NBER WORKING PAPER SERIES

DECENTRALIZATION AND ENVIRONMENTAL QUALITY: AN INTERNATIONAL ANALYSIS OF WATER POLLUTION

Hilary Sigman

Working Paper 13098
http://www.nber.org/papers/w13098

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
May 2007

I am grateful to GeoffreyWilliams for excellent research assistance and to Rosanne Altshuler, Howard Chang, Conan Crum, Arik Levinson, Molly Lipscomb, Mushfiq Mobarak and seminar participants at the Copenhagen Business School, Rutgers, Yale, the ALACDE Annual Meeting and the WCERE for helpful comments. The views expressed herein are those of the author(s) and do not necessarily reflect the views of the National Bureau of Economic Research.

Decentralization and Environmental Quality: An International Analysis of Water Pollution
Hilary Sigman
NBER Working Paper No. 13098
May 2007, Revised March 2013
JEL No. H77,Q5

ABSTRACT

This paper explores the empirical effects of decentralization on environmental quality by studying water pollution in rivers around the world. It examines the level of pollution and variation in pollution across jurisdictions within a country, for both a local and a regional pollutant. Federal countries exhibit greater interjurisdictional variation in pollution, supporting the traditional view that decentralization allows policies more tailored to local conditions. However, the analysis does not point to a "race to the bottom" in pollution levels.

Hilary Sigman
Department of Economics
Rutgers University
75 Hamilton Street
New Brunswick, NJ 08901-1248
and NBER
sigman@econ.rutgers.edu

Many countries are actively considering the appropriate level of government to conduct environmental policy. In the U.S., recent Supreme Court decisions limit the federal government's authority to undertake environmental regulation. In the European Union, the trend has been the reverse, with increased reliance on common or harmonized environmental policies. An extensive literature discusses the desirability of decentralization in provision of public goods and environmental quality.

Several arguments from this literature would suggest an effect of decentralization on the level of pollution and on the amount of variation in pollution across jurisdictions within a country. The traditional model of Oates (1972) suggests increased interjurisdictional variation with decentralization because it allows jurisdictions to control their own pollution levels. Destructive regulatory competition, in the form of a "race to the bottom," would lower environmental quality with decentralization, but probably not increase variation across regions. Interjurisdictional free riding might give rise to higher levels of transboundary pollutants with greater decentralization, but not higher levels of local pollutants. Models with distributive and interest group politics also may have implications for the effects of decentralization. Thus, the net effects of decentralization are uncertain and provide an opportunity to evaluate the empirical importance of various concerns.

Effects of decentralization on environmental policy and outcomes have begun to be documented in the empirical literature. List and Gerking (2000) and Millimet (2003) look at the net effect of changes over time in decentralization in the U.S. on policy outcomes; they find limited effects of the Reagan-era decentralization on air pollution and pollution abatement spending.[1] At a subnational level, Cutter and DeShazo (2007) examine an environmental policy that allows local governments to request control from the California government. They conclude that heterogeneity across the localities plays a large role in the apparent effects of devolution on stringency under this

[1]List and Gerking (2000) conclude that neither spending nor air pollution (nitrogen oxide and sulfur dioxide emissions) changed after 1980, whereas Millimet (2003) finds that spending (but not air pollution) rose by the mid-1980s. Both papers discuss their results in terms of destructive competition, but their results might be interpreted in terms of the broader set of hypotheses discussed here.

program. Unlike earlier work, the current paper incorporates international experience with decentralization and examines both a local and a regional pollutant. In addition, this paper is the first to examine interjurisdictional variation in levels of the public good, which allows a fairly direct test of the traditional model.[2]

For this study, data on water pollution in rivers derives from the U.N.'s Global Environment Monitoring System (GEMS) Water Quality Monitoring Programme. The pollutants studied are biochemical oxygen demand (BOD), which is transported far downstream, and fecal coliform, which has local effects and is thus less of a candidate for interjurisdictional free riding. The estimated equations model pollution levels and interjurisdictional variation in pollution as depending on a country's decentralization, other country characteristics, and characteristics of the monitoring location.

The results suggest higher interjurisdictional variation in pollution levels in federal countries for both pollutants. Such variation supports the traditional view of Oates (1972) that decentralization allows better tailoring of policies to local conditions. The results do not support higher average levels of pollution with greater decentralization, as would occur with destructive regulatory competition.

The outline of the paper is as follows. The next section outlines hypotheses about the association between decentralization and environmental quality. Section 2 describes the GEMS/Water data and variables matched from other sources. Section 3 presents the estimates of equations for the levels of the two pollutants, with and without monitoring station fixed effects. Section 4 analyzes interjurisdictional variation in pollution levels within countries. Section 5 estimates models that allow endogenous participation of countries in GEMS/Water, but does not find much evidence that such selection affects earlier results. A final section concludes.

[2]In a similar spirit, Faguet (2004) finds that decentralization in Bolivia resulted better "tailoring" of spending, for example increasing sewerage spending in places where access to sewers was lower. My approach does not evaluate where environmental quality yields higher net welfare; it just looks for evidence of heterogeneity.

1 Effects of decentralization

An extensive theoretical literature describes conditions under which decentralization of public goods provision improves welfare. This section discusses this literature with the goal of deriving predictions about the empirical effect of decentralization on environmental quality.

In a foundational study, Oates (1972) posits that central governments find it difficult to generate optimal local variation in policy stringency. The central government may be unable to vary stringency because it finds variation costly for political reasons or because it lacks the information about local conditions to chose regionally-varying optimal responses. This model does not have clear implications for the typical level of pollution; whether average pollution levels rise or fall with decentralization will depend on how the central government aggregates preferences (Fredriksson et al., 2010).

The Oates model does suggest a positive association between decentralization and within-country interjurisdictional variation in environmental quality. If the central government allows insufficient variation in standards, decentralization will yield a higher variance in these levels as local governments choose standards that reflect their heterogeneous preferences. Thus, an increase in variation is a likely outcome and can be tested in practice.[3]

However, destructive competition between jurisdictions might cause an association between decentralization and pollution levels. Welfare-maximizing subnational governments will make efficient choices for local pollutants in the absence of market imperfections and redistributive policies (Oates and Schwab, 1988; Wilson, 1996). But these conditions are unlikely in practice, raising the possibility of destructive competition (Oates, 2002; Kunce and Shogren, 2005). Such competition

[3] For a case in which decentralization might reduce variation, suppose preferences for in-stream water quality are identical across regions, but consequences of different levels of emissions for in-stream water quality vary because of hydrological or climate conditions. Since the government usually regulates (or taxes) emissions rather than in-stream pollution, a local government may use its information to achieve an environmental outcome closer to the optimum than the outcome the national government could achieve. My empirical analysis looks at interjurisdictional variation conditional on some characteristics of the location, but probably not all the conditions that an optimizing local government could consider.

may take the form of a "race to the bottom," in which countries lower environmental standards to compete for capital. In other situations, it may be a "race to the top" or Not in My Backyard (NIMBY) syndrome, in which local governments raise standards to shift environmental damages to other jurisdictions. Empirical evidence supports the view that environmental competition arises within the U.S. federal system (Levinson, 2003; Fredriksson and Millimet, 2002).

Interjurisdictional environmental spillovers might also create an association between decentralization and pollution levels. Failing to consider the welfare of neighbors, subnational governments may choose higher levels of pollutants that cross state borders than the national government would choose (Silva and Caplan, 1997). Studies report empirical evidence of such free riding within the United States (Helland and Whitford, 2003; Sigman, 2005; Gray and Shadbegian, 2004) and within Brazil (Lipscomb and Mobarak, 2011), although some research does not support free riding (Konisky and Woods, 2010). Free riding would increase the level of pollution with decentralization for regional pollutants, such as BOD, but not for local pollutants, such as fecal coliform.

Strategic decision-making in the central government may also create effects. Besley and Coate (2003) conclude that the central government may provide too much of local public goods when regional spillovers arise, as a result of strategic voting for representatives to the central legislature. Thus, they would predict that pollution would rise with decentralization; in contrast to the effects of destructive competition and spillover, however, this increase would improve welfare.

Finally, a few authors have advanced hypotheses about interest group influence and regulatory capture at different levels of government. Bardhan and Mookherjee (2000) argue that local governments may be more or less subject to capture, depending on factors such as within- and across-district heterogeneity in voters and relative voter awareness of local and national politics. In the environmental policy literature, some argue that industry groups can better afford to have informed staff in many places and thus are more influential at the subnational level (Esty, 1996). Others have argued that interest groups must overcome a spending threshold to be heard at a national level. Such a threshold would imply that centralization works in favor of industry, whereas environmental organizations have a comparative advantage in the more grass-roots arena of sub-national politics (Revesz, 2001).

2 Data

2.1 Data on water quality

The U.N.'s GEMS/Water provides data on various water quality measures in rivers, lakes, and groundwater (United Nations, 2009). This study focuses specifically on the data for rivers, which account for most of the observations. GEMS/Water reports triennial average pollution levels from 1979 through 1999. Figure 1 shows the location of the river monitoring stations (in 47 countries) that report the pollutants studied here.[4] The possibility of endogenous participation by countries in GEMS/Water is addressed later in the paper. Most stations do not report pollution in every triennial period: the mean number of observations per station is 4.1 out of a possible 7.

Two pollutants are used in the analysis, biochemical oxygen demand (BOD) and fecal coliform. These pollutants are very common; both arise mostly from release of human and agricultural wastes into rivers. They are also commonly reported in the GEMS data, providing a relatively large number of observations for analysis.[5] The two pollutants differ greatly in their potential for downstream transport. BOD has much slower natural attenuation and may affect the rivers tens of kilometers downstream of its source, whereas fecal coliform affects at most several kilometers of the river. Thus, BOD may give rise to substantial interjurisdictional spillovers, whereas fecal coliform will spill over only very near borders.

[4] Stations located on rivers when they form an international border have been excluded because it is difficult to assign country characteristics (including decentralization) to these stations. For each pollutant, this restriction eliminated 15 stations, mostly in Europe.

[5] Other commonly available measures in GEMS/Water are either related to BOD (dissolved oxygen, chemical oxygen demand) or from more types of specific source (e.g., nitrates) and thus less general characterizations of pollution. A companion database, GEMS/Air, provides data for air pollution, but only for major cities, so the geographic spread within countries is insufficient to provide the interjurisdictional variation measures studied here. In Sigman (2008), I analyzed the cross-country association between the level of air pollution and decentralization using these GEMS/Air data and did not find a statistically significant association.

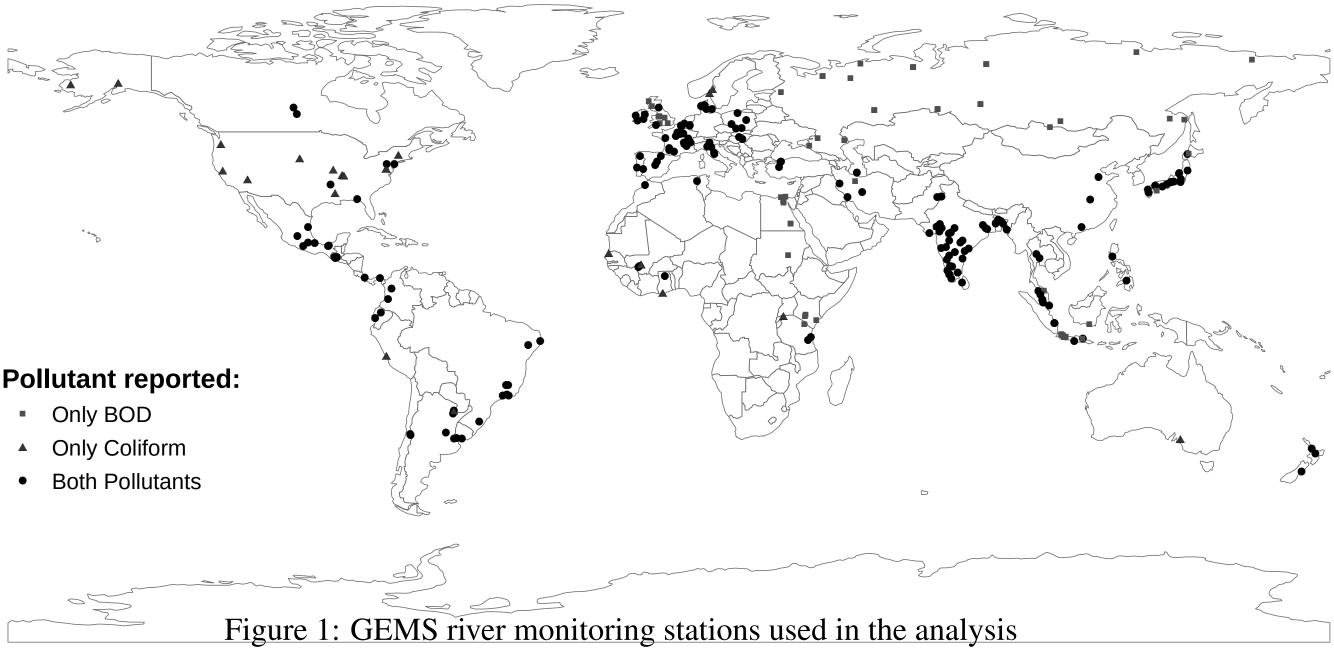

Figure 1: GEMS river monitoring stations used in the analysis

Table 1 reports the statistics for the two pollutants. The average concentrations for both pollutants are very high.[6] The average concentrations are 5.4 mg/l of BOD and over 10,000 colonies/100 ml of fecal coliform. For comparison, rivers with BOD higher than 4 mg/l or fecal coliform higher than 2,000 colonies/100 ml would not be acceptable for any recreational use according to the Resources for the Future Water Quality Ladder (Vaughan, 1986). Medians are not as bad: 2.2 mg/l for BOD (acceptable for swimming) and 920 colonies/100 ml for fecal coliform (acceptable for fishing).

GEMS reports a mean pollution level for measurements taken at different times during the three-year period, with little information about the timing of these measurements. The third row in Table 1 reports that the observations are based on an average of 31 measurements in nonfederal country and 26 in federal countries, or about 8 to 10 a year.[7] However, the number of measure-

[6]Fecal coliform has some exceedingly high values, with concentrations in the millions of colonies per 100 ml, concentrations that would characterize raw sewage and probably represent data entry errors. Concentrations above the 95th percentile (200,000 colonies/100 ml) have been discarded for the rest of the analyses; including these observations did not change any of the substantive results below.

[7]Stations may report one pollutant but not the other in a given period, so the samples are somewhat different for the two pollutants. For simplicity, the two samples are pooled in Table 1 because the differences in sample statistics were very small.

Table 1: Means and standard deviations of the data

	Nonfederal		**Federal**	
Variable	Mean	S.D.	Mean	S.D.
Mean BOD concentration (mg/l)	3.74	9.92	6.25	20.21
Mean fecal coliform (thousand colonies/100 ml)	10.8	26.5	9.8	27.6
Number of measurements per observation	30.7	26.2	26.4	17.4
Country-level variables				
Expenditure decentralization (percent)	18.0	9.9	38.3	11.2
Expenditure decentralization missing	.40	–	.22	–
Expedenditure decentralization without defense (percent)	19.9	11.5	46.7	14.8
Expedenditure decentralization without defense missing	.51	–	.33	–
GDP per capita (thousand 2005 dollars)	15.4	10.3	9.5	10.1
Democracy score (-10 (autocratic) – 10 (democratic))	4.9	6.9	6.3	4.2
Control of corruption index (0 (worst) – 6 (best))	4.1	1.6	3.6	1.1
Country population (millions)	104	216	385	355
Country area (thousand km^2)	853	1845	6050	5743
Station-level variables				
Population within 20 km (thousands)	751	1292	510	733
Flow (m^3/sec)	1549	5820	2646	5861
Temperature	16.2	6.3	20.3	7.8
Upstream basin area (thousand km^2)	117	361	342	681
Total observations:				
BOD	487		579	
Coliform	359		403	
Number of stations:				
BOD	137		110	
Coliform	116		87	

Notes: Standard deviations for continuous variables only.
Variables have been pooled across pollutants.

ments has a high standard deviation, so the precision of the observations varies considerably. The estimated equations use the number of measurements as weights to address the heteroskedasticity from this variation.

2.2 Explanatory variables

Decentralization measures. An ideal measure of decentralization in environmental policy is difficult to construct for both practical and conceptual reasons. First, countries use very different regulatory structures, so a single metric of the extent of environmental decentralization is not available. Second, statutory rules may be a poor guide for true power. For example, in the U.S., the federal government sets most environmental standards, but states implement and enforce these standards (Sigman, 2003). States exercise substantial discretion in setting allowable water pollution permits, despite what would appear to be clear federal standards (GAO, 1996). Third, environmental regulation may not be the only government function to affect pollution. Pollution also depends on decisions about land use and spending on sewage treatment, which may not be in the portfolio of an environmental agency or ministry.

For these reasons, this paper uses two general definitions of decentralization, both common in previous literature. One measure is a categorization of countries into federal and nonfederal systems from the established political science literature on federalism (see, e.g., Treisman, 2002). This measure has the advantage of being exhaustive in coverage and of characterizing a broad range of government functions, including policies such as command-and-control regulation that may have limited fiscal impact.

A second measure is expenditure decentralization: the ratio of subnational (state, provincial, and local) government spending to total governmental spending, netting out intergovernmental transfers. Expenditure decentralization has the advantage of varying over time, allowing analyses with fixed effects. However, expenditure decentralization is not consistently available, with much sparser coverage in lower income and non-federal countries.

The World Bank (2001) provides an expenditure decentralization measure, based on data from the International Monetary Fund's Government Finance Statistics (GFS) (International Monetary Fund, 2005).[8] Using GFS, I calculated an additional version of expenditure decentralization that excludes national defense spending because defense is a large and exclusively national category of spending. The additional information requirements for the defense-free measure decrease the number of available observations. The overall correlation between the two measures is very high, so this modified measure is used only in fixed effects equations where time-series variation in defense spending might be a concern.[9] Both expenditure decentralization measures may reflect high frequency budgetary shocks that are irrelevant to the relative power of national and subnational authorities. The data set partially addresses this concern by using three-year averages, which also match the GEMS reporting periods.

Table 1 divides the observations according to the qualitative federalism measure. GEMS stations are found in both federal and nonfederal countries, with the later only somewhat more common. Federalism and expenditure decentralization are closely related; subnational expenditure shares average 38% in federal countries, compared to 18% in other countries.[10] Data on expenditure decentralization is also much more common in federal countries, with 22% missing in federal countries and 40% missing in other countries. As Table 1 reports, average pollution levels are higher for both pollutants in the federal countries.

Figure 2 provides summary information on expenditure decentralization by country to illustrate the range of values across countries and over time. The ranges are presented for those countries

[8]When I recalculated these values directly from GFS, a few values differed from the World Bank and more observations were missing. The difference probably stems from different versions of the GFS. Because the World Bank has greater coverage, the equations primarily use the World Bank values, with my calculations filled in for a few observations that were otherwise missing.

[9]Since 1990, environmental protection is a category of GFS expenditures, which presents the prospect of a more specific expenditure decentralization measure. However, this variable is only present from 1998 onward, too late to be useful here, and even then for very few countries.

[10]Treisman (2002) reports that expenditure decentralization measure is also highly correlated with other qualitative measures of decentralization from countries' constitutions and moderately correlated with the frequency of elected subnational governments.

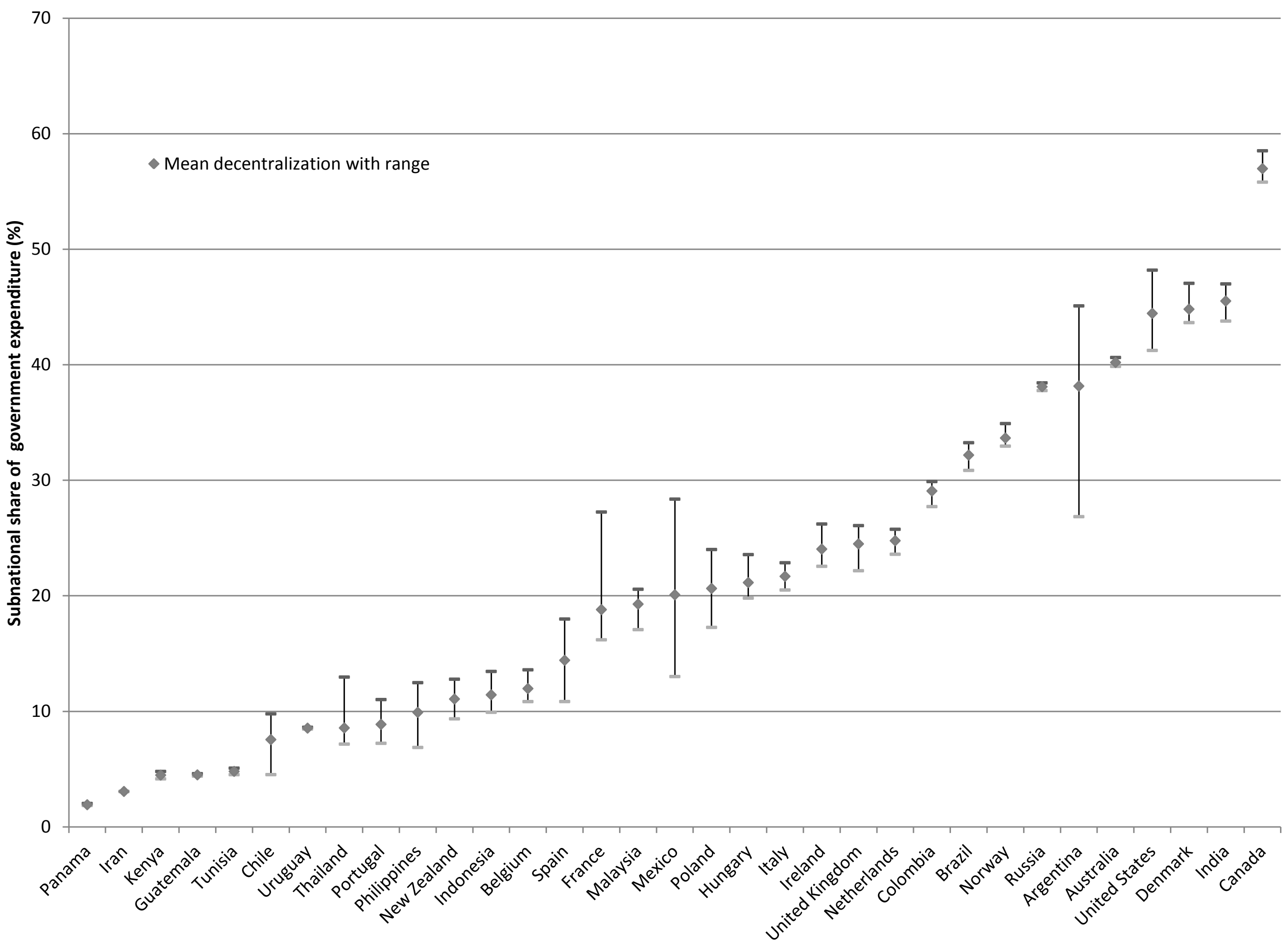

Figure 2: Expenditure decentralization ranges by country

that are the basis of the fixed effects equations below. The values appear to be fairly stable in most countries. The countries experiencing the greatest changes over time are in Latin America. Argentina experienced the greatest change, an increase followed by stabilization in the later part of the period. Mexico saw the second largest change, also with generally increasing decentralization. The expenditure decentralization data are thus consistent with other accounts of declining central government power in Latin American countries in the 1970s and 1980s (Gibson, 2004). The limited number of countries exhibiting large changes in decentralization means that results of fixed effects equations should be interpreted with caution.

Other explanatory variables. Several other characteristics of countries are included. First, national per capita income may affect the costs of pollution control and the benefits of water quality. The Penn World Table provides annual income levels standardized for cross-country comparisons (Heston et al., 2011). As Table 1 reports, countries that participate in GEMS/Water have high income on average; European countries in particular are overrepresented. The relatively high-income population may be desirable because countries must have binding environmental restrictions for any effect of decentralization to be detected.

Second, earlier research has suggested that more democratic governments choose lower pollution than autocratic regimes (Congleton, 1992; Barrett and Graddy, 2000; Deacon and Saha, 2006). Because more authoritarian governments may also tend to be more centralized, it is important to consider this factor in the estimated equations. The equations include the score from the Polity IV project (Marshall et al., 2011). The polity score ranges from -10 (hereditary monarchy) to +10 (consolidated democracy).

Third, studies have found that corruption plays an important role in environmental outcomes (Welsh, 2004; Damania et al., 2003) and that decentralization or federalism is a source of corruption (Fisman and Gatti, 2002; Treisman, 2000). The International Country Risk Guide (ICRG) provides annual corruption scores for countries, based on surveys of professionals (PRS Group, 2007).[11] Higher scores indicate lower perceived corruption. Consistent with earlier literature, Table 1 reports that federal countries in our data are somewhat more corrupt, with an average ICRG score of 3.6 compared to 4.1 for nonfederal countries.

Population may also affect water quality, principally by determining uncontrolled pollution levels. I used a Geographic Information System to calculate population within 20 kilometers of each GEMS station, using the the station's latitude and longitude and the Gridded Population of the World 3 (CIESIN, 2005). Population grids are available for 1990, 1995, and 2000. For other years,

[11] ICRG does not provide data for three countries in the GEMS data (Fiji, Laos, and Cambodia), which are therefore dropped. Corruption scores are available from 1984 onward; the value for the country in 1984 was used for earlier years.

local population variables are linearly interpolated or extrapolated. To provide better time-series population information, the equations also include annual country population density.

Three river characteristics are also included in the equations. The river flow determines dilution and thus the effect of a given amount of waste on in-stream pollution concentrations. Rivers also vary in the rate of natural attenuation of pollutants; water temperature is an important determinant of this rate. GEMS provides time-varying measures of both flow and temperature. A final non-time-varying river characteristic is the river basin area upstream of the station; although this variable is closely related to flow, it may help capture the total waste inputs affecting the river at the monitoring station.

3 Results for pollution levels

The first set of estimated equations examine the effect of decentralization on pollution levels and have the form:

$$\log p_{ict} = f(D_{ct}, GDP_{ct}, GOV_{ct}, DENS_{ct}, LOCALPOP_{ict}, R_{ict}, UPCHAR_{ict}) + \alpha_t + \mu_{ic} + \varepsilon_{ict}, \quad (1)$$

where p_{ict} is the mean pollution concentration at station i in country c in three-year period t; D_{ct} is the measure of decentralization; GDP_{ct} is annual per capita GDP; GOV_{ct} is the quality of government (political rights and corruption); $DENS_{ct}$ is country population density; $LOCALPOP_{ict}$ is local population; and R_{ict} are river characteristics (flow, temperature, and upstream basin area). One equation for each pollutant also includes $UPCHAR_{ict}$, which includes a dummy variable for whether the station is within 100 km downstream of a different country and, if so, the characteristics of the upstream country. These variables are intended to reflect the upstream country's contributions to pollution that has flowed downstream to this spot. Effects for the three-year period, α_t, are included to capture changes over time in pollution control technologies and environmental preferences. In Table 4, the equations also include station fixed effects, μ_{ic}.

A log-log functional form was chosen for equation (1) because factors that affect the uncontrolled pollution levels, such as population and river flow, should have effects that are multiplicative. However, GDP variables enter the equations with a cubic in levels to allow the nonlinearities found by the "environmental Kuznets curve" literature. The two scores (democracy and corruption) are also entered linearly because there seems no basis for rescaling them; results for the coefficients on the decentralization variables are not sensitive to this choice.

3.1 Pooled equations for pollution levels

For BOD and coliform respectively, Tables 2 and 3 present the results of equations without fixed effects, taking advantage of both cross-section and time-series variation. Errors are clustered by country to address the potential correlation in errors within a country at a given time and over time at the same station.[12]

In the first column of Table 2, the qualitative federalism measure has a positive and statistically significant coefficient, suggesting higher BOD levels in federal countries. In the second column, the expenditure decentralization variable has a small and statistically insignificant coefficient. This coefficient is not much changed by the inclusion of upstream country characteristics in column 3, although the characteristics themselves are jointly statistically significant.

Column 4 in Table 2 presents instrumental variables (IV) estimates to address possible endogeneity of expenditure decentralization. Following a study of decentralization by Fisman and Gatti (2002), the instruments for expenditure decentralization are the categories for the origin of a country's legal system from La Porta et al. (1999). This approach provides identification only of cross-sectional differences; it cannot be used in the fixed effects analyses that follow. The point

[12] I use least squares estimates with corrected standard errors rather than random effects models to avoid the need to assume that country-specific unobserved factors are uncorrelated with the decentralization measures. A heteroskedacity-robust version of the Hausman test strongly rejects random effects in favor of fixed effects for both pollutants.

Table 2: Pooled equations: Log(BOD) as dependent variable

	Weighted Least Squares			IV
	(1)	(2)	(3)	(4)
Federal country	0.499*			
	(0.230)			
Log(Decentralization)		0.141	0.153	0.464
		(0.136)	(0.150)	(0.309)
Other country characteristics:				
GDP per capita (thousand 2005 $)	0.180+	0.364	0.352	0.454*
	(0.0890)	(0.244)	(0.247)	(0.192)
GDP per capita squared	-0.0118*	-0.0189	-0.0160	-0.0224*
	(0.00576)	(0.0133)	(0.0140)	(0.00995)
GDP per capita cubed	0.000202+	0.000270	0.000191	0.000309+
	(0.000106)	(0.000219)	(0.000232)	(0.000161)
Control of corruption score	-0.177**	-0.370+	-0.354+	-0.437**
	(0.0609)	(0.215)	(0.202)	(0.168)
Democracy score	-0.0158	0.0172	0.0170	-0.000460
	(0.0203)	(0.0216)	(0.0220)	(0.0204)
Log(Population density)	0.387*	0.406+	0.344	0.421**
	(0.144)	(0.207)	(0.219)	(0.143)
Local characteristics:				
Log(Local population)	0.115*	0.146*	0.145*	0.102+
	(0.0508)	(0.0558)	(0.0624)	(0.0575)
Log(River flow)	-0.125**	-0.111**	-0.0873**	-0.105*
	(0.0279)	(0.0363)	(0.0276)	(0.0437)
Log(Water temperature)	0.00928	-0.110	-0.0919	-0.0357
	(0.214)	(0.404)	(0.442)	(0.253)
Log(Upstream basin area)	0.0815**	0.0824*	0.0956**	0.0494
	(0.0201)	(0.0332)	(0.0290)	(0.0396)
Upstream country characteristics?	No	No	Yes	No
R^2	0.283	0.195	0.223	0.204
Number of observations	635	447	443	447
Number of countries	36	28	28	28

Notes: + $p < .10$, * $p < .05$, ** $p < .01$
Weighted by number of measurements.
Standard errors clustered at the country level.
Equations also include time period and UN world region dummies.
Instruments for decentralization in equation (4) are legal origin dummies.

estimate on decentralization is higher in the IV equation, but is not statistically significant. A Hausman test fails to reject exogeneity of expenditure decentralization ($p = .13$).

Table 3 repeats the same equations for fecal coliform. The point estimates on both the qualitative federalism variable and the decentralization variable are negative, but not statistically significant in any equation. As with the earlier estimates, inclusion of the upstream country characteristics in column (3) does not much affect the results, although the upstream country characteristics are jointly statistically significant. In column (4), the IV coefficient on decentralization is even more negative than the weighted least squares estimates, but still not statistically significant. The Hausman test again fails to reject the exogeneity of decentralization ($p = .39$) in the equations for this pollutant. Thus, the results for coliform do not provide any support for a race to the bottom, which would give rise to a positive relationship between pollution and decentralization.

The equations in Tables 2 and 3 include several other country characteristics. For both BOD and fecal coliform, the GDP coefficients have an inverted U-shape in the relevant range, with peak pollution around $10,000 per capita (in 2005 dollars) for both pollutants. The GDP coefficients are not jointly statistically significant for BOD but are for fecal coliform.[13] The corruption score has a statistically significant positive coefficient in some equations for each pollutant, which suggests that more corrupt countries provide poorer environmental quality and is consistent with the earlier literature (Welsh, 2004; Damania et al., 2003).

By contrast, the estimates do not support an important role for political freedom. The coefficient on the democracy score is not statistically significant in any equation. Earlier studies have similarly found that water pollution may not be as responsive to political rights as some other environmental variables; for example, Barrett and Graddy (2000) do not find statistically significant effects of scores for political rights and civil freedoms on many water pollutants.

[13]The failure to find statistically significant coefficients for BOD is not consistent with Grossman and Krueger (1995) or with Bradford et al. (2005); the latter conclude that BOD is more likely to have an inverted U-shape than fecal coliform is. However, the current specification includes many variables absent from environmental Kuznets curve equations and the relationship is known to be very sensitive to specification (Harbaugh et al., 2002).

Table 3: Pooled equations: Log(Fecal coliform concentration) as dependent variable

	Weighted Least Squares			IV
	(1)	(2)	(3)	(4)
Federal country	-0.431			
	(0.561)			
Log(Decentralization)		-0.365	-0.368	-0.822
		(0.312)	(0.354)	(1.031)
Other country characteristics:				
GDP per capita (thousand 2005 $)	0.586*	1.184**	1.268**	1.195**
	(0.229)	(0.299)	(0.313)	(0.382)
GDP per capita squared	-0.0324*	-0.0587**	-0.0637**	-0.0668**
	(0.0144)	(0.0161)	(0.0172)	(0.0206)
GDP per capita cubed	0.000508+	0.000874**	0.000953**	0.00109**
	(0.000266)	(0.000259)	(0.000278)	(0.000329)
Control of corruption score	-0.162	-0.660*	-0.660*	-0.179
	(0.180)	(0.293)	(0.281)	(0.283)
Democracy score	-0.0798	-0.0130	-0.0224	-0.0135
	(0.0510)	(0.0496)	(0.0533)	(0.0835)
Log(Population density)	0.484	0.670*	0.684**	0.502+
	(0.288)	(0.252)	(0.235)	(0.297)
Log(Local population)	0.231+	0.183	0.208	0.257*
	(0.120)	(0.131)	(0.138)	(0.114)
Local characteristics:				
Log(River flow)	-0.0414	0.0211	0.0312	0.0560
	(0.133)	(0.0897)	(0.0953)	(0.0872)
Log(Water temperature)	1.420*	1.430*	1.271+	1.612*
	(0.634)	(0.652)	(0.692)	(0.763)
Log(Upstream basin area)	0.0331	-0.0671	-0.0443	-0.0954
	(0.133)	(0.0892)	(0.0988)	(0.100)
Upstream country characteristics?	No	No	Yes	No
R^2	0.323	0.340	0.338	0.365
Number of observations	529	395	391	395
Number of countries	37	28	28	28

Notes: + $p < .10$, * $p < .05$, ** $p < .01$

Weighted by number of measurements.

Standard errors adjusted for clustering at the country level.

Equations also include time period and UN world region dummies.

Instruments for decentralization in equation (4) are legal origin dummies.

The local population variable has the expected positive coefficients and is statistically significant in some equations in Tables 2 and 3. The point estimate, however, is substantially less than one, suggesting that pollution does not increase in proportion to population. Some of the river characteristics also show the expected effects. Higher river flow reduces BOD levels, consistent with the hypothesis that it tends to dilute pollution, but is not statistically significant for coliform. Higher temperature is associated with statistically significantly higher fecal coliform, but not BOD. Upstream basin area enters with statistically significant positive coefficients for BOD, but not for fecal coliform; this difference may reflect the regional nature of BOD and local nature of fecal coliform.

3.2 Station fixed effects equations for pollution levels

In Table 4, the equations include monitoring-station fixed effects to check the robustness of the estimated coefficients. The fixed effects may help address concerns about the selection of monitoring locations by removing unobserved heterogeneity in characteristics of the chosen locations. They also subsume unobserved heterogeneity across countries. The fixed effect equations identify the coefficients only from time series variation and restrict the analysis to the expenditure decentralization measure.

When station fixed effects are added in Table 4, the results support an effect of expenditure decentralization on BOD, but not fecal coliform. For BOD, the coefficient is statistically significant and positive, with an elasticity of BOD levels to expenditure decentralization of .188.[14] A somewhat higher point estimate emerges when the decentralization measure excludes national defense spending in column (2), which is consistent with expenditure decentralization containing measurement error when defense is included. In the fecal coliform equations, the coefficients are not statistically significant for either measure of decentralization. The coliform estimates are also

[14] The coefficient on decentralization is both larger in absolute value and more precisely estimated with the station fixed effects than without them. The increase in the coefficient may indicate that unobserved heterogeneity in pollution is negatively correlated with decentralization. The expansion in the sample does not explain the change.

Table 4: Station fixed effects estimates for pollution levels

	Dependent variable:			
	Log(BOD)		Log(Colif)	
	(1)	(2)	(3)	(4)
Log(Overall decentralization)	0.188*		-0.0442	
	(0.0795)		(0.583)	
Log(Decentralization – no defense)		0.246**		1.188
		(0.0821)		(0.791)
Other country characteristics:				
GDP per capita	-0.0546	0.0730	0.153	0.790
	(0.142)	(0.128)	(0.750)	(0.923)
GDP per capita squared	0.00578	-0.00231	-0.000745	-0.0341
	(0.00817)	(0.00589)	(0.0336)	(0.0375)
GDP per capita cubed	-0.000121	0.0000232	-0.0000589	0.000424
	(0.000144)	(0.0000927)	(0.000496)	(0.000518)
Control of corruption score	0.148*	0.162*	-0.539	-0.530
	(0.0644)	(0.0786)	(0.388)	(0.436)
Democracy score	-0.000572	0.0103	-0.0178	-0.0788
	(0.0172)	(0.0119)	(0.0275)	(0.0754)
Log(Population density)	-0.164	-0.434	1.466	-1.692
	(1.191)	(1.373)	(4.985)	(7.523)
Station characteristics:				
Log(Local population)	0.812	1.583	-1.975	-2.023
	(1.201)	(1.305)	(3.108)	(3.474)
Log(Flow)	-0.0229	-0.0194	0.0236	0.0492
	(0.0149)	(0.0174)	(0.0379)	(0.0543)
Log(Temperature)	0.323	0.267	-0.282	-0.609
	(0.424)	(0.648)	(0.473)	(0.534)
R^2 (includes station effects)	0.908	0.912	0.839	0.842
Number of observations	694	559	586	517
Number of countries	35	29	35	28

Notes: * $p < .05$, ** $p < .01$

Standard errors clustered by country. Equations are weighted by the number of pollution measurements. Equations also include year dummies.

very unstable across the equations. Interjurisdictional spillovers might explain the presence of an effect for BOD, but not for coliform: free riding would lead to higher levels of the regional pollutant, but not the local one. However, only a few countries exhibit significant time-series variation in expenditure decentralization, so these results are at best suggestive.[15]

The coefficients on other covariates also differ between the pooled and fixed effects equations. The GDP coefficients are not jointly statistically significant in any of the fixed effects equations, consistent with earlier studies that find that fixed effects greatly reduce the evidence for an inverse U-shape pollution-income relationship (e.g., Harbaugh et al., 2002; Bradford et al., 2005). In the fixed effects equations for BOD in Table 4, control of corruption has a counterintuitive positive coefficient that is statistically significant. Rapidly improving conditions in Eastern European countries are the largest change in corruption over time in these data; the coefficient may reflect worsening of (reported) pollution in this region.[16]

The monitoring station characteristics, many of which had statistically significant coefficients in the pooled equations, are no longer statistically significant with the station fixed effects. Typical geographic characteristics, such as the usual temperature and flow, may matter more to pollution than fluctuations in these values do. In addition, the local population variable is based on only three snapshots and may not adequately capture time series changes in the true value.

4 Interjurisdictional variation in pollution

Decentralization may affect not just the level of pollution but also the variance in these levels across jurisdictions. GEMS/Water provides an opportunity to explore interjurisdictional variation

[15] However, the country with the highest time series variation, Argentina (see Figure 2) does not drive the results; dropping Argentina yields point estimates for the BOD that are slightly higher and still statistically significant.

[16] In equations not shown in Table 4, the log of government spending per capita (based on Penn World Table data) was added as an explanatory variable. The coefficient on this new variable was negative, but statistically insignificant, in the equations for both pollutants. With this variable included, the coefficients on all the decentralization variables are slightly lower in absolute value, but remain statistically significant at the 5% level for BOD. Since government spending is one of the mechanisms through which decentralization may affect pollution, this variable is potentially endogenous and thus is not included in the central specification.

in pollution levels because it has multiple monitoring stations within a country. To create a measure of interjurisdictional variation, I assigned each GEMS station to a sub-national jurisdiction, using the station's latitude and longitude and the highest level of administrative regions in the country from the UN's Global Administrative Unit Layers spatial database.

A two-step approach was used to calculate variation across regions. In the first step, log pollution levels are regressed on station-level characteristics and a fixed effect, γ_{ct}, for the country and period of the observation:

$$\log p_{ict} = g(LOCALPOP_{ict}, R_{ict}) + \gamma_{ct} + \varepsilon_{ict}. \tag{2}$$

where local population, $LOCALPOP_{ict}$, and river characteristics (flow and temperature), R_{ict}, entered in cubics for flexibility. The errors ε_{ict} were then averaged for each subnational region. The interjurisdictional variation was calculated as the standard deviation for these regional values for country c in period t, $sd_{ct}(\varepsilon)$.

The second stage, which is reported in Table 5, uses this variation as the dependent variable.

$$sd_{ct}(\varepsilon) = h(D_{ct}, CountryChar_{ct}) + \alpha_t^{sd} + \nu_c^{sd} + \eta_{ct}. \tag{3}$$

The equation includes decentralization, D_{ct}, and other country characteristics, $CountryChar_{ct}$. Time and country effects (now α_t^{sd} and ν_c^{sd}) can still be included.

The equations in Table 5 include either federalism or expenditure decentralization as the explanatory variable of interest. The equations in columns (1) and (4) start with only two other country characteristics, country population, POP_{ct}, and country area, $AREA_c$. Both variables are associated with greater decentralization (see Table 1), probably because larger countries are more difficult to run centrally. At the same time, these variables may affect interjurisdictional variation. In particular, countries with larger areas may have more diverse physical environments and thus greater variation in pollution levels. Other equations include the full set of country characteristics used above, although it is unclear what association to expect with most of these variables.

The mean number of jurisdictions represented for a country-period observation is only 5.9 for BOD and 5.2 for fecal coliform. As a result, the standard deviation estimates contain a large amount of noise. Observations are weighted by the number of jurisdictions to address resulting heteroskadacity. However, the hypothesis tests may lack power because of the limited available information. Thus, a definitive study of interjurisdictional variation may await a more extensive international data collection effort.

The equations in Table 5 suggest a relationship between decentralization and interjurisdictional variation, but only through the qualitative federalism measure. The point estimates of this coefficient are positive and statistically significant for both pollutants.

Expenditure decentralization has coefficients that are positive but not statistically significant for either pollutant. Equations with country fixed effects (not shown in Table 5) also did not yield statistically significant coefficients on expenditure decentralization. The point estimates on expenditure decentralization in the fixed effects equations are negative and thus should be viewed as weakening the suggestion of a positive relationship with expenditure decentralization with variation in columns (3) and (6) of Table 5. To address concerns about possible endogeneity of expenditure decentralization, the equations in columns (3) and (6) were also estimated using the legal origin instruments used in Tables 2 and 3. Hausman tests fail to reject exogeneity of expenditure decentralization (p-value of .45 for BOD and .30 for coliform). These estimates also do not yield consistently positive coefficients on expenditure decentralization.

A positive effect of federalism on interjurisdictional variation is consistent with the traditional view of decentralization: when localities have more power, they choose environmental quality levels to correspond to local tastes and costs, resulting in greater heterogeneity than under central authority. Several explanations might be offered for the finding that the qualitative federalism variable has a statistically significant coefficient whereas expenditure decentralization does not. One possibility is that this reflects data limitations. The loss of observations due to lack of expenditure

Table 5: Weighted least squares estimates for interjurisdictional variation

	Dependent variable:					
	$sd_{ct}(\varepsilon_{BOD})$			$sd_{ct}(\varepsilon_{Colif})$		
	(1)	(2)	(3)	(4)	(5)	(6)
Federal country	0.236*	0.322*		1.000**	1.109**	
	(0.0972)	(0.141)		(0.221)	(0.162)	
Log(Decentralization)			0.125			0.117
			(0.102)			(0.218)
Log(Country area)	-0.0465	-0.134+	-0.161+	-0.215+	-0.248*	-0.390+
	(0.0299)	(0.0712)	(0.0844)	(0.114)	(0.0934)	(0.225)
Log(Country population)	0.0589	0.168+	0.214+	0.373**	0.459**	0.646**
	(0.0502)	(0.0913)	(0.112)	(0.110)	(0.101)	(0.174)
GDP per capita		0.1000	0.257*		0.0887	0.0719
		(0.0745)	(0.119)		(0.107)	(0.131)
GDP per capita squared		-0.00593	-0.0138*		-0.00733	-0.00669
		(0.00483)	(0.00665)		(0.00700)	(0.00745)
GDP per capita cubed		0.0000951	0.000207+		0.000142	0.000120
		(0.0000898)	(0.000111)		(0.000129)	(0.000127)
Democracy score		-0.139	0.0984		0.00895	0.213
		(0.119)	(0.116)		(0.151)	(0.296)
Control of corruption		0.0122	-0.429*		-0.262	0.326
		(0.141)	(0.159)		(0.250)	(0.359)
R^2	0.295	0.358	0.395	0.475	0.568	0.547
Number of observations	140	131	99	121	118	90
Number of countries	36	35	30	35	34	27

Notes: Pooled cross-section time-series estimates.
$+\ p < .10$, $*\ p < .05$, $**\ p < .01$
Standard errors adjusted for clustering at the country level.
Weighted by number of jurisdictions reporting the pollutant for each observation.
Equations also include time dummies and UN world region dummies.

decentralization data may pose an obstacle to estimating this coefficient.[17] However, it is also possible that the federalism variable more accurately measures the powers necessary for localities to differentiate their provision of the good. Expenditure decentralization may not extend local government power into the relevant regulatory sphere.

In the equations in Table 5, a few country characteristics beyond federalism are associated with interjurisdictional variation. Country population has the expected positive coefficient, which is statistically significant in all equations for coliform. Country area has a negative coefficient, but this unexpected coefficient is statistically significant at the 5 percent level only in column (5). The variation in BOD has a statistically significant relationship with per capita GDP in column (3); the point estimates suggest an everywhere positive relationship within the sample range. The relationship appears in only one set of estimates and does not have any evident conceptual basis. Interestingly, control of corruption has a negative and statistically significant negative coefficient in column (3). A negative relationship might arise if more corrupt countries enforce environmental laws less consistently. However, this effect is not at all robust, with positive point estimates appearing in several other equations.

5 Selection of countries

This section addresses the possibility of nonrandom selection of countries into the GEMS/Water data. It reports models that endogenize participation in a country-year, using the Penn World Table as the universe of possible participants. A selection model is estimated with two equations — one for pollution level or interjurisdictional variation in pollution and one for participation — with possibly correlated errors.

The participation equation includes all of the covariates in the main equation. To avoid iden-

[17] Running the equation with the federal variable on the sample with non-missing expenditure decentralization yields coefficients on federalism of similar magnitude to columns (1) and (4); the federalism coefficient is statistically significant for coliform, but not BOD.

Table 6: Selection-corrected models

	Federal country coefficient		Wald Test $\rho = 0$	Number of observations	
	OLS	Selection MLE	(p-value)	Uncen-sored	Cen-sored
BOD levels	0.273	0.309	.65	188	602
	(0.186)	(0.244)	(.42)		
Coliform levels	-0.415	-0.551	2.12	181	609
	(0.463)	(0.613)	(.15)		
BOD variation	0.236*	0.240*	4.50	140	1145
	(0.0972)	(0.109)	(.033)		
Coliform variation	1.000**	0.828**	.86	121	1164
	(0.221)	(0.240)	(.35)		

Notes: * $p < .05$, ** $p < .01$
For the coefficients, the standard errors in parenthesis are adjusted for clustering at the country level.
All equations also include time period and UN region effects.
Equations for levels also include a cubic in per capita GDP, political rights, corruption, and population density. Equations for variation also include country area and country population.

tification by functional form alone, the selection equation also includes a variable that is excluded from the main equation: whether or not the country sits on the 40 member Governing Council of the UN Environment Program, the program responsible for GEMS. Membership in the Governing Council was collected biannually and changes substantially over time. This variable does have statistically-significant positive effects on the probability of participation in GEMS/Water in the estimated models. The two equations are jointly estimated using maximum likelihood estimation (MLE), assuming the errors are normally distributed, and errors are clustered as before at the country level.

Table 6 presents estimates of the coefficient on the federal country dummies with and without the selection equation. The first column presents WLS estimates for comparison to the estimates with selection.[18] The results do not suggest much selection bias in the earlier estimates. Wald tests, reported in the third column of Table 6, fail to reject the hypothesis that the correlation between the main equation and the participation equation, ρ, equals zero for most equations. The one exception is the equation for variation in the BOD level across provinces, where the hypothesis that $\rho = 0$ can be rejected at the 5% level. For all equations, however, the selection-corrected model does not yield materially differently coefficients on the federalism variables. Thus, the results presented earlier appear robust to possible concerns about selection in country participation in GEMS/Water.

6 Conclusion

A substantial literature addresses the question of optimal decentralization in public goods provision. This paper empirically tests some of the most basic hypotheses from this literature. It looks specifically at two public bads, a pollutant with interjurisdictional spillovers and a pollutant with local effects.

The empirical evidence does not suggest higher overall pollution levels with greater decentralization. Thus, the results do not support destructive regulatory competition in the form of a "race to the bottom." A few equations do suggest the possibility of higher levels of the regional pollutant; if this effect does exist, it could result from interjurisdictional free riding. In addition, the empirical analysis suggests higher interjurisdictional variation in pollution in countries with federal systems. Such variation supports the traditional view of Oates (1972) that decentralization allows better tailoring of policies to local conditions and thus improves in economic efficiency.

[18]The equations for pollution levels in column 1 differ from those previously presented in Tables 2 and 3; the equations for the variation are the same as in Table 5. For the pollution levels equations, the country-period fixed effects, γ_{ct} from equation 2 are now the dependent variables; the first stage allows a more flexible functional form for the station characteristics. The coefficient on federalism is no longer statistically significant for BOD with the revised specification.

References

Bardhan, Pranab and Dilip Mookherjee. Capture and governance at local and national levels, *American Economic Review,* 90 (2000), 135–139.

Barrett, Scott and Kathryn Graddy. Freedom, growth, and the environment, *Environment and Development Economics,* 5 (2000), 433–56.

Bradford, David F., Rebecca A. Fender, Stephen H. Shore, and Martin Wagner. The environmental Kuznets curve: exploring a fresh specification. *Contributions to Economic Analysis & Policy,* 4 (2005), Iss. 1, Article 5.

Besley, Timothy, and Stephen Coate. Centralized versus decentralized provision of local public goods: A political economy approach, *Journal of Public Economics,* 87 (2003), 2611–37.

Center for International Earth Science Information Network (CIESIN), Columbia University. *Gridded Population of the World Version 3 (GPWv3): Population Grids.* http://sedac.ciesin.-columbia.edu/gpw, 2005.

Congleton, Roger D. Political institutions and pollution control, *Review of Economics and Statistics,* 74 (1992), 412–21.

Cutter, W. Bowman and J. R. DeShazo. The environmental consequences of decentralizing the decision to decentralize, *Journal of Environmental Economics and Management*, 53 (2007), 32–53.

Damania, Richard, Per G. Fredriksson, and John A. List. Trade liberalization, corruption, and environmental policy formation: Theory and evidence, *Journal of Environmental Economics and Management,* 46 (2003), 490–512.

Deacon, Robert T. and Sarani Saha. Public good provision by dictatorship: a survey. In A. F. Ott and R. J. Cebula (Eds.), *The companion in public economics: empirical public economics.* Cheltenham: Edward Elgar, 2006.

Esty, Daniel C. Revitalizing environmental federalism, *Michigan Law Review,* 95 (1996), 570–653.

Faguet, Jean-Paul. Does decentralization increase responsiveness to local needs? Evidence from Bolivia, *Journal of Public Economics,* 88 (2004), 867–93.

Fisman, Raymond and Roberta Gatti. Decentralization and corruption: Evidence across countries, *Journal of Public Economics,* 83 (2002), 325–45.

Fredriksson, Per G., Xenia Matschke, and Jenny Minier. Environmental policy in majoritarian systems, *Journal of Environmental Economics and Management,* 59 (2010), 177–91.

Gibson, Edward L., ed. *Federalism and democracy in Latin America.* Baltimore, MD: Johns Hopkins University Press, 2004.

General Accounting Office. *Water Pollution: Differences in Issuing Permits Limiting the Discharge of Pollutants,* Washington, DC: US GAO, 1996.

Gray, Wayne and Ronald J. Shadbegian. Optimal pollution abatement: Whose benefits matter, and how much? *Journal of Environmental Economics and Management,* 47 (2004), 510–534.

Grossman, Gene M. and Alan B. Krueger. Economic growth and the environment, *Quarterly Journal of Economics,* 110 (1995), 353–77.

Harbaugh, William T., Arik Levinson, and David M. Wilson. Reexamining the empirical evidence for an environmental Kuznets curve, *Review of Economics and Statistics*, 84 (2002), 541–51.

Helland, Eric and Andrew B. Whitford. Pollution incidence and political jurisdiction: Evidence from the TRI, *Journal of Environmental Economics and Management,* 46 (2003), 403–24.

Heston, Alan, Robert Summers, and Bettina Aten. Penn World Table Version 7.0, Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania (CICUP). http://pwt.econ.upenn.edu/ 2011.

International Monetary Fund. *GFS Historical CD-ROM.* Washington, DC: International Monetary Fund, 2005.

Konisky, David M. and Neal D. Woods. Exporting air pollution? Regulatory enforcement and environmental *Political Research Quarterly,* 63 (2010): 771–82.

Kunce, Mitch and Jason F. Shogren. On interjurisdictional competition and environmental federalism, *Journal of Environmental Economics and Management,* 50 (2005), 212–24.

La Porta, Rafael, Florencio López-de-Silanes, Andrei Shleifer and Robert Vishny. The quality of government. *Journal of Law, Economics and Organization* (1999).

Levinson, Arik. Environmental regulatory competition: A status report and some new evidence, *National Tax Journal,* 56 (2003), 91–106.

Lipscomb, Molly and A. Mushfiq Mobarak. Decentralization and Pollution Externalities: Evidence from the Re-drawing of County Boundaries in Brazil. Yale School of Management Working Paper, 2011.

List, John A. and Shelby Gerking. Regulatory federalism and environmental protection in the United States, *Journal of Regional Science,* 40 (2000), 453–71.

Marshall, Monty G., Keith Jagger, and Ted Robert Gurr. Polity IV Project: Political Regime Characteristics and Transitions, 1800-2010. http://www.systemicpeace.org/polity/polity4.htm, 2012.

Millimet, Daniel L. Assessing the empirical impact of environmental federalism, *Journal of Regional Science,* 43 (2003), 711–33.

Oates, Wallace E. *Fiscal Federalism.* New York: Harcourt, 1972.

Oates, Wallace E. "A reconsideration of environmental federalism." in *Recent Advances in Environmental Economics*, John A. List and Aart de Zeeuw (eds.), Cheltenham, U.K.: Edward Elgar, 2002, pp. 1–32.

Oates, Wallace E. and Robert M. Schwab. Economic competition among jurisdictions: Efficiency enhancing or distortion inducing? *Journal of Public Economics,* 35 (1988), 333–54.

PRS Group. *International Country Risk Guide Researchers' Dataset.* Electronic media, 2007.

Revesz, Richard. Federalism and environmental regulation: A public choice analysis, *Harvard Law Review,* 115 (2001), 553–641.

Sigman, Hilary. Letting states do the dirty work: State responsibility for federal environmental regulation, *National Tax Journal,* 56 (2003), 107-22.

Sigman, Hilary. Transboundary spillovers and decentralization of environmental policies, *Journal of Environmental Economics and Management,* 50 (2005), 82–101.

Sigman, Hilary. A cross-country comparison of decentralization and environmental protection, in Greg Ingram and Yu-Hung Hong, eds. *Land Policies and Fiscal Decentralization* (Cambridge, MA: The Lincoln Institute for Land Policy, 2008), 195–215.

Silva, Emilson C. D. and Arthur J. Caplan. Transboundary pollution control in federal systems, *Journal of Environmental Economics and Management*, 34 (1997), 173–86.

Treisman, Daniel. The causes of corruption: A cross-national study, *Journal of Public Economics,* 76 (2000), 399-457.

Treisman, Daniel. Defining and Measuring Federalism: A Global Perspective. UCLA Working Paper, 2002.

United Nations, Global Environment Monitoring System Water Programme. http://www.gemstat-.org, 2009.

Vaughan, William J. "The RFF Water Quality Ladder," Appendix B in Mitchell, Robert Cameron and Richard Carson, *The Use of Contingent Valuation Data for Benefit/Cost Analyses in Water Pollution Control,* Washington, DC: Resources for the Future, 1986.

Welsch, Heinz. Corruption, growth, and the environment: A cross-country analysis. *Environment and Development Economics*, 9 (2004), 663–93.

Wilson, John D. "Capital mobility and environmental standards: Is there a race to the bottom?" in *Harmonization and Fair Trade,* J. Bhagwati and R. Hudec, eds. Cambridge, MA: MIT Press, 1996, pp. 395–427.

World Bank. Fiscal Decentralization Indicators. http://www1.worldbank.org/publicsector/decentralization/fiscalindicators.htm, 2001.