Biases in International Environmental Datasets: Evidence from Water Quality Monitoring in Europe

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Summary

Most international environmental datasets rely heavily on information that governments and their agents decide to collect and make available. Does this mean they are systematically influenced (i.e. biased) by political, economic, and other non-environmental factors? To find out we study data from the European Environment Agency's (EEA) water quality monitoring network in 1965-2005. If we can detect systematic biases in the data generated by this network, which is operated by relatively rich countries in a coordinated manner, biases in datasets covering more heterogeneous sets of countries in less coordinated settings are likely to be even stronger. We find that, ceteris paribus, data reporting is more extensive in international upstream-downstream river settings, EU membership has a negative effect on reporting, reported monitoring activity is less extensive in river basins where environmental pressure is higher, and richer, more democratic and economically more open countries report more. These results suggest that the EEA data is systematically affected by non-environmental factors. Our findings are likely to be relevant to most areas of environmental monitoring, except those few where data can be generated independently of governments.

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Problem

Comparisons of environmental performance across countries have become very popular, and international agencies and scientific institutions are compiling large amounts of data for such purposes. One prominent example is the Environmental Performance Index.2 International environmental datasets are also widely used by policy-makers and their scientific advisors for 'diagnostic' and 'therapeutic' purposes, that is, for identifying problems, designing new policies, and implementing them.

Even if we assumed – quite adventurously, and in many cases probably wrongly – that environmental conditions, whenever measured, are measured with the best scientific methods and tools available and that existing data for any given location and environmental parameter at a specific point in time is of high quality, there is yet another problem. Even a cursory look at various sources of environmental information reveals that data coverage for most environmental indicators varies very strongly across countries and time. The main reason is that international datasets rely primarily on information that governments and their agents decide to collect and make available. The willingness and/or ability of governments to do so clearly varies across environmental issues, countries, and time.

Are there systematic political, economic or other biases in international environmental datasets, besides the obvious problem that richer countries are usually more able and willing to collect and deliver data? Many users of environmental data would probably assume so. Yet, we could not find studies that have systematically examined this issue. In view of the scientific and practical importance of environmental data, this lacuna is rather surprising.

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[2] http://epi.yale.edu/Home.

Water Quality Monitoring in Europe

We could not study all international environmental datasets in sufficient detail at once. So we focus, for a start, on what is widely viewed as one of the most important international environmental monitoring networks in Europe, the one for water quality. The analysis covers the time-period 1965-2005. We focus on this data for two simple reasons. Income-related effects are very likely to overshadow other potential effects if we compare, say, African countries with countries in Europe or North America. The same is likely to hold true if we focus on geographic areas and/or environmental issues where data collection and reporting efforts are subject to very weak or no international coordination or standardization.

Focusing on water quality monitoring in Europe makes it harder to identify systematic biases in the data: European countries are, in global comparison, rich, and the European Environment Agency (EEA) coordinates and sets standards for water quality monitoring and reporting. In the EEA's own words:

"Through Eionet {the EEA's reporting system}, the EEA brings together environmental data from individual countries concentrating on the delivery of timely, nationally validated, high-quality data. This forms the basis of integrated environmental assessments and knowledge that is disseminated and made accessible through the EEA website. This information serves to support environmental management processes, environmental policy making and assessment, and public participation at national, European and global levels. Data which countries are obliged to report to the European level are collected and analysed in a transparent way by the EEA and ETCs to give a picture of the state of, and pressures on, Europe's environment…In this way, it also becomes possible to benchmark the environmental performance of countries." (EEA 2007b)

In other words, if we can identify systematic non-environmental effects in the EEA water quality data, we can be quite sure that biases will be stronger in datasets that cover more heterogeneous sets of countries in settings with less international coordination or standardization.

Spatial and Temporal Clustering of Reported Monitoring

Using data from the EEA's reporting systems and from other sources we set up a geographic information system (GIS). This GIS is used to generate a dataset that contains information on the location and other characteristics of several thousand active monitoring stations in Europe.[3] We then examine whether and to what extent the spatial and temporal clustering of reported monitoring activity is driven by non-environmental factors, that is factors unrelated to an ecosystems or human health logic.

Figure 1 depicts all locations from which water quality data has been reported to the EEA. It shows snapshots for four years in the time-period 1965 – 2005.[4] It indicates that monitoring activities, captured in terms of stations from which data is reported to the EEA in a given year, varies strongly both spatially and over time. The figure also identifies whether the reporting stations are located in a national or a transboundary (international) river basin (the latter are marked in darker shade). Some patterns, such as the increasing density of reported monitoring activity in most countries over time and its

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[3] Most of the data we use is taken from the following sources: http://water.europa.eu/; EEA 2007a; Bredahl and Sousa 2008; Owen et al. 2004; Vogt et al. 2003, 2007a, 2007b; ESRI; GISCO NUTS; Mitchel et al. 2003; Landscan 2005; UNSTAT 2008; Eurostat 2008; Heston et al. 2006; Marshall and Jaggers 2004; Gleditsch 2002; Pevehouse et al. 2004. For details, see the support material.

[4] A film showing monitoring locations over time (yearly) is included in the support material.

expansion to Eastern Europe after the end of the Cold War are obvious. More subtle patterns and their driving forces remain to be identified.

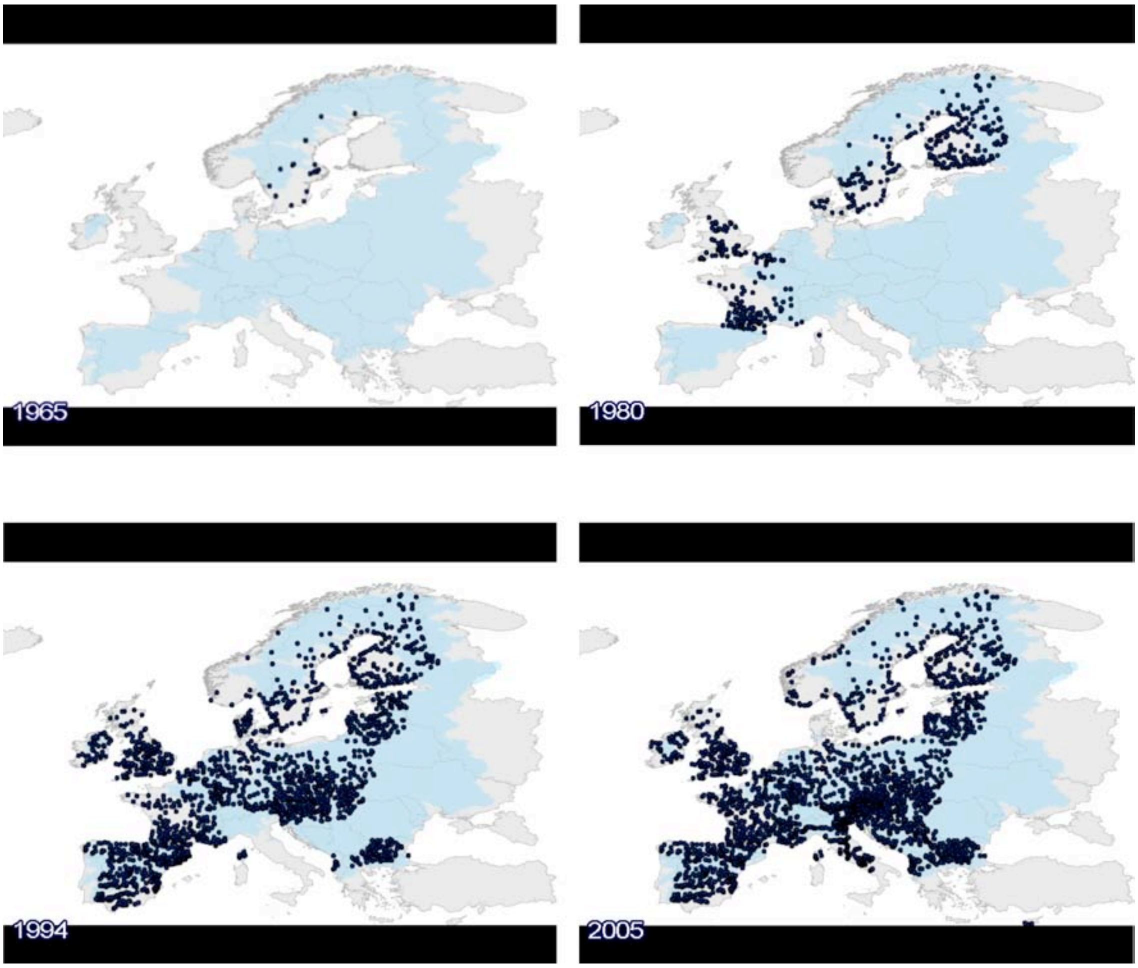

Figure 1: Evolution of the European water quality monitoring network Note: The darker shaded land areas are international river basins. Data for Portugal and Switzerland is not available

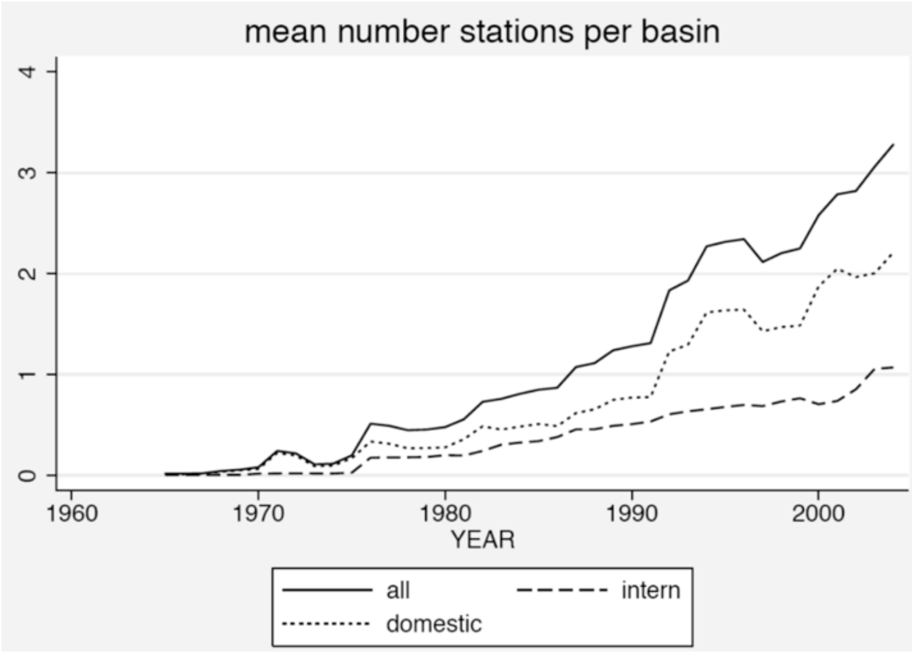

Figure 2: Monitoring activity in domestic and international settings.

Figure 2 shows the average number of all, domestic, and international monitoring stations reporting to the EEA per river basin and year. International monitoring stations are defined as stations located in an international river system within a distance of 10 km from an international border. All other stations are defined as domestic monitoring stations. The figure shows that international monitoring has expanded particularly since the 1990s.

We carried out a statistical analysis to better understand the determinants of differences in reported monitoring across countries and time. The dependent variable in this analysis measures how many monitoring stations report data from a given country per river basin and year. The analysis uses event count models (negative binomial regressions) to model the data generating (reporting) process (cf. Long 1997:230ff). We are particularly interested in the effects of economic, political, and environmental factors, and river geography. The statistical models include several controls. We control for time-invariant effects of unit heterogeneity by means of country-river basin fixed effects. Time dependencies are controlled by including a lagged dependent variable. General time trends are controlled by including a year counter.

The analysis is implemented for three samples, each of which relies on a specific definition of the dependent variable. In the first sample, the dependent variable measures the number of active (reporting) monitoring stations per country and river basin and year. This sample includes observations for up to 41 countries[5], 328 river basins, and 40 years (1965-2005). The second sample covers monitoring stations located in „domestic“ river systems. Our definition of domestic extends to all stations except those located in an international river system within a distance of 10 km from an international border. This sample includes observations for up to 41 countries, 328 river basins, and 40 years (1965-2004). The third sample covers „international“ monitoring stations. Those are stations located in an international river system within a distance of 10 km from an international border. This sample includes observations for up to 41 countries, 299 river basins, and 40 years (1965-2004).

[5] This number varies over time since the number of independent states in Europe has changed during our period of investigation.

Results

Figure 3 summarizes the results. Income (GDP per capita) has the expected positive effect: richer countries report more. The same holds for democracy: more democratic countries report more. Openness to international trade has a positive effect. We also observe an interesting peer-group effect: countries report from more monitoring stations if other countries in the same income group (we distinguish three income groups) report more in the previous year.

Another interesting finding is that data reporting is more extensive in international upstream-downstream settings. Such settings are defined in our analysis in terms of rivers that cross from one country into another, rather than flowing along an international border or corresponding to some other geographic pattern (e.g. lakes). The positive effect of upstream-downstream settings is likely to reflect the fact that such settings are usually more prone to international conflict because they lend themselves to beggar-thy-neighbour behaviour. Hence they attract greater attention from policy-makers and their agents, who decide on the location of monitoring activity. Figure 4 suggests, however, that there is only a weak beggar-thy-neighbour effect in the country-specific location of monitoring stations. We had suspected that we would – in international upstream-downstream settings – find more monitoring downstream, the assumption being that downstream countries have an incentive to demonstrate their victim status, whereas upstream countries have an incentive to ignore their pollution „exports“. The percentage share of international upstream-downstream river basins where more monitoring takes place in the downstream than the upstream country exhibits a sharp increase over time, but is small in absolute terms (less than five percent). Besides this upstream-downstream effect we observe no other important geographic effects. Notably, as shown in Figure 3, the results are very consistent across the domestic and the international samples.

Explanatory variable	Sample 1: all stations (n=4608)	Sample 2: domestic stations (n=3404)	Sample 3: international stations (n=3369)
Income	+	+	+
Democracy	+	+	+
Trade openness	+	+	+
Peer-group (income)	+	+	+
Upstream-downstream	+	+	+
Upcoming EU WFD	-	-	-
International policy networks	-	-	-
EU membership	-	-	-
Population density	-	-	-

Figure 3: Results of statistical analysis

Note: The dependent variable counts the number of monitoring stations per country and river basin and year. All models are based on negative binomial regressions. + (-) means positive (negative) effect, statistically significant at the 1% level. All variables listed in the figure are simultaneously included in the models. The models also include a lagged dependent variable and a year counter (results not shown). Note that the sum of observations in the second and third sample does not add up to the number of observations in the first sample because our unit of analysis is the country per river basin and year, and not the monitoring station. All variables are defined in detail in the support material.

Year dummies for 1998, 1999, and 2000, the years that capture the run-up to the EU Water Framework Directive (WFD), have a negative effect. It thus appears that the WFD may have exerted a crowding out effect in the sense of diverting attention from reporting to the EEA monitoring network in favor of the WFD process.

Some results may be reason for concern. Cosmopolitans tend to assume that countries that are more involved in international policy-making networks should be more cooperative also in terms of data reporting. There is no evidence for this claim. On the contrary, the effects of memberships in international organizations and participation in global environmental agreements are even negative. Moreover, EU membership has a statistically significant, negative effect in all models. Population density has a statistically significant, negative effect on reporting. To the extent population density can serve as a proxy for environmental pressure, and looking at it from an environmental policy perspective, more extensive monitoring in river systems exposed to greater environmental pressure would, arguably, be desirable.

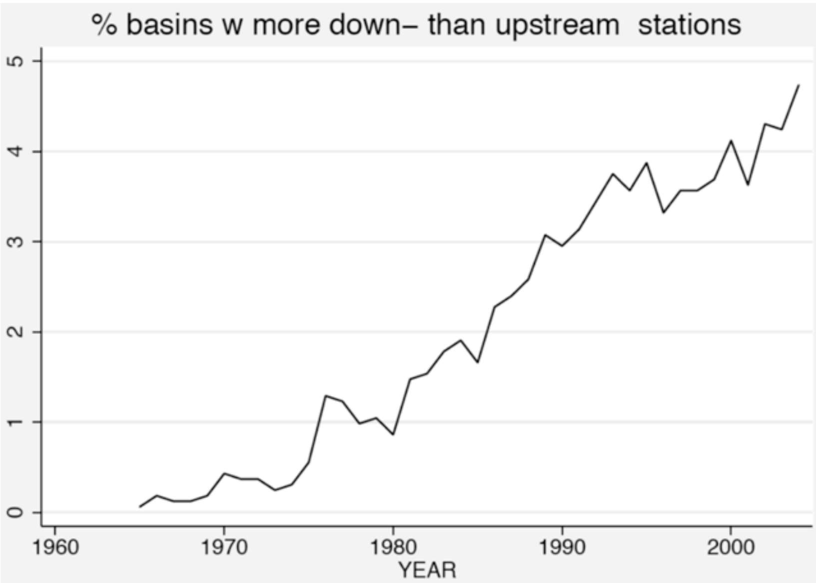

Figure 4: Monitoring downstream and upstream. Note: the sample on which this figure is based includes boundary-crossing (upstream-downstream) international water systems.

Implications for Policy and Research

Our findings have two types of implications. First, international coordination and standardization of environmental monitoring should be intensified, and those who aggregate locally produced environmental data into national averages or use such averages for scientific research or policy-making should be alert to potential biases, such as the ones studied in this paper. International agencies, such as the EEA, UNEP, OECD, or World Bank should invest much more in standardizing and controlling data quality as well as naming, but also helping countries that perform poorly in environmental monitoring and data reporting. The EEA, for example, has taken some, albeit still very gentle, steps in this direction by publishing reports that rate the quality of countries' environmental monitoring and reporting behavior. Figure 5 depicts such ratings for water quality in a simplified form. Similar efforts are being undertaken by the EU in the context of implementing Article 8 (which asks for better monitoring) of the Water Framework Directive.

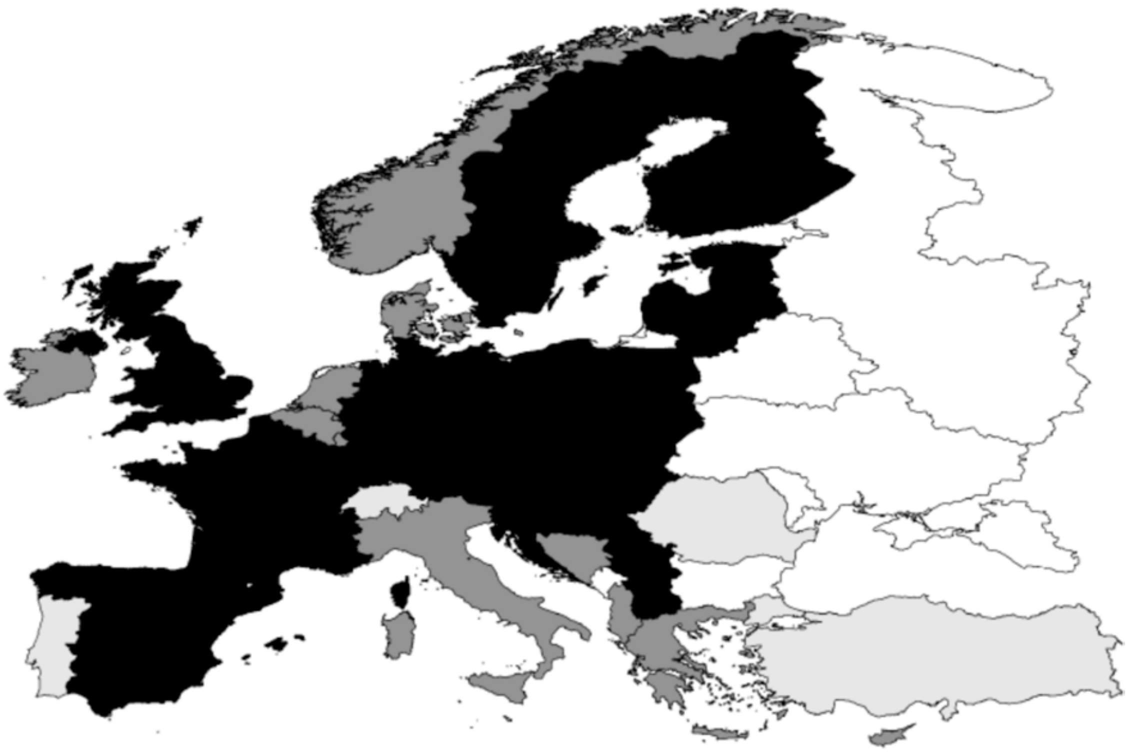

Figure 5: Compliance with EEA requirements for water quality data reporting (2002-2005). Based on data provided by the EEA. Low (light grey), medium (grey) and high compliance (black)

The second implication is that more research on how international environmental datasets are generated and what the potential biases are is urgently needed. Further research in the specific area studied in this paper should concentrate on at least three issues.

(1) The negative effect of EU membership and the negative time-effect in the run-up to the Water Framework Directive (WFD) require further study. Systematic surveys of national water management or environmental authorities will be required to establish whether this effect is due to negligence once countries have made it into the EU, whether the WFD exerts a crowding out effect on the EEA's monitoring network, or whether other causes are responsible for the observed effect.

(2) The finding that the extent of reported monitoring in river basins with higher population density is lower looks rather worrying. We need better times-series data for land-use and other types of environmental pressure to corroborate this finding. Further research also needs to establish whether our results are in fact bad news, or whether there is a shaming effect that motivates countries to monitor pollution locally but then underreport or ignore data from locations subject to greater environmental pressure when reporting to the international level.

(3) The analysis could be expanded to look not only at the location of monitoring activity, but also at what types of pollutants are measured, and how frequently. We are quite confident, however, that the findings reported in this paper will be similar when studying the specific contents of data reporting. Ideally, such research could also establish what data from what location and at what time-intervals would have to be collected and reported in order to generate a truly representative or accurate picture – from an ecological and public health viewpoint – of national or aquatic system-specific environmental performance.

The research reported in this paper may, at first glance, look somewhat narrow in scope, but it directs attention to a much larger issue. Scientists have invested very heavily in describing and explaining environmental performance in international comparison. It would be great if they could also invest some time in reflecting in depth on how the data they use is generated, whether there are systematic biases in existing datasets and processes through which they are constructed, and explore ways and means of mitigating such biases.

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Support Material For:

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Data

Based on EEA data on the location of active (i.e. reporting) monitoring stations as well as data from other sources we set up a geographic information system (GIS). First we define and distinguish between national and international watersheds and rivers by connecting hydrological maps to political boundaries. International watersheds and rivers are defined as aquatic systems that have an outlet to the ocean and are shared by two or more countries. National watersheds and rivers also have an outlet to the ocean, but are located entirely within a single country.[1] Second, we identify the position of the monitoring stations with reference to rivers, watersheds and political boundaries. This includes the riparian position, distance to international boundaries, and also the positioning in the same basin relative to other stations. In particular, we distinguish national and international monitoring stations and upstream-downstream from other geographic settings. International stations are defined as stations located in an international river basin within a distance of up to ten kilometres from an international border. As illustrated by Figure 1, identification of stations as national, international, upstream, or downstream can be rather complicated.

Our GIS is based on the following spatial data sources:

1) Information on location and station properties is taken from the EEA databases operating in the context of the Eionet-Waterprocess (EEA 2007). This data does not describe the position of a station in terms of up- or downstream location or in relation to political boundaries. Moreover, some station location data from the original dataset (Version 7) had to be adjusted manually because some reported locations did not correspond with reality or other datasets we used to cross-check the EEA data. As illustrated in Figure 1, we also found some stations that could not be attributed to any water system – we assigned these stations to a specific river basin if plausible/possible and removed the other non-attributable stations from our GIS.

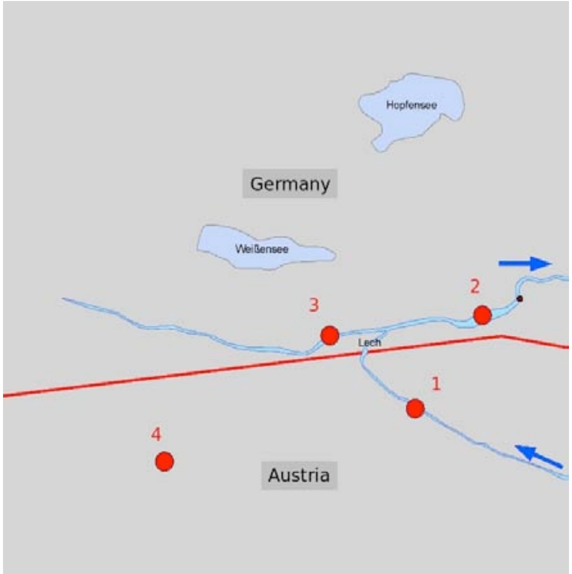
2) Information from the EEA European river catchments database (Bredahl and Sousa 2006). This database covers national and international watersheds. To the extent possible, this information was merged with information from the Shared River Basins Database by Owen et al. (2004). Basins with an area of less than one square kilometre were excluded.

3) Information from the CCM River and Catchment Database (Vogt et al 2003 and 2007a) is used to identify the location of monitoring stations within catchments as well as partial river length and catchments. This database offers a hierarchical set of river segments and catchments, structured by hydrological feature codes based on the so called Pfafstetter system, which forms a basis for queries on topological relationships within the database (Vogt et al 2007b). The CCM2 database offers additional possibilities for characterizing the relative position of monitoring stations.

[1] We decided not to use existing GIS layers for international river systems in Europe (e.g. Wolf et al. 2005), but used new data because existing layers are not available at a level of detail and precision that would allow us to connect the EEA data on monitoring station location to particular domestic and international rivers. See further below.

Figure 1: Location of monitoring stations near borders (example)

(1) upstream, (2) downstream, (3) national station (this part of the river does not cross the international border), (4) not identifiable.



4) For GIS layers showing country borders and major rivers we used standard datasets provided by the Environmental Systems Research Institute (ESRI) and data from the GIS of the European Commission (GISCO NUTS). For changes over time in the delineation of country boundaries (e.g., the unification of the two Germanies) we produced a new dataset covering the period from 1965 to 2005 (surprisingly, there is no comprehensive GIS dataset covering political boundaries as they change over time, e.g., in the Balkans and Center and Eastern Europe).

5) For information on precipitation we use average values derived from CRU time series between 1901 and 2002 at a 0.5 degree resolution (Mitchel et al. 2003). Together with the catchment area derived from the CCM2 dataset, this information is used as an indicator for discharge at each point.

Characterizing and positioning the monitoring stations in the European rivers and catchments is more difficult than it might seem. All stations that we define as international stations fall into a buffer of 10 km around international borders. This reference distance seems reasonable because we are dealing with a large geographic area. In addition to difficulties emanating from our use of data that differs in accuracy and stem from different sources there is an unavoidable deformation bias due to the projection of different layers in the GIS system. This reduces the overall accuracy of our data when measuring distances. In the CCM River database, for example, the reported total accuracy is 2662m for the location of river confluences at a confidence interval of 95% (Vogt et al, 2003).

Similar difficulties exist in characterizing rivers and monitoring stations in international basins near the ocean, where basins are usually small and the intersection with political boundaries is not always clear. Improved characterizations in our dataset lead to some differences between our dataset and the International River Basin Register of the Transboundary Freshwater Dispute Database (Wolf et al. 2005), notably with respect to

Scandinavia and Eastern Europe. Figures 2 and 3 show two maps to illustrate these differences. The first map shows international river basins as defined by Wolf et al (2005). The second map shows the international river basins identified in our GIS. Figure 4 illustrates additional challenges in creating the GIS.

Figure 2: International river basins, as identified by Wolf et al. (2005)

Figure 3: International river basins, as identified in our GIS

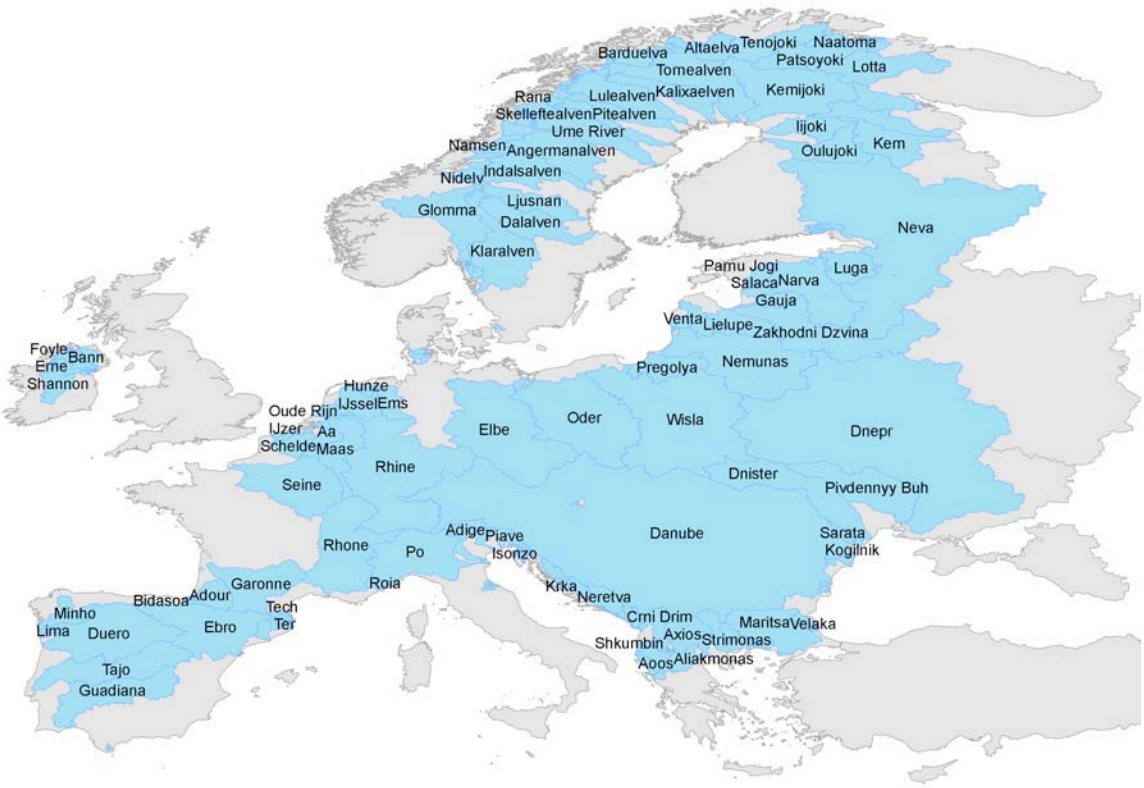
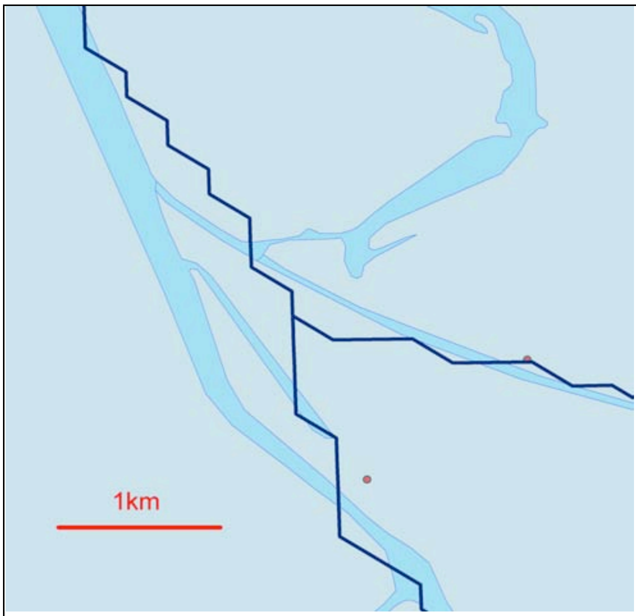
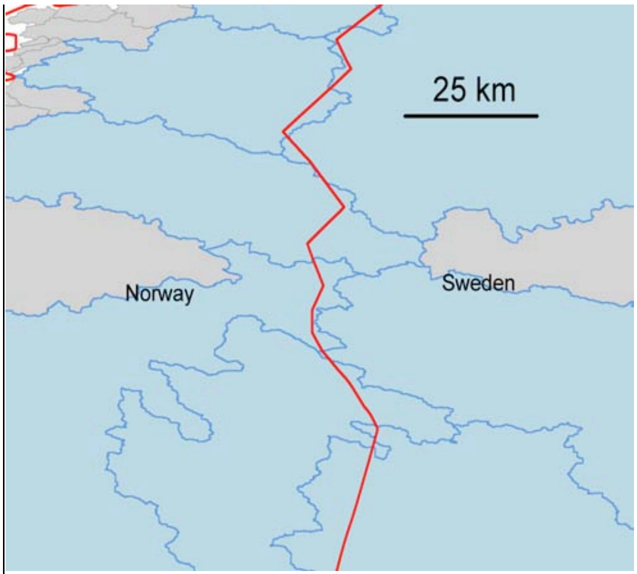


Figure 4: Additional challenges in creating the GIS



This example shows the river Rhine north of Basel, Switzerland, as projected by different river datasets. The monitoring stations are shown as red dots. The differences between the main rivers as provided by ESRI (light blue), rivers which define basins (single dark blue line), and monitoring stations (red dots) are obvious. We had to relocate some stations manually to make their location in the GIS consistent with the location (in a given country) indicated by the EEA databases. In some cases, the EEA datasets contained wrong coordinates (e.g., British monitoring stations with geographic coordinates located in the North Sea and in Belgium).



Especially in the area between Norway and Sweden it is difficult to identify whether a river basin is international or national. The red line shows the political boundary between the two countries. The light blue areas are river basins that are defined as international watersheds in our dataset.

We then used the GIS to extract data in table form for statistical analysis. Table 1 identifies the three samples we use. It indicates the unit of analysis, the respective dependent variable, and the population.

Table 1: Samples, units of analysis, dependent variables, population

	Unit of analysis	*Dependent variable*	*Population*
Sample 1: all monitoring stations	Country per river basin and per year	number of active (reporting) monitoring stations per country and river basin and year	up to 41 countries[2], 328 river basins, and 40 years (1965-2004)
Sample 2: international monitoring stations	Country per international river basin and per year	number of active (reporting) monitoring stations located in an international river basin within a distance of 10 km from the relevant international border	up to 41 countries[2] 299 river basins, and 40 years (1965-2004)
Sample 3: domestic monitoring stations	Country per river basin and per year	number of active (reporting) monitoring stations located in non-international river basins or in international river basins more than 10 km from the relevant international border	up to 41 countries[2], 328 river basins, and 40 years (1965-2004)

[2] This number varies since the number of independent states in Europe has changed during our period of investigation (collapse of Sowjet Union, etc.)

In contrast to conventional panel datasets the maximum number of possible observations cannot be identified by multiplying countries, river basins, and years. While the dataset covers an equal number of years for each country-basin pair the number of countries varies over time (e.g., due to the unification of Germany or the disintegration of former Yugoslavia). Changes in the number of countries also have effects on the distinction of domestic and international river basins.

Data for the explanatory variables was taken from various sources, as shown in Table 2.

Table 2: Explanatory variables and data sources

Variable	*Description*	*Source*
Environmental pressure	Population density. We use population data from the Landscan Global Population Dataset (Landscan, 2005). Time series from 1965 to 2005 are estimated backward using UN (UNSTAT, 2008) and Eurostat national population estimates (Eurostat, 2008) that are based on national census statistics. The resulting dataset includes spatially disaggregated population estimates since 1965 with a spatial resolution of 30" x 30".	Landscan (2005), UNSTAT (2008), Eurostat (2008)
Income, income group	GDP/capita; income groups are defined as low, middle, high (according to the empirical sample distribution)	Heston et al. (2006)
Democracy	Revised combined Polity IV score	Marshall & Jaggers (2004)
Trade openness	Sum of exports and imports divided by GDP	Gleditsch (2002); Heston et al. (2006)
Trade intensity	Ratio of the sum of exports and imports of country *i* to/from country *j* to the sum of exports and imports of country *i*	Gleditsch (2002); Heston et al. (2006)
Membership in intergovernmental organizations (IGO)	Number of (joint) memberships in IGOs	Pevehouse et al. (2004)
Global environmental policy involvement	Cumulative number of ratifications of global environmental treaties	Own data generated from data provided by Ronald Mitchell and CIESIN/ENTRI
EU membership		http://europa.eu/abc/european_countries/index_en.htm
River type	Upstream/downstream, other geographic setting (dummy variable)	Own data

Statistical Method

The dependent variable is the number of monitoring stations in a given country and water system (river basin) per year reporting to the EEA network. It thus appears most appropriate to model the data generating (reporting) process with event count models (cf. Long 1997, 230ff). Because of overdispersion, we opted for negative binomial rather than poisson regressions. Note that we might face positive contagious overdispersion, since the reporting of monitoring stations might not be independent, i.e. if one monitoring station is reported, it might be more likely that other stations are reported. Since we are dealing with time-series-cross-sectional data, we use country-basin fixed effects to account for possible unit heterogeneity. Moreover, we include the lagged dependent variable to capture time dependencies indicated by the LM-test.

Descriptive Statistics

Table 3: Sample 1, all monitoring stations

Variable		*Mean*	*Std. Dev.*	*Min*	*Max*	Observations
pop.dens	overall	-4.269528	2.429383	-11.70679	0.5882645	N = 18214
	between		2.228357	-11.62235	0.5079842	n = 656
	within		0.0700442	-5.193552	-3.784464	T-bar = 27.7652
income	overall	9.306224	0.5801158	7.315963	10.6917	N = 16882
	between		0.5519429	7.650917	10.43916	n = 663
	within		0.2333616	8.481679	10.18291	T-bar = 25.463
democracy	overall	6.257789	6.492567	-9	10	N = 16723
	between		5.55145	-9	10	n = 640
	within		3.131622	-6.479053	21.40594	T-bar = 26.1297
trade openess	overall	81685.86	121779.1	89.99	744859.3	N = 16882
	between		89089.47	405.1161	522258.4	n = 663
	within		85621.94	-157974.1	566952.9	T-bar = 25.463
IGO membership	overall	69.2726	26.02864	12	134	N = 16882
	between		22.90545	13.57143	127.8182	n = 663
	within		13.85519	41.10593	104.0226	T-bar = 25.463
memb.GEA	overall	91.21194	56.41793	0	230	N = 19454
	between		41.19932	1.04	206.8333	n = 688
	within		42.30741	1.288859	181.2869	T-bar = 28.2762
EU memb.	overall	0.3659916	0.4817195	0	1	N = 19454
	between		0.4099535	0	1	n = 688
	within		0.2532705	-0.4673418	1.340992	T-bar = 28.2762
peergroup	overall	14.34299	21.56284	0	90	N = 32698
	between		10.34907	0	38.08333	n = 1142
	within		19.78696	-17.90701	96.86799	T-bar = 28.6322
upstream	overall	0.0197566	0.1391648	0	1	N = 32698
	between		0.1244202	0	1	n = 1142
	within		0.1038179	-0.8263973	0.9947566	T-bar = 28.6322

Table 4: Sample 2, international monitoring stations

Variable		*Mean*	*Std. Dev.*	*Min*	*Max*	*Observations*
pop.dens.	overall	-4.402667	2.469463	-11.70679	0.5882645	N = 14692
	between		2.254235	-11.6577	0.5079842	n = 624
	within		0.0729003	-5.32669	-3.917603	T-bar = 23.5449
income	overall	9.2549	0.5849557	7.315963	10.20583	N = 14338
	between		0.5427828	7.633032	10.19956	n = 637
	within		0.2313143	8.430354	10.15876	T-bar = 22.5086
democracy	overall	5.667557	6.900773	-9	10	N = 13855
	between		5.755506	-9	10	n = 617
	within		3.192727	-7.069285	19.55645	T-bar = 22.4554
trade	overall	74117.16	113067.1	89.99	744859.3	N = 14338
	between		82644.5	405.1161	522020.1	n = 637

	within		79340.32	-165542.8	652812.8	T-bar = 22.5086
IGO	overall	67.03676	25.57573	12	134	N = 14338
	between		22.31923	13.57143	129.3333	n = 637
	within		13.3075	38.87009	115.0368	T-bar = 22.5086
memb.GEA	overall	84.19288	54.91263	0	230	N = 15932
	between		40.62734	0.6	227	n = 656
	within		40.52498	-5.730195	216.4429	T-bar = 24.2866
EU memb.	overall	0.3439618	0.4750434	0	1	N = 15932
	between		0.416471	0	1	n = 656
	within		0.2422817	-0.47422	1.318962	T-bar = 24.2866
peergroup	overall	7.618385	13.03487	0	58	N = 29176
	between		6.995656	0	42	n = 1110
	within		12.00964	-23.71495	61.2958	T-bar = 26.2847
up	overall	0.0189882	0.1364855	0	1	N = 29176
	between		0.1831541	0	1	n = 1110
	within		0.0862753	-0.8560118	0.9926724	T-bar = 26.2847

Table 5: Sample 3, domestic monitoring stations

Variable		*Mean*	*Std. Dev.*	*Min*	*Max*	*Observations*
population density	overall	-4.269528	2.429383	-11.70679	0.5882645	N = 18214
	between		2.228357	-11.62235	0.5079842	n = 656
	within		0.0700442	-5.193552	-3.784464	T-bar = 27.7652
income	overall	9.306224	0.5801158	7.315963	10.6917	N = 16882
	between		0.5519429	7.650917	10.43916	n = 663
	within		0.2333616	8.481679	10.18291	T-bar = 25.463
democracy	overall	6.257789	6.492567	-9	10	N = 16723
	between		5.55145	-9	10	n = 640
	within		3.131622	-6.479053	21.40594	T-bar = 26.1297
trade openness	overall	81685.86	121779.1	89.99	744859.3	N = 16882
	between		89089.47	405.1161	522258.4	n = 663
	within		85621.94	-157974.1	566952.9	T-bar = 25.463
IGO	overall	69.2726	26.02864	12	134	N = 16882
	between		22.90545	13.57143	127.8182	n = 663
	within		13.85519	41.10593	104.0226	T-bar = 25.463
membership GEA	overall	91.21194	56.41793	0	230	N = 19454
	between		41.19932	1.04	206.8333	n = 688
	within		42.30741	1.288859	181.2869	T-bar = 28.2762
EU membership	overall	0.3659916	0.4817195	0	1	N = 19454
	between		0.4099535	0	1	n = 688
	within		0.2532705	-0.4673418	1.340992	T-bar = 28.2762
peergroup	overall	8.632516	13.63785	0	58	N = 32698
	between		6.399041	0	23.25	n = 1142
	within		12.57077	-11.61748	62.25752	T-bar = 28.6322
up	overall	0.0197566	0.1391648	0	1	N = 32698
	between		0.1244202	0	1	n = 1142
	within		0.1038179	-0.8263973	0.9947566	T-bar = 28.6322

Countries included in the Analyses:

Albania
Andorra
Austria
Belgium
Bosnia and Herzegovina
Bulgaria
Belarus
Croatia
Czech Republic
Czechoslovakia
Denmark
Estonia
Finland
France
German Democratic Republic
German Federal Republic
Germany
Greece
Hungary
Ireland
Italy
Latvia
Liechtenstein
Lithuania
Luxembourg
Macedonia
Moldova
Monaco
Netherlands
Norway
Poland
Portugal
Romania
Russia
San Marion
Slovakia
Slovenia
Spain
Sweden
Switzerland
Turkey
Ukraine
United Kingdom
Yugoslavia

Regression Results

Table 6 reports the details for the models presented in the main paper.

Table 6: Regression Analysis

	all stations	domestic stations	international stations
lagged dependent variable	0.0119***	0.0226***	0.00597**
	(0.000872)	(0.00129)	(0.00269)
ln(population density)	-0.353***	-0.440***	-0.154***
	(0.0382)	(0.0492)	(0.0516)
ln(gdp/cap)	2.027***	2.162***	0.927***
	(0.146)	(0.196)	(0.205)
democracy	0.147***	0.150***	0.154***
	(0.0113)	(0.0132)	(0.0148)
trade openness	1.61e-06***	1.49e-06***	1.14e-06***
	(2.66e-07)	(3.07e-07)	(3.96e-07)
# IGO memberships	-0.0104**	-0.00318	-0.0116**
	(0.00410)	(0.00528)	(0.00487)
# MEA memberships	-0.0160***	-0.0233***	-0.00726**
	(0.00243)	(0.00310)	(0.00303)
EU membership	-0.375***	-0.287***	-0.412***
	(0.0554)	(0.0710)	(0.0673)
monitoring in same income group	0.00813***	0.0190***	0.0132***
	(0.00141)	(0.00274)	(0.00307)
upstream-downstream	0.427***	0.232***	0.423***
	(0.0635)	(0.0794)	(0.0744)
year	0.144***	0.146***	0.149***
	(0.00758)	(0.00933)	(0.0108)
1998	-0.280***	-0.171**	-0.359***
	(0.0611)	(0.0727)	(0.0746)
1999	-0.432***	-0.349***	-0.423***
	(0.0617)	(0.0752)	(0.0717)
2000	-0.582***	-0.520***	-0.628***
	(0.0633)	(0.0760)	(0.0775)
constant	-304.8***	-311.5***	-304.8***
	(15.16)	(18.91)	(21.10)
observations	4608	3404	3369
# groups	160	119	121
Wald chi2	3217	2204	1813
p	0	0	0

Negative binomial regression, fixed effects *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

Additional Analysis of Data

We re-examined the results shown in Table 6, focusing on bilateral relations between pairs (i.e. dyads) of countries. The unit of analysis changes from the country-(international)basin-year to the country pair-international basin-year. Model 1 uses a sample including all international river basin locations within 10 km of the relevant international border. Model 2 excludes upstream-downstream settings from the former sample.

Table 7: Regression analysis with dyadic data

	Model 1: all international stations	Model 2: non-upstream-downstream international stations
lagged dependent variable	0.0282***	0.0279***
	(0.00231)	(0.00228)
bilateral trade dependence	93.96	85.01
	(72.67)	(72.71)
# joint IGO memberships	0.00594	0.00596
	(0.00423)	(0.00424)
neighbour country's reporting	-0.00453	-0.00389
	(0.00328)	(0.00326)
ln(population density)	-2.046***	-2.040***
	(0.280)	(0.282)
ln(gdp/cap)	1.565***	1.540***
	(0.242)	(0.242)
democracy	0.137***	0.138***
	(0.0115)	(0.0115)
trade openness	1.11e-06***	1.14e-06***
	(3.45e-07)	(3.43e-07)
# MEA memberships	0.00390	0.00355
	(0.00268)	(0.00268)
both are EU member	-0.388***	-0.366***
	(0.0952)	(0.0946)
monitoring in same income group	0.0160***	0.0175***
	(0.00241)	(0.00232)
upstream-downstream	0.0880**	
	(0.0373)	
year	0.0352***	0.0371***
	(0.0129)	(0.0128)
1998	-0.300***	-0.321***
	(0.0576)	(0.0566)
1999	-0.562***	-0.539***
	(0.0594)	(0.0584)
2000	-0.478***	-0.484***
	(0.0595)	(0.0596)
constant	-90.26***	-93.73***
	(24.23)	(24.22)
observations	2514	2514
# groups	111	111
Wald chi2	2538	2526
p	0	0

Negative binomial regression, fixed effects *** p<0.01, ** p<0.05, * p<0.1. Standard errors in parentheses.

The results are consistent across the two samples. Both the effects of bilateral trade dependency and joint membership in IGOs are positive, but statistically insignificant. The reason for the latter might be that many European countries are members of the same IGOs. Rather than following their riparian neighbours' behavior, countries appear to report less if their neighbor countries reported more previously, but this effect is not statistically significant. Joint EU membership has a statistically significant, negative effect on monitoring, whereas membership in multilateral environmental agreements has no statistically significant effect. All other variables have the same effects as in the models for country-basin-years.

One potential problem is that we are losing a lot of observations in the regression analyses due to missing data for explanatory variables. This might bias the coefficients if missings correlate strongly with the dependent variable.
In all three samples, the mean number of stations per basin-country-year is statistically significantly lower when data for income and/or trade openness is missing (tested using an unequal two-sample mean-comparison tests).

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