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DECENTRALIZATION AND ENVIRONMENTAL QUALITY:
AN INTERNATIONAL ANALYSIS OF WATER POLLUTION

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ABSTRACT

The normative literature on decentralization of public goods provision has many testable empirical implications. This paper explores some of these implications by looking at the relationship between decentralization and an environmental public good, water quality in rivers at monitoring stations around the world. It examines pollution levels and interjurisdictional variation in these levels for both a local and a regional pollutant. When fixed effects are included, greater decentralization is associated with higher levels of the regional pollutant only, suggesting interjurisdictional free riding. Federal countries exhibit greater interjurisdictional variation in both pollutants, consistent with the traditional view that decentralization allows policies more tailored to local conditions.

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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 (Barringer, 2006). 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, specifically, environmental quality.

Several arguments in the decentralization debate would lead to an effect of decentralization on the level of environmental quality (or pollution) and on interjurisdictional variation in this quality. The traditional model of Oates (1972) suggests an increase in interjurisdictional variation, although it does not have a clear implication for typical environmental quality. 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 more local pollutants. Distributive politics within the central government may cause the national government to overprovide public goods (Besley and Coate, 2003; Lockwood, 2002). Finally, central governments may be either more or less susceptible to industrial interest groups than subnational governments (Bardan and Mookherjee, 2000; Esty, 1996; Revesz, 2001). Thus, the net effects of decentralization remain uncertain and provide an opportunity to differentiate empirically among the normative arguments.

Effects of decentralization on environmental policy and outcomes have begun to be documented in the empirical literature (discussed at greater length below). Papers by List and Gerking (2000) and Millimet (2003) are most similar to the current paper because they look at the net effect of changes over time in decentralization on policy outcomes; they find limited effects of the U.S. Reagan-era decentralization on air pollution and pollution abatement spending.[1] Unlike ear-

[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. Similarly, Oates (2002) points to the many cases in which U.S. states do not use discretion to lower environmental standards. A more extreme example is the current state-level drive to address global climate change.

lier work, this paper incorporates international experience with decentralization and examines the differences between local and regional pollutants. This paper also may be the first in the environmental or public economics literature to examine interjurisdictional variation in the level of the public good provided as a test of the Decentralization Theorem.[2]

This study focuses on water pollution in rivers around the world, using data from the UN's Global Environment Monitoring System Water Quality Monitoring Programme (GEMS/Water). 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. Panel data analyses are conducted because both the pollution and some decentralization measures vary over time within countries.

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 for pollution levels are more ambiguous, which is perhaps consistent with the profusion of hypotheses. When fixed effects are included, the regional pollutant, BOD, increases with decentralization. This positive association could result from interjurisdictional free riding in such regional pollutants. Although some estimates also suggest higher local pollution with decentralization, the coefficient estimates are unstable. Thus, the evidence is weaker for more general problems from decentralization, such as destructive regulatory competition or greater sensitivity of local governments to interest group politics.

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 data and variables matched from other sources. Section 3 presents the estimates of equations for the

[2] In a similar spirit, Faguet (2004) finds that a decentralization in Bolivia resulted better "tailoring" of spending, for example increasing sewerage spending in places where access to sewers is lower. My approach makes no judgments about who needs better environmental quality, simply looking at heterogeneity for evidence of improved tailoring.

levels of the two pollutants, with and without monitoring station fixed effects. Section 4 describes the procedure used to calculate interjurisdictional variation in pollution levels within a country and looks at the association between this variation and decentralization. A final section concludes.

1 Effects of decentralization

An extensive theoretical literature describes conditions under which decentralization in public goods provision is welfare improving. In this section, I discuss five hypotheses from this literature with goal of deriving positive implications about the effect of decentralization on environmental quality.

First, 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 (e.g., whether the central legislature has proportional representation or a plurality voting system such as those in the U.S. and U.K.) and how this system interacts with the distribution of preferences for environmental quality across jurisdictions.[3]

This model does suggest a positive association between decentralization and 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.[4]

[3]For example, suppose voters with greener preferences are concentrated in a few jurisdictions. With decentralized decision-making, these jurisdictions choose stricter standards than the rest of the country. With centralized decision-making and a decisive median voter, the standard may be similar to the median of the standards chosen under decentralization. But, it is not difficult to construct examples where a national government elected by the jurisdictions chooses, for example, a less stringent standard because green voters concentrated in a few jurisdictions are less influential.

[4]For a case in which decentralization might reduce variation, suppose preferences for in-stream water quality are

A second normative hypothesis with positive implications is destructive competition (a "race to the bottom" or "race to the top") between jurisdictions. Without market imperfections or redistributive public policies, welfare-maximizing subnational governments will make efficient choices for local pollutants (Oates and Schwab, 1988; Wilson, 1996). However, both market failures and redistributive policies are common, so destructive competition seems a possibility in practice (Oates, 2002; Kunce and Shogren, 2005). The competition 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 are a third hypothesis with positive implications.[5] 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). Several studies report empirical evidence of such free riding within the United States (Helland and Whitford, 2003; Sigman, 2005; Gray and Shadbegian, 2004). Lipscomb and Mobarak (2007) find evidence of free riding by counties in Brazil, where the jurisdictional borders shift over time. Free riding would increase the level of pollution with decentralization for regional pollutants, such as BOD, but not for local pollutants.

Central government decision-making can create a fourth set of effects (Lockwood, 2002; Besley and Coate, 2003). Besley and Coate (2003) conclude that the central government may overprovide local public goods when regional spillovers arise. The overprovision comes from strategic voting for representatives to the central legislature. Thus, they would predict that pollution would

identical across regions, but consequences of different levels of emissions for in-stream water quality varies (perhaps because of geography or climate conditions). Since the government usually regulates (or taxes) emissions rather than in-stream pollution, a local government may exploit an informational advantage to yield an environmental outcome closer to the optimum than what the national government could achieve with a uniform emission standard. In the empirical work, I look at interjurisdictional variation conditioning on some characteristics of the location, but presumably not all the conditions that an optimizing local government might consider.

[5] Interjurisdictional spillovers are also the source of destructive competition. However, I distinguish between spillovers in costs (destructive competition) and the physical movement of pollutants between jurisdictions.

rise with decentralization (although, in contrast to the destructive competition and spillover hypotheses, this increase is welfare-improving). One of the legislative models in Besley and Coate (2003) gives rise to uncertainty in provision of the local public good across jurisdictions because of the vagaries of the minimum winning coalition. If public goods provision is less predictable, it could appear as greater interjurisdictional variation in the equations below because they look at the variance in a residual. This would imply a negative relationship between pollution variation and decentralization (i.e., the opposite of the predictions thus far).

Lockwood (2002) also finds inefficient provision of local public goods under a variety of decision-rules governing the decisions of the central legislature. Although he does not report results about the level of the public good, he does conclude centralization can yield uniform provision of a public good when regional spillovers are strong enough. For the current paper, this result implies a positive relationship between decentralization and interjurisdictional variation; in addition, it could suggest that this relationship would only characterize regional pollutants.

Finally, a few authors have advanced hypotheses about the interest group influence and capture at different levels of government. Bardan and Mookherjee (2000) present reasons that local governments may be more subject to capture, depending on factors such as within district 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; Morriss, 2000). 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 subnational politics (Revesz, 2001). Thus, the prior literature suggests that differential capture may occur, but its direction is an empirical question, which we can take up here.

The literature discussed in this section is normative and does not usually examine the determinants of decentralization.[6] One question is how well these predictions will describe the effects of

[6]A few papers endogenize the process. Strumpf and Oberholzer-Gee (2002) turn Oates's argument into a positive theory of the level of decentralization and present empirical evidence that more heterogeneous preferences encourage

equilibrium (or at least endogenously-determined) decentralization. Because even optimal decentralization would involve trade-offs across various dimensions, it seems likely the positive effects predicted by the normative literature will arise even in the context of endogenous decentralization. For example, a country that decentralizes to allow tailoring of programs to local preferences will do so at the cost of increased free riding and thus may stop short of full decentralization. The prediction that decentralization would be associated with greater pollution because of free riding would still hold (as would the prediction that decentralization would be associated with greater interjurisdictional variation). In addition, much of the empirical analysis here focuses on federalism, an aspect of a country's political organization that was determined in most countries by the time the environment became an area of government activity. Thus, the remainder of this paper brings these hypotheses from the normative literature to the data.

2 Data

2.1 Data on water quality

The UN'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 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.[7] 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 agricul-

decentralization of policies for regulation of alcohol. Cutter and DeShazo (2007) examine an environmental policy that allows local governments to request control from the state government. They conclude that heterogeneity across the localities plays a large role in the apparent effects of devolution on stringency under this program.

[7] 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.

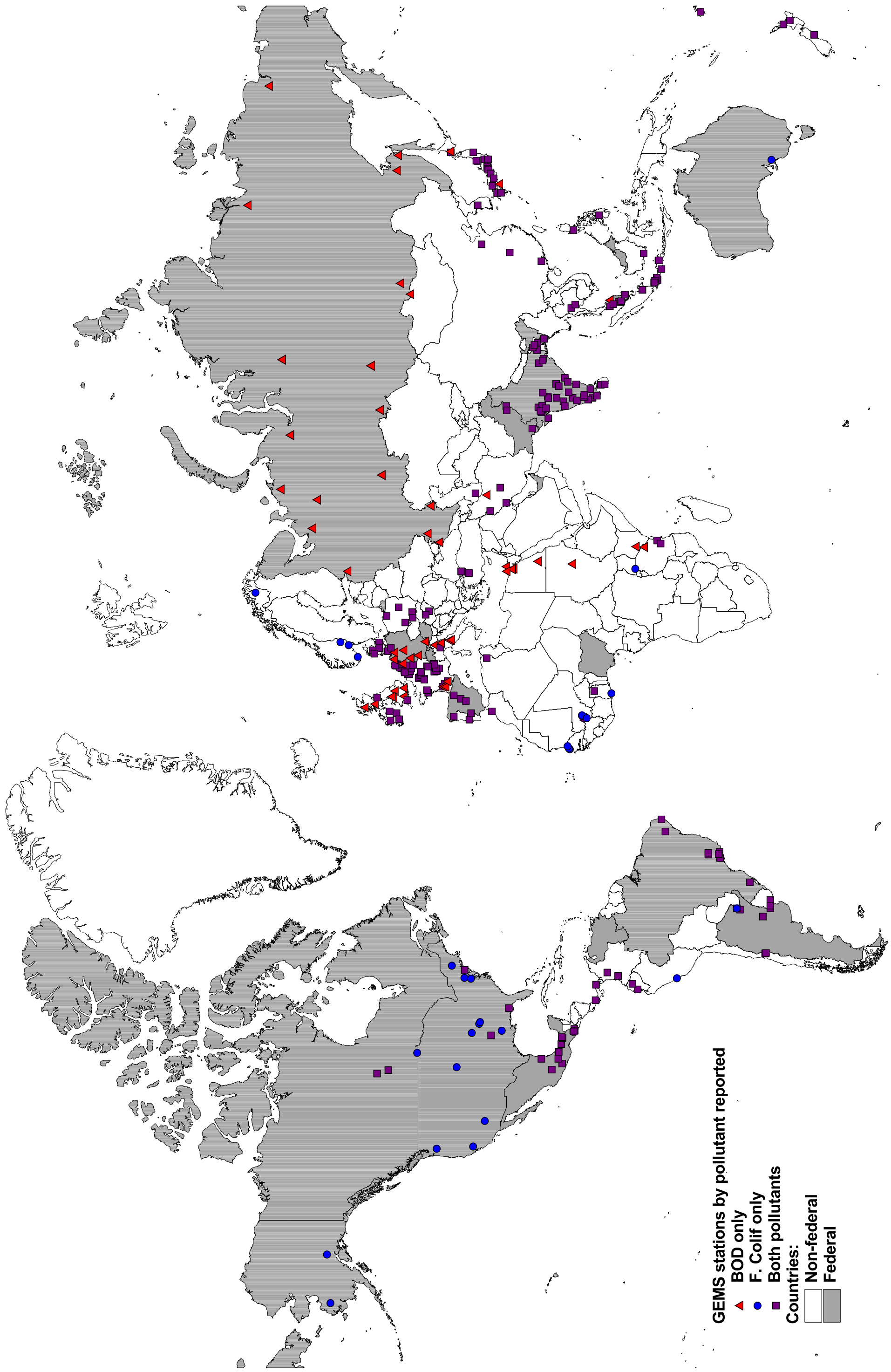

Figure 1: GEMS river monitoring stations used in the analysis with country type

tural wastes into rivers. They are also commonly reported in the GEMS data, providing a relatively large number of observations for analysis. 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 is likely to give rise to substantial interjurisdictional spillovers, whereas fecal coliform will only have interjurisdictional spillovers very near borders.

Table 1 reports the statistics for the two pollutants. The average concentrations for both pollutants are very high.[8] 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 (including boating) according to the Resources for the Future (RFF) Water Quality Ladder (Vaughan, 1986). Medians are not as bad: 2.2 mg/l for BOD (acceptable for swimming according to RFF) 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 30 measurements in nonfederal country and 24 in federal countries, or about 8 to 10 a year.[9] However, the number of measurements has a high standard deviation, so the precision of the observations varies considerably. The number of measurements are used as weights in the estimated equations to address the heteroskedasticity from this variation.

[8]Fecal coliform, in particular, 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 only affects the results in one equation below and is discussed there.

[9]Stations may report one pollutant but not the other in a given year, 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)	3.76	9.95	6.99	22.01
Mean fecal coliform (thousand colonies/100 ml)	10.9	26.6	9.8	27.6
Number of measurements per observation	30.7	26.3	25.2	14.8
Country-level variables				
Expenditure decentralization (percent)	18.0	9.8	38.5	10.9
Expenditure decentralization missing	.40	–	.08	–
Expedenditure decentralization without defense (percent)	19.9	11.5	46.8	14.8
Expedenditure decentralization without defense missing	.51	–	.26	–
GDP per capita (thousand 1996 dollars)	12.8	7.9	8.44	8.39
Political rights (1 (best) – 7 (worst))	2.5	2.0	2.4	1.2
Corruption index (0 (worst) – 6 (best))	4.1	1.6	3.5	1.2
Country population (millions)	105	216	411	364
Country area (thousand km^2)	853	1845	4906	4776
Station-level variables				
Population within 20 km (thousands)	756	1296	553	756
Flow (m^3/sec)	1562	5844	2204	5110
Temperature	16.1	6.3	21.5	7.1
Upstream basin area (thousand km^2)	118	363	280	615
Total observations:				
BOD	483		485	
Coliform	356		403	
Number of stations:				
BOD	136		110	
Coliform	115		87	

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

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., most environmental standards are established by the federal government, but implementation and enforcement is devolved to the states (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 be only one of the government functions that affects pollution. Decisions about land use and spending on sewage treatment will also be important, but 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 establish 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. Figure 1 shows the countries that are federal and nonfederal in this taxonomy.

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 more robust treatment of unobserved heterogeneity among countries. 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).[10] I also recalculated ex-

[10] I found some very small disparities between the World Bank values and those I calculated directly from the GFS

penditure decentralization from GFS, excluding defense spending as a potentially large and exclusively national category of spending. The additional information requirements for this measure decrease the number of available observations. The overall correlation between the two measures is very high, so this modified measure is used only for equations focusing on time-series variation.[11] 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.[12] Data on expenditure decentralization is also much more common in federal countries, with only a few missing observations for federal countries and 39% missing in the other countries. Average pollution levels are higher for both pollutants in the federal countries.

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., 2006). 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 responsive governments choose lower pollu-

and had a greater number of missing observations in my calculations. 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.

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

[12]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.

tion than autocratic regimes (Congleton, 1992; Barrett and Graddy, 2000). Because more repressive governments may also tend to be more centralized, it is important to consider this factor in the estimated equations. Freedom House (2006) annually evaluates countries' "political rights" on a scale from 1 (most extensive rights) to 7 (fewest rights). Political rights are fairly good in the GEMS sample, with an average index of 2.5 in both federal and nonfederal countries.

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). International Country Risk Guide (ICRG) provides annual corruption scores for countries, based on surveys of professionals (PRS Group, 2007).[13] Consistent with earlier literature, Table 1 reports that federal countries are somewhat more corrupt, with an average ICRG score of 3.5 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 (GIS) to construct local population, specifically population within 20 kilometers of the station. The GEMS stations are superimposed (based on their latitude and longitude) on the Gridded Population of the World 3 (CIESN, 2005). Population grids are available for 1990, 1995, and 2000. For other 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 rates 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.

[13] 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.

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 ith station in country c in year 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). The equations for the regional pollutant, BOD, also include $UPCHAR_{ict}$, which are dummy variables for whether the station is within 100 km of an international border (up or downstream) and, if it is downstream, the country characteristics for the upstream country. These variables are intended to reflect the upstream country's contributions to pollution that has flowed downstream to this spot. Year dummies, α_t, are included to capture changes over time in pollution control technologies and environmental preferences. Some 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. In an exception to the log-log specification, GDP variables enter the equations with a cubic in levels to allow the nonlinearities found by the "environmental Kuznets curve" literature (e.g., Selden and Song, 1994; Grossman and Krueger, 1995).

Table 2 presents the results without fixed effects, taking advantage of both cross-section and time-series variation. In this table, 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.

In Table 3, the equations include monitoring station fixed effects. This approach allows identification only from time series variation and restricts the analysis to the expenditure decentralization measure. Once cross-sectional identification is abandoned, no information is lost by allowing fixed

Table 2: Weighted least squares estimates for pollution levels

	Dependent variable: Log(BOD) (1)	(2)	Log(Colif.) (3)	(4)
Federal country	.353	–	-.292	–
	(.256)		(.561)	
Log(Decentralization)	–	.022	–	-.402
		(.218)		(.332)
Other country characteristics:				
GDP per capita	.026	.172	.185	.944
	(.059)	(.306)	(.261)	(.420)
GDP per capita squared	.004	-.009	-.016	-.060
	(.006)	(.020)	(.021)	(.026)
GDP per capita cubed /100	-.019	.010	.032	.111
	(.016)	(.038)	(.047)	(.046)
Log(Lack of political rights)	.172	.036	-.018	-.036
	(.217)	(.268)	(.404)	(.385)
Log(Lack of corruption)	-.376	-.363	-.554	-1.28
	(.207)	(.511)	(.469)	(.929)
Log(Population density)	.112	.173	.427	.816
	(.106)	(.170)	(.230)	(.282)
Local characteristics:				
Log(Local population)	.091	.128	.181	.156
	(.046)	(.058)	(.125)	(.147)
Log(River flow)	-.091	-.088	-.049	.009
	(.021)	(.022)	(.128)	(.117)
Log(Water temperature)	.247	.131	2.044	1.611
	(.205)	(.467)	(.699)	(.769)
Log(Upstream basin area)	.076	.091	-.004	-.017
	(.021)	(.025)	(.123)	(.120)
R^2	.28	.20	.30	.33
Number of observations	635	442	535	395
Number of countries	37	28	38	28

Notes: Weighted by number of measurements.
Standard errors adjusted for clustering at the country level.
Equations also include year dummies, five world region dummies, and (for BOD only) upstream country characteristics.

effects at the most detailed geographical level, the monitoring station.

Decentralization. The coefficients on the decentralization variables depend greatly on the pollutant and on whether fixed effects are included. In the first column of Table 2, the qualitative federalism measure has a positive point estimate, suggesting higher BOD levels, but this coefficient is not statistically significant. The expenditure decentralization variable has a very small and statistically insignificant coefficient. In columns (3) and (4) for fecal coliform, both pooled equations have negative point estimates, but neither estimate is statistically significant.

When station fixed effects are added in Table 3, the results provide more support for an effect of expenditure decentralization. For BOD, the coefficient is statistically significant and positive, with an elasticity of BOD levels to expenditure decentralization of .275. A slightly larger point estimate emerges when the decentralization measure excludes national defense spending in column (2). In the fecal coliform equations, the coefficients are again not statistically significant for either measure of decentralization.[14]

The sensitivity of the estimated coefficients to inclusion of fixed effects may reflect the large amount of heterogeneity across countries that affects their pollution levels. Isolating only the change in decentralization within a country over the two decades facilitates finding an effect. It is also interesting that the more precise measure, expenditure decentralization without national defense, yields a higher point estimate for BOD than the broader measure, which would be consistent with measurement error in the broader measure.[15]

The estimates in Table 3 provide evidence of a positive effect of decentralization on BOD, but no evidence of an effect on fecal coliform. If the effect is only present for BOD, free riding would be a plausible explanation because it would lead to higher levels of the regional pollutant, but not the local one.

[14]Column (4) in Table 3 is the only equation where the policy result is sensitive to the exclusion of the very high observations for coliform. If the full sample is included, this equation yields a very large positive coefficient on decentralization (about 2.7) that is statistically significant.

[15]Running the equations from columns (1) on the restricted set of observations in columns (2) slightly reduced the decentralization coefficient.

Table 3: Station fixed effects estimates for pollution levels

	Dependent variable:			
	Log(BOD)		Log(Colif)	
	(1)	(2)	(3)	(4)
Log(Overall decentralization)	.275	–	-.355	–
	(.123)		(.575)	
Log(Decentralization – no defense)	–	.320	–	.851
		(.147)		(.734)
Other country characteristics:				
GDP per capita	-.126	.007	.047	.706
	(.133)	(.159)	(.582)	(.734)
GDP per capita squared	.009	-.002	.013	-.023
	(.009)	(.010)	(.032)	(.039)
GDP per capita cubed /100	-.021	.005	-.036	.023
	(.018)	(.021)	(.058)	(.068)
Log(Lack of political rights)	.107	.195	-.415	-.215
	(.112)	(.181)	(.519)	(.685)
Log(Lack of corruption)	.556	.614	-2.25	-2.06
	(.143)	(.169)	(1.23)	(1.44)
Log(Population density)	-.517	-1.61	4.187	3.450
	(.965)	(1.37)	(4.03)	(4.88)
Station characteristics:				
Log(Local population)	.884	1.692	-1.86	-1.91
	(.420)	(.542)	(1.22)	(1.32)
Log(Flow)	-.023	-.021	.033	.052
	(.017)	(.019)	(.084)	(.088)
Log(Temperature)	.251	.202	-.332	-.717
	(.206)	(.302)	(.759)	(.843)
R^2 (includes station effects)	.91	.91	.84	.84
Number of observations	725	552	596	517
Number of stations	201	175	162	144

Notes: Weighted by number of measurements per observation.
Equations also include year dummies and, for BOD, upstream country characteristics.

Other covariates. Other covariates also differ between the pooled and fixed effects equations and between the two pollutants. The GDP coefficients are not jointly statistically significant in any of the equations, with or without fixed effects. For the pooled equations, the world region dummies seem sufficient to absorb the variation GDP otherwise picks up. Contrary to earlier literature, the equations do not support an important role for political rights. The coefficient on this variable is not statistically significant in any equation. In most of the equations, it does have a positive point estimate, which would be consistent with the view that more repressive countries allow greater pollution.

Corruption has some conflicting point estimates. Consistent with earlier studies, less corrupt countries do appear to have lower pollution in the pooled equations in Table 2; however, the the coefficient is statistically significant at 10% only in column (1). In the fixed effects equations for BOD in Table 3, corruption has a counterintuitive positive coefficient that is statistically significant. Rapidly improving conditions in the Eastern European countries are the largest change in corruption over time; the coefficient may reflect worsening (reported) pollution in this region.

The local population variable mostly has the expected positive coefficients. In the pooled equations, this coefficient is statistically significant for both pollutants, but the estimated elasticities of pollution to local population are substantially less than one. For BOD, the fixed effects equations do yield elasticities that are near one and statistically significant, despite fairly limited information on the time series of local population. For coliform, however, the fixed effects coefficients are negative and not statistically significant. Even the 20 kilometer ring may be too broad a definition of the local area for this pollutant.

Some of the river characteristics also show the expected effects. Higher river flow reduces pollution levels in the pooled equations for BOD, consistent with the hypothesis that it tends to dilute pollution, but is not statistically significant elsewhere. Higher temperature is associated with statistically significantly higher pollution only in the pooled equations in Table 2. Upstream basin area, available only without fixed effects, enters with statistically significant positive coefficients for BOD, but not for fecal coliform. This difference again may reflect the regional nature of BOD and local nature of fecal coliform.

4 Results for interjurisdictional variation in pollution

GEMS provides an unusual opportunity to explore interjurisdictional variation in pollution levels because it has multiple monitoring stations within a country. Each station was mapped to the largest sub-national administrative region, using its latitude and longitude and the Global Administrative Unit Layers (GAUL) from the FAO.

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 year of the observation:

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

To allow the most flexible association, the local population and river characteristics (flow and temperature) are entered with a cubic. 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 year t, $sd_{ct}(\varepsilon)$.

The second stage, which is reported in Table 4, uses this variation as the dependent variable.

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

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. Because the left-hand-side of the equations is implicitly in logs, the right-hand-side variables are also in logs.

In Table 4, the equations examine both qualitative federalism and expenditure decentralization. Lacking any specific theory of the causes of variation, equations start with a minimal set of covariates. In addition to federalism or expenditure decentralization, country population, POP_{ct} and country area, $AREA_c$, are included. 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 greater diversity in types of ecosystems and thus pollution levels. Columns (2) and (5) in the table add the full set of country characteristics used above.

The mean number of jurisdiction represented in a country-period cell 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. Although robust standard errors address the heteroskedasticity from this noise, hypothesis tests may lack power because of the limited available information. Thus, a definitive study of interjurisdictional variation may await a more extensive global data collection effort.

Decentralization measures. The equations in Table 4 suggest a relationship between decentralization and interjurisdictional variation, but only through the qualitative federalism measure. The point estimate of this coefficient is positive and statistically significant for both pollutants. However, the expenditure decentralization measure produces coefficients that are very close to zero and statistically insignificant coefficients for both pollutants.

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. However, other hypotheses might also give rise to this pattern. Lockwood (2002) reports that one possible outcome of his model of the central government's legislative bargaining is uniformity in provision of the public good when regional spillovers are large enough.

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 decentralization data may pose an obstacle to estimating this coefficient.[16] However, it is also possible that

[16]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 sig-

Table 4: Determinants of interjurisdictional variation

	Dependent variable:					
	$sd_{ct}(\varepsilon_{BOD})$			$sd_{ct}(\varepsilon_{Colif})$		
	(1)	(2)	(3)	(4)	(5)	(6)
Federal country	.282	.307	–	.747	.799	–
	(.107)	(.108)		(.209)	(.235)	
Log(Decentralization)	–	–	.001	–	–	-.063
			(.097)			(.291)
Log(Country population)	.083	.122	.151	.321	.308	.509
	(.039)	(.060)	(.079)	(.130)	(.122)	(.162)
Log(Country area)	-.057	-.079	-.064	-.206	-.203	-.192
	(.035)	(.053)	(.068)	(.121)	(.105)	(.235)
GDP per capita	–	.052	–	–	-.015	–
		(.073)			(.176)	
GDP per capita squared	–	-.005	–	–	-.005	–
		(.005)			(.012)	
GDP per capita cubed /100	–	.009	–	–	.016	–
		(.009)			(.025)	
Log(Lack of political rights)	–	-.121	–	–	-.262	–
		(.174)			(.295)	
Log(Lack of corruption)	–	-.182	–	–	-.070	–
		(.115)			(.282)	
R^2	.31	.37	.29	.32	.36	.32
Number of observations	140	136	104	121	121	93
Number of countries	36	36	31	35	35	28

Notes: Standard errors adjusted for clustering at the country level.
Equations also include year dummies and region dummies.

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. Equations with country fixed effects also did not yield statistically significant coefficients on expenditure decentralization (and are not reported).

Other covariates. In the equations in Table 4, few country characteristics beyond federalism account for interjurisdictional variation. Country population has the expected positive coefficient, which is consistently statistically significant. Country area has an unexpected negative coefficient, but it is not statistically significant in any equation. Neither GDP nor the quality of government has a statistically significant effect on variation for either pollutant.[17]

5 Conclusion

A substantial literature addresses the question of optimal decentralization in local public goods provision. This paper attempts to test empirically 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 more local effects.

The evidence in this paper points to higher levels of the regional pollutant with more decentralization. The effects only appear in equations with fixed effects; cross-sectional analysis does not provide much support for any effect of decentralization. Greater levels of decentralization may provide more opportunities for free riding in regional pollutants, so these results are consistent with earlier empirical research suggesting free riding within the U.S. The results provide limited support for more general problems from decentralization, such as destructive regulatory competition or greater sensitivity of local governments to interest group politics.

In addition, the results suggest higher interjurisdictional variation in pollution in countries with

nificant for coliform, but not BOD.

[17]The regional dummies (which are not shown) suggest African countries have much smaller BOD variation than other countries, which may be a coincidence facilitated by small numbers of African observations; no such difference appears for fecal coliform. The year dummies (also not reported) suggest a slight trend toward reduced variation in BOD, but not fecal coliform.

federal systems. Such variation supports the traditional view of Oates (1972) that decentralization allows better tailoring of policies to local conditions. The results may thus support a welfare gain from decentralization, which needs to be weighed against the suggestion above of free riding. Thus, decentralization in practice seems to have both positive and negative consequences for the efficiency of environmental policies.

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