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DECENTRALIZATION AND ENVIRONMENTAL QUALITY: AN INTERNATIONAL ANALYSIS OF WATER POLLUTION

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ABSTRACT

Many arguments about decentralization in public goods provision have testable implications for the relationship between decentralization and the level and spatial variability of public goods. This paper explores the empirical relationship between decentralization and environmental public good, water quality in rivers at monitoring stations around the world. It examines pollution levels and spatial variability of pollution within a country for both a local and a regional pollutant. The results suggest higher pollution levels with greater decentralization when fixed effects are included; the evidence is strongest for the regional pollutant, where it might result from interjurisdictional free riding. Federalism is associated with greater spatial variability in pollution within a country, consistent with the traditional view that decentralization allows policies more tailored to local conditions.

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The choice of the level of government to regulate the environment is an active policy issue. In the U.S., recent Supreme Court decisions seem to auger limitations on the federal government's authority to undertake environmental regulation (Adler, 2005; 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 by extension, the environment.

Several hypotheses in the decentralization debate would lead to an effect on level of public goods and on spatial variability in these levels. The traditional model of Oates (1972) suggests an increase in spatial variability of pollution, although it does not have a clear cut implication for typical pollution levels. Other models also have implications, especially for pollution levels. Destructive regulatory competition, in the form of a "race to the bottom," would result in overall greater pollution with decentralization, but probably not increase variance. Interjurisdictional environmental free riding would 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 allow higher pollution with decentralization because the national government to overprovides public goods (Besley and Coate, 2003; Lockwood, 2002). Finally, a few authors posit that central governments are either more or less susceptible to industrial interest groups than subnational governments (Esty, 1996; Revesz, 2001). Thus, the net effects of decentralization remain uncertain and provide an opportunity to differentiate empirically among the arguments.

An empirical literature has started to document effects of decentralization on environmental policy. Studies support the conclusion that regulatory competition occurs in federal systems, but find it difficult to ascertain whether such competition is destructive (Fredriksson and Millimet, 2002; Levinson, 2003). Research finds evidence that U.S. states free ride on one another (Helland and Whitford 2003; Sigman, 2005; Gray and Shadbegian, 2004). In addition, List and Gerking (2000) and Millimet (2003) look at the net effects of decentralization on the environment, studying the effects of Reagan era decentralization on air pollution and pollution abatement spending.[1]

[1] List and Gerking (2000) conclude that neither spending nor air pollution (nitrogen oxide and sulfur dioxide emissions) changed after 1980, whereas Millimet finds that spending (but not air pollution) rose by the mid-1980s. Both

Like List and Gerking and Millimet, this paper looks at the net environmental effect of the various forces associated with decentralization. Unlike earlier work, it incorporates international experience with decentralization, examines the differences between local and regional pollutants, and studies spatial heterogeneity as well as levels of environmental quality.

This study explores the empirical effects of decentralization on the level and geographic variability of environmental quality, focusing on water pollution in rivers around the world. Pollution data derive from the UN's Global Environmental Monitoring System Water Quality Monitoring Project (GEMS/Water), which has data on a number of pollution measures. The pollutants studied are biochemical oxygen demand (BOD), which is transported far downstream, and fecal coliform, which has only local effects and is thus less of a candidate for interjurisdictional free riding. The estimated equations model pollution levels in a given year as depending on the country's level of decentralization and other country characteristics that the literature has suggested influence these levels, such as per capita GDP, political rights, and corruption. In addition, the equations include characteristics of river monitoring stations, such as river flow, temperature, and local population. Panel data analysis is conducted because both the pollution and some decentralization measures vary over time within countries.

The results suggest higher geographic variability in pollution levels in federal countries for both pollutants. Such variability 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

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. Golkany (1999) and Oates (2002) also describe circumstances in which U.S. states did not use their discretion to lower environmental standards.

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 levels of the two pollutants, with and without monitoring station fixed effects. Section 4 describes the procedure used to calculate variability in pollution levels within a country and looks at the association between this variability 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 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 like the U.S. and U.K.) and how this system interacts with the distribution of preferences for environmental quality across jurisdictions.[2]

Although the simplest version of this model does not have strong implications about the level of pollution, it does suggest a positive association between decentralization and spatial variability

[2]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 (such as the U.S. Senate) chooses a less stringent standard as the few green voters' preferences are less influential.

in environmental quality. If the central government allows insufficient variation in standards, decentralization will yield a large variance in these levels as local governments choose standards that reflect their heterogenous preferences. Thus, an increase in variability is a likely, but not necessary, outcome and can be tested in practice.[3]

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, ruling out destructive competition (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 the costs 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.[4] 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). Free riding would increase the level of pollution with decentralization for regional pollutants, but not for local pollutants. It may also increase the spatial variability in regional pollutants because it introduces an additional

[3]For a case in which decentralization might reduce variability, suppose preferences for in-stream water quality are 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 spatial variation conditioning on some characteristics of the location, but presumably not all the conditions that an optimizing local government might consider.

[4]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.

source of variation in the perceived benefits of pollution control.[5]

The central government decision-making process can yield 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.[6] Thus, they would predict that pollution would rise with decentralization (although, in contrast to the destructive competition and spillover hypotheses, this increase may be welfare-improving). On spatial variability, one of their legislative models gives rise to "uncertain" variation 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 spatial variability in the equations below because they attempt to control for local conditions before considering variability. This would imply a negative relationship between pollution variability 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 spatial variability; in addition, it could suggest that this relationship would only characterize regional pollutants.

Finally, a few authors have advanced hypotheses about the role of scale economies in interest groups' influence at different levels of government. The argument does not seem to have been formalized and proponents even disagree about the nature of the economy. Some argue that environmental groups cannot wield influence as effectively at the state level as the federal level (Esty, 1996). Better-funded industry groups may overcome high fixed costs to maintain an office and

[5] This prediction is partly because I measure total spatial variability, not specifically variation across jurisdictions. Locations where free riding occurs have especially high pollution, increasing total variability more than interjurisdictional variability. Still, if some jurisdictions have more opportunities to free ride than others, free riding could cause an increase in interjurisdictional variability.

[6] Pashigian (1985) regards the U.S. federal Clean Air Act as the result of interregional redistributive politics.

informed staff in each capital and thus be better represented at local levels. For example, Morriss (2000) argues that the US Clean Air Act's delegation to the states creates complexity that favors regulated industries. 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 quieter arena of subnational politics (Revesz, 2001).

The literature discussed in this section is normative and does not usually examine the determinants of decentralization.[7] One question is how well these predictions will describe the effects of 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 chooses high decentralization because it has a lot of preference heterogeneity will do so at the cost of increased free riding. 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 spatial variability). In addition, much of the empirical analysis focuses on federalism, an aspect of a country's political history that was safely exogenous 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 Global Environmental Monitoring System Water Quality Monitoring Project (GEMS/Water) provides data on various water quality measures in rivers, lakes, and groundwater. This study fo-

[7] 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 decentralization of policies for regulation of alcohol. Cutter and DeShazo (2007) examine an environmental policy that allows local governments to opt for control.

cuses 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. 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 derive 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. 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.[8] The average concentrations for both pollutants are high, 5.4 mg/l of BOD and over 80,000 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 1,100 colonies/100 ml for fecal coliform (a little too high 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. However, the number of measurements has a high standard deviation, so the precision of the observations varies considerably. The number

[8] 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 2 because the differences in sample statistics were very small.

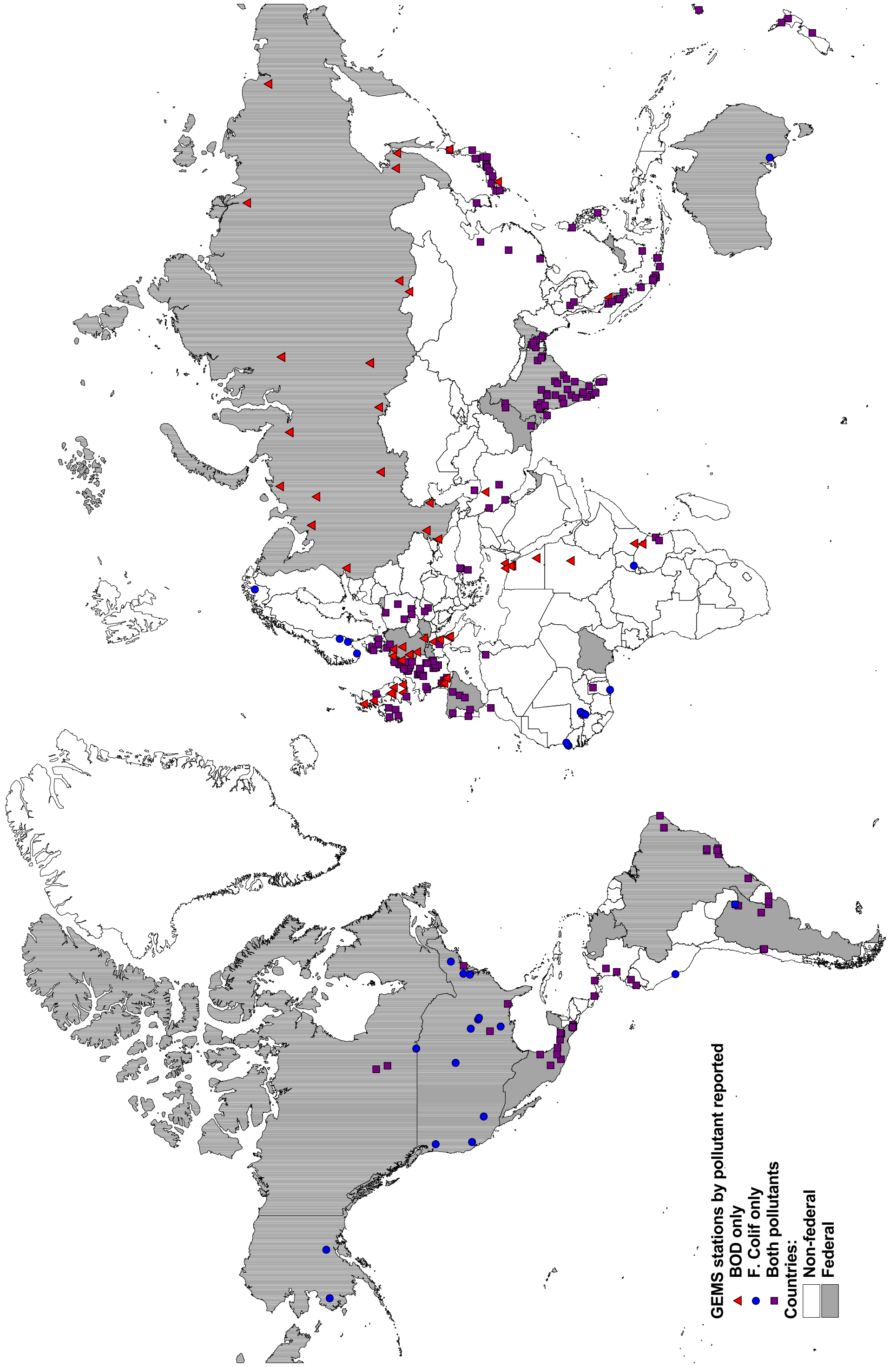

Figure 1: GEMS river monitoring stations used in the analysis with country type

Table 1: Means and standard deviations of the data

Variable	**Nonfederal observations** Mean	S.D.	**Federal observations** Mean	S.D.
Mean BOD concentration (mg/l)	3.76	9.95	6.98	21.99
Mean fecal coliform (thousand colonies/100 ml)	68.1	346.5	90.9	556.6
Number of measurements per observation	30.3	26.1	24.7	14.9
Country-level variables				
Expenditure decentralization (percent)	18.0	9.8	38.2	11.0
Expenditure decentralization missing	.39	–	.08	–
Expedenditure decentralization without defense (percent)	19.7	11.4	46.4	14.9
Expedenditure decentralization without defense missing	.50	–	.26	–
GDP per capita (thousand 1996 dollars)	12.5	7.9	8.3	8.3
Political rights (1 (best) – 7 (worst))	2.5	2.0	2.5	1.2
Corruption index (0 (worst) – 6 (best))	4.0	1.7	3.5	1.2
Country population (millions)	105	213	413	366
Country area (thousand km^2)	870	1828	4799	4709
Station-level variables				
Population within 20 km (thousands)	841	1465	580	801
Flow (m^3/sec)	1584	6005	2145	5021
Temperature	16.3	6.4	21.6	7.1
Upstream basin area (thousand km^2)	116.8	360.1	269.5	604.3
Total observations for BOD	483		486	
Total observations for coliform	378		442	
Number of stations for BOD	136		110	
Number of stations for coliform	123		88	

Notes: Standard deviations for continuous variables only.
Variables have been pooled across pollutants because there is little difference in sample statistics between the observations for each pollutant.

of measurements are used as weights in all the estimated equations to address the heteroskedasticity from this variation.

Using a Geographic Information System (GIS), I coded the locations of the GEMS monitoring stations relative to international borders (Sigman, 2002). 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.

2.2 Explanatory variables

Decentralization measures. An ideal measure of decentralization is difficult to construct, both practically and conceptually. Countries use very different regulatory structures and 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). State exercise substantial discretion in setting allowable water pollution permits, despite what would appear to be clear federal standards (GAO, 1996). In addition, 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 commonly used 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).[9] I also recalculated expenditure 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.[10] The 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 is anyway required to 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. A strong association between federalism and expenditure decentralization is evident, with subnational expenditure shares of 38% in the federal countries, compared to 18% in the other countries.[11] 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.

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

[10] 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 a very small set of countries.

[11] 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.

Other explanatory variables. Several other characteristics of countries are included. 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). Countries participating in GEMS are relatively high income as Table 1 reports; European countries in particular are overrepresented. The relatively high income of the sample may be desirable because countries must have some effective environmental policies for any effect of federalism to be detected. Some previous studies have found that pollution rises and then falls with income, a pattern sometimes called the "environmental Kuznets curve (EKC)" (e.g., Selden and Song, 1994; Grossman and Krueger, 1995). The estimated equations include a cubic in income to control for these effects.

A second country attribute is a measure of the political structure of the country. Earlier research has suggested that more responsive governments choose lower pollution 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.

Government corruption may also need to be included in the equations. 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). Thus, a link between decentralization and environmental outcomes may come through this pathway, unless the equations explicitly account for corruption. Annual measures of corruption (based on surveys) were available for all but three of the countries in the GEMS data (Fiji, Laos and Cambodia) from the International Country Risk Guide (ICRG) from 1984 onward. The value for the country in 1984 was used for earlier years. Consistent with earlier literature, Table 1 reports that federal countries are somewhat more corrupt, with an average ICRG score of 3.5 compared to 4.0 for nonfederal countries.

Population may also affect water quality, principally by determining uncontrolled pollution levels. Both a station-specific and country population measure are included. I used a GIS to construct a measure of local population, specifically population within 20 kilometers of the station. To construct this measure, 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.

Finally, three river characteristics are used for the estimates. 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. The GEMS data provide 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 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 suggested by the EKC literature.

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. The equations include six world region dummies to capture unmeasured geographic heterogeneity.

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 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), both pooled equations for fecal coliform 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

Table 2: Weighted least squares estimates for pollution levels

	Dependent variable:			
	BOD		F. Coliform	
	(1)	(2)	(3)	(4)
Federal country	.353	–	-.885	–
	(.256)		(.861)	
Log(Decentralization)	–	.022	–	-.532
		(.218)		(.555)
Other country characteristics				
GDP per capita	.026	.172	.253	1.361
	(.059)	(.306)	(.334)	(.634)
GDP per capita squared	.004	-.009	-.012	-.076
	(.006)	(.020)	(.026)	(.037)
GDP per capita cubed /100	-.019	.010	.016	.128
	(.016)	(.038)	(.059)	(.065)
Log(Lack of political rights)	.172	.036	.571	.169
	(.217)	(.268)	(.730)	(.709)
Log(Lack of corruption)	-.376	-.363	-1.54	-4.12
	(.207)	(.511)	(.942)	(2.00)
Log(Population density)	.112	.173	.010	.470
	(.106)	(.170)	(.360)	(.455)
Station characteristics				
Log(Local population)	.091	.128	.430	.442
	(.046)	(.058)	(.178)	(.184)
Log(River flow)	-.091	-.088	-.187	-.138
	(.021)	(.022)	(.190)	(.200)
Log(Water temperature)	.247	.131	2.214	1.294
	(.205)	(.467)	(.845)	(.898)
Log(Upstream basin area)	.076	.091	.027	.024
	(.021)	(.025)	(.135)	(.124)
R^2	.28	.20	.31	.36
Number of observations	635	442	569	427
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.

Table 3: Station fixed effects estimates for pollution levels

	Dependent variable: Log(BOD) (1)	Log(BOD) (2)	Log(Colif) (3)	Log(Colif) (4)
Log(Overall decentralization)	.275	–	.347	–
	(.123)		(.549)	
Log(Decentralization – no defense)	–	.320	–	2.083
		(.147)		(.649)
Other country characteristics:				
GDP per capita	-.126	.007	-.146	.859
	(.133)	(.159)	(.552)	(.667)
GDP per capita squared	.009	-.002	.030	-.024
	(.009)	(.010)	(.031)	(.036)
GDP per capita cubed /100	-.021	.005	-.071	.019
	(.018)	(.021)	(.056)	(.064)
Log(Lack of political rights)	.107	.195	-.253	-.006
	(.112)	(.181)	(.496)	(.645)
Log(Lack of corruption)	.556	.614	-.910	-.829
	(.143)	(.169)	(.804)	(.855)
Log(Population density)	-.517	-1.61	5.686	4.580
	(.965)	(1.37)	(3.98)	(4.74)
Station characteristics:				
Log(Local population)	.884	1.692	-1.82	-1.77
	(.420)	(.542)	(1.21)	(1.29)
Log(Flow)	-.023	-.021	-.064	-.010
	(.017)	(.019)	(.073)	(.077)
Log(Temperature)	.251	.202	-.309	-.759
	(.206)	(.302)	(.757)	(.830)
R^2 (includes station effects)	.91	.91	.87	.88
Number of observations	725	552	642	557
Number of stations	200	174	174	153

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

emerges when the decentralization measure excludes national defense spending in column (2). In the fecal coliform equations, the coefficient is positive, but not statistically significant for overall decentralization. However, a very large positive point estimate, that is statistically significant, emerges when the equations are run with the expenditure decentralization measure that excludes national defense.

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 higher point estimates than the broader measure, which would be consistent with measurement error in the broader measure.[12]

The estimates in Table 3 provide stronger evidence of a positive effect of decentralization on BOD than on fecal coliform, although the substantive effect might be larger for the latter. If the effect is only present for BOD, free riding would be a plausible explanation because it would lead to higher levels of regional pollution. However, if we credit the point estimate for fecal coliform in column (4) of Table 3, then the results may be evidence of regulatory competition or greater political influence for industrial interests at the local level.

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.

[12]Running the equations from columns (1) and (3) on the restricted set of observations in columns (2) and (4) (respectively) slightly reduced the decentralization coefficient for BOD and only slightly increased it for coliform. Thus, the difference in the coefficients is not only from the difference in the available observations.

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. The coefficients are statistically significant at 10% in column (1) and at 5% in column (4) of the table and quite large in magnitude in the column (4). In the fixed effects equations for BOD in Table 3, corruption has a counterintuitive positive coefficient that is statistically significant. In the data, the largest time series change in corruption is rapidly improving conditions in the Eastern European countries; this coefficient may reflect worsening (reported) pollution at this time in this region.

The local population variable mostly has the expected positive coefficients, pointing to higher pollution with greater population. In the pooled equations, this coefficient is statistically significant for both pollutants. The estimated elasticities of pollution to local population are substantially less than one, which is surprising. However, these elasticities are higher in the fixed effects equations, despite fairly limited information on the time series of local population (data are only for 1990, 1995, and 2000). In column (1) of Table 3, the point estimate of this elasticity is .89. However, the relationship breaks down in the fixed effects equations for fecal coliform, where the coefficients are negative and not statistically significant. The lack of a relationship may indicate that even the 20 kilometer ring is 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 equation for coliform in column (3) of 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 geographic variability in pollution

To explore the empirical relationship between decentralization and geographic variability in environmental quality, I exploit the fact that GEMS gives readings at multiple monitoring stations within a country. These readings can be used to calculate a time-varying country-level measure of geographic variability. The equations employ a two-step approach to try to distinguish variability resulting from public policy from heterogeneity in natural conditions. 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:

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

To allow the most flexible association, the local population and river characteristics (flow and temperature) are entered with a cubic. Then, the country-level variability is calculated, either by taking the standard deviation or interquartile range of the error ε_{ict} for a given country c and three-year period t.[13] For the standard deviation, the dependent variable for the second stage equation is

$$sd_{ct}(\varepsilon) = \sqrt{\frac{1}{I_{ct}-1}\sum_{i=1}^{I_{ct}} \varepsilon_{ict}^2}$$

where I_{ct} is the number of stations in country c, which sometimes varies over time because the GEMS/Water panel is unbalanced. The equation for variability then is

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

The equation includes decentralization, D_{ct}, and other country characteristics, $CountryChar_{ct}$, which mostly vary over time. Time and country effects (now α_t^{sd} and ν_c^{sd}) can still be included. Observations are necessarily dropped when $I_{ct} < 2$. The estimated equations are weighted by I_{ct} to reflect the lower variance in the estimated $sd_{ct}(\varepsilon)$ with larger numbers of observations in a country

[13] Results for interquartile ranges tracked standard deviations so closely that they are not reported.

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

Table 4 presents estimated equations. As above, the equations examine both qualitative federalism and expenditure decentralization. Lacking any specific theory of the causes of variability, 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 spatial variability. In particular, the geographic size of a country might influence the variability in ecosystems and thus in pollution levels. In columns (2) and (5) in the table, the equations add the full set of country characteristics used above.

The number of stations in any country is relatively small, even in the most active countries. The mean number of stations in a country-period cell is only 5.9 for BOD and 5.2 for fecal coliform. As a result, the standard deviation estimates on the left hand side contain a large amount of noise. Although robust standard errors and weights address the heteroskedasticity from this noise, hypothesis tests may lack power because of limited information. Thus, a definitive study of geographic variability may await a more extensive global data collection effort.[14]

Decentralization measures. The equations in Table 4 suggest a relationship between decentralization and spatial variability, but only through the qualitative federalism measure. The point estimate of this coefficient is positive for both pollutants. It is statistically significant at 10% for BOD and 5% for fecal coliform. For BOD, the expenditure decentralization measure produces a small, negative, and statistically insignificant point estimate. For coliform, the point estimates continue to suggest an increase in variability with decentralization, but the coefficients are not statistically significant.

A positive effect of federalism on geographic variability is consistent with the traditional view

[14] A better data set may be a long way off; the trend seems to be in the reverse direction. GEMS/Water has had a fairly dramatic fall off in the number of stations in the last period. A companion GEMS/Air project seems to have effectively ended in 2001, with old data archived on an unmaintained EPA website.

Table 4: Weighted least squares estimates for geographic variability

	Dependent variable:					
	$sd_{ct}(\varepsilon_{BOD})$			$sd_{ct}(\varepsilon_{Colif})$		
	(1)	(2)	(3)	(4)	(5)	(6)
Federal country	.258	.252	–	.717	.635	–
	(.142)	(.145)		(.350)	(.313)	
Log(Decentralization)	–	–	-.069	–	–	.284
			(.081)			(.324)
GDP per capita	–	-.047	–	–	.052	–
		(.073)			(.217)	
GDP per capita squared	–	.005	–	–	-.008	–
		(.006)			(.015)	
GDP per capita cubed /100	–	-.016	–	–	.015	–
		(.013)			(.029)	
Log(Lack of political rights)	–	-.103	–	–	-.520	–
		(.125)			(.372)	
Log(Lack of corruption)	–	.051	–	–	-.002	–
		(.141)			(.522)	
Log(Country population)	.048	.075	.219	-.068	.062	.380
	(.038)	(.046)	(.063)	(.204)	(.220)	(.243)
Log(Country area)	-.075	-.079	-.126	.123	.066	-.302
	(.045)	(.053)	(.060)	(.216)	(.220)	(.341)
R^2	.34	.38	.34	.37	.43	.34
Number of observations	162	158	118	157	157	116
Number of countries	41	41	38	43	43	35

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

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.[15] 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.

Country fixed effects equations did not yield statistically significant coefficients and are not shown in Table 4. The data may just contain too little information to estimate a relationship based only on time series variation.

Other covariates. In the equations in Table 4, few country characteristics beyond federalism account for geographic variability. Country population mostly has the expected positive coefficient, although it is statistically significant only in column (3). Country area has an unexpected negative coefficient, which is again statistically significant only in column (3). An explanation for the negative coefficient is that country area matters only indirectly through its contribution to population density.

Neither GDP nor the quality of government appear have a statistically significant effect on variability for either pollutant. The regional dummies (which are not shown) suggest African countries have much smaller BOD variability than other countries, but this result is likely a coincidence facilitated by small numbers of African observations; no such difference appears for fecal coliform.

[15] 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), but they are not statistically significant.

The year dummies (also not reported) suggest a slight trend toward reduced spatial variability in BOD, but not fecal coliform.

5 Conclusion

A sophisticated theoretical 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 interregional spillovers and a pollutant with only local effects.

The evidence in this paper points to higher levels of the regional pollutant with more decentralization, with weaker evidence of effects for the local pollutant. 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 geographic variability in pollution in countries with federal systems. Such variation might support the traditional view of Oates (1972) that decentralization allows better tailoring of policies to local conditions. If so, the results 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 environmental policies.

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