipality enjoys only internal benefits, $v(a)$. The municipality identifies the municipally optimal abatement level, denoted $a_{mb}*$, based on this condition:

$$\frac{d\Pi m}{da} = 0 ==> \quad \frac{dv}{da} = \frac{dk}{da} \quad (5)$$

The central government enjoys the same benefits because the other benefits are external to the central government. The central government sets the centrally optimal level of abatement for the border municipality, $a_{cb}*$, as follows:

$$\frac{dv}{da} + 0 = \frac{dk}{da} \quad (6)$$

As a reference, the social planner seeks to maximize social net benefits. For the interior municipality, the social planner sets the marginal net benefits of abatement to zero. For an interior municipality, this condition identifies the socially optimal abatement, denoted a_i*: $\frac{dv}{da} + \frac{dw}{da} + \frac{dz}{da} - \frac{dk}{da} = 0$. For a border municipality, this condition identifies the socially optimal abatement, denoted a_b*: $\frac{dv}{da} + 0 + \frac{dz}{da} - \frac{dk}{da} = 0$.

In conclusion, for an interior municipality, the municipally optimal abatement level is lower than the centrally optimal abatement level, which is lower than the socially optimal abatement level:

$$a_{mi}^* < a_{ci}^* < a_i^* \, . \qquad (7)$$

For a border municipality, the municipally optimal abatement level equals the centrally optimal abatement level, which is lower than the socially optimal abatement level:

$$a_{mb}^* = a_{cb}^* < a_b^* \, . \qquad (8)$$

Comparing equations (4) and (6) reveals that the central government values differently abatement for the interior municipality and the border municipality. The centrally optimal abatement level for the interior municipality exceeds the centrally optimal abatement level for the border municipality:

$$a_{ci}^* > a_{cb}^* \, . \qquad (9)$$

As important, equation (7) reveals a decision-making conflict for the interior municipality. Left to its own devices, the interior municipality expends less abatement effort than the amount desired by the central government.

Given this decision-making conflict, the central government transfers resources to the interior municipality, denoted a_{gi}, so that abatement effort rises directly, and/or apply regulatory pressure on the interior municipality, denoted, q_i, so that the interior municipality is induced to increase its own abatement effort. We first assume that the central government is only able to transfer funds. Under this assumption, the central government transfers a_{gi}* so that the sum of abatement equals the centrally optimal level, a_{ci}^*:

$$a_{ci}^* = a_{mi}^* + a_{gi}^* \, . \qquad (10)$$

This transfer resolves the discrepancy between a_{ci}* and a_{mi}*.

Now assume some institutional matter constrains direct investments so that the following condition holds:

$$a_g \leq \bar{a}_g \, . \qquad (11)$$

This constraint does not bind the central government's transfer unless the following condition holds:

$$a_{gi}^* > \bar{a}_g \, . \qquad (12)$$

Given this binding constraint, the central government chooses to expand regulatory efforts q_{ci}* in order to reach a_{ci}^* conditional upon the transfer of a_{gi}*. As long as transfers involve only minimal transactions costs, while regulatory pressure clearly involves real costs, e.g., the central government must hire inspectors. If regulatory pressure were costless, the central government still seeks to obtain the centrally optimal abatement level of a^*_{ci}. Of course, as the costs of regulatory pressure, the centrally optimal abatement level falls below a^*_{ci}. For simplicity, we assume that regulatory pressure is nearly costless.

We next focus on the interior municipality's decision in light of regulatory pressure. Regulatory pressure imposes costs on municipality, denoted x. This regulatory cost rises as the central government applies more pressure so x is a rising function of q. Moreover, the central government applies more pressure when the municipality expends less effort, a_m. Given these connection, we define regulatory costs as this function: $x[q(a_m)]$. Thus, the municipality's net benefits equal the following:

$$\pi_m = v(a) - k(a) - x\big(q(a_m)\big) \tag{13}$$

Knowing that the central government applies more regulatory pressure, which increases the municipality's regulatory costs, when the municipality's abatement investment is lower, the municipality chooses to expend greater abatement effort in order to avoid these regulatory costs. Thus, the chosen extent of abatement is rising in regulatory pressure:

$$\frac{da^*_{mi}}{dq} > 0 \tag{14}$$

The appendix describes the situation where the central government cares about the discharges generated by the municipalities, imposes limits on these discharges, and applies fines for discharges that lie above these limits.

We utilize equation (13) to derive the municipality's privately optimal choice of abatement, a_{mi}*, when facing regulatory costs:

$$\frac{dv}{da} - \frac{dx}{da} = \frac{dk}{da} \tag{15}$$

If $q_i = q_i{}^*$ then the central government is able to induce the centrally optimal abatement level:

$$a^*_{mi} + \overline{a}_g = a^*_{ci} \tag{16}$$

where a^*_{mi} is a function of regulatory pressure and the constraint on central transfers is binding.

In this case, the central government influences abatement in two ways: transfers resources for abatement equal to the constraint, $a^*_{gi} = \overline{a}_g$ and applies the amount of regulatory effort needed to induce the centrally optimal abatement level, $q_i{}^* > 0$.

In contrast, for the border municipality, the central government transfers no resources for abatement, $a*_{gb}= 0$ and applies no regulatory pressure, q^*_b =0, because the level of abatement chosen by the border municipality equals the centrally optimal abatement level, $a_{mb}* = a_{cb}*$. Thus, abatement by the interior municipality exceeds abatement by the border municipality:

$$a_i = a_{mi}^* + \bar{a}_g > a_{mb}^* = a_b \tag{17}$$

Moreover, central transfers to the interior municipality exceed central transfers to the border municipality:

$$a_{mi}^* > a_{mb}^* \tag{18}$$

And regulatory pressure against the interior municipality exceeds regulatory pressure against the border municipality: $q_i* > q_b* = 0$.

4.2. Department Government and Municipal Government

For this sub-section, we assume that the central government plays no role. This new situation only involves the department government and two municipalities: one municipality interior to the department (interior municipality i) and one municipality on the border of the department (border municipality b). We construct a setting in which the departmental government plays a role nearly identical to the central government. The only difference involves the tools available to the departmental government. Bothe the central government and departmental government are able to transfer resources for abatement by the municipality. However, unlike the central government, the departmental government is not able to apply regulatory pressure; instead, the departmental government can only provide technical assistance.

The departmental government maximizes its departmental net benefits, denoted Π_d. this maximization identifies the departmental government's optimal abatement level, denoted $a_{di}*$. In the absence of technical assistance, the department optimally transfers to the interior municipality resources, denoted $a_{ri}*$, so that the total amount of abatement equals the departmentally optimal amount:

$$a_{mi}^* + a_{ri} * = a_{di}^* \tag{19}$$

In contrast, the department government transfers no resources to the border municipality, $a_{rb}*$, since the chosen level abatement equals the departmentally optimal level: $a_{mb}* = a_{db}*$.

Thus, within a department, the interior municipality's chosen abatement level lies below the departmentally optimal abatement level, which lies below the socially optimal abatement level:

$$a_{mi}^* < a_{di}^* < a_i^* \tag{20}$$

More important, the interior municipality's departmentally optimal abatement level lies below the border municipality's departmentally optimal abatement level:

$$a_{db}^* < a_{di}^* \qquad (21)$$

However, institutional arrangements may constraint the amount of transfers from the departmental government to the two municipalities: $ar \; =< \; ar\sim$. This constraint binds for the interior municipality if this condition holds:

$$a_{di}^* > \overline{a}_r \qquad (22)$$

Obviously, this constraint cannot bind the transfer to the border municipality.

Given this constraint, the department chooses also to offer technical assistance, denoted η. This technical assistance facilitates the municipalities' abatement efforts. To demonstrate this point, we modify the abatement cost function so that it depends on technical assistance: *k(a,η)*. Abatement costs are still increasing in a but now decreasing in η. More important, *marginal* abatement costs, denoted as *MAC* and captured by $\partial k/\partial a$, are decreasing in technical assistance, i.e., $\frac{\frac{\partial k}{\partial a}}{\partial \eta} < 0$.

We modify the municipality's objective function to reflect the modified abatement cost function:

$$\pi_m = v(a) - k(a,\eta) \qquad (23)$$

In order to demonstrate the role of technical assistance, we capture the marginal value of abatement to the municipality as MV = dv/da. The municipality identifies its privately optimal choice of abatement, a_m*, by setting MV = MAC. As technical assistance increases, MAC falls; consequently, the privately optimal amount of abatement rises, i.e., as η rises, a_m* increases. Figure 3 captures this relationship between technical assistance and the municipality's chosen abatement level.

To accommodate the department's use of technical assistance, we modify the department's net benefits of abatement:

$$\pi d = v(a) + w(a) + z(a) - k(a,\eta) \qquad (24)$$

If η is nearly costless, the department government still wishes to reach the previously identified optimal abatement level, a_{di}*, by offering the necessary technical assistance, denoted η_i*. If technical assistance is costly, then the departmentally optimal abatement level when technical assistance is costly, denoted $a_{di}^{*\prime}$, exceeds the departmentally optimal abatement level when technical assistance is costless, a_{di}^*. Consequently, the departmental government offers less technical assistance than η_i*, which implies the interior municipality chooses to employ less abatement, denoted $a_{mi}^{*'}$, so that $a_{mi}^{*'} + \overline{a}_r = a_{di}^{*'} < a_{di}^*$. Regardless of the costs of technical assistance, we can safely conclude that the departmental government offers some positive amount of technical assistance to the interior municipality, which clearly exceeds the amount of technical assistance offered to the border municipality, which equals zero.

4.3. Interaction between Central Government and Departmental Government

For this sub-section the three level of government interact. First, the municipality chooses $a_{m;}$ second, the department chooses a_d, and the level of technical assistant to municipalities (η); and third, the central government chooses a_g and the level of regulatory efforts (q).

As mentioned above, within a department the interior municipality's chosen abatement level lies below the departmentally optimal abatement level ($a_{mi}^* < a_{di}^* < a_i^*$). This regardless its location relative to the international border. Therefore, for any department $a_{db}^* < a_{di}^*$ holds. Moreover, considering the technical assistance choice by the department we concluded that the departmental government offers some positive amount of technical assistance to the interior municipality, exceeding the amount of technical assistance offered to the border municipality.

Meanwhile, the central government optimal abatement level is greater than the optimal abatement level of an interior municipality, regardless its department location relative to an international border ($a_{mi}^* < a_{ci}^* < a_i^*$), even when it comes to regulatory pressure the central government decision favors the abatement levels of interior municipalities relative to border municipalities ($q_i* > q_b*$ and $a_{mi}^* > a_{mb}^*$).

Focus on a particular interior department. We have that $a_{db}^* < a_{di}^*$. In this case, the central government optimal abatement level for the border municipalities equals the department optimal abatement level ($a_{db}^* = a_{cb}^* = a_{mb}^*$). A similar situation occurs with the optimal abatement level in interior municipalities within this interior department. Then, ($a_{ci}^* > a_{mi}^* > a_{mb}^* = a_{cb}^*$).

Focus next on a particular border department. We know that $a_{db}^* < a_{di}^*$. The central government optimal abatement level for the border municipalities equals the optimal abatement level ($a_{db}^* = a_{cb}^*$). Now, for the case of the interior municipalities the central government optimal abatement level may not follow the same pattern, considering that these interior municipalities are located at a border department. Assuming the central government favors interior locations more than border locations, in terms of abatement levels and regulatory efforts; then for a border department we have $a_{mi}^* < a_{ci}^* < a_{di}^*$. In other words, optimal abatement levels and optimal regulatory effort levels are greater for interior departments than the optimal abatement, and optimal regulatory efforts in at a border department.

Hence, given that the central government prioritizes interior location over closeness to an international border and considering that departments optimize both the abatement level (a_{di}^*, a_{db}^*), and the technical assistance provided to the municipalities, regardless of their location relative to international borders, we have a relationship summarized in Figure 4.

5.. Empirical Strategy

This study analyzes the effect of location relative to borders on municipal investments into wastewater treatment management. To do so, we assess the water related investments at the municipal level in 1,120 municipalities in Colombia from 2000 to 2013. First, we identify municipalities located at the border or at the interior of a department (state), as a discrete explanatory variable to identify differences in the amount of water related investments. Second, we use a continuous measure of distance to explain differences on investment levels. For both cases, we expect that the location of the municipality relative to a border have an impact on the amount of investments on wastewater treatment management.

5.1. Sample Selection and Data

Using different data sources, we assemble a panel data including information for municipalities 1120 in Colombia for the period 2000–2013 (Table 1B). We are interested in the investments allocated to water related issues by municipality. The Colombian Ministry of Finances and the National Department – DNP, annually collect this data, along with data on municipal revenues. The Center for Development Studies – CEDE affiliated to the Universidad de los Andes built a panel for municipal budgetary information using these inputs. Similarly, CEDE assembles a panel with demographic variables for municipalities using Census data from the National Statistics Department from Colombia – DANE. Finally, we consult conflict and violence data assembled by CEDE and the Conflict Analysis Resource Center – CERAC, based on official sources (National Police, National Army, and Ministry of Defense), and primary information respectively.

We also use data from the Hydrology and Meteorology Institute (IDEAM) and the Geographic Institute (IGAC), to gather geographic information on Water bodies (water streams, rivers, basins), and municipal and departmental boundaries. These are the inputs to define the location of each municipality with respect to a department border or an international border.

First, we define the set of main rivers that we include within our sample. Based on the criteria, and information publicly provided by IGAC, we use a set of 124 rivers, joining two sets of water streams information: double drainage and simple drainage.[5] Second, using IGAC and IDEAM definitions on the main hydrological regions and minor basins in Colombia, we identify flow direction. Third, using the water flow direction we identify a border for each department as a

[5] See Table 2B in the Appendix.

reference point to measure a distance from the municipality until the point where the main river abandons the department toward the next. Similarly, we identify an international border for each hydrological region where the river abandons the country toward other country or the oceans.

After defining the set of rivers and joining this information with the municipal and department boundaries, we propose to use a concept of distance that relates the municipal border to the departmental border, as well as an international border. At this step, we seek to answer these three questions: (1) does the municipality lies along a departmental border?, (2) is the municipality located upstream or downstream of a waterway? and (3) does this municipality lie along an international border?

Figure 5 shows our categorization of each municipality within these definitions. We consider not only their location relative to the department border, but also the river flow direction. Consider a country formed by four departments, and several municipalities within each of these, and consider a river flowing left to right crossing the country from northwest to southeast. Under these conditions, a municipality located in the Department A is upstream of any municipality located at Department B and Department D. Within a Department A, municipality A2 is upstream and interior, meanwhile municipality A1 is downstream A2, and at the border of Department A. In this case, the benefit of allocating wastewater treatment resources within department A is higher at the interior of the department, in other words in municipalities like A2, than at the border in A1 and similar municipalities. Department B faces a similar situation regarding their own municipalities. In this case, B2 is likely to receive more support from the Department government than B1.

These definitions are helpful to understand the hypotheses previously stated in the conceptual framework. First, from the department A and B examples, we see that departmental governments send greater amount of resources when the municipality is located upstream (in-department) relative to municipalities downstream (on-border); Second, the central government earmarks for investments in wastewater treatment increases when the municipality is located upstream (in-country). In general, we argue that the amount of environmental investments, in other words wastewater treatment, is greater as the distance from the municipality to the department border or to the international border increases.

5.2. Empirical Specification

This study examines the effect of location, relative to a border, on the municipal wastewater management investments in Colombia. Let y_{it} denote the environmental investment made by a municipality i at time t. Let Di and I_i represents distance measurements relative to a department border and an international border respectively. First, we estimate the effect of distance on municipal investments, but then, there are additional covariates that we assume can affect municipal environmental investments X_{it}, as well as regional characteristics (r_i), municipal categories (c_i) and time specific characteristics (t_t). Therefore, the more general specification for our model is given by the following equation:

$$y_{it} = \alpha + \beta_1 D_i + \beta_c I_i + \gamma X_{it} + \sigma r_i + \delta t_t + c_{it} + \varepsilon_{it} \ . \quad (25)$$

Our set of estimations include all wastewater related municipal investments, and include as controls general municipal characteristics (Gross Domestic Product, Population, Land area and altitude), budget variables (tax revenues, transfer revenues and capital revenues), and includes dummies for presence of minorities within the municipality, and presence of conflict in the municipality.

As alternative specifications, we assess a non-linear effect of the distance on the wastewater management investments. First, we include a quadratic term for both the department and the international distance.

$$y_{it} = \alpha + \beta_1 D_i + \beta_2 D_i^2 + \beta_3 I_i + \beta_4 I_i^2 + \gamma X_{it} + \sigma r_i + \delta t_t + c_{it} + \varepsilon_{it} \quad (26)$$

Likewise, we create splines for the distance measures to check whether the effect of distance differs across splines. Therefore, the effect of distance for those municipalities located at a distance in the first spline (D^{*}_{i}) is given by β_1, the effect for those municipalities located within the second spline (D^{**}_{i}) is given by $\beta_1+\beta_2$, and the effect for those municipalities located in the third spline (D^{***}_{i}) is given by $\beta_1+\beta_2+\beta_3$. A similar logic follows for the international distance splines:

$$y_{it} = \alpha + \beta_1 D_i^{*} + \beta_2 D_i^{**} + \beta_3 D_i^{***} + \beta_4 I_i^{*} + \beta_5 I_i^{**} + \beta_6 I_i^{***} + \gamma X_{it} + \sigma r_i + \delta t_t + c_{it} + \varepsilon_{it} \ . \quad (27)$$

6.. Empirical Results

To understand how the relative location of a municipality can affect the amount of investments on wastewater management, we estimate a set of models assessing the effect of distance relative to a domestic or to an international border. We present first different estimations including as explanatory variable the distance to a department border. Second, we estimate adding a distance to an international border within these estimations; and finally, we create splines to check for non-linear effects of the distance on municipal investments.

a) Location relative to a Department border (domestic border)

Table 1C show that the distance with respect to a Department border has an effect on the investments in wastewater treatment on the municipalities. Column 1 does not include controls for general characteristics, budget variables or any dummy for region or time effects, and indicates that an increase in 1 km in the distance relative to the border reduces the investments by 9.6%. Column 2 adds measure for general characteristics such as Gross Domestic Product, population, land area and altitude, as well as fixed effects for region and time, and the effect of distance changes to an increase in 4.1% the investments on wastewater treatment management. Column 3 includes budget variables (tax revenues, transfer revenues, and capital revenues) and drops to 3.0%. Columns 4 and 5 include a variable for municipal category, which is an indicator summarizing population and total revenue, and shows on average an effect of 2.2% increase in the municipal investments as the distance increases. The OLS estimates in table 1C are therefore consistent with the hypothesis that the wastewater treatment management investments in a municipality are positively affected by the location (distance) relative to a department (domestic) border.

Table 2C shows that the location at a department border has an effect on the investments in wastewater treatment on the municipalities. Similar to the continuous case, column 1 indicates that a municipality located at the border of a department has a positive and significant effect on the municipal investments on wastewater treatment management. However, Columns 3, 4, and 5 reveal a negative effect for those municipalities located at the department border on the wastewater investment.

b) Location relative to a Domestic and an international border

Table 3C shows that when including the distance to the department border (domestic) and the distance to the international border (international), the distance to the department border influences the investments in wastewater treatment on the municipalities, but the effect of the international border vanishes. Column 1 shows a first estimation that does not include any control, and indicates that the effects of both distances are negative on the municipal investments on wastewater treatment. Column 2 includes general characteristics, regional dummies, and year dummies as controls, and shows that both distances have a statistically significant effect, however, when including additional controls the effect of the international distance vanishes, and the effect of the domestic distance remains positive meaning greater investments on wastewater treatment as the distance relative to the international border increases (columns 3-5). This OLS estimates in table 3 test the hypothesis that distance with respect to a department border (domestic) affects positively the wastewater management investments in a municipality.

c) Department and international border: quadratic form

As a robustness check, we estimate the effect of domestic and international distance on the investments in wastewater treatment on municipalities including a quadratic form. Table 5C

Column 1 does not include any control, and indicates that both distances, domestic and international, have a positive effect on the municipal investments on wastewater treatment management until a turning point where the effect becomes negative, supporting the hypothesis of decreasing investments at the margin. Column 2 includes general characteristics for the municipalities, as well as region and year dummies, and indicates that the effect of the international distance on the wastewater treatment management investments is positive and decreasing, similarly for the domestic distance. Columns 3-5 includes controls related to budget variables, and shows that domestic distances have a positive and decreasing effect on the municipal investments on wastewater treatment, meanwhile the international distance have a negative effect and increasing.

d) Domestic and international border: Splines

As a second robustness check, we create splines using the measures of distance both to the domestic and the international border. To verify the nonlinear effect of distance on the municipal investments, we divide the distance measures into three knots using a linear spline, so we can estimate the effect of different distances on the municipal investments on wastewater treatment.

Regarding the distance with respect to the department border, we define three knots. First, municipalities located in a distance lower than 50 kms from the department border; second municipalities located within 50-100 kms; and third, municipalities located farther than 100 kms from the department border. Similarly, we define three knots for the international distance, starting with departments located within a distance lower than 200 kms, following departments with a distance within 200-300 kms, and finally, departments located at a distance greater than 300 kms.

Table 6C show the results for \the domestic distance, column 1 indicates a negative effect for those municipalities located at less than 50 kms (0.42%), meanwhile the effect of the distance for municipalities within 50-100 km is still negative (-0.28%), and those municipalities located at a distance greater than 100 kms is positive (0.12%); Column 2 includes controls for general characteristics, and region and year dummies, and indicates no effect of the distance for the municipalities located at a distance less than 50 km of the department border, but a positive effect for the other two knots. Columns 3-5 add budgetary variables as controls, and indicate a negative effect on those municipalities located more than 100 km from the department border;

Meanwhile for the international distance (table 6C), column 1 indicates that those municipalities located less than 200 kms experiment a positive effect on municipal investments on wastewater management investments, but the sign of the effect reverses as for those located between 200 and 300 km, and those located more than 300 kms. Column 2 includes controls for general characteristics, region and year dummies, and indicates no statistically significant effect of the international distances on the municipal investments on wastewater management. Columns 3-5 add budgetary variables, other variables, and municipal categories as controls, and they indicate a negative effect on those municipalities located more than 100 km from the department border; however, for the international distances they indicate a negative effect for those located less than 200 km from the international border, but a positive effect for those located within 200-300 km, and those located more than 300 km from the international border.

In sum, distances have an effect on wastewater management investment at the municipal level. This impact is consistent when it comes to distance relative to the department border, using a continuous measure, as well as it confirms the expected effect a binary measure for the location (interior or border). If we include the international distance measure, the effect of the distance to a departmental border remains significantly positive. Similarly, the significantly positive effect of the distance to a departmental border remains with the inclusion of quadratic terms. These results are consistent with the notion that intra-national governments induce municipalities located at an intra-national border to invest less in environmental management (Cai et al., 2016; Duvivier and Xiong, 2013). We do not reach the same conclusion for the measure of international distance. Although the effect proves significantly positive in the parsimonious model, significance vanishes once we include more control factors.

7.. Conclusions

This study analyzes the effects of location relative to a border on the municipal investments on wastewater management. In particular, it examines both the effect of domestic distances, and international distances at the municipal level in the country of Colombia. The analysis controls for municipal characteristics, such as GDP, population, land area and municipal altitude; budget variables including municipal tax revenues, transfer from other government levels, and municipal capital revenues; geographic regional effects and time effects. This empirical analysis examines municipal investments on wastewater management in the country of Colombia for the years 2000 to 2013.

Estimation of the effect of distances on municipal investments on wastewater management generates the following results. First, considering solely the measure of distance to a department border we find a positive and statistically significant effect. This means that for an increase in 1 standard deviation in the distance relative to a department border, the municipal investments increase on average 0.02 standard deviation. The positive effect of the distance to a department distance remains consistent after various specifications, and the inclusion of the international distance measure.

Second, considering the distance to an international border, the results are inconclusive. Although we expect a consistent and monotone relation between the distance to an international border and the investments on wastewater management, the significance of this measure vanishes when including additional controls such as municipal categories and budget variables.

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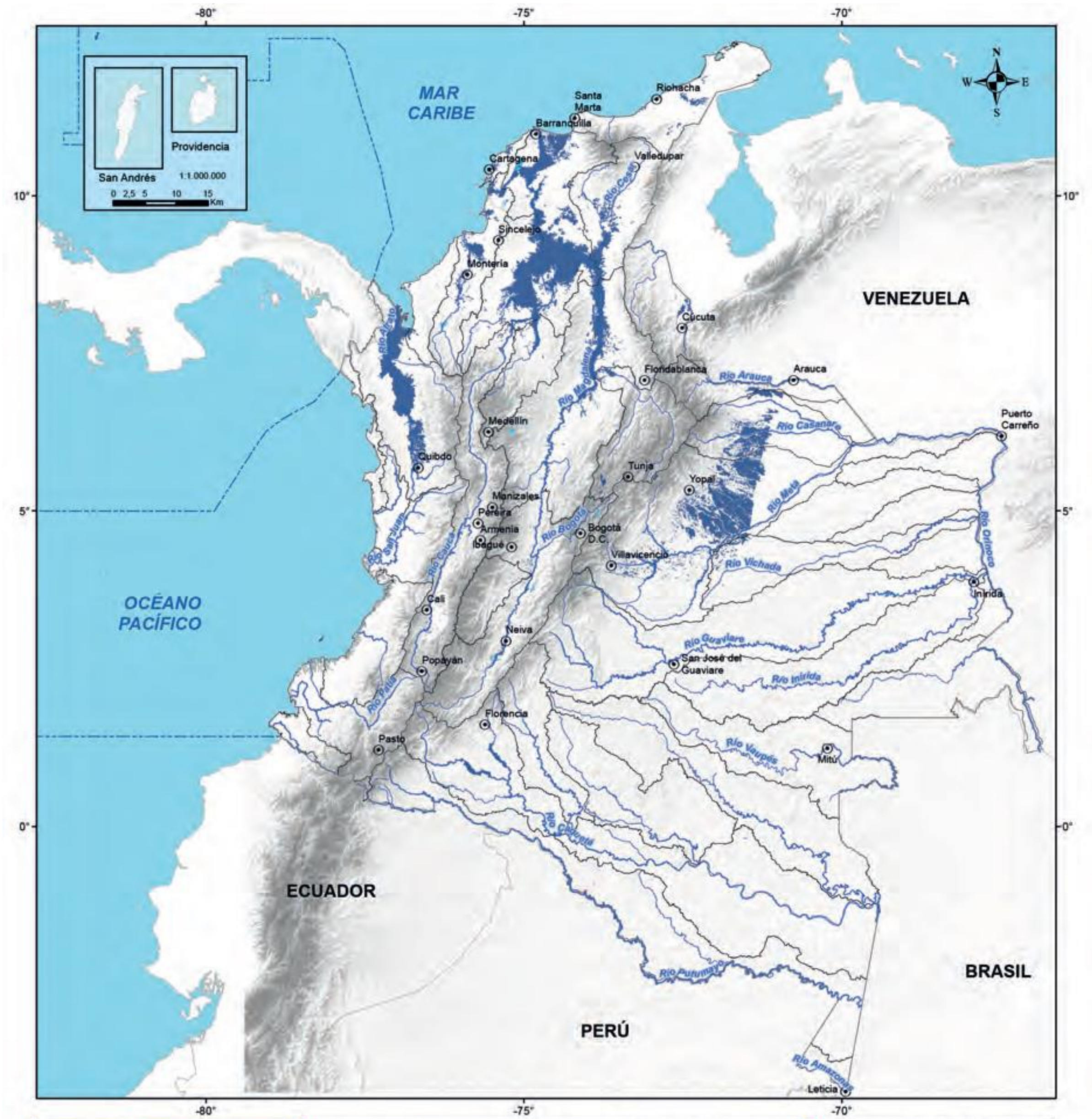
Figure 1

Major Rivers in Colombia



Source: IDEAM (2014)

Figure 2

Water Quality Index - Magdalena and Cauca Streams

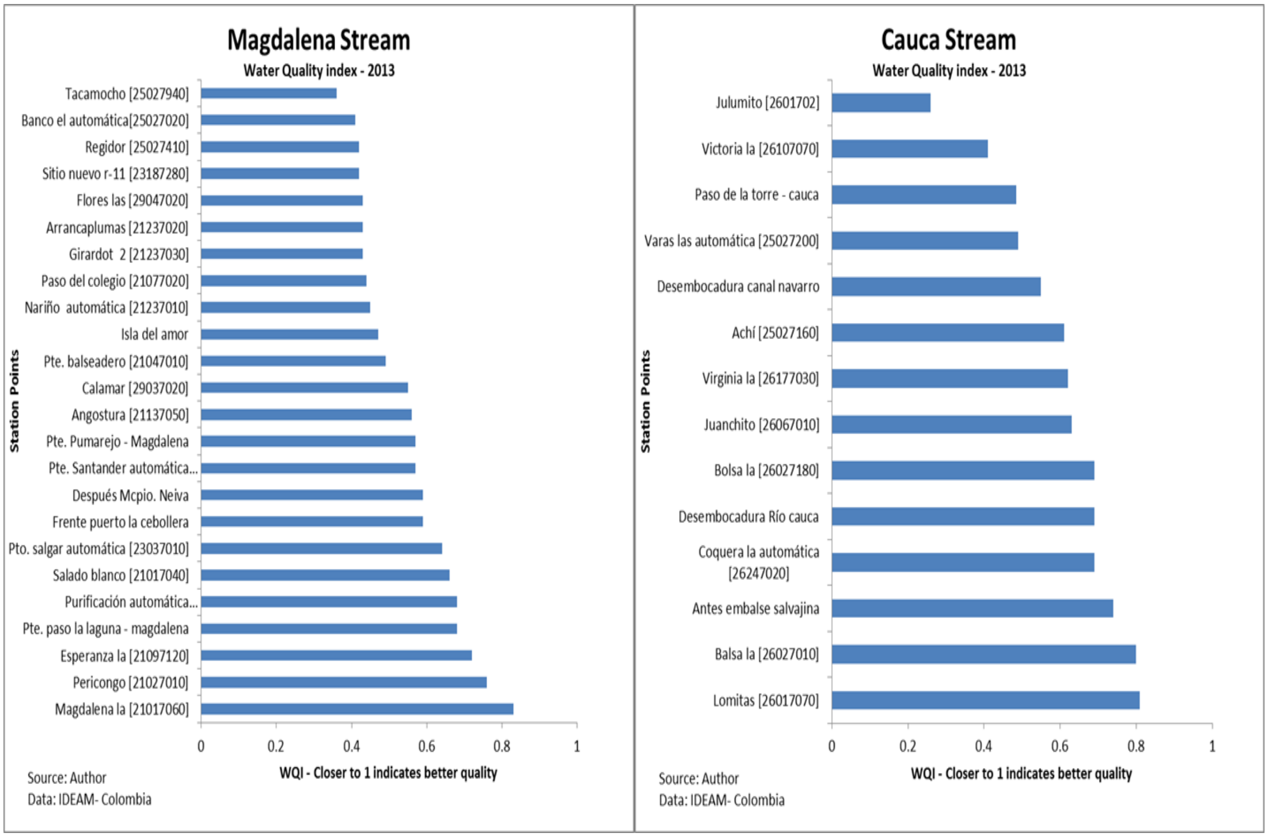


Figure 3

Investment and Technical Assistance

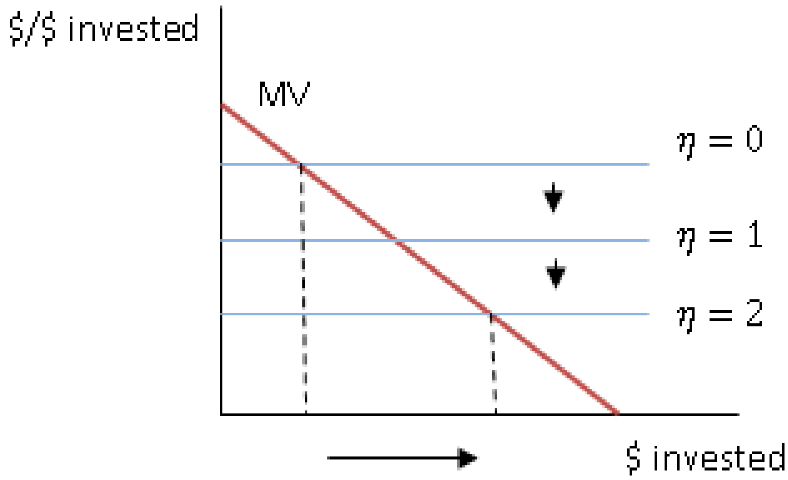


Figure 4

Hypotheses on Wastewater Treatment Level

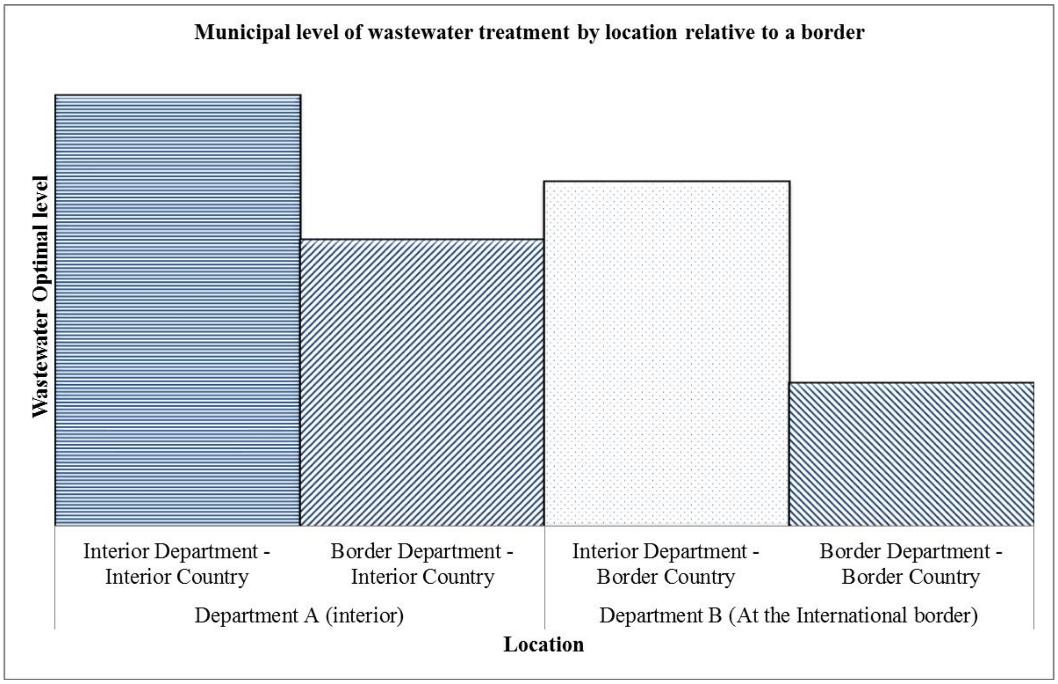


Figure 5

Categorization of Municipalities regarding Location

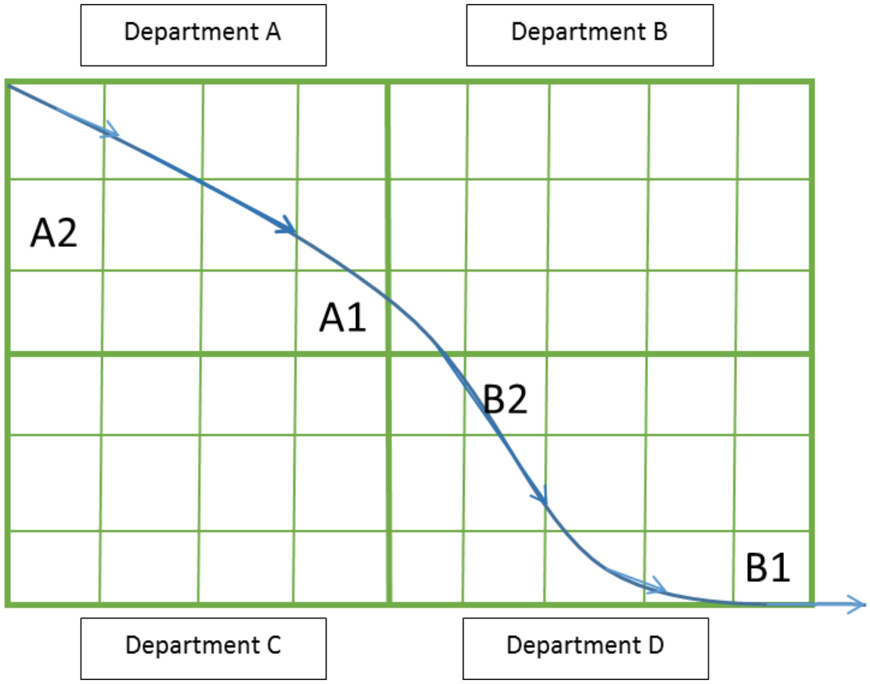


Table 2

Regulatory Framework

Executive Order 2811/1974	Natural Resources and Environment Protection National Code
Act 99, 1993	National Environmental System – SINA
Act 9, 1979	Sanitary National Code
Executive Order 1594, 1984	Water use and Dumping
Res. 1433, 2004	Wastewater treatment management plans – PSVM
Res. 1096, 2000	Technical Regulations Water Supply and Sanitation Sector –RAS
Executive order 2667, 2012	Retributive rates and contributions
Act 142, 1994	Public Utilities National Regime
Executive Order 3100, 2003	Stablish redistributive rates for environmental use
Res. 372, 1998	Stablishes the minimum for redistributive env. Rates
Executive Order 1180, 2003	Environmental licenses and permits

Source: National Plan for Municipal wastewater treatment – MVADT (2004)

Appendix

a) Appendix A. Conceptual framework:

The central government imposes a lower legal limit on the amount of abatement offered by the municipality, denoted *L*. If the municipality is caught falling below this legal minimum, the central government imposes a fine, denoted *F*, that represents a linear transformation of the difference between the municipal investment in abatement, a_m, and the legal abatement limit, L: $F = \alpha (L - a_m)$, where α is a positive constant. The municipality lowers the magnitude of this fine by investing more into abatement.

b) Appendix B. Data:

Table 3B. Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
All wastewater related municipal investments (log)	15,014	13.5984	1.00838	8.39309	21.5289
Distance to international border	15,400	422.196	277.73	0	872.202
Distance to department border	15,400	127.785	77.7554	0	428.956
Distance to international border (log)	12,936	6.05318	0.67949	4.02019	6.77102
Distance to department border (log)	14,980	4.6654	0.72676	1.79123	6.06136
GDP total (Log)	10,960	11.2735	1.28223	6.93638	18.4443
Population (Log)	15,364	9.56382	1.08291	6.63857	15.8534
Land area (Log)	15,400	5.76932	1.21467	2.70805	11.0925
Altitude (Log)	15,400	6.23188	1.76994	0.69315	10.1354
Tax revenues (log)	15,021	6.31476	1.67874	-3.5582	15.2227
Transfer revenues (log)	14,705	6.27394	0.63122	-5.7617	11.2627
Capital revenues (log)	15,038	8.49289	0.96884	3.17327	14.9111

Table 4B. Main Colombian Rivers defined by official sources

Colombian Rivers Considered			
RÍO USARAGA	RÍO CUSAY	RÍO MICAY	RÍO SAN JUAN
RÍO USARAGÁ	RÍO CUSIANA	RÍO MIRA	RÍO SAN LOPE
RÍO ABAQUÍA	RÍO DOCAMPADÓ	RÍO MULATOS	RÍO SAN LORENZO
RÍO AGUACATAL	RÍO DUDA	RÍO MURINDÓ	RÍO SAN MIGUEL
RÍO AMAZONAS	RÍO GAUAGUAQUÍ	RÍO MURRÍ	RÍO SAN PABLO
RÍO APAPORIS	RÍO GAZAUNTA	RÍO NARE	RÍO SANQUIANGA
RÍO ARAUCA	RÍO GIVIRU	RÍO NAYA	RÍO SATOCA
RÍO ARIARI	RÍO GUACAVÍA	RÍO NECHÍ	RÍO SEQUIHONDA
RÍO ATABAPO	RÍO GUAINÍA	RÍO NEGRO	RÍO SINÚ
RÍO ATRATO	RÍO GUAJUÍ	RÍO NULPE	RÍO SOGAMOSO
RÍO BAUDO	RÍO GUAMAL	RÍO OPÓN	RÍO SUCIO
RÍO BOJABÁ	RÍO GUAPE	RÍO ORDO	RÍO TAMANA
RÍO BONGO	RÍO GUAPI	RÍO ORINOCO	RÍO TAMBOR
RÍO BUBUEY	RÍO GUATIQUÍA	RÍO ORPUA	RÍO TAME
RÍO CAGUÁN	RÍO GUAVIARE	RÍO ORTEGUAZA	RÍO TANANDÓ
RÍO CAJAMBRE	RÍO GUAYABERO	RÍO PATÍA	RÍO TAPAJE
RÍO CALAFITA	RÍO GUAYAS	RÍO PATÍA VIEJO	RÍO TAPAJE VIEJO
RÍO CAQUETÁ	RÍO GUAYURIBA	RÍO PICHIMA	RÍO TARAIRÁ
RÍO CARARE	RÍO GUIZA	RÍO PORCE	RÍO TARAZA
RÍO CASANARE	RÍO HUMADEA	RÍO PURARE	RÍO TELEMBI
RÍO CATRIPE	RÍO HUMEA	RÍO PURRICHA	RÍO TIMBA GRANDE
RÍO CAUCA	Río IJUA	RÍO QUIPARADÓ	RÍO TIMBIQUÍ
RÍO CERTEGUI	RÍO ISCUANDÉ	RÍO QUITO	RÍO TIMBITA
RÍO CIMITARRA	RÍO LA CAL	RÍO RAPOSO	RÍO TOCARAGUA
RÍO COBARÍA	RÍO LA MIEL	RÍO ROSARÍO	RÍO TOLA
RÍO CRAVO NORTE	RÍO LA SIERPE	RÍO ROTAYA	RÍO TRAIRÁ (TARAIRÁ)
RÍO CRAVO SUR	RÍO LIMONES	RÍO SAIJA	RÍO TUA
RÍO CUBUGÓN	RÍO LOS URUIMES	RÍO SALDAÑA	RÍO UPÍA
RÍO CUCUANA	RÍO MAGDALENA	RÍO SAMANÁ	RÍO VAUPÉS
RÍO CUCUNA	RÍO META	RÍO SAN JORGE	RÍO VICHADA
Río CURBARADÓ	RÍO METICA	RIO SAN JUAN	RÍO YURUMANGUÍ

Source: National Geographic Institute- Colombia
Simple and Double drainage- Shape files
Recovered from: http://sigotn.igac.gov.co/sigotn/default.aspx

c) Appendix C. Results:

Table 1C Log-Log

OLS Estimates of the Effect of Location on Wastewater related municipal investments
Dependent variable: Log of Municipal water related investments

	(1)	(2)	(3)	(4)	(5)
Distance to Dept. Border (log)	-0.09647***	0.04174***	0.03033***	0.02254***	0.02221**
	[0.00000]	[0.00011]	[0.00048]	[0.00937]	[0.01425]
General characteristics		X	X	X	X
Budget variables			X	X	X
Other variables					X
Region Dummies		X	X	X	X
Year Dummies		X	X	X	X
Municipal Category Dummy				X	X
Observations	14,622	10,333	9,940	9,940	9,940
R-squared	0.00491	0.51850	0.67481	0.65278	0.65341

Robust pval in brackets

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

Note to table 1. P-values are in brackets. Data are from the Municipal Panel created by the Center for Development Studies – CEDE at Universidad de los Andes, using publicly available information from official sources, and include municipalities in Colombia between 2000 and 2013. General characteristics includes variables such as GDP, Population, land area and altitude; Budget variables includes tax revenues, capital revenues, and transfer revenues; and other variables include a dummy variable for the presence of land belonging to minorities within the municipality and a dummy variable for the presence of at least one irregular army.

Table 2C. Log-Log

OLS Estimates of the Effect of Location on Wastewater related municipal investments
Dependent variable: Log of Municipal wastewater related investments

	(1)	(2)	(3)	(4)	(5)
Dept. Border indicator	0.18967***	-0.00791	-0.03544***	-0.03052**	-0.03279***
	[0.00000]	[0.59026]	[0.00320]	[0.01118]	[0.00746]
General characteristics		X	X	X	X
Budget variables			X	X	X
Other variables					X
Region Dummies		X	X	X	X
Year Dummies		X	X	X	X
Municipal Category Dummies				X	X
Observations	15,014	10,605	10,195	10,195	10,195
R-squared	0.00838	0.51271	0.64486	0.64613	0.64680

Robust pval in brackets

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

Note to table 2. P-values are in brackets. Data are from the Municipal Panel created by the Center for Development Studies – CEDE at Universidad de los Andes, using publicly available information from official sources, and include municipalities in Colombia between 2000 and 2013. General characteristics includes variables such as GDP, Population, land area and altitude; Budget variables includes tax revenues, capital revenues, and transfer revenues; and other variables include a dummy variable for the presence of land belonging to minorities within the municipality and a dummy variable for the presence of at least one irregular army.

Table 3C Log-Log

OLS Estimates of the Effect of Location on Wastewater related municipal investments Dependent variable: Log of Municipal wastewater investments					
	(1)	(2)	(3)	(4)	(5)
Distance to Intl. Border (log)	-0.17672***	0.10859***	0.02311	0.02310	0.01481
	[0.00000]	[0.00001]	[0.24592]	[0.25295]	[0.54970]
Distance to Dept. Border (log)	-0.08116***	0.05574***	0.04686***	0.03724***	0.03624***
	[0.00000]	[0.00000]	[0.00000]	[0.00019]	[0.00025]
General characteristics		X	X	X	X
Budget variables			X	X	X
Other variables					X
Region dummies		X	X	X	X
Year dummies		X	X	X	X
Municipal category dummies				X	X
Observations	12,330	8,722	8,404	8,404	8,404
R-squared	0.01685	0.52278	0.66927	0.66911	0.66983

Robust pval in brackets

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

Note to table 3. P-values are in brackets. Data are from the Municipal Panel created by the Center for Development Studies – CEDE at Universidad de los Andes, using publicly available information from official sources, and include municipalities in Colombia between 2000 and 2013. General characteristics includes variables such as GDP, Population, land area and altitude; Budget variables includes tax revenues, capital revenues, and transfer revenues; and other variables include a dummy variable for the presence of land belonging to minorities within the municipality and a dummy variable for the presence of at least one irregular army.

Table 4C Log-Log

OLS Estimates of the Effect of Location on Wastewater related municipal investments Dependent variable: Log of Municipal wastewater investments					
	(1)	(2)	(3)	(4)	(5)
International Border Ind.	0.01145	0.33409***	0.33617***	0.39168***	0.53047***
	[0.94114]	[0.00003]	[0.00001]	[0.00000]	[0.00185]
Dept. Border indicator	0.01434	0.05174**	-0.01836	-0.01825	-0.01831
	[0.60254]	[0.02380]	[0.31767]	[0.31990]	[0.31798]
0b.dwborder#1.exterior	-0.15142***	0.06646**	0.01287	0.00741	0.00850
	[0.00001]	[0.02810]	[0.60396]	[0.76522]	[0.73211]
General characteristics		X	X	X	X
Budget variables			X	X	X
Other variables					X
Department dummies	X	X	X	X	X
Region dummies					
Year dummies		X	X	X	X
Municipal category dummies				X	X
Observations	15,014	10,605	10,195	10,195	10,195
R-squared	0.13465	0.56199	0.66231	0.66537	0.66586

Robust pval in brackets

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

Note to table 5. P-values are in brackets. Data are from the Municipal Panel created by the Center for Development Studies – CEDE at Universidad de los Andes, using publicly available information from official sources, and include municipalities in Colombia between 2000 and 2013. General characteristics includes variables such as GDP, Population, land area and altitude; Budget variables includes tax revenues, capital revenues, and transfer revenues; and other variables include a dummy variable for the presence of land belonging to minorities within the municipality and a dummy variable for the presence of at least one irregular army.

Table 5C. Log-Log

OLS Estimates of the Effect of Location on Wastewater related municipal investments Dependent variable: Log of Municipal water related investments					
	(1)	(2)	(3)	(4)	(5)
Distance to Intl. Border	0.30919*	0.58412***	-0.75004***	-0.59207***	-0.78039***
	[0.06718]	[0.00053]	[0.00000]	[0.00002]	[0.00000]
Distance to Intl. Border Sqr.	-0.04463***	-0.04646***	0.06697***	0.05249***	0.07281***
	[0.00350]	[0.00157]	[0.00000]	[0.00001]	[0.00000]
Distance to Dept. Border	0.46307***	0.59476***	0.48125***	0.49871***	0.50731***
	[0.00001]	[0.00000]	[0.00000]	[0.00000]	[0.00000]
Distance to Dept. Border Sqr.	-0.06433***	-0.06457***	-0.05054***	-0.05391***	-0.05560***
	[0.00000]	[0.00000]	[0.00000]	[0.00000]	[0.00000]
General characteristics		X	X	X	X
Budget variables			X	X	X
Other variables					X
Region dummies		X	X	X	X
Year dummies		X	X	X	X
Municipal category dummies				X	X
Observations	12,330	8,722	8,404	8,404	8,404
R-squared	0.01956	0.52533	0.67197	0.67140	0.67238

Robust pval in brackets

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

Note to table 5. P-values are in brackets. Data are from the Municipal Panel created by the Center for Development Studies – CEDE at Universidad de los Andes, using publicly available information from official sources, and include municipalities in Colombia between 2000 and 2013. General characteristics includes variables such as GDP, Population, land area and altitude; Budget variables includes tax revenues, capital revenues, and transfer revenues; and other variables include a dummy variable for the presence of land belonging to minorities within the municipality and a dummy variable for the presence of at least one irregular army.

Table 6C. Log-Log

OLS Estimates of the Effect of Location on Wastewater related municipal investments Dependent variable: Log of Municipal water related investments	(1)	(2)	(3)	(4)	(5)
Dist. Dept. Border (<50)	-0.00417***	-0.00098	0.00057	0.00050	0.00052
	[0.00030]	[0.34481]	[0.52944]	[0.58436]	[0.57115]
Dist. Dept. Border (50-100)	0.00142	0.00413***	0.00164	0.00166	0.00159
	[0.37529]	[0.00364]	[0.18797]	[0.19017]	[0.21021]
Dist. Dept. Border (>100)	0.00269***	-0.00404***	-0.00278***	-0.00283***	-0.00283***
	[0.00009]	[0.00000]	[0.00000]	[0.00000]	[0.00000]
Dist. Intl. Border (<200)	0.00206***	0.00031	-0.00098***	-0.00083***	-0.00081***
	[0.00000]	[0.32516]	[0.00008]	[0.00100]	[0.00133]
Dist. Intl. Border (200-300)	-0.00658***	-0.00067	0.00244***	0.00252***	0.00187**
	[0.00000]	[0.50853]	[0.00269]	[0.00204]	[0.02461]
Dist. Intl. Border (>300)	0.00434***	0.00027	-0.00130**	-0.00158***	-0.00081
	[0.00000]	[0.71597]	[0.02949]	[0.00845]	[0.19628]
General characteristics		X	X	X	X
Budget variables			X	X	X
Other variables					X
Department dummies					
Region dummies		X	X	X	X
Year dummies		X	X	X	X
Municipal category dummies				X	X
Observations	15,014	10,605	10,195	10,195	10,195
R-squared	0.02733	0.51551	0.64752	0.64858	0.64951

Robust pval in brackets

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

Note to table 6. P-values are in brackets. Data are from the Municipal Panel created by the Center for Development Studies – CEDE at Universidad de los Andes, using publicly available information from official sources, and include municipalities in Colombia between 2000 and 2013. General characteristics includes variables such as GDP, Population, land area and altitude; Budget variables includes tax revenues, capital revenues, and transfer revenues; and other variables include a dummy variable for the presence of land belonging to minorities within the municipality and a dummy variable for the presence of at least one irregular army.

Table 7C. Log-Log

OLS Estimates of the Effect of Location on Wastewater related municipal investments Dependent variable: Log of Municipal water related investments					
	(1)	(2)	(3)	(4)	(5)
Distance to Intl. Border (log)	-0.12003***	0.02922	0.00532	0.03320**	0.02968*
	[0.00000]	[0.15142]	[0.73918]	[0.03935]	[0.06611]
General characteristics		X	X	X	X
Budget variables			X	X	X
Other variables					X
Department dummies	X	X	X	X	X
Region Dummies					
Year Dummies		X	X	X	X
Municipal category dummies				X	X
Observations	14,902	10,529	10,124	10,124	10,124
R-squared	0.13378	0.56218	0.68336	0.66629	0.66681

Robust pval in parentheses

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

Note to table 6. P-values are in brackets. Data are from the Municipal Panel created by the Center for Development Studies – CEDE at Universidad de los Andes, using publicly available information from official sources, and include municipalities in Colombia between 2000 and 2013. General characteristics includes variables such as GDP, Population, land area and altitude; Budget variables includes tax revenues, capital revenues, and transfer revenues; and other variables include a dummy variable for the presence of land belonging to minorities within the municipality and a dummy variable for the presence of at least one irregular army.