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Transboundary spillovers and decentralization of environmental policies

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Abstract

Most US federal environmental policies allow states to assume responsibility for implementation and enforcement of regulations; states with this responsibility are referred to as “authorized” or having “primacy.” Although such decentralization may have benefits, it may also have costs when pollution crosses state borders. This paper estimates these costs empirically by studying the free riding of states authorized under the Clean Water Act. The analysis examines water quality in rivers around the US and includes fixed effects for the location where water quality is monitored to address unobserved geographic heterogeneity. The estimated equations suggest that free riding gives rise to a 4% degradation of water quality downstream of authorized states, with an environmental cost downstream of \$17 million annually. © 2004 Published by Elsevier Inc.

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1. Introduction

Public policies for pollution control in the United States are a hybrid of centralized standard setting and decentralized implementation and enforcement. Some observers question the efficiency of centralization and argue for greater decentralization of environmental decision-making. Decentralization may allow policies to vary more with their local benefits and costs:

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although centralized policies could contain local variation, federal authorities may find much variability politically difficult and may have less information than state authorities. However, decentralization may be costly if the federal government can realize economies of scale in expertise, if “a race to the bottom” in environmental quality occurs as states compete for new investment, or if there are transboundary spillovers and states free ride.¹

This study evaluates the empirical relevance of the latter concern about decentralized environmental policy. In particular, it examines whether states that control their Clean Water Act (CWA) programs free ride on downstream states. States received this control—known as “authorization”—over their programs at different times. Using data on in-stream water pollution levels at about 500 river monitoring stations around the country from the National Stream Quality Accounting Network (NASQAN), I estimate equations that model water quality at a station as a function of whether the state or any upstream neighbor has authority over its CWA program, time-varying state and river characteristics, and a monitoring-station fixed effect for unobserved geographic heterogeneity. The paper uses a water quality index (WQI) based on levels of five common pollutants.

A few empirical recent papers examine interstate free riding in environmental policy. Gray and Shadbegian [10] analyze the emissions of pollutants by pulp and paper plants and find evidence of higher water and air pollution when out-of-state residents receive a larger share of the benefits of pollution control. They also examine monitoring activities, but find no evidence of border effects there. Helland and Whitford [12] find toxic chemical releases to be higher in border counties, which they interpret as evidence of spillovers.

My study builds on this research in several ways.² Examining the effects of authorization offers some econometric advantages. The identification of the coefficients comes from changes in policies over time, allowing the estimated equations to include fixed effects for the location where water quality is measured. Earlier studies of free riding are identified only by geography and thus potentially confounded by other heterogeneity associated with proximity to state borders. For example, locations near borders, such as along the Mississippi River, may have higher populations and different economic activities than other locations, even within the same region. In addition, for a coefficient of particular interest in the current study, identification comes entirely from changes in the status of a neighboring state, thus reducing concerns about policy endogeneity.

Examining the effects of authorization not only helps to establish that the border effects are free riding, but also provides information on the mechanism through which free riding occurs. It provides an assessment of the type of decentralization that most federal environmental programs employ.

I examine effects on in-stream water quality, which offers advantages and disadvantages relative to earlier studies. Water quality captures free riding regardless of the source of pollution.

¹Recent overviews of federalism in environmental policy include [5,21,23]. Dinan et al. [6] provide an example of the costs of uniform federal standards in the Safe Drinking Water Act. A substantial literature addresses the “race to the bottom” (see [15–17,22,28]).

²A small literature also examines free riding across international borders [20,26]. Like the previous literature examining interstate spillovers, this international literature relies on geographic variation only. Thus, the current research differs from this research methodologically, by allowing fixed effects, and conceptually, by focusing on free riding in a federal systems, where safeguards against free riding should be in place.

For example, if free riding states are less strict with municipal water treatment facilities than with industrial polluters (which may have out-of-state ownership), earlier studies may miss this effect by focusing on industrial pollution only. On the other hand, in-stream water quality does not indicate whether permitting, monitoring, or enforcement provide the flexibility that makes free riding possible.

My results suggest that states do free ride when authorized. The WQI is 4% lower at stations downstream from an authorized state than at other stations. When rivers form a border between states, authorization of at least one of the states lowers the WQI by 6%, although the latter effect is not robust. To interpret the magnitude of these effects, I use earlier estimates of willingness to pay for freshwater quality to construct a rough measure of the costs of this free riding. This calculation suggests that the environmental cost of free riding at downstream stations was \$17 million in 1983.

The paper begins with brief background on US water pollution policy that describes the authorization process and identifies sources of state discretion. Section 3 discusses the data on water quality and the explanatory variables. Section 4 presents the estimated equations, which account for station fixed effects and clustering within riversheds. Section 5 provides some welfare calculations. The paper concludes by discussing the implications of these results for federalism in environmental policies.

2. State discretion in water pollution policy

U.S. federal water pollution regulation originally gave states considerable discretion [11]. However, over time Congress centralized the regulation, culminating in the Clean Water Act of 1972. Under CWA, point source polluters must obtain permits that set numerical effluent limitations for various pollutants. For each production process, the federal government specifies the pollution control technologies and water quality standards that form the basis for these effluent limitations. Facilities had to meet the first effluent limitations in 1977 and a more restrictive set by 1983.

EPA authorizes states to issue and enforce permits. When the state does not have this authority, the regional EPA office issues permits. States received authorization at different times. Fig. 1 presents the authorization years by state. Most states obtained authorization early, with a few that authorized in 1973, the first year of the NASQAN data. However, a number of states authorized in the late 1970s and 1980s, in the middle of these data. Seven states had not authorized by 1995, the last year of the data. Sigman [27] explores various hypotheses about the determinants of authorization, such as green preferences, private information, and regulatory economies of scale, and finds no single overriding cause.

Although EPA may in principle revoke authorization if a state fails to comply with its obligations, this action is politically and legally difficult and financially costly for the regional EPA. For example, Arkansas refuses to impose federal discharge limits and monitoring requirements for municipal water pollution sources because they are too strict [9]. The regional EPA office says its “only recourse would be to take back responsibility for the program—an unrealistic option [9, p. 6]”. Thus, once authorized, states have quite a free hand to conduct (or ignore) the program.

Even if authorized states follow the program, they have several forms of discretion that might allow them to free ride. First, the federal technology and water quality standards do not greatly

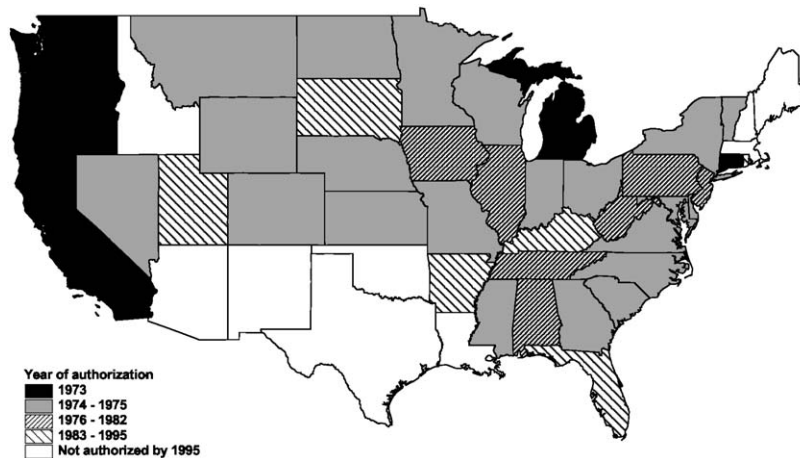


Fig. 1. Clean Water Act authorization years.

constrain the states in writing the numerical effluent limitations in permits. GAO [9] documents a variation in permit levels for similar size municipal treatment works of several orders of magnitude. These variations may arise through interpretation of the technology standards or through the environmental modelling required to implement water quality standards. EPA long delayed issuing technology standards, allowing state authorities to use “best professional judgement” in the interim, which may be much of the period of this study for some facilities.

Second, authorized states have primary enforcement authority under CWA. In fiscal year 1995, states conducted 81% of CWA inspections and undertook 77% of the administrative actions against violators [7]. Although the regional EPA may step in if a state fails to take action against a violator, control of inspections and enforcement may give states the ability to direct resources toward the problems they regard as most pressing.

Downstream states do complain about upstream states’ implementation. For example, GAO relates a challenge from Oklahoma of a permit issued to an Arkansas municipal treatment facility. Bartlett [2] describes complaints and law suits from Tennessee about proposed permits for a Champion Paper plant just upstream in North Carolina. However, one would expect states to lobby on their own behalf, so these complaints do not prove the existence of free riding.

3. Data and model

This section describes the data on water quality in rivers and the policy and other explanatory variables that have been merged with these water quality data.

3.1. Water quality data

The National Stream Quality Accounting Network, maintained by the US Geologic Survey (USGS), contains measurements of 121 different water quality parameters at 618 monitoring

stations on rivers in the United States [1]. The data span 1973 to 1995, with the most stations operating in 1980 and considerably fewer at the beginning and end of the period. Most stations report data approximately monthly during the period they operate, but this frequency varies. Regional USGS labs conduct most the sampling and analysis.³ The stations are spread across the country with the intent of providing a picture of human impact on water quality in major rivers. They are typically located at the bottom of watersheds, as defined by the USGS's watershed classification system.

With pollution measurements from NASQAN, I calculate the EPA's water quality index, based on five major pollutants: dissolved oxygen, fecal coliform, total suspended solids, phosphorous, and nitrogen. The calculation involves a nonlinear translation of each pollution level into a severity index and then a weighted aggregation of these indices [18].⁴ This index provides an overall picture of environmental conditions in the river, reflecting experts' judgements about the effects of pollution on the use of the river. It assists in drawing welfare implications of the empirical results because it can be mapped into willingness to pay estimates.

The pollutants that are the basis for the index are very common; several principally result from sewage and animal waste and others from fertilizer use [19]. Thus, they should not be especially sensitive to heterogeneity in the mix of industrial activity, unlike, for example, heavy metals. In addition, these pollutants have been the focus of the most regulatory efforts, which is important to assess the free riding hypothesis. If states always choose the corner solution of no pollution control, they cannot increase their pollution even if they desire to free ride. Thus, regulatory efforts suggest that at least some states do not choose the corner solution and may free ride.

I classify water quality based on average pollution levels for measurements taken during the summer months (defined as May through September). Constructing a daily WQI gives far fewer observations because not all pollutants are measured on a given day, even though all may be measured several times over the course of the summer.⁵ Previous studies have used summer averages, starting with the pioneering work by Vaughan and Russell [30].

Table 1 presents the water quality levels at stations on intrastate and interstate rivers. The total number of stations in Table 1 and the subsequent empirical analyses is 501, smaller than the 618 in NASQAN because of several exclusions for missing or ill-defined data.⁶ The average WQI is about 60. Rivers with this WQI would be considered fishable, but slightly below the cutoff for swimmable, according to thresholds used in the welfare analysis below. A recent run of the EPA's water quality model finds an average WQI per mile of river of about 75 [8], so the water quality in

³A very small number (under 1%) of the observations are conducted by state agencies, for which there might be concerns about strategic reporting. A dummy for these observations did not have a statistically significant coefficient, nor did interactions of this dummy with the policy variables. Thus, strategic reporting does not appear to be a major issue in these data.

⁴The original EPA index included 12 different pollutants; I have reweighted to include only these five on which NASQAN provides relatively thick data. EPA's recent studies using this index conduct a similar reweighting (e.g., [8]).

⁵Footnote 15 below discusses the results if an annual average is used.

⁶Stations were excluded if they never measured all of the pollutants necessary to calculate the WQI for a summer. Stations outside the contiguous United States were excluded for lack of population data. Eleven stations that never measured flow in the same summer as pollution were excluded. Three stations in the Great Lakes were excluded to restrict the sample to rivers. In addition, 16 stations downstream of Mexico or Canada were excluded because their upstream authorization status and LCV scores cannot be defined.

Table 1
Means and standard deviations of variables for intrastate and interstate observations

	Intrastate Obs = 836 (18%) Stations = 102 (20%)		Interstate Obs = 3869 (82%) Stations = 399 (80%)	
	Mean	S.D.	Mean	S.D.
Water quality index	60.8	9.5	58.7	10.5
<i>Locations</i>				
Station upstream of state border	—	—	.809	—
Distance to border (miles)	—	—	80	(111)
Station within 50 miles upstream of state border	—	—	.422	—
Station downstream of state border	—	—	.578	—
Distance to border (miles)	—	—	83	(140)
Station within 50 miles downstream of state border	—	—	.184	—
Station on state border	—	—	.140	—
<i>Authorization</i>				
State authorized	.559	—	.680	—
Upstream state authorized (if downstream station)	—	—	.667	—
<i>Socioeconomic variables</i>				
Personal income per capita (thousand 1995 dollars)	20.75	(3.22)	19.66	(2.78)
League of Conservation Voters (LCV) score	46.1	(15.2)	46.1	(17.4)
Percent cropland in watershed	12.2	(12.5)	22.2	(19.6)
Percent urban land in watershed	10.4	(12.7)	6.05	(7.47)
<i>River physical characteristics</i>				
Flow (cft/s)	2123	(4223)	13990	(60325)
Temperature (°C)	23.1	(4.5)	21.8	(4.0)

Note: Standard deviations reported for continuous variables only.

this sample is poorer. This difference should not be surprising because the NASQAN data are earlier (and the estimates below suggest significant improvement over time) and intentionally overrepresent rivers near populated areas.

As reported in Table 1, water quality is somewhat better in intrastate rivers than interstate rivers. Although this pattern is consistent with free riding, intrastate and interstate observations differ in many other ways that may explain the disparity. In particular, intrastate observations are mostly in coastal states, with the exception of a few on river systems that flow into inland sinks in the desert Southwest. Interstate observations may be in coastal or landlocked states.

3.2. Explanatory variables

Water quality at a given monitoring station is a function of pollution inputs as a river flows downstream. Thus, water quality WQ_{it} at a station at location i in year t is a function of pollution

inputs from upstream:

$$WQ_{it} = \sum_{h=i}^H \frac{p_{ht}}{f_{ht}} \delta^{h-i}, \quad (1)$$

where H indicates the headwaters, p_{ht} indicates pollution inputs at upstream locations h , and f_{ht} is the flow that dilutes these inputs. The effect of upstream pollution inputs diminishes through natural attenuation, represented here for simplicity by a constant δ (with $\delta < 1$).

We do not have direct information about pollution inputs or attenuation rates, but know some of the factors on which these depend. For pollution at location h ,

$$p_{ht} = u_{ht}(y_{ht}, L_{ht}) - a_{ht}(g_{ht}, y_{ht}, S_{ht}), \quad (2)$$

where uncontrolled pollution, u_{ht} , depends on factors such as the level of economic activity, y_{ht} , and land use, L_{ht} . These uncontrolled pollution levels may be reduced by the application of costly pollution control, a_{ht} . The extent of abatement may depend on green preferences, g_{ht} , income (y_{ht} again), and policy variables, S_{ht} , such as authorization status. The potential for free riding enters here in this analysis.⁷ The natural attenuation variable δ is also a function of some observable variables, particularly the temperature of the river, m_{it} .

Ideally, therefore, the equations would characterize both local and upstream conditions. In practice, the ability to measure upstream conditions depends on the variable. The values for land use describe the watershed and thus do characterize local and upstream conditions (as a result, these variables are denoted L_{it}^h below). For variables that change at state boundaries, such as authorization status and income, the equations can include the upstream state's value. For some variables, however, such as the river flow and temperature, the value at the station is the only indication we have of upstream conditions.

Therefore, we have an equation in which water quality at station i is a function of local and upstream variables. A reduced form equation for these relationships is

$$WQ_{it} = G(S_{it}, S_{ht}, y_{it}, y_{ht}, g_{it}, g_{ht}, L_{it}^h, f_{it}, m_{it}, A_i), \quad (3)$$

where variables are represented at station i and at upstream locations, h , when possible. All the estimated equations also include a station-specific fixed effect, A_i , to address heterogeneity across states and stations that might be correlated with the policy variables.

3.2.1. Policy variables

The principal policy variables, S_{it} and S_{ht} , depend upon whether states are authorized to conduct their own permitting and enforcement activities under CWA. States had this authority in 65% of the observations in the sample. The empirical analysis examines the interaction between authorization and location, specifically if the location is subject to free riding.

Three different location variables were coded by mapping the NASQAN stations using a Geographic Information System. These variables indicate whether the station is upstream

⁷Free riding could also affect the uncontrolled pollution level through land use or industrial siting decisions. However, authorization will not change state control of these variables, so this mechanism is not explored here.

of a state border, downstream of a border, or located on a river when it forms a border between two states.⁸ The location variables are based on river systems rather than the name of the river; for example, if a station is on a tributary that flows into the main river before the river crosses a border, the station would be coded as upstream. Many stations fall into all three interstate categories. Table 1 reports that 81% of interstate observations (67% of the total) are upstream of a border, 58% are downstream of a border, and 14% are on border rivers.

The table also reports the distance from the station to the nearest upstream or downstream border, which may be important because of natural attenuation. The average distance is 80 miles for upstream observations and 83 miles for downstream observations. A variable used in the regressions later indicates whether stations are relatively close to borders (defined as within 50 miles). 42% of interstate observations are within 50 miles of a downstream border and 18% are within 50 miles of an upstream border.

The measures of potential to free ride are calculated from a combination of authorization status and the station's location. Three measures are constructed. For stations located downstream of borders, the measure is whether the upstream state was authorized. Authorized upstream states have the discretion and motivation to choose less abatement, resulting in higher pollution downstream. Downstream states, finding themselves the recipient of higher pollution, may adjust their own controls upward. However, with the usual curvature assumptions on costs and benefits of pollution control, states will respond to a higher pollution endowment partly by tolerating higher pollution.

For stations located upstream of a border, the measure is an interaction of the upstream dummy with own-state authorization status. Because the equations also include a variable for authorization, this interaction term picks up the differential effect of authorization when the state can free ride. Finally, when the station is on the border, the measure is a dummy variable that equals one if either state is authorized; this variable indicates that at least one state might free ride.⁹

As with any study of the effects of policy variation, nonrandom assignment of policies raises some concern about the estimated effects. The current study addresses this concern in a few ways. First, monitoring-station fixed effects should absorb cross-sectional heterogeneity—including attributes of the state, such as state willingness to enforce regulations—that may cause early or late authorization. Second, for downstream stations, the policy variable characterizes a different state than the one in which water quality is being measured, which should limit the extent to which unobserved time-series heterogeneity in the state can explain both the policy variable and the water quality. Finally, even for observations in the state of the policy variable, we are not interested in the level of water quality before and after authorization, but the difference in these levels at stations upstream of borders. Although several factors might link overall water quality

⁸Several stations are upstream of the Great Lakes (even after stations *in* the Great Lakes are excluded, see footnote 6). The point at which a river enters the Great Lakes is treated as a downstream state boundary because the lakes represent a shared resource.

⁹The equations were also run with the addition of a second variable for borders indicating that both states (as opposed to at least one) were authorized. This variable never entered with a statistically significant coefficient and is not shown here for clarity.

levels with the time of authorization, it is more difficult to think of factors beside free riding that would result in differential levels at these upstream stations, especially with the geographic heterogeneity absorbed by fixed effects.

3.2.2. Other explanatory variables

Several additional variables provide time-varying determinants of pollution releases or their impact of water quality. For y_{it} , annual state-level personal income data from the Bureau of Economic Analysis have been converted to 1995 dollars using the national CPI. As Table 1 reports, income is slightly higher for intrastate observations, reflecting a difference between coastal and other states. For stations on border rivers, the arbitrary choice of measuring state should not influence the value of state characteristics, so all state characteristics, such as income, average the two neighbors' values.

The measure of environmental preferences, g_{it} , is the average League of Conservation Voters (LCV) score for the House delegation of the state in a given year. The LCV score (which ranges from 0 to 100) represents the share of a legislator's votes on selected measures that the LCV considers pro-environment [14,25]. As a measure of environmental sentiment, LCV scores have the virtue of varying over time and of perhaps reflecting the position of the median voter in the state (in contrast, for example, to environmental group membership, which focuses on the upper tail).¹⁰ I use House rather than Senate scores because the House scores usually average more individual legislators' data than Senate scores, reducing noise, and also can adjust more rapidly to changes in sentiment. As Table 1 reports, the LCV scores are similar between intrastate and interstate observations.

Local land use, L_{it}^h , is an important determinant of water quality because of the effects of nonpoint sources of pollution, such as agricultural and urban stormwater runoff. To capture these pollution sources, the equations include estimates of percent of land in cropland and in urban uses in the 8-digit HUC watershed in which the station is located. Stations are largely located at the base of these watersheds, so this measure should be a summary of upstream conditions. The land use data are available every 5 years, beginning in 1983, from the Department of Agriculture's Natural Resources Inventory (NRI). I linearly interpolated values in years between the NRI surveys and extrapolated backward linearly to years before 1983. Table 1 shows that interstate watersheds had a much higher share of land in cropland and lower share in urban uses than intrastate watersheds. These differences result from the predominance of coastal states in the intrastate group.

The equations also include two river characteristics. The river's flow, f_{it} , is included to capture dilution and flooding, which greatly increases non-point source pollution in rivers. Not surprisingly, Table 1 reports that stations on interstate river systems have dramatically more flow than intrastate stations. Water temperature, m_{it} , is included in the estimated equations because it affects biological activity and chemical conditions in the river and thus the natural attenuation rates of pollutants. Both flow and temperature are collected by NASQAN on about the same schedule as the pollutant concentrations.

¹⁰LCV scores are potentially endogenous to water quality in the state, if, for example, poor environmental performance causes voters to select greener candidates. However, this concern may be somewhat allayed by the fact that the LCV scores pertain to federal office holders, whose control over local environmental quality is limited.

Table 2
Estimates of determinants of water quality with station fixed effects

	Dependent variable: log(WQI)					
	(1)		(2)		(3)	
State authorized	.0070	(.0147)	.0114	(.0195)	.0008	(.0135)
Upstream * authorized	.0373	(.0283)	—		.1501	(.0668)
Upstream * authorized * LCV score	—		—		-.0298	(.0168)
Within 50 miles upstream * authorized	—		.1265	(.0705)	—	
Downstream * upstream state authorized	-.0401	(.0160)	—		-.0613	(.0559)
Downstream * upstream state authorized * upstream LCV	—		—		.0063	(.0155)
Within 50 miles downstream * upstream state authorized	—		-.0270	(.0127)	—	
Border * at least one state authorized	-.0584	(.0208)	-.0380	(.0270)	-.0584	(.0202)
<i>Socioeconomic variables</i>						
Log (State income)	-.0155	(.0716)	-.0055	(.0715)	-.0185	(.0715)
Log(League of Conservation Voters score)	.0041	(.0078)	.0072	(.0081)	.0156	(.0089)
Downstream * Log(Upstream income)	.0476	(.0667)	—		.0464	(.0664)
Downstream * Log(Upstream LCV)	.0078	(.0056)	—		.0035	(.0152)
Within 50 miles downstream * Log(Upstream income)	—		.00002	(.0006)	—	
Within 50 miles downstream * Log(Upstream LCV)	—		-.0075	(.0162)	—	
Log(Urban land share)	-.0503	(.0334)	-.0510	(.0344)	-.0471	(.0332)
Log(Cropland share)	-.0037	(.0161)	-.0048	(.0164)	-.0043	(.0161)
<i>River characteristics</i>						
Log(Flow)	-.0322	(.0041)	-.0319	(.0041)	-.0320	(.0041)
Log(Temperature)	.0295	(.0322)	.0314	(.0322)	.0289	(.0321)
Year	.0056	(.0013)	.0057	(.0013)	.0055	(.0013)
R-squared (including station effects)	.629		.629		.630	
R-squared (within only)	.098		.099		.099	

Notes: All equations include station fixed effects. Standard errors (in parentheses) robust to contemporaneous clustering at the watershed level. Number of observations: 4704; Number of stations: 501.

4. Results

In the estimates in Table 2, the log of WQI depends on the logs of the explanatory variables. A log–log form was chosen to conform to physical water quality models that have multiplicative effects of variables such as flow and temperature. All equations include a fixed effect for the monitoring station: Hausman tests reject random effects. An appendix reports the results for similar equations without station fixed effects.

Because stations are on river systems in which one station may be upstream of another, errors may be correlated across stations during the same summer. To account for these correlations, the standard errors of the equations are estimated with clustering of contemporaneous observations within the USGS hydrologic subregion.¹¹ Although these estimates are potentially inefficient in

¹¹The subregions correspond to 4-digit Hydrologic Unit Codes (HUCs) and there are 222 in the country. The results are not noticeably different if clustering is at 2-digit (region) or 6-digit (accounting unit) HUC levels.

not modeling the upstream–downstream relationships precisely, they also make the equations robust to some other spatial relationships that may arise in the data, such as watershed-level public policies.

This section discusses the coefficients on the policy-related variables first and other covariates later.

4.1. Policy-related coefficients

The first column in Table 2 presents estimates of the basic equation. The equation includes whether the state of the monitoring station is authorized along with several interactions of location and authorization status. The coefficient on own-state authorization is positive; however, it is substantively very small and not statistically significant in any of the equations in Table 2. Thus, the results do not suggest a strong time-series association between water quality and authorization, either from authorized states creating better (or worse) water quality or from the EPA granting authorization to states once they begin to achieve good results. However, as reported in Table 4 in the appendix, authorization is associated with better water quality when the equation does not include state or station effects.

The next variable is an interaction between this authorization status variable and upstream-of-border location. The variable is included to measure whether authorized states use their privileges to free ride on downstream neighbors. This interaction does not enter with a statistically significant coefficient. The point estimate is positive, however, which would could arise if states free ride by shifting polluting activity to very near the border, resulting in an improvement upstream in all but the last few miles.¹²

The coefficient on being downstream from an authorized state is negative and statistically significant, which is consistent with free riding.¹³ The point estimate suggests a 4% reduction in the water quality index.¹⁴ Because the WQI is an abstract measure, the next section provides an attempt to quantify the welfare effects of this reduction. An effect is also seen at borders, where

¹²This “shifting” hypothesis suggests upstream state authorization should cause river water quality to fall more dramatically as a river flows downstream than it would with federal authority. To test this hypothesis, I identified 52 pairs of upstream and downstream stations with a state border between them. Of these station pairs, 32 had pollution data at upstream and downstream locations in same year at least once, with 203 annual observations on the change in water quality between upstream and downstream states (ΔWQI). Regressing ΔWQI on the distance between the two stations ($DIST$) and the upstream state’s authorization ($UPSTAUTH$) yields

$$\Delta WQI = 3.18(3.67) - .012(.011)DIST - 1.47(3.55)UPSTAUTH,$$

where numbers in parentheses are standard errors adjusted for clustering at the station-pair level. Although the point estimate on upstream state authorization is negative, the equation offers little support for the shifting hypothesis.

¹³This coefficient also includes non-free-riding effects. If authorized states are different from other states (either cleaner or dirtier), some of this difference would reach downstream neighbors. However, the direct test of the effect of authorization does not show a consistent net effect of authorization, reducing this concern. In addition, the point values of the own-state authorization coefficient are positive, so this effect would tend to make the estimated coefficient an underestimate of true free riding.

¹⁴Another concern is that authorization of the state immediately upstream does not capture the full extent of free riding because a downstream station may be downstream from more than one state. However, the authorization status of the next upstream state (i.e. any state upstream of the upstream state) had a substantively tiny and statistically insignificant coefficient. Natural attenuation appears to make any cumulative effect trivial.

the rivers are about 6% dirtier if at least one of the adjacent states is authorized. This coefficient too is statistically different than zero.¹⁵

Column 2 in [Table 2](#) alters the location variables to reflect proximity to the border. Far downstream of a border, the pollution endowment from upstream free riding dwindles with natural attenuation; far upstream of a border, the polluting state experiences almost all the damage. The second equation therefore considers stations to be upstream or downstream of the border only if they are within 50 miles of the relevant border.¹⁶ This change substantially reduces the number of stations classified as susceptible to free riding.

Nonetheless, the pattern observed above continues to hold. At downstream stations within 50 miles of the border, the upstream state's authorization has a negative and statistically significant effect. The magnitude of the effect is similar to before. At upstream locations, authorization again does not have a statistically significant effect at 5%, although the positive coefficient is statistically significant at 10%. However, only 9 stations identify the effect in this group, so the result is unreliable. With this change in other policy variables, the coefficient on border state authorization falls enough that it is no longer statistically different than zero, but the point estimate remains negative.

Finally, the third column adds an interaction between the earlier variables that measure free riding and the LCV score. States with greater preference for the environment might free ride less than other states because they have higher existence values for environmental quality outside the state. They also might free ride more because they have more costly controls within the state and therefore greater incentive to reduce these controls.¹⁷

The results in column 3 of [Table 2](#) could be consistent with the former hypothesis. Upstream state's authorization and this variable interacted with the LCV score are jointly statistically significant at 5%. According to the point estimates, the effect of upstream state authorization is negative, but a higher LCV score offsets this effect (although the latter coefficient is not individually statistically significant). However, the individual coefficients are so imprecisely estimated that they are uninformative on the net effect. The coefficients on authorization at an upstream station and its interaction with LCV score show opposite effects, but are not jointly significant at the 10% level. This is surprising because the upstream coefficients have smaller estimated standard errors than the coefficients at downstream stations.

Column 3 also provides some information about an alternative (non-free-riding) reason for effects of proximity to borders. Kahn [13] argues that pollution may be especially high just outside the borders of stringent states as facilities seek pollution havens with good access to markets

¹⁵If the water quality index is based on annual (rather than summer) averages of pollution levels, the coefficients on the three location-authorization interactions remain the same sign. At downstream stations, authorization of the upstream state is associated with a 2% decline in WQI, but this effect is no longer statistically significant; at border stations, authorization is associated with a 4% decline. At upstream stations, the coefficient is positive, but very small and statistically insignificant. Ten more stations can be included in the analysis with this change.

¹⁶This figure was chosen based on the rates of attenuation for oxygen depletion. Setting a higher or lower threshold (20 or 100 miles) did not greatly change the coefficient estimates, although the number of stations identifying the effect becomes quite small at 20 miles.

¹⁷Interactions are provided for upstream and downstream stations, but not stations on borders. Although an analogous effect might be examined at borders, it is difficult to define a single interaction variable for this case and seems unwise to enter a number of interactions, given the small number of stations involved.

whose regulation they prefer to avoid. Similarly, pollution should be particularly low just inside the borders of stringent states as activities near the border jump more readily to neighboring states than those in the heart of the state. If green states use authorization to increase regulatory stringency, therefore, Kahn's hypothesis would suggest a positive coefficient on the interaction between authorization at an upstream location and LCV score, but the point estimate on this coefficient is negative.¹⁸ Thus, the estimates do not support Kahn's hypothesis.

4.2. *Other coefficients*

Only a few of the other covariates enter the equations with statistically significant coefficients. State personal income per capita does not have a statistically significant effect. The estimated coefficient is positive, which would suggest that the effect of income on preferences dominates its effect on uncontrolled pollution.¹⁹ The time-series variation in green preferences, as measured by LCV scores of the state's House delegation, also does not enter with a statistically significant coefficient, although the coefficient is positive as expected. Changes over time in LCV scores may be largely noise rather than underlying environmental preferences; in the cross-section, these scores are positively associated with water quality, as reported in Table 4 in the appendix. Since own state's income and LCV scores do not have statistically significant coefficients, it is not surprising that upstream states' income and LCV scores also do not seem to matter.

Neither of the land use measures, percent of the watershed in cropland or in urban uses, enters statistically significantly, although both have negative point estimates as expected. Again, when the equations are estimated without station fixed effects in Table 4 in the appendix, these land use variables have a significant negative coefficients. The failure to find this effect with station fixed effects probably results from the relatively small variation over time in land use, making it difficult to identify the effect of changes. It could also be a data-quality issue: interpolation between inventories every fifth year may not adequately capture the time-series variation.

River flow enters with a statistically significant negative coefficient. The discussion above suggested that flow would have a positive effect on water quality because of dilution of waste. However, floods dramatically increase nonpoint source pollution (for example, with erosion of farmland), so the negative coefficient likely results from flooding. Temperature does not enter with a statistically significant coefficient.

Finally, the time trend has a positive coefficient in all equations, which may indicate that implementation of CWA during this time did indeed improve water quality. The estimates are all around a .5 percent increase in the water quality index per year, so the cumulative effect over the 23 year period is substantial.

¹⁸Downstream of the border, the hypothesis does not yield a clear prediction. Although we would expect to see diminished pollution inputs upstream with an authorized green upstream state, these would be counterbalanced by higher inputs in the downstream state to which the polluting industries migrate.

¹⁹I also ran the equations with a quadratic in income to allow the nonlinear relationship between income and pollution that some research has found. However, higher order terms were never statistically significant, failing to support an "environmental Kuznets curve" relationship. As the appendix reports, this relationship is not even found without fixed effects.

Table 3
Calculation of willingness to pay (WTP) for water quality improvements in 1983

	Current use to boatable	Boatable to fishable	Fishable to swimmable
Carson and Mitchell total WTP	\$93	\$70	\$78
Threshold WQI for water quality improvement	34.7	49.0	63.3
WQI units required to achieve threshold	26	339	1750
Estimated WTP per unit of WQI	\$3.55	\$.21	\$.04

Note: All dollar values in 1983 dollars per household.

Sources: Carson and Mitchell [4] and calculations based on WQI at NASQAN stations in 1983.

5. Welfare effects

An evaluation of the welfare effects of free riding requires information about the costs of water pollution control and benefits of water quality in upstream and downstream states. Upstream states that free ride reduce their pollution control costs by more than the losses they bear from a lower level of water quality in their state.²⁰ Downstream states bear a burden both in environmental damage and in pollution control costs, if they increase their control levels to offset the pollution endowment they receive from upstream. Because this study does not have information on pollution control costs, a complete evaluation of the welfare effects of observed free riding is outside its scope. However, calculating the cost of environmental damage from free riding in downstream states helps assess the magnitude of the effects estimated above.

A rough calculation of willingness to pay for improvements in the WQI is shown Table 3. The basis for the calculation is Carson and Mitchell's national survey of the value of recreational uses of freshwater in 1983 [4]. As reported in the first row of Table 3, they estimate that households would be willing to pay an average of \$93 to improve all water from its 1983 condition to at least boatable, \$70 to improve all water from at least boatable to at least fishable, and \$78 to improve all water from at least fishable to swimmable (all values are in 1983 dollars). Respondents attributed 67% of their values to in-state waters and the remainder to out-of-state waters. Carson and Mitchell consider the in-state component to be use value and the remainder to be existence value.

To use Carson and Mitchell's results to value the WQI improvements estimated in the equations requires calculating a willingness to pay per unit of WQI. The second row in Table 3 contains the thresholds of the WQI for boatable, fishable, and swimmable rivers.²¹ Assuming that the NASQAN stations are a representative sample of all relevant river locations, the third row contains the number of WQI points necessary to meet each of the three goals nationally.²² Only a

²⁰This statement assumes states adopt the in-state optimal pollution level, which is sufficient but not necessary for incentives to free ride.

²¹The classification uses thresholds provided in [3], without the requirement for BOD for which NASQAN does not provide data. BOD is closely associated with dissolved oxygen, for which a threshold is included, so dropping the BOD requirement probably does not greatly affect the numbers.

²²Although NASQAN overrepresents river areas with human influence, this overrepresentation may be desirable in the current context because it is a sample of the areas likely to be visited by people and thus to have use values.

small number of rivers start below boatable, so assuring boatable water requires far the smallest total increase in WQI. Dividing Carson and Mitchell's valuations by the WQI improvements in the fourth row yields an estimate of average willingness to pay for a point of WQI in the different use classes. These values are reported in the final row of the table. Average values of WQI improvements, as expected, decline as water quality improves. The rate of decline, however, is surprisingly steep.

These willingness to pay values can then be applied to the difference between predicted water quality with and without any authorization of upstream stations.²³ Applying these averages assumes that the value of improving only a share of waters is that share of the value of improving all waters. This assumption may underestimate the value of partial improvements because the marginal valuation probably declines with the share of water affected. I restrict the welfare estimate to the 67% of the value above attributable to in-state benefits. For each state, the total value of WQI improvements is multiplied by the number of households in 1983.

Using the estimates in column 1 of Table 2, the result is an environmental cost to downstream households of \$17 million in 1983 (in that year's dollars).²⁴ For comparison, a recent study using the same willingness-to-pay data placed the overall benefits of CWA at \$11 billion per year [3]. The \$17 million is only the environmental costs (not the costs of any pollution abatement response), but does provide a lower bound on the losses at downstream stations.

6. Conclusion

The empirical results are consistent with the hypothesis that states have both the will and the way to free ride under Clean Water Act regulations. Federal policies that grant states authority to run their own programs appear to allow free riding. By focusing on changes in policy regimes in upstream states, the estimated equations address unobserved geographic heterogeneity that might otherwise make it difficult to isolate such effects.

Although such transboundary free riding is often cited as a justification for federalizing environmental policies, the results in this paper do not necessarily support more centralized policy for three reasons. First, my empirical results suggest that federal standards do not prevent free riding. Allowing states discretion in implementation and enforcement of standards appears to be sufficient for free riding to continue.²⁵

Second, problems with free riding must be weighed against the benefits of decentralization. Because free riding costs only \$17 million, it may not overcome the greater flexibility and informational advantages of decentralization. In addition, the optimal response to free riding may

²³I use willingness to pay from Carson and Mitchell as willingness to accept compensation for degradation from free riding. This assumption may underestimate the values because willingness to accept often exceeds willingness to pay by a large amount in survey data.

²⁴These values would be different in other years. First, over time, benefits of water quality improvements may decline as water quality improves or increase with income. Second, expansion in authorized states would increase the number of sites subject to free riding. Rather than stretch the benefits transfer any further (for example, by assuming an income elasticity for willingness to pay), the paper presents the values in the year for which they are most appropriate.

²⁵Revesz [24] observes that the Clean Air Act may similarly permit (or even encourage) free riding despite centralized standards.

not be centralization, but rather decentralization in combination with more targeted responses to spillovers. For example, the federal government might continue to decentralize decision-making but provide subsidies (or levy fees) on the chosen environmental standards to reflect costs to other states. However, Oates [21] questions the political feasibility of such approaches.

Finally, free riding may not be detrimental if pollution control policies are inefficient. Recent studies suggest that CWA may not pass a cost-benefit test [11,29]. If so, the observed free riding could provide a net benefit by reducing overcontrol of pollution.

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Appendix A. Estimates without station fixed effects

This appendix reports the results of regressions without station fixed effects. Although equations with station fixed effects absorb unobserved heterogeneity that might otherwise bias the estimated coefficients, they also identify the coefficients of interest from only the subset of stations whose own or upstream state authorized during the study years. Cross-sectional heterogeneity between authorized and unauthorized states might provide information that is not exploited.

The equations are similar to those in column 1 of Table 2 in the text, but with a richer set of station characteristics. Three location variables—indicating whether the station is upstream of a border, downstream of a border, or on a river when it forms a border—are now included. In addition, the equations also include three more descriptive variables that either do not vary over time or for which time-series variation was not available.²⁶

First, the equations include population density in the station's watershed in 1990, provided by the USGS. Because the stations are typically at the bottom of the watershed, this variable measures upstream population and thus reflects variation in uncontrolled pollution levels.

Second, the equations add the size of the drainage area upstream of the station, again provided by the USGS NASQAN files. Pollution may increase as a river travels downstream and accumulates wastes. Including drainage area should help to avoid picking up this effect in the coefficients on the variables that indicate the position of the station relative to state borders.

Finally, the distance from the station downstream to the ocean is included. Using a Geographic Information System, I calculated this variable from NASQAN latitude–longitude data and a flow direction grid from the USGS's Global 1K data. Distance to the ocean may belong in the equations for two reasons. First, it may be efficient for river pollution to increase downstream because human and ecological exposure to the pollution falls as the ocean nears. Second, people in

²⁶Table 4 drops the upstream state's income and LCV score variables, so the coefficient on downstream location can be interpreted simply as the effect of being downstream of an unauthorized state. These variables were not statistically significant and did not change the qualitative results.

Table 4
Estimates of determinants of water quality without station fixed effects

	Dependent variable: log(WQI)			
	(1)		(2)	
State effects?	No		Yes	
State authorized	.0446	(.0195)	.0246	(.0308)
Station upstream of a border	.0343	(.0232)	-.0755	(.0368)
If upstream: State authorized	-.0375	(.0260)	.0310	(.0348)
Station downstream of a border	.0064	(.0201)	-.0231	(.0199)
If downstream: Upstream state authorized	-.0031	(.0208)	.0372	(.0207)
Station on a border	-.1183	(.0361)	.0100	(.0333)
If border: At least one state authorized	.1152	(.0427)	-.0031	(.0372)
<i>Socioeconomic characteristics</i>				
Log(State income)	-.0425	(.0505)	-.0685	(.0714)
Log(League of Conservation Voters score)	.0209	(.0110)	.0184	(.0089)
Log(Urban land share)	-.0186	(.0105)	-.0189	(.0094)
Log(Cropland share)	-.0157	(.0051)	-.0181	(.0048)
Log(Population density in watershed)	-.0033	(.0075)	-.0190	(.0076)
<i>River characteristics</i>				
Log(Flow)	.0109	(.0042)	-.0054	(.0040)
Log(Temperature)	-.1402	(.0370)	-.1297	(.0382)
Log(Drainage area)	-.0031	(.0065)	.0165	(.0067)
Log(Distance to ocean)	-.0298	(.0057)	-.0217	(.0074)
Year	.0043	(.0010)	.0055	(.0011)
R-squared	.16		.30	

Notes: Standard errors (in parentheses) robust to clustering at the monitoring-station level. Number of observations: 4704; Number of stations: 501.

interior areas do not have opportunities for ocean disposal of sewage and other wastes, so water may be more contaminated when the station is far from the ocean.

Table 4 presents two estimated equations, one without any geographic effects and one with state effects.²⁷ The state effects in column 2 have the advantage of absorbing policy conditions that may be correlated with authorization status. However, they may absorb some relevant variation as well. For example, states may free ride by reducing their overall enforcement

²⁷The state effects for stations on border rivers average the effects of the two neighboring states, rather than assigning one state's value arbitrarily.

intensity, which would alter pollution in all rivers in the state. If states lack the ability to target pollution control toward interstate rivers, the within-state effect underestimates the true extent of free riding. Although the equations do not include station effects, the standard errors in [Table 4](#) have been adjusted for clustering at the station level.

A.1. Policy variables

The state's authorization status is positively associated with its water quality in the first equation in [Table 4](#) (without state effects). The point estimate suggests 5% higher water quality in authorized states. The causality for this effect is unclear: cleaner states may receive authorization preferentially or authorized states may become cleaner if they do a better job in implementing the rules. The effect is no longer statistically significant when state effects are added in the second column, suggesting the former interpretation.

In the first equation, authorization at upstream stations and of the upstream state at downstream stations have negative coefficients, as in [Table 2](#), but they are not statistically significant. The downstream and upstream location dummies also do not have statistically significant coefficients. With state effects in column 2 of [Table 4](#), the upstream and downstream dummies are negative, which is consistent with free riding. Only the upstream coefficient is statistically significant, with a point estimate suggesting 7% worse water quality at these locations. However, the authorization effects remain insignificant and the point estimates are even positive. Thus, the only evidence of free riding through any mechanism is the negative coefficient at upstream stations. Nonetheless, the absence of station fixed effects make the specifications in [Table 2](#) preferred to those in this appendix.

Without state effects, stations on border rivers have negative and statistically significantly lower water quality, which is offset by a significant positive coefficient when one state is authorized. The first coefficient could represent free riding. Interpreting the second coefficient is harder, however, because it combines any free riding from authorization with the overall positive association between water quality. For a station located on a border river, the dummy at the top of the table represents authorization for only the state on one side of the river; the coefficient on borders with at least one authorized state may pick up the positive association for the state on the other side. When state effects are added in the second equation in [Table 4](#), the main authorization effect and this border effect both vanish, supporting this interpretation.

A.2. Other covariates

Without fixed effects, the other covariates play a larger role, given the cross-sectional variation left to be explained. State income is not statistically significant, even without state fixed effects in column 1. Equations estimated with a quadratic in income (not shown) also failed to support an environmental Kuznets curve relationship. However, LCV scores are positive as expected, even with the inclusion of state effects.

Land use plays an important role in the equations in [Table 4](#) even though it did not in [Table 2](#), perhaps because of the greater difficulty in isolating effects once the cross-sectional variation is absorbed. Population density has the expected negative effect on water quality when state effects are included. Flow, which had significant coefficients in [Table 2](#), also enters significantly in the

second equation in Table 4. Temperature enters statistically significantly only in Table 4. Drainage area enters only the second equation in Table 4 with a positive sign; perhaps this coefficient picks up the dilution effect of higher water volumes. Distance to the ocean has a negative and statistically significant coefficient in both equations, consistent with the hypothesis that the availability of ocean disposal improves water quality. The time trend continues to suggest the same magnitude of improvement as in Table 2.

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