Inter-Jurisdictional Coordination in the Management of Natural Resources: Evidence from Water Basin Committees in Brazil*

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Abstract

Decentralized management of public goods creates the potential for spillovers across jurisdictions. These spillovers may be particularly large in the case of river management where the river has little value to upstream constituents once it has left the jurisdiction. Cross border cooperation in management of public goods can reduce spillovers, but negotiation between jurisdictions can be difficult to achieve. This paper estimates the effectiveness of policy interventions designed to increase the potential for coordination and negotiation between jurisdictions and investigates the mechanisms through which water management committees and other forums designed to enable cooperation between jurisdictions may improve cross border cooperation.

We develop a simple theoretical model, based on a two stage bargaining game, in which we analyze negotiation between jurisdictions. We arrive at several key theoretical predictions: 1) Pollution levels between jurisdictions decrease following the institution of water basin committees, 2) These reductions in pollution loads are largest in the downstream areas of the river, and 3) Political affiliation and other factors which reduce transactions costs between counties also lead to larger negotiated pollution reductions by the upstream county.

We find that overall, water basin management committees have a mixed impact on water quality. Organic pollution loads appear to decrease with the institution of water basin committees, but the overall health of the river as measured by dissolved oxygen content appears to be relatively unaffected by the institution of water basin committees. Consistent with the model, we find that the impact of water basin committees is largest in the downstream portion of the river where information asymmetries about the origin of the pollution are largest. We also find that increases in political cohesion between the upstream and downstream counties lead to decreases in organic pollution loads between the upstream and downstream counties. These decreases in pollution arising from decreased costs of negotiation between local leaders appear to be largest when combined with dedicated forums for negotiation between the counties.

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1 Introduction

Water is a public good of fundamental importance. Ninety percent of the world's sewage and 70 percent of the world's industrial waste enters the water supply untreated (Revenga (2000)). The World Health Organization estimates that water-borne diseases cause 12 percent of deaths of children under 5 (World Health Organization (2000)). With many interest groups vying for the control of scarce water resources, conflicts are inevitable. These conflicts are magnified when the management of water resources spans more than one jurisdiction.

The flow of rivers creates 'upstream' and 'downstream' regions; conflicts concern actions taken by the upstream jurisdiction which affect welfare in the downstream jurisdiction. For example, the opening of a diversion gate upstream or the discharge of pollutants into the water as it flows downstream have proven to be key sources of conflict along the Jordan River, the São Francisco, the Tigris and Euphrates rivers, and even within the United States along the Colorado River.

With negative spillovers on downstream users, the economics of externalities suggests that in the absence of coordination, water use upstream may be inefficient from a societal perspective. Decentralized management may exacerbate these spillovers if jurisdictions make unilateral decisions that account only for their electorate's concerns, ignoring the welfare of downstream users. This paper identifies factors which affect the success of negotiation between jurisdictions over water resources and the impact of new water management techniques. We use detailed micro data on water quality, geography and politics to assess the externality costs associated with decentralized decision-making in the water sector in Brazil, and evaluate the effectiveness of a particular policy intervention - water basin committee management - in mitigating pollution spillovers.

Decentralization of resource management to local governments has been promoted by many academics, international organizations, and non-governmental organizations (NGOs) as a way to improve service delivery (Bardhan (2002), World Bank (2003)). Given the possibility of negative spillovers across borders, inter-jurisdictional coordination is key, and this paper helps address our knowledge gaps on the political economy determinants of coordination and on the effectiveness of coordination mechanisms in limiting spillovers between jurisdictions.

A few papers estimate the impact of water spillovers across jurisdictional boundaries. Sigman (2005) estimates the effect of being downstream of a state border in the United States. Select states have control over water pollution permits under the Clean Water Act. She finds that states which have the authority to issue water pollution permits have an incentive to increase pollution allowances close to their downstream borders. She estimates a 4 percent decrease in water quality downstream of authorized states. The costs associated with these spillovers are large: Sigman (2005) estimates that the downstream environmental costs are $17 million annually. Where international borders are concerned, pollution spillovers may be even larger. Sigman (2002) finds that stations upstream of international borders have biochemical oxygen demand levels 42 percent higher than stations located away from the country borders.

Most closely related to the project described here, Lipscomb and Mobarak (2007) assess the quantitative importance of pollution externalities across county borders along Brazilian rivers using a unique research design that takes advantage of the fact that the county borders in Brazil change over time due to re-districting. The number of jurisdictional boundaries each river crosses and the distance of a water quality monitoring station from the nearest border thus change over time. The time variation in border crossings allows for identification of the impact of a border while holding all geographic, political and economic characteristics of a given location fixed. Consistent with theoretical predictions, Lipscomb and Mobarak (2007) find that pollution increases by 2% for every kilometer closer a river gets to the exiting border, but in the stretch within 5 kilometers of the border, this increase jumps to 18% per kilometer. The greatest polluting activity therefore appears to be very close to the exit border; counties dump pollution just as the river exits its jurisdictional boundaries. Pollution shows a downward trend across the border–emissions allowances are low in the upstream part of the next county, which is again consistent with strategic behavior.

When a river flows across jurisdictional boundaries, inter-jurisdictional cooperation is essential. Political factors may play a role in promoting such cooperation, if for example, politicians from the same party or coalition are more likely to make joint decisions on water preservation. Negotiation between jurisdictions is often difficult as political partisanship can obstruct the ability of leaders to negotiate with neighboring counties and to commit to long term projects across their borders. Cooperative and non-cooperative game theory has been used to analyze negotiation between jurisdictions over water resources (see, for example, Carraro et al. (2005), Parrachino et al. (2006), and Frisvold and Caswell (2000)). This literature focuses on identifying conditions under which pollution spillovers across jurisdictions can be reduced through unilateral action, negotiation, or cooperation between jurisdictions. Empirical work by Dinar et al. (2007) suggests that water scarcity has a strong role in inducing jurisdictions toward bilateral cooperation, but geography or shared rivers between borders play a relatively small role in inducing cooperation.

Recognizing the political difficulty of reducing pollution externalities across borders, water experts and academics now promote “river basin level management.” River basins are the natural geographic units which encompass the interests of all potential users (Saleth (2002), Mody (2004), Abu-Zeid and Biswas (1996)). River basin committees are meant to increase the flow of information and spur bargaining over water quality and quantity between upstream and downstream counties. A case-study-based descriptive literature reports that river-basin management has met with mixed success, but quantitative or empirical evaluations of such initiatives is lacking (Biswas and Tortajada (2001), and Kemper et al. (2007)).

Given the strong evidence on spillovers across Brazilian counties reported in Lipscomb and Mobarak (2007) and the dearth of careful quantitative evidence on the effects of inter-jurisdictional cooperation, the next natural set of questions to ask is whether certain economic, political or geographic conditions help mitigate these pollution externalities, and whether particular policy interventions are successful at limiting spillovers. We address the following research questions:

1. Has river basin committee management been effective in promoting pollution control and equitable water sharing between upstream and downstream users? Evaluation of the impact of water basin management must include a careful treatment of the endogeneity issues associated with measuring the impact of groups which may be forming more quickly in areas where cooperation is most likely or where the pollution problems are largest.

2. Under what political conditions are committees most successful at reducing pollution? For example, when a river crosses a jurisdictional boundary, is there a smaller deterioration in water quality and flow if the two jurisdictions have the same political leanings (e.g. same party in power, or politicians who have formed coalitions)?

We develop a simple theoretical model in which we analyze the relative impact of the addition of water basin management committees in different areas. Our model suggests the following empirically testable predictions: 1). There is an overall decrease in the level of pollution between counties belonging to a water basin management committee. 2). The decrease in pollution following from the implementation of a water basin committee should be larger in the downstream area of a river. 3). Decreases in transaction costs between the upstream and the downstream jurisdiction lead to decreases in pollution in the upstream jurisdiction. 4). Negotiation should have the largest impact on pollution levels in areas where the cost of poor water quality in the downstream county is higher. In this paper, we test predictions 1-3; we expect to treat the fourth prediction in future work.

Empirical estimation of the impact of water basin committees poses several challenges. Large amounts of data are required in order to estimate the impact of the formation of a new committee on subsequent water quality. In addition, the fact that water basin committees are not randomly forming makes isolation of the effect of the creation of a new committee from other unobserved factors which may have influenced committee formation difficult. Careful econometric modeling through instrumental variable techniques is necessary in order to pinpoint the causal effect of newly established committees.

The large data requirements necessary for careful empirical identification of the impact of water basin committees make Brazilian rivers uniquely well suited as a setting for this study. Brazil reports high quality water pollution data from across the country and has a large degree of variation in water management policies across states. Our data is comprised of a substantial panel database of water quality measures collected at monthly intervals at over 800 monitoring stations located in all eight major river basins across Brazil. We combine the water quality data with GIS maps of jurisdictional boundaries and geo-coded political, socio-economic, geographic, and climatologic data for river basins and counties.

In response to the deteriorating water quality and increased water conflicts over use in recent years, Brazil has shifted toward integrated river basin management (Porto and Kelman (2005)). A 1997 national water management act encouraged the formation of river basin committees with participation by all actors with a vested interest: federal, state and county government representatives, user groups, and members of civil society were all included. Within the set of 112 sub-basin level watershed committees, there is variation in the dates in which they became operational (1990-2005). In addition, there is variation in the mix of actors allowed to participate (county government, state level government, user groups, and civil society), types of users (hydro-electric plants, sugar refineries, irrigated agriculture, and the public), and the extent of the committees' authority (Finatec (2003)). These variations present us with a unique opportunity to study the consequences of various aspects of the decentralization process to the river basin level.

States in Brazil have decentralized water management to the water basin level at different times. A few states, particularly Sao Paulo and Minas Gerais, have led national water policy (Sao Paulo state was the first to legally create water basin management committees in all catchment areas in 1994-national water policy followed, advising creation of water basin committees in 1997). The variation across states in implementation of water management at the basin level provides an additional mechanism for identifying the effect of water basin committees. The range of water basin committee types has also been large. The proportion of representation given to NGOs, local government authorities, and large water users has been determined by each state. Each committee elects its representatives, typically on a biannual basis. Changes in representation of a particular interest group provide variation over time in the strength of the interest group in the committees.

With 13% of the world's surface water resources, Brazil is an important developing country in which to study water management. Extremely unequal spatial distribution of water across regions results in water scarcity and conflicts in the semi-arid Northeast and the industrial densely populated south, which makes Brazil a very relevant setting (Agencia Nacional de Aguas (November,2002)). The importance of water policy in Brazil coupled with the large dataset of geo-coded water quality measures and the varied implementation of the 112 water management committees created since 1990 in Brazil make it an ideal environment for the project.

In section 2, we develop a simple model of bargaining between jurisdictions and analyze the effects on bargaining under multilateral versus bilateral negotiation. We have water quality data from monitoring stations across Brazil for the period 1990-2005. Over the period, water basin management committees were developed in the catchment areas of many of the stations. In section 3 we describe the data and the expansion of water basin management committees in Brazil over the period. In section 4 we explain the estimation strategy and results, and in section 5, we suggest areas for future research.

2 Bargaining Model

Assume there are three communities A, B, and C, located along a river. A is the most upstream community, B is the middle community, and C is the downstream community. Each community has quasi-linear preferences and gets some utility from polluting. The utility a community receives from polluting is denoted p(x) where x is the amount that the community pollutes. In addition, communities get positive utility from monetary receipts R. Communities have negative utility from pollution received from upstream communities c(X) where X is the amount of pollution that occurs upstream. Pollution decays at a rate δ when it passes through a county. Upstream counties are given the right to pollute, up to a maximum pollution amount $\overline{x}$, above which a community can not pollute without being fined a prohibitive sum by the federal government. Assume p(x) and c(x) are both monotonically increasing and meet the following conditions: $\frac{dp(x)}{dx} > 0$, $\frac{d^2p(x)}{dx^2} < 0$ $\frac{dc(x)}{dx} > 0$, $\frac{d^2c(x)}{dx^2} < 0$ The utility function for each community is therefore defined as follows:

$$U_A(x_A, R_A, X_A) = p(x_A) + R_A - c(X_A) \tag{1}$$

$$U_B(x_B, R_B, X_B) = p(x_B) + R_B - c(X_B) \tag{2}$$

$$U_C(x_C, R_C, X_C) = p(x_C) + R_C - c(X_C) \tag{3}$$

Because A is the most upstream community, we know that $X_A = 0$, $X_B = x_A$, and $X_C = \delta x_A + x_B$. Transfers are received from another county with some iceberg transaction cost τ. Therefore, a transfer from C to A, T_C^A yields receipts in A of $\frac{T_C^A}{\tau_{AC}}$ where $\tau_{AC} > 1$. These transactions costs may be caused by uncertainty as to actual reductions in pollution made by the upstream county, difficulty in writing contracts between two separate jurisdictions, or political differences between the leadership of two different jurisdictions, making negotiation costly.

We have the following equations for county receipts of transfers: $R_A = \frac{T_B^A}{\tau_{AB}} + \frac{T_C^A}{\tau_{AC}} - T_A^B - T_A^C$, $R_B = \frac{T_A^B}{\tau_{AB}} + \frac{T_C^B}{\tau_{BC}} - T_B^A - T_B^C$, $R_C = \frac{T_A^C}{\tau_{AC}} + \frac{T_B^C}{\tau_{BC}} - T_C^B - T_C^A$.
It can be shown that $T_A^B = 0$, $T_A^C = 0$, $T_B^C = 0$.

We can therefore characterize receipts as follows: $R_A = \frac{T_B^A}{\tau_{AB}} + \frac{T_C^A}{\tau_{AC}}$, $R_B = \frac{T_C^B}{\tau_{BC}} - T_B^A$, $R_C = -T_C^B - T_C^A$. For simplicity, we adopt functional forms; assume that marginal costs are an affine function, so that $c(x) = cx$, and assume that the pollution function takes the form $p(x) = ln(x)$.

There are 8 possibilities for negotiation between communities:

1. No negotiation, A, B, C all maximize their own profits
2. A and B negotiate
3. B and C negotiate
4. A and B negotiate, B and C negotiate
5. A, B, and C negotiate

6. A and C negotiate
7. A and B negotiate, A and C negotiate
8. A and C negotiate, B and C negotiate

We are particularly interested in the cases in which bilateral negotiation occurs only between neighbors as information costs between counties which are not neighbors would be prohibitive. We therefore focus on cases 1, 2, 3, 4, and 5. We solve the model using backward induction, beginning with the second stage in which participants to the negotiations select their levels of pollution and transfers.

2.1 Case 1: No negotiation, each acts separately

Each community chooses x and T to maximize its utility.

Solution: There is no negotiation, so all $T = 0$. Then $x_A = \overline{x}$, $x_B = \overline{x}$, $x_C = \overline{x}$. This implies:

$$U_A(x_A, 0, X_A) = p(\overline{x}) \tag{4}$$

$$U_B(x_B, 0, X_B) = p(\overline{x}) - c(\overline{x}) \tag{5}$$

$$U_C(x_C, 0, X_C) = p(\overline{x}) - c(\delta\overline{x} + \overline{x}) \tag{6}$$

Then we have the following welfare values for each county: $V_A = ln(\overline{x})$, $V_B = ln(\overline{x}) - c\overline{x}$, $V_C = ln(\overline{x}) - c\overline{x}(\delta + 1)$.

In the absence of negotiation, the upstream counties set the marginal cost of pollution equal to 0. Because they can not be charged for any pollution rate below $\overline{x}$, they have no incentive to reduce their pollution levels. This leaves downstream counties to pay the full cost of the maximum pollution levels, $\overline{x}$ imposed by the upstream counties. Clearly, if $c > 0$, then both the upstream and the downstream counties could do better by negotiating.

2.2 Case 2: Bilateral Upstream negotiation: A and B negotiate, C does not negotiate

Under bilateral negotiation between A and B, B sets its pollution at $\overline{x}$ since it is not paid by C to reduce it, and C sets its pollution at $\overline{x}$. However, there is some negotiation between A and B to set transfer T_B^A in return for a reduction in pollution x_{AB}. B pays A the transfer T_B^A for a reduction in its level of pollution. Assume that B pays A per unit of reduction of pollution so that $T_B^A = tx_{AB}$. Then we have the following equations:

$$max_x U_A(x_A, R_A, X_A) = p(\overline{x} - x_{AB}) + \frac{tx_{AB}}{\tau_{AB}} \tag{7}$$

$$max_x U_B(x_B, R_B, X_B) = p(\overline{x}) - tx_{AB} - c(\overline{x} - x_{AB}) \tag{8}$$

Taking the first order conditions we get:

$$\frac{dU_A}{dx} = -p'(\overline{x} - x_{AB}) + \frac{t}{\tau_{AB}} = 0 \tag{9}$$

$$\frac{dU_B}{dx} = -t + c = 0 \tag{10}$$

so we get the solution that if A and B negotiate, they arrive at a negotiated level of x_{AB} such that: $p'(\overline{x} - x_{AB}) = \frac{c}{\tau_{AB}}$. That is, the pollution rate is set such that the marginal cost of pollution to B, weighted by the transaction cost, is equal to the marginal benefit of pollution to A. Using the assumed functional forms, we get $x_{AB} = \overline{x} - \frac{\tau_{AB}}{c}$. This implies the following indirect utilities:

$$V_A = ln(\frac{\tau_{AB}}{c}) + \frac{c\overline{x}}{\tau_{AB}} - 1 \tag{11}$$

$$V_B = ln(\overline{x}) - c(\overline{x}) \tag{12}$$

$$V_C = ln(\overline{x}) - \delta\tau_{AB} - c(\overline{x}) \tag{13}$$

The equations above show that B is willing to pay A up to the cost of pollution imposed by A on B in order to reduce the pollution. Because of constant marginal costs, B is driven down to zero surplus from the negotiation as it pays A up to the cost of the pollution it imposes on B in order to reduce its pollution. However, because there are iceberg transaction costs, the transfer payment which B makes to A does not reach A in full. Therefore, the parties do not reach pollution levels where marginal benefits of pollution in A equal marginal costs in B; A pollutes until its marginal benefits weighted by the transaction cost for the transfer payment between A and B are equal the marginal costs of its pollution to B.

Because it is downstream of A and B but not party to the negotiation between A and B and therefore does not contribute to the transfer payment to A in return for its reduction in pollution, C benefits from the negotiation between A and B. The reduction in pollution between A and B (of an amount $\overline{x} - \frac{\tau_{AB}}{c}$) reduces C's cost of pollution by $\delta c(\overline{x} - \frac{\tau_{AB}}{c})$. Therefore, by free riding on the negotiation between A and B, C has a net increase in welfare which it derives from A's negotiated reduction in pollution levels.

2.3 Case 3: Bilateral Downstream Negotiation: B and C negotiate, A does not negotiate

A sets its pollution at $\overline{x}$ as it receives no payment from B or C to reduce its pollution. C also sets its pollution at $\overline{x}$. However, there is some negotiation between B and C to set a transfer T_C^B in return for a reduction in pollution x_{BC}. C pays B an amount T_C^B for reduction in pollution x_{BC}. Assume that C pays B per unit of reduction of pollution so that $T_C^B = tx_{BC}$. Then we have the following equations:

$$max_x U_B(x_{BC}) = p(\overline{x} - x_{BC}) + \frac{tx_{BC}}{\tau_{BC}} - c(\overline{x}) \tag{14}$$

$$max_{x_{BC}} U_C(x_{BC}) = p(\overline{x}) - tx_{BC} - c(\delta\overline{x} + \overline{x} - x_{BC}) \tag{15}$$

Taking the first order conditions we get:

$$\frac{dU_B}{dx} = -p'(\overline{x} - x_{BC}) + \frac{t}{\tau_{BC}} = 0 \tag{16}$$

$$\frac{dU_B}{dx} = -t + c = 0 \tag{17}$$

so we get the solution that if B and C negotiate, they arrive at a negotiated level of x_{BC} such that $p'(\overline{x} - x) = \frac{c}{\tau_{BC}}$, or the marginal utility of pollution to B is equal to the marginal cost of the pollution to C less the transaction cost. Substituting in the assumed ln(x) function for the pollution function, $x_{BC} = \overline{x} - \frac{\tau_{BC}}{c}$. This implies the following indirect utilities:

$$V_A = \ln(\overline{x}) \tag{18}$$

$$V_B = \ln(\frac{\tau_{BC}}{c}) - c\overline{x}(1 - \frac{1}{\tau_{BC}}) - 1 \tag{19}$$

$$V_C = \ln(\overline{x}) - c(\delta + 1)(\overline{x}) \tag{20}$$

In this case A continues to pollute at its maximum allowable level, ignoring the costs imposed on B and C. B reduces its pollution to an agreed level, $\frac{\tau_{BC}}{c}$. B's level of pollution does not reach the point where B's marginal benefit of this pollution equals C's marginal cost of pollution, but this wedge between the marginal cost of pollution to C and the marginal benefit of pollution to B is caused by the transaction costs. In this case, there is no free riding by any party, since the negotiations take place in the downstream portion of the river.

2.4 Case 4: Bilateral Neighbors negotiate: A and B negotiate, B and C negotiate

If there are bilateral negotiations between both the pairs A, B, and B, C, we have the following problem with bilateral negotiation between both A and B and B and C:

$$max_{x_{AB}} U_A(x_{AB}, R_A, X_A) = p(\overline{x} - x_{AB}) + \frac{tx_{AB}}{\tau_{AB}} \tag{21}$$

$$max_{x_{AB}, x_{BC}} U_B(x_{AB}, x_{BC}) = p(\overline{x} - x_{BC}) - tx_{AB} + \frac{tx_{BC}}{\tau_{BC}} - c(\overline{x} - x_{AB}) \tag{22}$$

$$max_{x_{BC}} U_C(x_{BC}) = p(\overline{x}) - tx_{BC} - c(\overline{x} - x_{BC} + \delta(\overline{x} - x_{AB})) \tag{23}$$

Taking the first order conditions we get:

$$\frac{dU_A}{dx_{AB}} = -p'(\overline{x} - x_{AB}) + \frac{t}{\tau_{AB}} = 0 \tag{24}$$

$$\frac{dU_B}{dx_{AB}} = -t + c = 0 \tag{25}$$

$$\frac{dU_B}{dx_{BC}} = -p'(\overline{x} - x_{BC}) + \frac{t}{\tau_{AB}} = 0 \tag{26}$$

$$\frac{dU_C}{dx_{BC}} = -t + c = 0 \tag{27}$$

We arrive at the solution that if A and B negotiate and B and C negotiate separately, they arrive at a negotiated level of x_{AB} such that: $p'(\overline{x} - x_{AB}) = \frac{c'(\overline{x} - x_{AB})}{\tau_{AB}}$, and $p'(\overline{x} - x_{BC}) = \frac{c'(\overline{x} - x_{BC} + \delta(\overline{x} - x_{AB}))}{\tau_{BC}}$ Using our functional forms, this implies: $x_{AB} = \overline{x} - \frac{\tau_{AB}}{c}$, and $x_{BC} = \overline{x} - \frac{\tau_{BC}}{c}$.

The indirect utility values are then:

$$V_A = \ln(\frac{\tau_{AB}}{c}) + \frac{(c\overline{x})}{\tau_{AB}} - 1 \tag{28}$$

$$V_B = \ln(\frac{\tau_{BC}}{c}) - c\overline{x}(1 - \frac{1}{\tau_{BC}}) - 1 \tag{29}$$

$$V_C = \ln(\overline{x}) - c\overline{x} + \delta\tau_{AB} \tag{30}$$

In this case, C continues to derive an excess benefit from B's negotiation with A in which C has not participated. By free riding on B's negotiation with A, C is able to increase utility by $\delta\tau_{AB}$.

2.5 Case 5: Multilateral Negotiation: A, B and C negotiate simultaneously

Here we look for a simultaneous solution to the three player Nash game. We assume here that in the joint negotiation that B and C have with A, B pays α of the transfer to A while C pays $1-\alpha$. C also pays the full amount of the transfer to B.

$$U_A(x_{ABC}, R_A) = p(\overline{x} - x_{ABC}) + \frac{t_1 x_{ABC}}{\tau_{ABC}} \tag{31}$$

$$U_B(x_{ABC}, x_{BC}, R_B) = p(\overline{x} - x_{BC}) + \frac{t_2 x_{BC}}{\tau_{ABC}} - c(\overline{x} - x_{ABC}) - \alpha t_1 x_{ABC} \tag{32}$$

$$U_C(x_{ABC}, x_{BC}, R_B) = p(\overline{x}) - c(\delta(\overline{x} - x_{ABC}) + \overline{x} - x_{BC}) - (1-\alpha)t_1 x_{ABC} - t_2 x_{BC} \tag{33}$$

We get the following first order conditions:

$$\frac{dU_A}{dx_{ABC}} = -p'(\overline{x} - x_{ABC}) + \frac{t_1}{\tau_{ABC}} = 0 \tag{34}$$

$$\frac{dU_B}{dx_{BC}} = -p'(\overline{x} - x_{BC}) + \frac{t_2}{\tau_{ABC}} = 0 \tag{35}$$

$$\frac{dU_B}{dx_{ABC}} = c - \alpha t_1 = 0 \tag{36}$$

$$\frac{dU_C}{dx_{BC}} = c - t_2 = 0 \tag{37}$$

$$\frac{dU_C}{dx_{ABC}} = \delta c - (1-\alpha)t_1 = 0 \tag{38}$$

It follows that $\alpha = \frac{1}{1+\delta}$, so $(1-\alpha) = \frac{\delta}{1+\delta}$. Then $x_{A|ABC} = \overline{x} - \frac{\tau_{ABC}}{(1+\delta)c}$, $x_{B|ABC} = \overline{x} - \frac{\tau_{ABC}}{c}$

$$V_A = \ln(\frac{\tau_{ABC}}{(1+\delta)c}) + \frac{c(1+\delta)}{\tau_{ABC}}(\overline{x} - \frac{\tau_{ABC}}{(1+\delta)c}) \tag{39}$$

$$V_B = \ln(\frac{\tau_{ABC}}{c}) - c\overline{x}(1 - \frac{1}{\tau_{ABC}}) - 1 - \frac{\tau_{ABC}}{1+\delta}(1 - \frac{1}{c}) \tag{40}$$

$$V_c = \ln(\overline{x}) - c(\delta+1)\overline{x} \tag{41}$$

Notice that in all cases, the agreed rate of pollution, $\frac{\tau}{c}$ decreases in c, the marginal cost of pollution in the downstream county. This suggests that under negotiation, changes in pollution rates will be largest in areas where an increase in pollution imposes large costs on the downstream county.

The agreed rate of pollution increases in τ, the transaction cost of negotiations between the counties. The transaction cost determines the size of the difference between the marginal cost of pollution in the downstream county and the marginal benefit to pollution in the upstream county. Where the transaction cost is high, marginal costs of pollution in the downstream county must be that much larger than the marginal benefits of pollution in the upstream county in order for an agreement over the level of pollution to be reached. This suggests that when negotiation is attempted between counties where there is difficulty assigning blame for the pollution levels, the agreed rate of pollution will be closer to the case in which each county acts unilaterally. We expect to see that information costs are higher in the downstream areas of the river as downstream areas of the river are affected by the actions of agents all the way through the river. This suggests that transaction costs in the downstream portions of the river will be higher under bilateral bargaining.

The model yields several testable implications. 1) We should see a larger decrease in pollution from negotiation in basin committees than from bilateral negotiations. This follows from the fact that basin committees reduce the transactions cost to multilateral bargaining and under multilateral basin committee negotiation downstream counties contribute to the payment to the most upstream counties for a reduction in their pollution as well as paying the neighboring upstream county to reduce their pollution level. 2) The impact of basin committees should be largest in the downstream portion of the river. Bilateral negotiations had high transactions costs in this portion of the river because of larger information asymmetries in this region. Multilateral negotiation in basin committees reduces the transaction cost by more in the downstream portion of the river than in the upstream portion of the river; therefore the largest decreases associated with the creation of a water basin committee should be expected in the downstream portion of the river. 3) Decreases in the transactions cost (even absent a water basin committee) should increase the size of the pollution reduction following from negotiation between jurisdictions. 4) An increase in negotiation should have the largest impact on pollution levels where the downstream county is highly dependent on water quality and pays a high marginal cost of pollution.

Solving the individual rationality constraints associated with determination of parties likely to enter negotiations suggests several endogeneity issues which we will need to address in the empirical work.

2.6 Stage 1: Selection of Negotiation Partners

We now solve for parameter values under which each type of negotiation strategy will be an equilibrium. We assume that if any of the agents back out of negotiation, they revert to case 1, or unilateral decision making by all agents.

2.6.1 Case 2: Bilateral Negotiation between A and B

Case 2 is an equilibrium if neither A nor B have an incentive to deviate toward unilateral action. This means that we have the following conditions:

$$\ln \overline{x} \leq \ln(\frac{\tau_{AB}}{c}) + \frac{c\overline{x}}{\tau_{AB}} - 1 \tag{42}$$

and

$$\ln(\overline{x}) - c\overline{x} \leq \ln(\overline{x}) - c(\overline{x}) \tag{43}$$

43 always holds, so this gives the following condition:

$$\ln \frac{c\overline{x}}{\tau_{AB}} \leq \frac{c\overline{x}}{\tau_{AB}} - 1 \tag{44}$$

Which holds as long as $\tau_{AB} \leq c\overline{x}$, or the costs of pollution are sufficiently large compared to the transaction costs.

2.6.2 Case 3: Bilateral Negotiation between B and C

Case 3 will hold if neither B nor C has an incentive to deviate toward unilateral action. For B, this requires:

$$\ln(\overline{x}) - c\overline{x} \leq \ln(\frac{\tau_{BC}}{c}) - c\overline{x}(1 - \frac{1}{\tau_{BC}}) - 1 \tag{45}$$

In order to guarantee that C has no incentive to deviate, we require:

$$\ln(\overline{x}) - c(\delta + 1)\overline{x} \leq \ln(\overline{x}) - c(\delta + 1)\overline{x} \tag{46}$$

46 always holds, so we have the following condition:

$$\ln(\frac{c\overline{x}}{\tau_{BC}}) \leq \frac{cx}{\tau_{BC}} - 1 \tag{47}$$

Which holds as long as $\tau_{BC} \leq c\overline{x}$. Again, the cost of pollution to C must be larger than the transaction cost.

2.6.3 Case 4: Bilateral Negotiation between A and B, and Bilateral negotiation between B and C

The following individual rationality conditions must hold in order for this to be equilibrium:

$$\ln \overline{x} \leq \ln(\frac{\tau_{AB}}{c}) + \frac{(c\overline{x})}{\tau_{AB}} - 1 \tag{48}$$

$$\ln \overline{x} - c\overline{x} \leq \ln(\frac{\tau_{BC}}{c}) - c\overline{x}(1 - \frac{1}{\tau_{BC}}) - 1 \tag{49}$$

$$\ln(\overline{x}) - c(\delta + 1)\overline{x} \leq \ln(\overline{x}) - c\overline{x} - \delta\tau_{AB} \tag{50}$$

Which simplifies to:

$$\ln \frac{c\overline{x}}{\tau_{AB}} \leq \frac{(c\overline{x})}{\tau_{AB}} - 1 \tag{51}$$

$$\ln \frac{c\overline{x}}{\tau_{BC}} \leq \frac{\overline{x}c}{\tau_{BC}} - 1 \tag{52}$$

$$c(\delta)\overline{x} \geq \delta\tau_{AB} \tag{53}$$

Then we have $\tau_{BC} \leq \overline{x}c$ and $\tau_{AB} \leq \overline{x}c$.

2.6.4 Case 5: Negotiation between A, B, and C

$$\ln \overline{x} \leq \ln(\frac{\tau_{AB}}{c}) + \frac{(c\overline{x})}{\tau_{AB}} - 1 \quad (54)$$

$$\ln \overline{x} - c\overline{x} \leq \ln(\frac{\tau_{BC}}{c}) - c\overline{x}(1 - \frac{1}{\tau_{BC}}) - 1 \quad (55)$$

$$\ln(\overline{x}) - c(\delta + 1)\overline{x} \leq \ln(\overline{x}) - c\overline{x} - \delta\tau_{AB} \quad (56)$$

Which gives the following conditions:

$$\ln \frac{c\overline{x}(1+\delta)}{\tau_{ABC}} \leq \frac{c\overline{x}(1+\delta)}{\tau_{ABC}} - 1 \quad (57)$$

$$\ln \frac{c\overline{x}}{\tau_{ABC}} \leq \frac{c\overline{x}}{\tau_{ABC}} - 1 \quad (58)$$

$$\tau_{AB} \leq c\overline{x} \quad (59)$$

The individual rationality constraints listed above show that entrance into bilateral negotiation by either the upstream or the downstream party depends on the cost of pollution to the downstream party being larger than the transaction cost of negotiation between the parties. That is, the counties will be able to arrive at an agreement if the marginal cost of pollution to the downstream party is high enough and the transaction cost is low enough.

Under bilateral bargaining, counties further downstream of the two participants free ride and enjoy the benefits of pollution reduction upstream without paying for it; we see this in cases 3 and 5. County C does not participate in the negotiation between A and B, and therefore does not contribute to the payment which B makes to A. Therefore, county C has a net benefit from B's negotiation with A, while B pays the full cost of the settlement. The agreed settlement between A and B is therefore too low, as the impact of the pollution in A on county C is not accounted for in determining the agreement. The social inefficiency from (partial) bilateral bargaining is larger the further upstream the counties negotiating are. This is because further upstream there are more downstream jurisdictions affected by the pollution who are not participating (i.e. free riding).

Under multilateral bargaining, downstream counties are no longer free riding, as a result pollution reductions are larger than under bilateral bargaining. The upstream counties are better off, but the downstream county is worse off under multilateral bargaining as compared to the case of bilateral negotiation between the upstream counties. The downstream county is no longer able to free ride, and contributes to the settlement with A under multilateral negotiation. This introduces the possibility of selective participation or endogeneity in basin committee formation. Counties are more likely to create basin committees or join existing committees where they believe the basin committee will improve their negotiating position or reduce transactions costs in their favor.

The model shows that the emergence of any form of bargaining (bilateral or multilateral) will depend on relative transaction costs. This implies that in the data we need to look for exogenous sources of variation in transaction costs, since the existence of a particular type of bargaining outcome might be endogenously determined. For example,

a) A party may be in power in a certain region precisely because it has a reputation for its ability to bargain with other local jurisdictions,

b) A basin committee might emerge in a certain location because parties in the different jurisdictions within the basin have a history of cooperation.

Adding location fixed effects and identifying effects of party identity on pollution by relying only on changes in party identity at election cycles is more likely to be exogenous. Location fixed effects remove all time-invariant variation in the data related to each location so that we do not need to be concerned about fixed characteristics of counties jointly determining local water quality and basin committee adherence. For example, we may be concerned that two counties which have a history of cooperation will be more likely to form a basin committee. However, location fixed effects will remove the impact of the counties cooperation over time, and identification will be based uniquely on changes over time.

We may be concerned that the endogeneity surrounding the development of water basin committees is not limited to time-invariant factors. That is, one party may be more likely to be elected in a given election cycle if they are expected to be able to negotiate with the leadership of the other jurisdictions or join a basin committee and water quality is an important issue in that election cycle. We develop an instrument in order to isolate the component of the membership in the basin committee orthogonal to local water quality. We also propose other instruments which we expect to use in future developments of this work.

3 Data

We have assembled a database of approximately 36,000 water quality observations taken between 1975 and 2003 from over 800 water monitoring stations managed by the Brazilian national water monitoring agency, ANA. The positions of the stations on the rivers have been overlaid on GIS maps with political and water basin committee boundaries. In addition, we established the relative upstream and downstream positions of stations along the length of the river using flow direction vector maps from USGS. Figure 1 shows a map of the location of the water monitoring stations and figure 2 is a map of county boundaries as of 1994.

We have collected information on the 112 water basin committees operating in Brazil and the years in which they have been active. Different states have undergone initiatives for the formation of water basin committees in different years, and committees have been slower to establish in certain segments of some states. Chart 3 shows the variation in state formation of water basin committees over the period 1990-2005. Committees give small stake-holders a larger voice in the formation of water policy, while large stake-holders are able to negotiate with the government at upper levels without the framework of a water basin committee. As a result, they are more likely to form in areas where small stakeholders are prevalent. Table 1 shows that in areas where fishing and farming are among the top three industries in a county, the likelihood of there being a local water basin committee increases by approximately 2%.

We overlay GIS maps of the water monitoring stations with maps of the expansion of water basin committees in Brazil. We then match these stations to local political data in order to identify the impact of political factors on the success of negotiation over water issues.

We use a variety of water quality monitoring variables in order to estimate the impact of negotiation on various types of enforcement activities. Table 2 reports summary statistics for pollution measures used as dependent variables. Higher levels of BOD, COD, Nitrates, Fecal Coliform, and Ammonia all indicate higher levels of pollution, while higher levels of dissolved oxygen indicates better water quality. Biochemical oxygen demand, BOD, is a commonly used summary measure of organic pollution loads. High levels of BOD are evidence of increased levels of organic pollution in the water. This may come from a variety of sources including raw sewage, industrial waste, and fertilizer run-off. COD, or chemical oxygen demand, is evidence of industrial pollution. Nitrates are primarily a result of non-point source pollution from fertilizer run-off. Fecal

Coliform is evidence of pollution from sewage. Ammonia is a result of both sewage pollution and fertilizer pollution.

3.1 The Development of Water Basin Management Committees in Brazil

In 1997, the federal government passed Federal law 9,433 which formally decentralized the management of water resources across Brazil. This had been preceded by state level initiatives in several states, led by Ceara and Sao Paulo, to improve the management of water in their jurisdictions. The need for coordinated management of water resources quickly became apparent as more decentralized areas saw highly uneven enforcement of pollution norms.

Water basin management committees have been developed for a variety of reasons in the political context of Brazil. While some authority over water management in rivers crossing state boundaries has been centralized in the federal authorities, there has been little coordination between the federal government authorities and the state and local actors responsible for local management. In addition, several different government agencies had control over water management policy within each state, and the fragmentation of policy making between these authorities made management ineffective.

Water basin management committees are often formed in response to a federal or state law, but the impetus for the creation of a water basin committee generally comes from a local issue. In response to a survey of water basin committees, 53% of representatives of water basin management committees said that the impetus to form the committee came in large part from a conflict over water use. 50% of representatives said that the committee was formed because the conditions of the river were worsening (R. Abers and Jorge (2005)).

Water basin management was developed with the expectation that it would involve stakeholders at all levels and devolve authority to a more local level, thereby decentralizing authority and democratizing decision making (R. Abers et al. (2008)). This democratization constitutes a large transfer of authority to previously disenfranchised small stake holders, but in practice, small stake-holders have had trouble participating in the water basin committees because of financial and time constraints.

Water basin management committees are often promoted by environmental management officials as a policy response to the spillovers between jurisdictions which occur as a result of decentralized management of rivers. The committees were promoted by the World Bank in Brazil as a best practice tool for environmental management. In several cases, the World Bank linked loans for water infrastructure projects to the use of water basin management committees in an effort to encourage their development and the further involvement of small stakeholders commonly left out of the policy making process. The result has been a proliferation of committees in Brazil from 1990-2005. As of 2004, there were 91 state run water basin management committees and 6 federal level water basin management committees.

Water basin committees are charged with determining and implementing water use charges, determining expected water quality, creating a forum for negotiation between stakeholders along a river, and overseeing the management of the river by approving plans and resolving conflicts. Bulk water charges (cobrança), set by the committee, were expected to finance the expenses of the committees (R. N. Abers and Keck (2006)). Many committees have not yet set bulk water charges; these committees are more active in elaborating water basin management plans, encouraging negotiation between stake-holders, and forming partnerships between the members of the committees (R. Abers and Jorge (2005)).

Water basin committees have so far had mixed success. Many require unanimous consent for all decisions, and therefore have trouble arriving at binding agreements. Representatives on water basin committees surveyed by Marca d'Agua believe that their actions in the committees are partially successful: 56% said that they thought that the decisions of the committees influenced the major projects which were carried out in the water basin, 47% said that the decisions influenced the actions of governments, 37% said that they felt their decisions influenced the actions of large companies, and 36% said that they thought their decisions influenced the actions of the public (R. Abers et al. (2008)). Water basin committees are active in managing water quality and use in several different ways. More than 50% of surveyed members of water basin committees said that they were active in community education about the use of resources. 45% were active in community organization for the improved use of environmental resources, and 42% said that they were active in the planning of soil and forest use. 38% said that they were active in designing the expansion of sanitation networks. (Frank (2008)).

3.1.1 Representation and Participation in Water Basin Management Committees

Water basin management committees gather the primary interest groups using the water and are responsible for determining a tariff for water use. State laws differ significantly in their requirements of water basin management committees from federal law, and even within a state there is considerable variation between water basin management committees in terms of their design. Federal law states that the committees should be composed of 40% major water users, 20% small water users and civil society, and 40% representatives of the state, local, and federal government. However, in practice, less than 20% represent major water users, nearly 40% represent civil society, and over 40% represent state, federal and local governments (R. Abers et al. (2008)).

The amount of participation of different stakeholders varies across the basins, but municipal governments and large stakeholders tend to devote the most time to the water basin committees, with 82.1% of municipal representatives and 80.5% of large industry representatives spending at least one day per month on the management of the committee (Gutiérrez (2008a)). Local control over basin committee management is jealously guarded–state and federal representatives tend to be the least appreciated members of the committees. Surveyed members of committees are most likely to cite state and federal government authorities as getting in the way of the committees (46.5%), local industries (40.8%), and county governments (35.9%) (R. Abers et al. (2008)).

Small stakeholders had the most trouble financing the cost of attending basin committee meetings and making time to attend. Only rarely does the committee pay part of the cost of attending the meetings–4.4% of surveyed respondents reported the basin committee having paid part of their cost of attending meetings, while 34% reported having paid the cost of attending their meetings themselves, and 55% reported their organization to have paid the cost of attending the meetings. When questioned on the difficulty of attending meetings, 36.9% said that there were no impediments to going to basin committee meetings. Those that did face impediments to going to meetings most often cited lack of time (24.9%), distance and length of the trip (16.1%), and the cost of transport (12.6%)(Gutiérrez (2008a)).

Despite their relatively low cost of attendance, municipalities are less likely to participate in basin committee meetings. While the overall average attendance rate for representatives at basin committee meetings is 75.4%, county representatives participate at a rate of 68.6%. They also are less likely to talk or present at the meetings when they do participate: the overall average rate of participation in debates is 54.1%, and counties participate at a rate of 47.7%, counties are also less likely to present at meetings–average rates of presentation by representatives are 42%, while counties present at a rate of 35% (Gutiérrez (2008a)). This relatively low level of involvement among county representatives may be one factor reducing the impact of water basin committees on cross border spillovers.

Representatives of large users tend to be weighted toward sanitation companies (24%), Associations of non-agricultural private users (24%), private companies (19%) and municipal water and sewer companies (12%). Hydropower figures in at only 7% of civil society representation–a total of 1% of representation on the committees overall. Private farmers and cooperatives represent 4% of the seats taken by civil society (or 1% overall), and associations of farmers represent 8% (1%) of seats (R. Abers et al. (2008)). This represents a major deviation from traditional power and decision making over water policy, as traditionally hydropower companies in cooperation with the largest agricultural users had the most power over water use policy.

Civil society, which prior to water basin management committees had little to no role in the determination of policy making, has on average 27% representation. NGOs and associations of local inhabitants play the largest roles in participation, with University professors and professional associations following closely (R. Abers et al. (2008)). However, this move toward inclusion of civil society in participation in water basin management committees is not matched by involvement in negotiations: qualitative studies of negotiations suggest that the elites still control decision making within the committees. Despite the fact that the water basin management committees have representatives of various sectors of society, these representatives tend to be far more wealthy and educated than the rest of Brazilian society. Perceived inequality in economic status (30%) is seen as less of an impediment in the decision making process than inequality in technical knowledge about water management (67%) or political affiliation (51%) (R. Abers et al. (2008)). Technical knowledge and education is on average highest among representatives of Federal and state entities, and lowest among representatives of small producers(Frank (2008)).

3.1.2 Case Study: The Formation of Water Basin Management Committees to Combat Water Shortages in Northern Brazil

Our theoretical model predicts that when the cost of lack of cooperation between jurisdictions are high there is a larger impetus to form negotiations between jurisdictions, and when agreements are reached, they will be larger. Similarly, Dinar et al. (2007) show that jurisdictions which face water shortages are more likely to cooperate over the management of the shared water resources.

This finding is borne out by the states in Northeastern Brazil where water management committees were formed early in order to combat water shortages. The push for participatory management in the Northeast has been tempered by a tradition of oligarchy in the structure of local government. Low rates of education reduce the ability of local small stakeholders to participate in the decision making process. Involvement by major stake-holders in the decision making process is not new: hydropower generators, municipalities, and large industries requiring bulk water inputs have traditionally played a large role in policy formation at some level. Participatory management primarily benefits relatively small actors who otherwise would not be involved in the process such as fishermen and small irrigators as they gain a voice in the process under decentralized management (Lemos and Oliveira (2004)).

Northern Brazil was among the first areas to structure state policies on water use in an effort to combat water shortages. However, management was typically centralized as the Northeast has a tradition of oligarchy. Development of water management therefore came primarily from the state environmental bureaucracies. Much of the support for water management reform in Ceará came from DNOCS, the national drought management agency. Together with the University, DNOCS provided the technical support and personnel needed for improved management (Gutiérrez (2008b)).

The government of Ceará retained centralizing authority over the water resources for two key reasons. Because portions of the country relied on water transfers to areas outside of a water basin, the key level of negotiation transcended water management boundaries. In addition, the largest necessary investments in Ceará were in terms of water reservoirs, and the costs and benefits of reservoirs were not well matched within a water basin (Gutiérrez (2008b)).

The management of the Jaguaribe basin in Ceará is the most advanced of water management bureaucracies in the country. This is largely a result of the political necessity of controlling water use and storage in the basin. However, water management in the Northeast is distinguished from management in the Southern regions of Brazil in that the jurisdictional boundaries of management institutions often are not restricted to the boundaries of the local water basins. This is because water in the Jaguaribe basin is often diverted for water access in urban areas which do not otherwise have consistent water sources (this is particularly true for the lower Jaguaribe which is diverted to Fortaleza).

The Jaguaribe river is the most important water source for the state of Ceará as it supplies Fortaleza (even though Fortaleza actually lies outside of the water basin). Forty-three percent of water demand from the Jaguaribe is from the metropolitan area of Fortaleza. (Johnsson and Kemper (2005)). The Jaguaribe is used in large part for water storage; the natural flow of the river is intermittent and the area is highly prone to drought. The Jaguaribe water basin committee is a federal committee with strong support from Ceará's water management agency, COGERH. The basin is sub-divided into 5 sub-basin level management committees; the Upper, Middle, and Lower Jaguaribe, and the Salgado and Banabuiù. The lower Jaguaribe is the most important of the sub-basin in terms of the local economy, and it is also the largest beneficiary of improved management of the river from the institution of water basin committees (Johnsson and Kemper (2005)).

Water basin committees in Ceará are expected to promote their policies primarily through the state government agencies SRH and COGERH: they do not have agencies charged with acting on their decisions. However, there are a few mechanisms through which they can affect policy making. Funds from water taxes are supposed to be prioritized toward projects in the basin in which they were collected. At least fifty percent of the funds collected in a given water basin must be spent on projects in that basin. Finally, the allocation of water management funds within a basin are to be targeted toward projects approved by the water basin committees. (Gutiérrez (2008b))

The government of Ceará created COGERH, the centralized state water bulk supply company, in response to a demand by the World Bank as the World Bank was loaning money to the government for the creation of water resources infrastructure. The operation of water reservoirs depends on the balancing of interests between urban water use, generators of hydropower, agricultural irrigation schemes, and industrial use. User groups were formed in order to balance the competing interests of stake-holders along the river.

Water tariffs are set by state law, but collected by COGERH, the state bulk water supply company. Domestic use is privileged by state law as being the most important, and the idea of having to pay for the use of water is politically quite difficult. CAGECE, the water agency providing water for domestic use in Fortaleza, is one of the largest water customers of COGERH, but their tariffs are set 60 times below that of the normal bulk-water pricing because domestic tariffs are set artificially low. Low level agriculture does not yet pay for their water use, as they have traditionally had unrestricted access to the water, and charging them for the water is politically difficult. Tariffs were expanded gradually in Ceará; in 1996 municipal users were charged, as of 1998 industrial users were charged, and in 2000 large scale irrigators began to be charged for their water use. (Johnsson and Kemper (2005)).

While COGERH had no institutional authority to promote basin level activities beyond bulk water pricing and tariff collection, it encouraged the formation of water basin committees which had increased institutional and legislated authority. It had the support of the World Bank for the river basin management committees which it helped to create between 1997 and 2002. The river basin committees had 30% representation by bulk water users, 30% representation by members of civil society and NGO's, 20% representation by municipal governments, and 20% representation by federal and state agencies. (Gutiérrez (2008b))

In 2002, with the change in government following the election, the competition between COGERH and SRH ended as COGERH was subordinated to SRH and both were put under the same political leadership. The level of participation by civil society in the formation of water policy was further reduced by the formation of water policy by the newly strengthened group. However, small and mid-size rural landowners refused to pay water charges when they were implemented in 2004, as they suggested that they had never been formally discussed in committee. (Gutiérrez (2008b))

3.1.3 Case Study: Water Basin Management Committees Combatting Water Pollution and Water Shortages in South-Central Brazil

Water management in South Central Brazil grew out of a concern for maintaining the production of electricity in the hydro-power plants. DAEE, São Paulo's department of water and electricity, was the agency directly responsible for water policy, and they were primarily interested in water availability.

Water policy in São Paulo developed to encompass water quality issues as public outcry arose from the pollution issues in the Tiete and Piracicaba river basins. In 1991 São Paulo preempted Federal water policy by passing a state water law emphasizing the importance of creating water basin management committees, with formation to begin in the Alto Tiete and Piracicaba rivers (R. N. Abers and Keck (2006)).

In Minas Gerais, the creation of water basin committees varied by regions. In the Velhas river basin, the water basin management committee was formed in response to a request by the World Bank which accompanied financing for sanitation facilities. In the Araçuaí basin, the water basin management committee formed in response to major pollution, flooding, and water scarcity issues between 1997 and 2000. In the river basin Parà, water quality was quickly deteriorating because of a complete lack of municipal control over sewage and industrial enforcement. Between 1988 and 1993, counties met in order to deal with the water quality problems, and were able to increase sanitation facilities in the largest cities.(Projeto Marca d'Agua (2003)).

4 Estimation Strategy and Results

Our empirical strategy identifies upstream-downstream station pairs on the same river and uses the change in pollution level from the upstream to the downstream station as the dependent variable. We then identify the impact of a change in whether or not the area has a water basin committee using an indicator variable for whether a water basin committee had been instituted in a given area. We separately identify the impact in areas where the downstream station is a member of a committee and the impact in areas where both the upstream station and downstream station belong to the same committee. Following the predictions of the theoretical model, we expect to see a decrease in pollution following the institution of a water basin committee, as basin committees reduce the transaction cost between jurisdictions. This decrease should be larger in the downstream area of the river where transaction costs are typically high due to information asymmetries.

In addition, we identify the impact of political factors on spillovers between stations. These political factors may reduce the transaction cost associated with negotiation and therefore our model predicts a reduction in spillovers between counties following the institution of a committee. Consistent with the model, we find that when local mayors belong to the same political party, local pollution spillovers decrease.

We use a variety of pollution measures in order to differentiate between point source and non-point source polluters. Dissolved oxygen measures the general health of the river. BOD and COD content are commonly used point source measures of pollution in a water body. They measure the level of organic pollution in the water. For non-point source pollution, nitrates and nitrites measure farm runoff, and phosphates measure urban runoff. Comparing coefficient estimates across specifications for different pollution measure helps us gauge the relative efficacy of basin committees in mitigating point-source versus non-point source pollution spillovers and pollution arising from a variety of sources.

The estimates show that political identity matters in determining the level of certain types of pollution spillovers and that the creation of water basin committees helps mitigate pollution spillovers across borders. All of the regressions include basin-month dummies (to account for seasonal variation, and seasonality is specific to region), year dummies (to account for country-wide trends in pollution over time), and GDP, county size, and population density, all of which are separately computed for the county where the upstream station is located, the county where the downstream station is located, and finally, the distance weighted average for the "intermediate" counties traversed by the river between the upstream and downstream stations. Station pair fixed effects are also included, and standard errors are clustered at the station pair level.

4.1 The Effect of Water Basin Management Committees on Water Quality

We examine the impact of the institution of a water basin committee on water pollution spillovers between counties by estimating the decrease in pollution spillovers associated with a change in the status of the local water basin committee. Water basin committees are assigned an indicator variable for whether they exist (indicator takes the value 1) or not (indicator takes the value 0). The estimation equation is specified as follows:

$$\Delta(Pollution_D - Pollution_U) = \alpha_{stp} + \beta_1 LocalWaterBasinCommittee_{stp,t} + \gamma X_{stp,t} \qquad (60)$$

Where X is a full set of controls for population density, county size, and GDP in the upstream, downstream, and the intermediate counties, and year and basin-month dummies. Station pair fixed effects are included in the regressions, so identification is based uniquely on a change from a committee not having yet been formed to the institution of a new committee. Table 3 shows the estimates for when both the upstream and downstream counties belong to the same river basin management committee, and table 4 shows the estimates for when the downstream county belongs to a river basin management committee (while the upstream county has not). We find that when both the upstream and the downstream counties belong to the same water basin committee, the estimated level of pollution as measured by COD and BOD in the river decreases.

No overall changes in water quality spillovers are associated with the institution of a water basin management committee. Dissolved oxygen is a general measure of the capacity of a water body to sustain life. Increases in dissolved oxygen suggest that the water body is a healthier ecosystem. Tables 3 and 4 show that there is no significant change in the difference in dissolved oxygen between two stations associated with a change in the status of the local water basin management committees.

Tables 3 and 4 show that biochemical oxygen demand and chemical oxygen demand decrease when the stations are within a water basin management committee. Both biochemical oxygen demand and chemical oxygen demand are measures of organic pollution. Table 3 shows that the institution of a water basin management committee is associated with a 24% decrease in chemical oxygen demand spillovers and a 34% decrease in biochemical oxygen demand spillovers between the upstream station and downstream station. This suggests that the institution of water basin committees is associated with increased monitoring of the treatment of industrial waste or increased use of sewage treatment facilities.

Water basin management committees appear to impact fecal coliform levels. Fecal coliform levels are fast to dissipate, so the local measurement is a good proxy for pollution in the region directly upstream of the water monitoring station. We would expect to see lower fecal coliform levels at both the upstream and the downstream station in cases where both stations are included in the water basin management committee. We find that there is no significant impact of the institution of water basin management committees on the difference in water quality between the upstream and downstream stations in table 3. However, when we look at all cases where the downstream station belongs to a water basin management committee, we find that the estimated coefficient is -60% (although this impact is not statistically significant at conventional levels of significance). This suggests that there are local reductions in fecal coliform at the downstream station when the water basin management committee is instituted.

Fecal coliform is a quickly dissipating measure of pollution, and therefore the distance between the upstream and downstream stations may be too large to capture changes in management between the counties. If the impact is stronger on the downstream county, as it would be in the case of the relevant management committee being the committee for the downstream station, then the coefficient is negative. In cases where the effect on the upstream and downstream station are similar, the estimated coefficient should be close to 0. In future work, it will be interesting to investigate the impact of the institution of the water basin management committee with water quality level of the downstream station as the dependent variable.

Non-point source pollution is notoriously difficult to manage, because the location of the pollution source can not be directly determined. Therefore, we would expect to see less of an impact of water basin committees on non-point source pollutants such as Ammonia and Nitrates which are commonly associated with fertilizer waste from farms. Tables 3 and 4 show that consistent with this reasoning, the impact of water basin committees on these pollutants is much smaller, in fact in table 4 the impact appears to be positive.

In order to further investigate the impact of water basin management committees on water quality, we separate the sample into the observations taken in the upstream portions of rivers and the observations taken in downstream portions of the rivers. We expect the impact of the water basin management committees to be largest in the downstream portion of the rivers as they collect the interests of the downstream users and allow them to negotiate jointly with the upstream users. Therefore, we should see larger impacts on spillovers for the regressions run in the downstream portion of rivers than for regressions run on the upstream portion of rivers. Table 5 shows that this intuition is correct.

Water basin management committees are designed to enable multilateral negotiation between parties involved in the use and dispensation of water rights. We expect to see that basin groups create the largest benefit for water quality in areas where multilateral negotiation would be necessary in order to improve the water quality, or in the downstream portion of rivers where the river has had to pass through multiple jurisdictions.

In table 5 we see that the reduction in spillovers between stations associated with the institution of a water basin committee in the downstream portion of the rivers is larger than the reduction in spillovers between stations in the upstream portion of rivers. We find that in the downstream portion of rivers when a water basin committee is instituted, there is a 48% decrease in COD, a

43.2% decrease in BOD and a 48% decrease in fecal coliform spillovers (although the result for fecal coliform is not significant at conventional levels). The results in the upstream portion of the rivers suggest increased spillovers following the institution of a water basin management committee which may indicate strategic behavior by upstream counties, but these results are not statistically significant.

Because there may be unobserved factors which affect both the formation of water basin committees and pollution levels in the areas in which committees were formed, there is a potential for bias in the regressions described above. In section 4.2, we test the robustness of the results to the use of instruments for membership in water basin management committees.

4.2 Robustness: Instrumenting for Formation of Water Basin Management Committees

As shown in the theoretical model, there is the potential for endogeneity in the formation of water basin management committees. The bias from endogeneity in the formation of water basin management committees could go in either direction. We could expect that water basin management committees are most likely to form in areas where water pollution spillovers are observed to be largest as local governments try to resolve these problems, or water basin management committees may be least likely to form in areas where cross-border tensions are high causing elevated transaction costs–these are also areas in which cross jurisdiction spillovers may be particularly large.

In order to test for the robustness of the results to the possibility of endogeneity bias, we develop an instrument for the state's propensity to form water basin management committees. Much of the impetus for the formation of water basin committees came from pressure at the state level. States passed laws or resolutions in varying years in order to increase the incentives for local water basin management committees to be formed. These laws generally corresponded with other environmental legislation and pressures at the state level including increased protection of forests, and increased enforcement of anti-burning, or "queimadas" laws.

States are large and water monitoring stations tend to be in areas where the population is relatively dense while forests and the largest amount of forest fires are in less population dense areas. These environmental initiatives targeted at stemming forest fires would have little direct effect on water quality changes between two monitoring stations. However, a state environmental initiative aimed at reducing forest fires is likely to be correlated with state initiatives aimed at creating water basin management committees as legislators may pass a basket of environmental legislation together. Because water pollution abatement occurs primarily at the county level, these legislative initiatives are unlikely to be directly related to local spillovers between station monitoring pairs.

Counties which have local environmental agencies may be most likely to quickly respond to state legislative initiatives aimed at the creation of water basin management committees. Any direct impact of the agencies will be removed by the station pair fixed effects, so the remaining impact will be from the likelihood that counties with environmental agencies are most likely to be faster adopters of state initiatives pushing for basin management committees.

In table 6 and 7, we see that decreases in queimadas are associated with an increased probability that the counties of the upstream and downstream stations will be in the same water basin management committee. As our intuition suggested, we also see that this impact is stronger for counties which have a county environmental agency. These instruments are relatively weak instruments in the sample reporting COD, with F-statistics of 2.9-3.7 as shown in table 6. They are relatively stronger instruments for the sample of counties where there are observations on fecal coliform. F-statistics for the instruments in these regressions are between 4.8 and 10.3.

In the IV regressions for COD, we find that the reduction in COD spillovers between water monitoring stations is an impact which is robust, although not significant in the instrumented regressions. The magnitude of the coefficient is similar to the magnitude in the uninstrumented regressions–we find that the upstream and downstream counties belonging to the same water basin management committee corresponds to an approximately 36% decrease in spillovers between jurisdictions. It should be noted that the instruments are weak and further research remains to be done on developing improved instruments.

In the IV regressions for fecal coliform, we find limited evidence of strategic behavior by counties which belong to water basin management committees. If we believe that the instrument meets the exclusion restriction, the regressions in 7 show that the stations located in counties which form water basin management committees actually have an increase in fecal coliform levels following their accession to the management committees. While OLS regressions suggest a 57.6% increase in fecal coliform following the adhesion of the county to the water basin management committee, the instrumented regressions suggest either a 236% or 339% increase in fecal coliform levels following the development of the committee depending on the specification of the instrument. This suggests that upstream counties may actually be behaving strategically by increasing their levels of pollution in the short term in order to gain larger amounts of transfers from the other counties in the group in future periods. Further work is necessary in order to refine the instrument and to investigate whether this type of strategic behavior occurs.

4.3 The Effect of Political Affiliation on Negotiation between Jurisdictions

The empirical evidence we have presented in section 4.1 and 4.2 suggests that the effects of water basin management committees have been weak at best. However, following the Coase theorem and our theoretical model, we would expect to see transfers between counties in order to reduce the impact of the significant pollution spillovers between jurisdictions imposed between counties. While multilateral negotiation may be difficult in practice, water basin management committees appear to be one mechanism which would facilitate coordination between the counties. It is therefore worthwhile to look at political factors which may directly influence the transaction cost of transfers between counties. Our theoretical model suggests that when the upstream and the downstream county are more politically similar, transaction costs decrease and pollution reductions by the upstream county increase.

Tables 8-12 examine the effects of political party affiliations on generating pollution spillovers for different measures of water pollution. Interviews with water quality experts in Brazil suggested that it was much easier for a political leader to negotiate with political leaders of the same party or coalition than to negotiate with political leaders from opposing parties. Using municipio-level electoral data from IPEA and the Brazilian Election Commission, we identify election cycles during which the mayor of the county where the downstream station is located has the same party affiliation as the mayor of her neighbor immediately upstream. We also create a variable for whether this downstream mayor has the same party affiliation as the party most commonly in power across the different municipios in this river basin. The idea is to examine whether political partisanship affects counties' ability to commit to long term agreements with their regional peers to control the pollution spillovers problem. Given the inclusion of upstream-downstream station pair fixed effects, the party affiliation effects are being identified off only changes in party identity over time at each location. A change in leadership of a county may jeopardize agreements which have been made between counties during a previous administration. County mayors in Brazil exert a large amount of influence over the local government budget. Our interviews with political scientists in Brazil suggest that prior to a January 2007 law on inter-municipal consortiums, counties were unable to credibly commit to projects, because contracts between counties could be broken by future administrations.

We estimate the impact of political affiliation by generating an indicator for whether neighboring counties belong to the same political coalition. The indicator takes the value of 1 if the mayor of the county to which the downstream monitoring station belongs is of a party belonging to the same political coalition as the mayor of the closest upstream county. The estimating equation is:

$$\Delta(Pollution_D - Pollution_U) = \alpha_{stp} + \beta_1 MatchingPoliticalAffiliation_{stp,t} + \gamma X_{stp,t} \quad (61)$$

Where X is a vector of control variables for population density, GDP per capita, and county size in the upstream, downstream, and the averaged intermediate counties, and dummies for year and basin month. Standard errors are clustered by station pair. Only observations for which the river crosses at least one county boundary are included.

In table 8 we find that when two neighboring municipios are governed by parties which belong to the same coalition, pollution measures associated with the general health of the river are recorded to improve in the downstream county. The measured impact of the upstream and downstream counties having mayors of similar political affiliations is a 4.1% improvement in dissolved oxygen levels at the downstream station compared to the upstream station, this effect is significant at the 5% level. A similar, but larger impact is observed on chemical oxygen demand levels. Pollution spillovers between the two stations as measured by chemical oxygen demand reduce by 22.3% when the upstream and downstream counties have mayors of similar political affiliations as shown in table 9. However, the mechanism for this effect is not completely clear. 10 shows that the effect is not also seen in measured BOD levels, and 11 shows that the measured impact on fecal coliform levels is opposite in sign (although not statistically significant). Nitrate and Ammonia levels as shown in 12 and 13 do follow similar impacts, however.

Many water quality issues are multi-lateral in nature rather than bilateral, so it is possible that our indicator for matching pairs of counties is not sufficiently representative of the local political climate in order to measure local political cohesiveness as required for effective negotiation over water pollution issues. In order to test the impact of political cohesiveness within a basin region, we generate an indicator for whether the county of the downstream station has a mayor whose party belongs to the same political coalition as the coalition most common among the counties across the water basin catchment area. The indicator takes the value of 1 if the political coalition of the mayor in the downstream county matches the modal political coalition in the catchment area, 0 otherwise. The results are shown for the different pollutants in tables 8-13.

We find that the measured impact on water quality in the downstream station as compared to the upstream station is a 1.5 percent increase in quality as measured by dissolved oxygen, but this impact is not significant at standard levels. The impact on both chemical oxygen demand and biochemical oxygen demand is an increase in pollution spillovers, although this impact is not significant at standard levels. We do find that the matching political affiliation characteristic is associated with a 36% decrease in ammonia levels which is significant at the 5% level, and a 5% decrease in nitrate levels although this impact is not significant at standard levels. This suggests that political cohesion may be impacting the spillovers resulting from non-point source pollution between counties more than point source pollution, although further research is necessary for the full interpretation of these coefficients.

One effort that counties have made in order to facilitate negotiation outside of the framework of water basin management committees has been to form inter-municipio consortiums. These consortiums have in large part been in existence for long periods of time, as certain municipios have a tradition of participating together in consortiums. In the 2003 environmental census of counties, counties were polled as to whether or not they belonged to an inter-municipio consortium. Because the census does not identify the members of the consortiums, we are not able to directly identify whether or not two municipios belong to the same consortium. However, we create an indicator variable identifying whether both the upstream and downstream county belong to an inter-municipio consortium. In cases where they belong to different consortiums, the measurement error will be larger.

We estimate the impact of matching political affiliations, and test whether the impact is larger in cases where the counties belong to an inter-municipio consortium, which is designed to facilitate negotiation. Our estimating equation is as follows:

$$\Delta(Pollution_D - Pollution_U) = \alpha_{stp} + \beta_1 MatchingPoliticalAffiliation_{stp,t} +$$

$$\beta_2 Consortium_{stp} * MatchingPoliticalAffiliation_{stp,t} + \gamma X_{stp,t} \tag{62}$$

Clearly if the consortiums were forming in response to water quality issues, there would be the potential for severe endogeneity bias in these regressions, similar to the concern for endogeneity in the formation of water basin management committees. However, most inter-municipio consortiums in Brazil have been in existence for decades and have been formed between the counties in order to address a variety of non-environmental concerns. Because these consortiums are formed prior to the beginning of our sample period, and we have only a cross sectional observation on whether or not the municipio belonged to a consortium in 2003, we can not directly measure the impact of the consortiums on water quality spillovers, but we can measure the differential impact of matched political affiliations between counties when the counties both belong to a consortium–this impact will be measured by the coefficient β_2.

We find that consortiums do not create an increase in the effect of matched political preference on water quality overall as measured by dissolved oxygen. However, we do find opposing results in terms of the different pollutants. When the downstream county's mayor has the same political coalition as the modal political coalition in the river basin catchment area and both the downstream and upstream county belong to an inter-municipio consortium, we find large and significant declines in fecal coliform levels. This impact is not matched by a similar impact on BOD or COD levels (they are measured to have positive, but not significant coefficients), which we would expect to see decrease in response to the decrease in fecal coliform. However, the measured impact on nitrate levels is positive, and the impact is also statistically significant. We see a 24% increase in nitrate levels where the political preferences match and there is an intermunicipio consortium. However, this may be evidence of political changes corresponding to changes in land use as an area becomes more agriculturally intensive. More research is necessary in order to parse the impact of political affiliation and local negotiation between counties.

Term limits provide an additional source of variation which we may exploit in future work. Popular mayors in their first term are likely to be re-elected. Counties with popular mayors can credibly commit to projects with a duration of less than two full election cycles. Mayors in their second terms are not able to stand for re-election, so their commitment to a project is less certain. We can estimate the costs of imperfect contracting by using the percent of funding devoted to cross-county long term water-infrastructure investments as the dependent variable, and the incumbency of the county mayor as the independent variable of interest. List and Sturm (2006) use term limits to estimate the impact of secondary policy issues in elections.

5 Conclusion

Decentralized management of a public good creates the potential for large spillovers between jurisdictions. Over the past few years, there has been an increasing push toward decentralization in developing countries. It is argued that decentralization can enable improved management of public services and better targeting toward local preferences. However, in cases where the public good extends beyond jurisdictional borders, decentralization may create inefficiencies in the management of the public good. Jurisdictions may overuse natural resources, imposing large costs on their neighbors.

The spillovers between jurisdictions may be particularly large in the case of water resources management. Lipscomb and Mobarak (2007) showed that jurisdictions strategically pollute in the downstream region of the county, creating large pollution spillovers. Many national and international conflicts are caused by ineffective management of water resources across borders. More empirical research is needed in order to understand the impact of new water management techniques. This paper analyzes the determinants and outcomes of negotiation between jurisdictions through water basin committees and the political barriers to the reduction of cross border pollution.

Our simple theoretical model sets up a two stage game in which jurisdictions choose whether or not to join negotiations in the first stage and the pollution choice and transfer made between jurisdictions in determined in the second stage. The model suggests several predictions which we test in the empirical work: 1) We should see a larger decrease in pollution from negotiation in basin committees than from bilateral negotiations. 2) The impact of basin committees should be largest in the downstream portion of the river. 3) Decreases in the transactions cost (even absent a water basin committee) should increase the size of the pollution reduction. 4) An increase in negotiation should have the largest impact on pollution levels where the downstream county is highly dependent on water quality and pays a high marginal cost of pollution. We test predictions 1-3 in the current paper. In future work, we expect to be able to test the fourth prediction.

We find that consistent with the predictions of the theoretical model, the institution of water basin committees is associated with some reduction in organic point source pollution. These reductions appear to be largest in the downstream areas of the river. Results of robustness checks based on instrumental variables methods appear to be mixed.

In order to test the third prediction of our model, we look for exogenous sources of variation in transactions costs between jurisdictions. Political affiliation of the local mayor being the same as the upstream county or counties within the same water basin should have little direct impact on water quality, but in the highly politicized environment of Brazil, it may have a strong impact on the ability of counties to negotiate with each other. We find mixed evidence that the reduction in transaction costs resulting from counties having local leadership of the same political coalition does lead to a reduction in local organic pollution, and that these reductions are largest where a forum for negotiation has already been instituted.

There is much work which remains to be done in evaluating the mechanisms through which water basin committees and other forums for negotiation between jurisdictions may reduce transactions costs and enable further reductions in local pollution spillovers. This paper provides an initial foray into the analysis of some of the basic impacts of water basin committees and local political alliances on environmental management.

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6 Charts and Figures

Figure 1: Location of Monitoring Stations

Figure 2: County Boundaries as of 1994

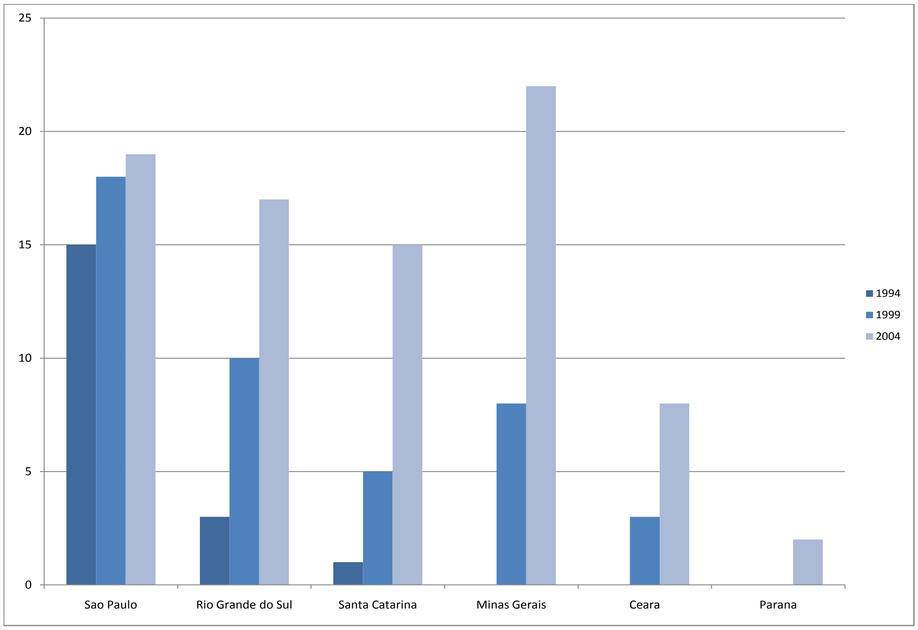

Figure 3: Within State River Basin Committee Expansion

7 Tables

Table 1: Small Stakeholders: Effect on the Creation of Water Basin Committees

	Committee Formation
Fishing or Farming Among primary industries in county	0.019*** (0.003)
R-squared	0.205
N	52257

Linear Probability Model: Dependent Variable is a 0 or 1 indicator of whether fishing or farming are among the principal industries in the county. Year dummies and state dummies are included.

Table 2: Summary Statistics

Variable	Obs	Median	Mean	Std. Dev.	Min	Max
Biochemical Oxygen Demand	12360	2	5.40	16.01	0	912
Chemical Oxygen Demand	13555	8.9	14.19	21.55	0	631
Dissolved Oxygen	33195	7.2	6.98	4.93	0	422
Nitrates	13841	0.23	0.40	1.01	0	29
Fecal Coliform	16239	350	428929.50	13200000	0	7.15E+08
Ammonia Nitrate	11016	0.1	0.42	1.38	0	19.8

Table 3: The Effect of Water Basin Committees on Water Quality

	DO	COD	BOD	Fecal Coliform	Ammonia
Upstream and Downstream Counties Belong to a Basin Committee	-0.057 (0.03)	-0.238 (0.13)	-0.335* (0.16)	0.159 (0.50)	-0.101 (0.18)
R-squared	0.063	0.058	0.073	0.045	0.061
N	37886	13769	10540	14063	8459

Table 4: The Effect of Water Basin Committees on Water Quality (Downstream station)

	DO	COD	BOD	Fecal Coliform	Ammonia	Nitrates
Downstream station within Water Basin	0.026 (0.04)	-0.322* (0.13)	-0.214 (0.16)	-0.595 (0.37)	0.373* (0.17)	0.070 (0.15)
R-squared	0.044	0.060	0.070	0.064	0.064	0.063
N	37886	13769	10540	14063	8459	11571

Table 5: Effects of Water Basin Committees in Upstream versus Downstream portions of Rivers

	DO		COD		BOD		Fecal Coliform	
	Upstrm	Dwnstrm	Upstrm	Dwnstrm	Upstrm	Dwnstrm	Upstrm	Dwnstrm
Downstream county and nearest upstream county belong to same Committee	0.024 (0.09)	-0.011 (0.04)	0.366 (0.25)	-0.476*** (0.18)	0.057 (0.19)	-0.432* (0.27)	0.033 (0.50)	-0.48 (0.80)
R-Squared	0.118	0.064	0.068	0.098	0.102	0.122	0.084	0.113
N Observations	10127	27759	3797	9972	3251	7289	4115	9948

Table 6: Robustness: Instrumenting for Water Basin Management Committee Formation (COD levels)

	OLS	IV-QM	IV-QM AG	OLS	IV-QM	IV-QM AG
Downstream County and Closest upstream	-0.342**	-0.363	-0.97			
County belong to the same Committee	(0.16)	(1.58)	(1.23)			
Downstream County and Upstream				-0.518	-0.329	-0.921
County belong to the same Committee				(0.40)	(1.45)	(1.22)
R-Squared	0.0093			0.0004		
Observations	6811	6811	6811	13769	6811	6811
F-Statistic		2.88	1.87		3.67	2.34
p-value		0.0912	0.157		0.057	0.0991
First Stage Coefficients						
Queimadas			-1.88E-06			-3.00E-06
			(1.51E-06)			(1.80E-06)
Queimadas*County Agency		-5.64E-06	-7.94E-06		-6.23E-06	-6.80E-06
		(3.32E-06)	(5.36E-06)		(3.25E-06)	(4.89E-06)

*Dependent variable is the change in COD levels between the upstream and downstream water monitoring stations. Fixed effects by station pair are included. Year and basin-month dummies are included, and controls for population density, county size, and GDP per capita are included. Standard errors have been clustered by station pair.

Table 7: Robustness: Instrumenting for Water Basin Management Committee Formation (Fecal Coliform Levels)

	OLS	IV-QM	IV-QM AG	OLS	IV-QM	IV-QM AG
Downstream County and Closest upstream	0.576*	2.36	3.39			
County belong to the same Committee	(0.30)	(2.57)	(2.41)			
Downstream County and Upstream				0.192	1.79	2.87
County belong to the same Committee				(0.43)	(1.89)	(2.05)
R-Squared	0.0053			0.0048		
Observations	7554	7554	7554	7554	7554	7554
F-Statistic		6.74	4.81		10.26	6.98
p-value		0.010	0.009		0.002	0.001
First Stage Coefficients						
Queimadas		-7.75E-06	-3.55E-06		-1.02E-05	-7.43E-06
		(2.99E-06)	(1.67E-06)		(3.20E-06)	(3.97E-06)
Queimadas*County Agency			-0.0000113			-7.57E-06
			(5.58E-06)			(6.02E-06)

*Dependent variable is the change in Fecal Coliform levels between the upstream and downstream water monitoring stations. Fixed effects by station pair are included. Year and basin-month dummies are included, and controls for population density, county size, and GDP per capita are included. Standard errors have been clustered by station pair.

Table 8: Impact of Party Politics on Dissolved Oxygen Levels

Downstream same as next upstream	0.041***				0.045***	
	(0.02)				(0.02)	
Downstream same as basin modal party		0.015				
		(0.04)				
Interact Consortium in upstream and downstream			-0.019		-0.034	
with Downstream same party as next upstream			(0.05)		(0.05)	
Interact Consortium in both closest upstream and				-0.01		-0.022
Downstream same as basin modal party				(0.09)		(0.08)
R squared	0.048	0.047	0.047	0.047	0.048	0.048
Observations	37886	37886	37823	37823	37823	37823

Table 9: Impact of Party Politics on Chemical Oxygen Demand Levels

Downstream same as next upstream	-0.223***				-0.261***	
	(0.10)				(0.10)	
Downstream same as basin modal party		0.057				0.038
		(0.10)				(0.11)
Interact Consortium in upstream and downstream			0.196		0.28	
with downstream party same as next upstream			(0.20)		(0.21)	
Interact Consortium in both closest upstream and				0.166		0.157
Downstream same as basin modal party				(0.18)		(0.19)
R squared	0.066	0.063	0.064	0.064	0.068	0.064
Observations	13769	13769	13769	13769	13769	13769

Table 10: Impact of Party Politics on Biochemical Oxygen Demand Levels

Downstream same as next upstream	0.044				-0.033	
	(0.11)				(0.12)	
Downstream same as basin modal party		0.023				-0.025
		(0.09)				(0.10)
Interact Consortium in upstream and downstream			0.416**		0.430**	
with downstream party same as next upstream			(0.19)		(0.21)	
Interact Consortium in both closest upstream and				0.293		0.299
Downstream same as basin modal party				(0.19)		(0.19)
R-squared	0.077	0.077	0.081	0.080	0.081	0.080
N	10540	10540	10540	10540	10540	10540

Table 11: Impact of Party Politics on Fecal Coliform Levels

Downstream same as next upstream	0.249				0.348	
	(0.22)				(0.23)	
Downstream same as basin modal party		-0.22				-0.072
		(0.28)				(0.28)
Interact Consortium in upstream and downstream			-0.547		-0.708	
with Downstream same party as next upstream			(0.35)		(0.36)	
Interact Consortium in both closest upstream and				-1.153***		-1.129***
Downstream same as basin modal party				(0.39)		(0.40)
R squared	0.07	0.07	0.07	0.073	0.071	0.073
Observations	14063	14063	14063	14063	14063	14063

Table 12: Impact of Party Politics on Ammonia Nitrate Levels

Downstream same as next upstream	-0.235				-0.218	
	(0.20)				(0.21)	
Downstream same as basin modal party		-0.365**				-0.353**
		(0.18)				(0.19)
Interact Coalition in upstream and downstream			-0.176		-0.096	
Downstream same party as next upstream			(0.22)		(0.22)	
Interact Coalition in both closest upstream and				-0.199		-0.153
Downstream same as basin modal party				(0.23)		(0.24)
R squared	0.072	0.074	0.071	0.072	0.072	0.074
Observations	8459	8459	8459	8459	8459	8459

Table 13: Impact of Party Politics on Nitrate Levels

Downstream same as next upstream	-0.118				-0.181	
	(0.11)				(0.11)	
Downstream same as basin modal party		-0.051				-0.080
		(0.14)				(0.14)
Interact Coalition in upstream and downstream			0.314**		0.393***	
Downstream same party as next upstream			(0.13)		(0.15)	
Interact Coalition in both closest upstream and				0.242*		0.262*
Downstream same as basin modal party				(0.13)		(0.14)
R-Squared	0.071	0.071	0.073	0.072	0.074	0.072
N	11571	11571	11571	11571	11571	11571