Preliminary
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Federalism and Transboundary Spillovers: Water Quality in US Rivers

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Abstract: The possibility that states allow greater pollution when pollution crosses state borders is sometimes used as an argument for centralized environmental policies. This paper investigates the empirical extent of such free riding in river pollution in the United States. Using data from monitoring stations in the National Stream Quality Assessment Network (NASQAN), it evaluates the effects of interstate spillovers on water quality. The empirical results suggest that states do free ride occur and that giving them authority to issue and enforce water pollution permits facilitates this behavior. The estimates imply that the environmental cost of free riding at downstream stations is over $300 million annually.

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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: 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.[2]

This study evaluates the empirical relevance of the latter concern about decentralized environmental policy. I examine the extent of free riding in river pollution, using data from the National Stream Quality Assessment Network (NASQAN) on water quality at monitoring stations throughout the United States. Rivers present a good opportunity to study the effects of transboundary spillovers for two reasons. First, rivers may cross state borders or remain entirely within one state, with such intrastate rivers providing a useful comparison group. Second, monitoring stations on various rivers provide observations on several separate rivers within a state. Thus, it is possible to compare water quality in intrastate and interstate rivers while controlling for state effects.

The empirical analysis looks for evidence that water quality is lower in the presence of spillovers.[3] Lower water quality in shared rivers suggests that states give lower weight to the effects of pollution on other states than on themselves.[4] Failure to find such elevated levels would have ambiguous implications. It might indicate that states give high weight to their neighbors' welfare, that interstate bargaining has resolved the externality problem, or that federal regulations constrain state behavior enough to preclude such free riding.

A related question concerns the effects of policies that decentralize regulation. The Clean Water Act (CWA) allows the federal Environmental Protection Agency (EPA) to authorize states to issue and enforce discharge permits. States (and their upstream neighbors) received this authority at different times, allowing both cross-section and time-series comparison of

[2]For recent discussions of federalism in environmental policy, see Oates (2000), CBO (1997), and Revesz (1997). Dinan et al. (1999) provide an example of the costs of uniform standards in the Safe Drinking Water Act. There is a substantial literature on conditions for a "race to the bottom": for example, see Oates and Schwab (1988), Markusen et al. (1995), Levinson (1997) and Wilson (1996). Revesz (1996) discusses the policy implications of interstate externalities, with special reference to the Clean Air Act.

[3]I use the term "spillover" to refer to the physical effect of upstream states' pollution levels on downstream states' water quality. This physical spillover should be distinguished from elevated pollution that crosses the border as the result of free riding.

[4]Smith et al. (1999) provide an example of the deviation of local (in their case, county) incentives for control from global welfare in river pollution.

transboundary free riding with and without state authorization.

The paper uses a discrete characterization of the water quality at the station based on in-stream recreational uses. The water quality levels — unusable, boatable, fishable, and swimmable — echo the goals of CWA and are often used by studies valuing water quality. They depend on four common pollutants regulated under CWA.

The results suggest that states do free ride. Eliminating free riding may increase the frequency of swimmable water 42% at stations upstream of borders and 10% at stations downstream of borders. Using survey data on the value of water quality, I estimate that the environmental cost of free riding at downstream stations was $377 million in 1983. In addition, authorizing states to conduct their own CWA programs appears to facilitate free riding: the elevated pollution levels observed upstream of borders are concentrated in authorized states. Thus, there is evidence that decentralization may allow free riding.

The paper begins with brief background on US water pollution policy to identify sources of state discretion. The second section discusses the data on water quality and the explanatory variables. The third section presents estimated equations, including equations with and without state effects. The fourth section provides some rough welfare calculations. The paper concludes by discussing the implications of these results for federalism in environmental policies.

1 State discretion in water pollution policy

US federal water pollution regulation originally gave states considerable discretion (Freeman, 2000). However, over time Congress increasingly 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 technologies that form the basis for these effluent limitations. In addition, the effluent limitations contained in permits must be consistent with standards for water quality in the river. Facilities had to meet the first effluent limitations in 1977 and a more restrictive set by 1983.

EPA may authorize 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, beginning with California in May 1973. Seven states had not received their authorization by 1995, the last year of my data. Although EPA may in principle revoke authorization if a state fails to comply with its obligations, this action is politically and legally difficult.

Despite the restrictions that federal technology standards impose, states may have discretion for several reasons. First, states continue to have flexibility in issuing permits (GAO, 1997; Lerner, 1999). The federal technology standard is only a minimum standard and states may increase stringency by adopting tighter standards for all facilities. When regulators in authorized states set effluent limitations, they also may tighten requirements for an individual facility to address in-stream water quality. For some pollutants and production processes, EPA long delayed issuing technology standards, allowing state authorities to use "best professional judgement" in the interim. The GAO (1997) found substantial variability in the structure and requirements of permits by state. It also documented complaints by downstream states about permits issued by upstream states.

Second, 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 (EPA, 1996 and 1997). 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.[5]

Third, federal regulation principally addresses point sources of pollution. States have considerable discretion in any activities taken to control nonpoint sources. Amendments to CWA in 1987 formally placed this responsibility in the hands of the states.

Fourth, federal regulations do not determine the siting of new pollution sources. State governments have incentives to direct new pollution sources to areas just upstream of their downstream borders to reduce the state's own share of the environmental impact.[6]

The empirical implications of free riding through these four sources of discretion may differ. For the first three types of discretion, free riding would elevate pollution levels in both the upstream state and the downstream state. Upstream levels are higher because upstream states respond to lower incentives for pollution control with higher pollution. Downstream levels are higher because downstream states receive a higher endowment of pollution; although they may respond with greater pollution control, they are not likely to find it optimal to compensate completely for the dirtier water they receive.

If free riding occurs through discretion in siting (the fourth type of discretion), stations in downstream states will still have higher pollution. However, stations in upstream states might exhibit lower pollution than in the absence of free riding because activities move to locations near the border. Thus, the empirical analysis will distinguish stations upstream and downstream of borders to explore the sources of discretion.

[5]Levinson (2001) finds substantial variation across states in the environmental compliance costs of manufacturing firms, even after accounting for industry mix. Because federal minimum standards address most major kinds of point source pollution, he attributes this variation to differential state enforcement.

[6]Ingerbman (1995) presents data on the location of landfills in Pennsylvania that suggests county governments frequently site these facilities near their borders.

2 Data

The estimated equations have the general form

$$Q_{it} = f(S_i, Y_{it}, R_{it}, A_i, t),$$

where Q_{it} is the water quality at station i at date t, S_i are various measures of the trans-boundary spillover at that station, Y_{it} are measures of the benefits and costs of pollution, R_{it} is a matrix of river characteristics that affect pollution attenuation, A_i are state effects, and t is a trend. This section discusses first the dependent variable and then the explanatory variables.

2.1 Water quality data

The US Geologic Survey (USGS) maintains the National Stream Quality Assessment Network. The data set contains measurements of 121 different water quality parameters at 618 monitoring stations on rivers in the United States (Alexander et al., 1998). 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.

Figure 1 shows the distribution of NASQAN stations within the continental US. The stations are distributed across the country with the intent of providing a picture of the human impact on water quality in major rivers of the US. They are typically located at the bottom of watersheds, as defined by the USGS's hydrologic unit classification system.

With pollution measurements from NASQAN, I classify water quality into four categories based on the Resources for the Future Water Quality Ladder (Vaughan, 1986). The categories are swimmable (the best water quality), game fishable, boatable, and unusable. Bingham et al. (2000) implement this classification with four water quality measures: dissolved oxygen saturation, biochemical oxygen demand (BOD), total suspended solids (TSS) and fecal coliform.[7] Because NASQAN does not report BOD, it does not play a role in my classification, but misclassification is probably uncommon because BOD is highly correlated with dissolved oxygen.

This classification has several advantages. It allows an examination of several pollutants at once, weighting these pollutants according to their seriousness in diminishing recreational use of the river. The classification also makes it possible to draw some welfare implications of

[7] I use Bingham et al. (2000) rather than the original Vaughan (1986) classifications because Vaughan relies on turbidity measures (in place of TSS) that are infrequently reported in the NASQAN data.

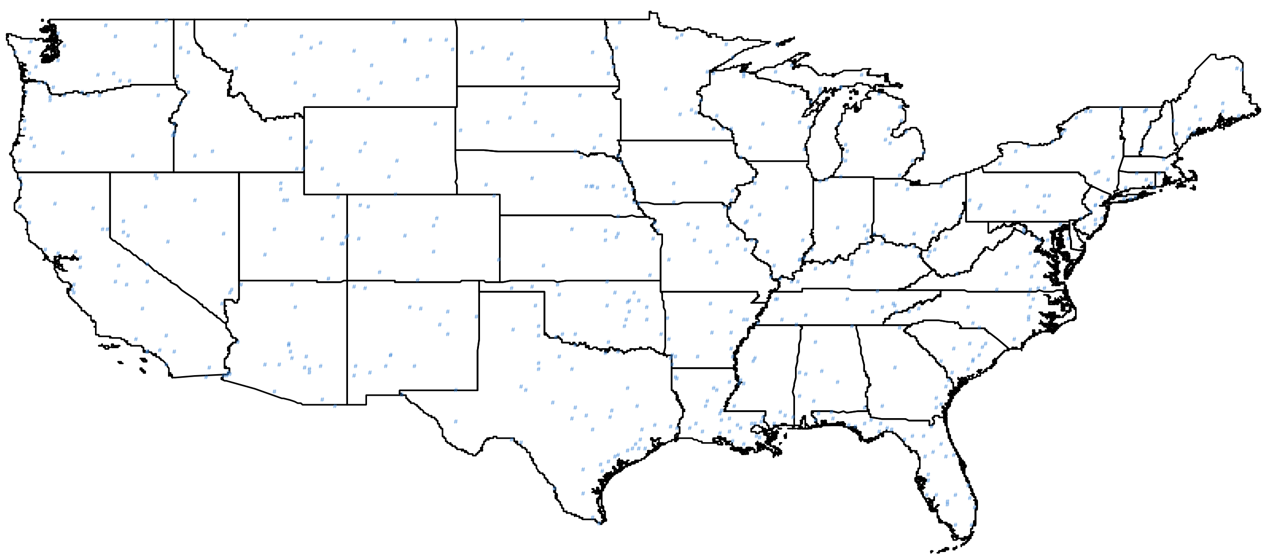

Figure 1: NASQAN stations in the contiguous US

the empirical results because it is the basis of willingness to pay estimates for water quality improvements. The classification is based on the pollutants that have been the focus of the most regulatory efforts. It is important to study heavily regulated pollutants because pollutants that are not subject to any control will not exhibit free riding. The pollutants that are the basis for the classification are also very common and not especially sensitive to heterogeneity in the mix of industrial activity (which I do not measure in my equations). However, the disadvantage of using this classification is that it gives up information by reducing continuous data to a few categories.

I classified water quality based on average pollution levels for measurements taken during the summer months (defined as May through September). Winter water quality in most locations is not relevant to the recreational uses described here. Averaging makes the dependent variable less subject to short-lived changes in natural conditions, especially floods. Such short-lived extreme conditions may not greatly affect use of the river and thus the welfare implications of free riding. Vaughan and Russell (1982) use a 90-day summer average for their pioneering work on valuing water quality.[8]

Table 1 presents the frequency of water quality levels at stations on intrastate and interstate rivers.[9] The values in the table show the share of observations that attain each level of water quality and no greater: for example, 14.6% of observations were suitable for boating, but not for game fishing. The water quality in this sample is poor: Bingham et al. (2000) estimate that 40% of river miles in the US were swimmable in the mid-1990s, but only 13% of these observations are swimmable. The difference reflects NASQAN's concentration on locations with substantial human impact.

In Table 1, water with no use is more common and all the better water quality categories are less common at interstate stations than intrastate stations. Although this pattern is consistent with free riding, there are other important differences between the intrastate and interstate observations that may account for this pattern.

[8]Running the equations with the classification based on individual measurements rather than summer averages did not affect the substantive results and is not as well-suited to the annual welfare calculation below.

[9]The total number of stations in Table 1 and the subsequent empirical analyses is 518, smaller than the 618 in NASQAN because of several exclusions. Stations were excluded if they never measured all of the pollutants necessary to classify the water quality. Stations outside the contiguous United States were excluded for lack of population data. Five stations that never measured flow or had missing upstream basin area were excluded. Three stations in the Great Lakes were also excluded to restrict the sample to rivers; the results were not sensitive to this exclusion.

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

	Intrastate Obs=991 (18%) Stations=105 (20%)		Interstate Obs=4532 (82%) Stations=413 (80%)	
	Mean	(S.D.)	Mean	(S.D.)
Water quality (maximum recreational use):				
No use	.198	–	.383	–
Boatable	.176	–	.146	–
Fishable	.401	–	.352	–
Swimmable	.226	–	.119	–
Spillover measures:				
Station upstream of state border	–	–	.811	–
Distance to border (miles)	–	–	100	(118)
Station downstream of state border	–	–	.573	–
Distance to border (miles)	–	–	139	(149)
Station on state border	–	–	.141	–
Other determinants:				
State authorized to issue permits	.654	–	.777	–
Population density in basin (per square mile)	241	(449)	76	(158)
Personal income per capita (thousand 1995 dollars)	20.99	(3.13)	19.72	(2.73)
Conservation group members (per 1,000)	8.49	(3.59)	7.69	(2.87)
River physical characteristics:				
Flow (cu ft/sec)	2010	(4043)	13063	(56546)
Temperature (degrees C)	22.7	(4.8)	21.6	(4.4)
Upstream drainage area (sq miles)	3581	(5440)	39211	(136489)
Downstream distance to ocean (miles)	99	(162)	1568	(1212)

Note: Standard deviations reported for continuous variables only.

2.2 Explanatory variables

The variables to reflect spillovers, S_i, derive from the location of the stations. Three different location variables were coded by mapping the stations using a Geographic Information System. These variables indicate whether the station is upstream of a state border, downstream of a border, or located on a river when it forms a border between two states.[10] 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 are upstream of a border, 57% 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. Pollution attenuates due to biological, chemical, and physical processes. Thus, the distance of the station to the border is a measure of the physical spillover at the station. The average distance is 100 miles for upstream observations and 139 miles for downstream observations.

In addition to these physical spillovers, the table also shows a measure of state discretion: whether a state is authorized to conduct its own permitting and enforcement activities. The state had this authority for 74% of the water quality measurements. To look at the effect of this discretion on free riding, two other variables are used in the analysis. For downstream stations, the variable indicates whether the upstream state is authorized and thus has the discretion to free ride. The analogous upstream variable is an interaction between whether this station is upstream of a border and whether its state is authorized.

Several additional measures capture variations in the cost and benefits of pollution control. USGS provides population density in the station's watershed in 1990. Because the stations are typically at the bottom of the watershed, this variable measures upstream population. Thus, it reflects variation in the pollution levels that would exist in absence of pollution reduction efforts, which is a determinant of the cost of water quality at the station. As the table reports, watersheds with intrastate observations have higher population densities. The difference probably arises because almost all intrastate observations are in coastal states, where the US population is concentrated.[11]

Personal income per capita may measure both the benefits of clean water (to the extent that it is a normal good) and its costs, in the form of uncontrolled pollution levels. Annual

[10] Borders to Canada and Mexico are treated the same as state borders for most of the analysis. The Great Lakes are also treated as a state boundary because they represent a shared resource.

[11] There are a few intrastate stations in noncoastal states because of rivers that flow into inland sinks, such as the Great Salt Lake.

state-level personal income data from the Bureau of Economic Analysis have been converted to 1995 dollars using the national CPI.

The share of the population that belongs to one of three prominent conservation groups is included as a measure of demand for clean water. This variable is only available for a single cross section (Hall and Kerr, 1991).[12] Both income and conservation group membership is slightly higher for intrastate observations, again reflecting a difference between coastal and other states.

Finally, the equations include a few river characteristics. They include the river's flow because water quality depends on pollution concentration and thus on both the quantity of waste and the amount of water to dilute this waste. Interstate rivers have substantially higher flow than intrastate rivers because interstate stations are on some of the largest rivers in the country, including several on the upper Mississippi. Flow measurements are taken at the same time as the pollution measurements.

Another time-varying river characteristic is water temperature. Temperature 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.

Two final characteristics describe the position of the station. The USGS provides an estimate of the size of the drainage area upstream of the station. 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.

Table 1 also reports the distance from the station downstream to the ocean. 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. There are two reasons to include ocean distance in the equations. 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 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.

[12]The groups are the Sierra Club, Greenpeace, and the World Wildlife Fund. Hall and Kerr do not specify the year, but the data presumably date from the late 1980s or 1990.

3 Results

Table 2 reports estimates of an ordered probit.[13] The ordered probit uses the four water quality categories described above, with higher values indicating better water quality and lower pollution.

The unobserved heterogeneity at a single station is likely to be correlated across multiple observations at a station. To address this problem, the standard errors in all estimated equations are adjusted so that they are robust to clustering at the station level.[14]

Except for the first equation, the results in table 2 include state effects. These effects are dummy variables for the state of the monitoring station, except for border stations, where the state effects for both neighboring states are each assigned values of .5. These effects are included to capture unobserved heterogeneity across states that is correlated with the number of intrastate stations. In particular, interior states may differ from coastal states in ways not fully captured by the income, population, and conservation group membership variables in the estimated equations.

However, the inclusion of the state effects changes the behavioral parameter being estimated. States may free ride by reducing stringency of their nonpoint source programs or their overall enforcement 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. Nonetheless, the equations include state effects as a conservative estimation strategy.

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

3.1 Effects of spillovers

The first column of results in table 2 makes the most basic distinction between intrastate and interstate rivers. The dummy variable for intrastate rivers has a substantively small and statistically insignificant coefficient. Including the covariates has eliminated the difference apparent in the means in table 1. In particular, the results are sensitive to the ocean distance variable, without which the coefficient on intrastate rivers is positive and statistically significant.

[13]The results were very similar with an ordered logit. Also, the equations shown here use levels for continuous independent variables. Using logs changed the sign of the coefficients on some variables, such as flow, but did not alter the results for the spillover variables.

[14]This approach is computationally simpler than estimating the equations with station random effects. Guilkey and Murphy (1993) find that a binomial probit with such adjusted standard errors performs compares favorably with a random effects maximum likelihood in finite sample.

Table 2: Ordered probit estimates without and with state effects

	Dependent variable: Four water quality levels (1)	(2)	(3)	(4)	(5)
State effects?	No	Yes	Yes	Yes	Yes
Intrastate station	.038	.208	–	–	–
	(.113)	(.115)			
Upstream station	–	–	-.469	-.500	.164
			(.185)	(.192)	(.372)
Upstream distance	–	–	–	.543	–
				(.566)	
Downstream station	–	–	-.210	-.151	-.570
			(.096)	(.115)	(.227)
Downstream distance	–	–	–	-.580	–
				(.474)	
Border station	–	–	.192	.182	.195
			(.144)	(.146)	(.147)
State authorized	–	–	–	–	.689
					(.306)
State authorized (if upstream)	–	–	–	–	-.798
					(.363)
Upstream state authorized (if downstream)	–	–	–	–	.369
					(.220)
Population density	-.325	-.677	-.705	-.714	-.720
	(.115)	(.169)	(.169)	(.170)	(.169)
Income	.033	.052	.048	.054	.048
	(.019)	(.024)	(.023)	(.023)	(.023)
Conservation group membership	.054	–	–	–	–
	(.019)				
Flow	1.26	-2.06	-2.31	-2.60	-2.68
	(1.14)	(1.23)	(1.28)	(1.30)	(1.32)
Temperature	-.048	-.052	-.050	-.050	-.046
	(.011)	(.011)	(.011)	(.012)	(.012)
Upstream drainage area	-2.13	-.597	-.495	-.284	-.388
	(.782)	(.615)	(.600)	(.598)	(.617)
Distance to ocean	-.307	-.133	-.042	-.071	-.061
	(.041)	(.069)	(.078)	(.081)	(.078)
Year	.116	.142	.155	.140	.144
	(.073)	(.081)	(.080)	(.080)	(.080)
Log-likelihood	-6144	-5409	-5379	-5343	-5353

Notes: Number of observations, 5523; number of stations: 518.
Standard errors (in parentheses) robust to clustering at the station level.

The next column modifies the equation by adding state effects to the equations. With these effects, the coefficient on intrastate stations become positive, consistent with free riding. However, it is statistically significant only at the 10% level. The ocean distance variable no longer greatly influences the intrastate coefficient, suggesting that coastal/noncoastal state heterogeneity is an important confounding factor.

The third equation distinguishes upstream, downstream, and border stations among the group of interstate rivers. There are three reasons to distinguish upstream and downstream stations. First, the water quality may depend on whether the station is upstream or downstream. For example, if downstream states aggressively cut back their pollution in response to an endowment of dirty water from upstream, the water quality observed in downstream states may be better than in upstream states. Second, as discussed above, if upstream states free ride by moving polluting activities near their downstream borders, we would be observe elevated pollution only at downstream stations.

Third, the effect at upstream and downstream stations may differ because of strategic reporting. Although NASQAN is a centrally-designed national network of stations, federal, state, and local governments and other organizations (such as universities) conduct the day-to-day sample collection and analysis. If downstream states wish to show their victimization, they may selectively report lower water quality. Upstream states have the reverse incentives.

In the third equation, poorer water quality is observed at stations upstream and downstream of a state border. The coefficients on both upstream and downstream stations are negative and statistically different from zero.[15] Table 3 shows the substantive effect of these coefficients. To provide a national snapshot, it focuses on 1983, one of the years of greatest coverage in NASQAN and the year of the willingness to pay for water quality that I use for the welfare calculations below. The first row shows the actual share of water quality by category in 1983 at NASQAN stations. The second row shows the predicted levels in 1983 from column 3 in table 2. The model somewhat overpredicts the poorest water quality and underpredicts the best in this year. The next rows illustrate the effects of free riding by category: the predicted water quality levels first without any upstream effects and then without any downstream effects. Eliminating free riding would increase the frequency of the best water quality (swimmable) by 42% at upstream stations and 10% at downstream stations. It would decrease the frequency of unusable water by 21% upstream of borders and

[15]This equation was also estimated with variables indicating if the nearest border is an international boundary (with the Great Lakes included in that designation). Neither upstream nor downstream of an international border had statistically significant coefficients. Stations on international borders had substantially lower water quality. However, because only two rivers (the Great Lakes-St. Lawrence and the Rio Grande) fall into this category, it is not clear that this coefficient is more than idiosyncratic. Sigman (2001) examines the effects of international spillovers in a broader set of rivers.

Table 3: Actual and predicted national water quality in 1983

	Water quality level			
	Unusable	Boatable	Fishable	Swimmable
Actual shares from NASQAN data	.374	.126	.372	.128
Predicted shares	.389	.151	.345	.115
No upstream effect				
Change in predicted share	-.085	-.005	.043	.048
Percent change in share	-21%	-3%	12%	42%
No downstream effect				
Change in predicted share	-.029	.001	.017	.012
Percent change in share	-7%	.6%	5%	10%

Note: Predicted shares based on equation in column 3 of table 2.

7% downstream of borders.[16]

The coefficient on downstream stations is lower in absolute value than the coefficient on upstream stations, although the difference is not statistically significant at 5%. Such a difference might arise if downstream states increase their pollution control to offset the elevated pollution they receive from upstream. The stronger effect at upstream stations is inconsistent with strategic reporting and suggests that free riding takes the form of elevated pollution rather than the siting of facilities near downstream borders.[17]

The coefficient on border stations in column 3 of table 2 is statistically insignificant and not of the expected sign. Border stations might have exhibited especially poor water quality because there is no natural attenuation to dull the effects of free riding. However, the polluting country continues to experience damages for border rivers, so perhaps the incentives for control are sufficiently great to offset the lack of natural attenuation.

The fourth equation adds a measure of the extent of the spillover, the distance between the station and the border.[18] Because pollution attenuates with distance, upstream states

[16]States with greater preferences for the environment might free ride less than other states on the grounds that they care more about the state of the environment outside of the state. They also might free ride more because they have more costly controls within the state and therefore greater incentives to reduce these controls. To test these alternative hypotheses, the equation in column 3 was run with an interaction between upstream station and conservation group membership. The interacted term was negative (suggesting the latter effect dominates) but substantively small and not statistically significant.

[17]A possible measure of the difficulty in resolving the free riding through bargaining is the number of states that share the river. The equations were reestimated with the addition of variables for the number of upstream and downstream states. Neither of these variables yielded statistically significant coefficients.

[18]I rescaled the distance variable for convenience in presenting the results in the table, so no inference should be made about the size of these effects from the point estimates.

will experience a higher share of total costs far from the border than close to the border. Similarly, natural attenuation means that the effects of free riding should be most evident close to the border for downstream stations. Thus, both distance coefficients would be positive with free riding.

For upstream stations, the distance variable has the expected positive sign, but is not individually statistically significant at 5%. The downstream distance variable is also individually insignificant and does not have the expected sign. The failure to find the expected effects of distance may reflect errors in coding distance to the border, which was sometimes difficult for complicated river systems.

The fifth equation explores a mechanism for free riding, namely authorization of states to conduct their own permitting programs. Three variables have been added to the equation: a variable for whether the state is authorized at the time of a given observation, an interaction between upstream location and whether the state is authorized, and the upstream state's authorization status for downstream stations.

The coefficient on own-state authorization is positive and statistically significant. This coefficient may indicate that states improve their water quality upon authorization. The reverse causality is also possible: states receive authorization when they have achieved good water quality. However, with state effects in the equation, persistent differences in the effectiveness of state regulators do not drive the association.

The coefficient on the interaction between state authorization and upstream-of-border location is negative and statistically significant. This coefficient suggests that states use the privileges provided by authorization to worsen the water quality they send to neighbors. In addition, when the interaction between authorization and upstream location is included, the coefficient on upstream location alone becomes statistically insignificant. Thus, an interpretation is that authorization entirely accounts for upstream states' ability to free ride.

Interpreting the coefficients for downstream stations is more complicated. Authorization may provide the upstream state with more ability to free ride, suggesting a negative effect on downstream water quality. However, the results above suggest that authorized states have better water quality all else equal, so the downstream station may receive a better endowment of water quality from an authorized upstream neighbor. The coefficient estimate is positive, consistent with the latter effect dominating, but is not statistically significant.

3.2 Other covariates

A number of results emerge from the remaining covariates. Population density in the watershed has a negative and statistically significant effect in all equations as expected. It raises the pollution levels that would occur in the absence of pollution reduction and thus the cost of water quality.

State personal income per capita has a statistically significant and positive effect when state effects are included; without state effects, it is statistically significant only at the 10% level. This coefficient is consistent with a positive income elasticity of demand for water quality. As an indication of the magnitude of the effect, the lowest income coefficient (in column 1) corresponds to a .5 percentage point (about 4%) increase in the percentage of swimmable waters per $1,000 of income.[19]

The number of conservation group members can be included only when state effects are absent because just one year of this data is available. When included in the first column, the coefficient is statistically significant and positive. This result may indicate that "green" preferences in a state's population successfully affect environmental policies and improve water quality. If so, it provides both evidence of state discretion and the desirability of decentralization because of heterogeneous preferences. However, one might also interpret this coefficient as evidence that environmentalists move to cleaner states.

The coefficients on the river characteristics are sensitive to the specification. Flow has a statistically significant negative coefficient in the final two columns and is statistically insignificant elsewhere. Flow might have a positive effect on water quality because it indicates the amount of dilution of a given amount of waste. However, floods dramatically increase nonpoint source pollution (for example, with erosion of farmland). Thus, the negative coefficient may be a result of poor water quality in seasons with more flooding.

The temperature variable has a negative coefficient as expected. Warmer temperatures allow pathogens to survive longer and thus travel further downstream. They also facilitate other biological activity and thus decrease dissolved oxygen.

Drainage area, indicating potential pollution accumulation, has the expected negative point estimate in all equations but is only statistically significant in the equation without state effects. The distance to the ocean variable is also statistically significant only in the equations without state effects. The negative sign of this variable is consistent with the hypothesis that lack of ocean disposal options lowers inland water quality.

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. For the lowest point estimate (in column 1), the annual improvement in the percentage of swimmable water is .2 percentage points. However, the trend is only statistically significant at the 10% level

[19] I also ran the equations with a quadratic in income to allow the nonlinear relationship that some cross-national research has found. However, higher order terms were never statistically significant, failing to support an "environmental Kuznets curve" relationship in interstate data.

Table 4: Environmental costs of free riding at downstream stations in 1983

	Lost water use			
	Boating	Fishing	Swimming	All uses
In-state costs	113	90	49	252
Out-of-state costs	56	45	24	125
Total costs	169	135	73	377

Notes: All values in millions of 1983 dollars.
Based on water quality changes in table 3 and willingness to pay values from Carson and Mitchell (1993).

in most equations.

4 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. Thus, a complete evaluation of the welfare effects of observed free riding is not possible with the current data. However, calculating the cost of environmental damage from free riding in downstream states helps assess the magnitude of the effects estimated above.

The rough welfare calculation presented in table 4 uses data from Carson and Mitchell's (1993) national survey of the value of recreational uses of freshwater in 1983. They estimate that households would be willing to pay an average of \$93 to improve all water from its contemporary 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. 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.

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

To apply the values to the estimated effects in this paper, I must make several assumptions. First, I assume that the value of improving only a share of waters is that share of the value of improving all waters. This assumption may understate the value of partial improvements because the marginal valuation probably declines with the share of water affected. Second, I use willingness to pay from Carson and Mitchell as willingness to accept compensation for degradation from free riding. This assumption may also understate the values because willingness to accept often exceeds willingness to pay by a large amount in survey data. Third, I assume that the NASQAN stations are a representative sample of all relevant river locations. Although NASQAN overrepresents river areas with human influence relative to all rivers, this overrepresentation may be desirable in the current context. It represents the areas likely to be visited by people and thus to be included in the use values of rivers. Using 1983 data on the number of households by state, I construct estimates of the in-state and out-of-state value of the downstream costs of free riding shown in table 4.

The results suggest that the environmental costs of free riding in downstream states were \$377 million, with \$252 million attributable to losses to residents of those states. The table breaks the quantities down by lost recreational use. Loss of boating accounts for the largest share of costs because the most stations experience this change and because this change has the highest incremental value in the Carson and Mitchell survey. For comparison, a recent study using the same willingness to pay data placed the overall benefits of CWA at \$11 billion per year (Bingham et al., 2000).

The costs reported in table 4 do not provide a complete assessment of the net costs of free riding for the reasons explained above. They do, however, provide a lower bound on the losses at downstream stations.

5 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. Water quality is significantly lower at stations upstream and downstream of state borders than at other stations. Federal policies that increase state discretion by granting states authority to run their own permitting programs may be responsible for most of this free riding.

Although such transboundary free riding is often cited as a justification for federalizing environmental policies, these results 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.[21]

Second, problems with free riding must be weighed against the benefits of decentralization. It may be that this free riding is not costly enough to overcome the greater flexibility and informational advantages of decentralization. In addition, the optimal response to free riding may 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.[22]

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 (Freeman, 2000; Van Houtven et al., 2000). If so, the observed free riding could provide a net benefit by reducing pollution control.

[21] Revesz (1996) observes that the Clean Air Act may similarly permit (or even encourage) free riding despite centralized standards.

[22] Oates (2000) questions the political feasibility of such approaches.

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