Environmental Kuznets Curve for Water Quality Parameters at Global Level

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Abstract

We examine the relationship between income and water pollutants using country-level global water quality data over the period 1980 to 2012. We include civil liberties and political rights in addition to income as explanatory variables. We use recent advances in econometric techniques to address the inclusion of continuous and discrete variables in nonparametric instrumental variable regression models. Results indicate an inverted U-shape relationship between income and pollution for one pollutant (lead) and a cubic shape for three pollutants (nickel, mercury and arsenic). In general, we find that improved civil liberties and political rights are correlated with better water quality. By estimating a nonparametric relationship between political variables and pollution and by accounting for the categorical nature of the political variables, we are able to detect a nonlinear relationship between political variables and pollution, which for some pollutants is an inverted U-shaped curve.

Key Words: Binary variable, environmental Kuznets curve, nonparametric instrumental variable regressions, water pollution

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The environmental Kuznets curve (EKC) is a relationship between income and pollution which is hypothesized to have an inverted U-shape. The idea of an inverted U-shaped Kuznets curve stems from the Kuznets' work in income equality (Kuznets, 1955). The EKC hypothesis states that as income increases, pollution goes up initially but when income is high enough, pollution eventually declines. The income level at which pollution level is the highest is called a turning point.

There exist numerous papers on the validity, application, and measurement of the EKC (Azomahou et al., 2006; Carson, 2010). This is evident from the seminal work by Grossman and Krueger (1995), as well as papers focusing specifically on air pollution (e.g. Bruvoll and Medin, 2003; Deacon and Norman, 2006; Heerink et al., 2001; List and Gallet, 1999; Merlevede et al., 2006), water pollution (e.g. Jha and Murthy, 2003; Paudel and Schafer, 2009; Paudel et al., 2005), deforestation (e.g. Barbier, 2004; Culas, 2007; Heerink et al., 2001; Rodriguez-Meza et al., 2004), hazardous waste and toxins (e.g. Gawande et al., 2001; Rupasingha et al., 2004), and carbon dioxide (CO_2) (e.g. Azomahou et al., 2006; Copeland and Taylor, 2004; Dasgupta et al., 2002; LeBude et al., 2012; Paudel and Schafer, 2009; Plassmann and Khanna, 2006). However, critics have challenged both the findings and policy implications of these studies (Dasgupta et al., 2002; Stern, 2008). Studies suggest that the EKC holds for different pollutants in different ways depending on the choice of the pollutant, study area, and time period (Harbaugh et al., 2002).

One strand in the EKC literature posits that there may be a political mechanism underlying the EKC relationship. These papers suggest that what cleaned up the environment was not rising income, but rather political institutions responding to public demand (Lomborg and Pope, 2003). For example, (Grossman and Krueger, 1995) speculate that the strongest link between income and pollution in fact is via an induced policy response, and that these policies are in turn induced by popular demand. According to this line of reasoning, impoverished countries, at first, have so little development that they have high environmental quality. Then, countries' environments degrade as they develop and become richer. Finally, they reach a point at which environmental quality is poor enough and the people are rich enough that they begin to desire to pay for improvements in environmental quality. At this point, they begin to demand changes from their government, and environmental degradation decreases. Similarly, Dasgupta and Mäler (1995) indicate that political rights and civil liberties are important components in protecting environmental rights.

The importance of political institutions in the EKC relationship has also been examined empirically in papers that include political variables in addition to income in the EKC regression. Barrett and Graddy (2000) find that, for many pollution variables, "political reforms may be as important as economic reforms in improving environmental quality worldwide" (p. 433). However, they also find an absence of significant results for some pollution variables, which suggests that something other than an induced policy response may be affecting pollution levels. Lin and Liscow (2013) find that political institutions have a significant effect on environmental quality for five of the eleven water pollutants that they have examined. Torras and Boyce (1998) hypothesize that changes in the distribution of power underlie the EKC relationship, and find that literacy, political rights and civil liberties have particularly strong effects on environmental quality in low-income countries. Farzin and Bond (2006) develop and estimate an econometric model of the relationship between several local and global air pollutants and economic development while allowing for critical aspects of the sociopolitical-economic regime of a state.

A related concept to political institutions that may need to be accounted for in the EKC relationship is social capital. Social capital is defined as shared norms, trust, and social networks that facilitate coordination and cooperation for mutually beneficial collective action. An example of social capital is membership in environmental groups. Paudel and Schafer (2009) and Paudel et al. (2011) include a social capital index in the EKC model. Other researchers have used population density, democracy, political rights, openness of countries, etc. as additional variables in the model.

(Israel and Levinson, 2004) use a different tactic in their attempt to discover the political mechanisms of the EKC, instead trying to extrapolate people's marginal willingness to pay (MWTP) for environmental protection from international survey data from the World Value Survey. They found little relationship between the MWTP and economic development, suggesting either that technological and institutional constraint stories do not explain the inverted-U shaped pollution-income path or that their data was inadequate.

In the traditional EKC relationship, the dependent variable is pollution level and independent variables include income and various polynomial specifications of income, primarily those of quadratic and cubic forms. Several authors (Millimet et al., 2003; Paudel et al., 2005; Poudel et al., 2009; Zapata and Paudel, 2009) have refuted the parametric forms and suggested a need to include a nonparametric form of income in the regression. These semiparametric forms were found to perform better than the parametric form in specification tests.

Besides the concerns related to an ad hoc functional form, researchers also think that the income variable in the EKC model could be endogenous. This endogeneity of income in the EKC model comes from simultaneity bias and omitted variable bias. The simultaneity bias is present because deteriorated water quality affects economic growth. Omitted variable bias in the EKC regression arises from such omitted variables as cultural or geographic factors that affect both environmental quality and income. To address these two biases in nonparametric model, we propose using a nonparametric instrumental variable estimation approach.

Although the literature on estimating the environmental Kuznets curve is growing fast and becoming very sophisticated in terms of empirical methodology used, hitherto published articles in the EKC literature have not properly addressed the properties of categorical, binary and/or ordered explanatory variables in the model. One problem that arises in incorporating political rights and civil liberties variables or any other categorical, ordered or binary variables in a semiparametric or nonparametric regression is that those cannot be treated as continuous variables.

To incorporate all these estimation related issues in EKC, we use a nonparametric instrumental variable approach that allows for the inclusion of continuous and discrete variables. We apply this method to analyze the relationship between water quality and per capita GDP at the global level over the period 1980 to 2012. We identify the role played by political rights and civil liberties in determining water quality.

Our results indicate an inverted U-shape relationship between income and pollution for one pollutant (lead) and a cubic shape for three pollutants (nickel, mercury and arsenic). In general, we find that improved civil liberties and political rights are correlated with better water quality. By estimating a nonparametric relationship between political variables and pollution and by accounting for the categorical nature of the political variables, we are able to detect a nonlinear relationship between political variables and pollution, which for some pollutants is an inverted U-shaped curve.

Methods

We are interested in identifying how different types of water pollutants relate to income, civil liberties and political rights.[2] Generally, the EKC relationships among these variables are studied using a parametric model with income variable regressed in a polynomial form (quadratic or cubic). These types of ad hoc functional form specifications put an a priori restriction on how the relationship should look like in the empirical estimation. One of the alternatives is to use a semiparametric or nonparametric form that allows more flexibility in modeling. Nonparametric techniques enable one to detect structures which sometimes remain undetected by traditional parametric estimation techniques. Although semiparametric and nonparametric methods are tedious in terms of computing resources, these methods are used by many researchers (Azomahou et al., 2006; Bertinelli and Strobl,

[2] A theoretical basis for the EKC can be found in a recent paper by Brock and Taylor (2010). Our focus is on the empirical model.

2005; Criado, 2008; List and Gallet, 1999; Luzzati and Orsini, 2009; Millimet et al., 2003; Nguyen Van and Azomahou, 2007; Paudel et al., 2005; Phu, 2003; Poudel et al., 2009; Roy and Cornelis van Kooten, 2004; Schmalensee et al., 1998) .

Often additional explanatory variables included in the EKC model include variables such as whether a country is open to trade or lacks democracy or not. These variables are qualitative in nature so these should be handled differently from continuous variables. The conventional nonparametric approach uses a "frequency estimator" to handle qualitative variables which involves splitting the samples into number of cells (Racine and Li, 2004). In this paper, we use nonparametric functional forms for both categorical and continuous variables.

Lin and Liscow (2013) observe that the reduced form model used to examine the EKC hypothesis has a potential endogeneity problem. They posit that simultaneity bias and omitted variable bias are two main sources of endogeneity problems in EKC regressions that have not addressed by previous literature on the subject. According to Lin and Liscow (2013), the simultaneity bias comes from the reverse causality of GDP and environmental degradation. While the increases in economic activity that come along with increases in GDP may increase pollution, increases in pollution may, at the same time, harm people's health, for example, thereby reducing GDP. Output and pollution may also be jointly produced in the production process, causing GDP and pollution to be simultaneously determined. Omitted variable bias arises if there is a third variable such as cultural or geographic factors that are not used in the EKC model that simultaneously causes both economic growth and environmental degradation.

Lin and Liscow (2013) use a parametric instrumental variables regression approach with and without fixed effects. They use debt service and age dependency ratio as instruments for per capita GDP. They suggest that the age dependency ratio is not strong instrument, so in this paper we only use debt as an instrument for GDP. Debt is correlated with GDP, but does not have a direct effect on environmental quality, and is therefore a good instrument for GDP. Total debt service, which includes the principal repayments and interest actually paid on debt, is positively correlated with GDP because more debt is likely to be paid off when GDP is higher. Debt service may be correlated with types of degradation like deforestation, if countries liquidate natural assets to pay off debts, but there is little reason to believe that countries with high debts would pollute more.

According to the results of Lin and Liscow (2013), evidence for an inverted-U relationship between income and environmental degradation are found for at least two out of the four IV specifications for seven out of eleven water pollutants: biological oxygen demand, chemical oxygen demand, arsenic, cadmium, lead, nickel, and fecal coliform. For these pollutants, there is both a peak and a trough. Their IV results therefore provide some support for an environmental Kuznets curve in global water quality. In contrast, the OLS results, which do not address the endogeneity of income, show no inverted-U relationship for any of the pollutants.

Recent papers in the econometrics literature, such as Darolles et al. (2011) and Horowitz (2011), have developed nonparametric instrumental variable estimation methods. In this paper we use a method suggested by Horowitz (2011) to estimate a nonparametric instrumental variable EKC regression model.

Parametric methods put a priori restrictions on how the relationship should look like in the empirical estimation. One of the alternatives for relaxing the assumption of parametric methods is to utilize a nonparametric estimation method. In addition, nonparametric estimates are more robust in detecting structures which sometimes remain undetected by traditional parametric estimation techniques. The nonparametric regression model is given by:

$$P = g_y(y) + \sum_{j=1}^{p} g_j\left(x_j\right) + \epsilon \ , \qquad (1)$$

where P is pollution, $g_y(.)$ is an unknown smooth function for income y, and $g_j(.)$ is the unknown function for other factors x_j such as civil liberties and political rights.

The civil liberties and political rights variables are ordinal. We thus need an estimation procedure that can address ordinal nature of variables. For simplicity, let us consider $g(y, X) = g_y(y) + \sum_{j=1}^{p} g_j\left(x_j\right)$. Then, equation (1) can be written as:

$$P = g(y, X) + U; \qquad E(U|W = w, X = x) = 0 \qquad (2)$$

for all instruments w and exogenous covariates x, which is equivalent to:

$$E[P - g(y, X)|W = w, X = x] = 0 \, . \qquad (3)$$

In this model, y denotes per capita GDP which is endogenous, X denotes exogenous explanatory variables (political rights and civil liberties), W denotes our instrument (debt). To address ordinal and categorical variables in a nonparametric model, we use a method suggested by Ma and Racine (2011), Nie and Racine (2012), and Ma et al. (2011) to estimate the nonparametric instrumental variable model[3] given in equation (3).

Data

We use water pollution data from the Global Environment Monitoring System (GEMS) Water Dataset, which consists of annual surveys of water quality statistics from 1980 to 2012 from 82 developed and developing countries.[4] The GEMS data set consist of over 70,000 observations of dozens of different types of water pollution, providing a substantive amount of data on varied measures of water quality. Each data point consists of the average over every years of one or more data point from one of GEMS/water's hundreds of sites around the world. We use this data to construct a panel data set; however, since values of pollutants are not available for all years for each country, our data is set is an unbalanced panel with different numbers of observations for different pollutants. This paper focuses on four types of water pollutants: heavy metal (nickel, mercury, arsenic, cadmium, lead), pathogenic contamination (fecal coliform, total coliform), oxygen regime (dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD)) and nutrients

[3] The 'crs' R package is available to estimate the nonparametric model which contains both categorical and continuous variables. See Racine et. al (2012) for the 'crs' package manual.

[4] The countries used in this research are: Algeria, Argentina, Australia, Austria, Afghanistan, Argentina, Bangladesh, Belgium, Bolivia , Brazil, Bangladesh, Bolivia, Brazil, Cambodia, Canada, Chile, China, Colombia, Congo, Cuba, Denmark, Ecuador, Egypt, Ecuador, Fiji, Finland, France, Germany, Ghana, Greece, Guatemala, Hong Kong, Hungary, India, Indonesia, Iran, Ireland, Israel, Italy, Japan, Jordan, Kenya, Korea, Laos, Lithuania, Luxembourg, Malaysia, Mali, Marshall Islands, Mexico, Morocco, Netherlands, New Zealand, Norway, New Zealand, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Peru, Russian Federation, Senegal, Singapore, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Singapore, Tanzania, Thailand, Tunisia, Turkey, Uganda, United Kingdom, United States of America, Uruguay, Vietnam, and Zimbabwe.

(nitrate).[5] All data are in the form of concentrations of mg/l except for the mercury data, which is in the form of μg/l and the coliform data, which is in the form of measured count/100 ml.

For our income measure, we use data on gross domestic product (GDP) in constant 2005 international dollars from the World Development Indicators (WDI). For data on political mechanisms, we use indices on political rights (PR) and civil liberties (CL) from Freedom House. Each index varies from 1 to 7, with 1 meaning the most political rights or civil liberties. For example, the United States has a 1 in each category in all years, Indonesia has recently been in the middle of the range, and China has 7 in both categories for most years. Freedom House attempts to use a methodology not bound by culture, but instead uses standards drawn from the Universal Declaration of Human Rights (House, 2010). Political rights measure factors such as the fairness of the electoral process, the degree of political pluralism and participation, and the presence of a non-corrupt and transparent government (House, 2010). Civil liberties measure freedom of expression and beliefs, the ability to associate, the rule of law, and the degree of individual autonomy. The mean of the political rights variables is lower than that for civil liberties, which implies that political rights are more prevalent in many countries than civil liberties are. In previous studies, political rights and civil liberties have been combined into one democracy measure that takes on values from 1 to 14.

[5] Although the existence/nonexistence of an EKC for some of these pollutants for different time periods and different sets of counties has been established, changes in the data period and the inclusion of additional variables in the regression may give different results. This is exactly the point raised by Harbaugh et al. (2002).

For the instrumental variable for GDP, we tried several variables such as share of GDP from manufacturing sector, age dependency ratio and total debt service. In the end, we choose to use total debt service (% of GNI), as it was found to have a very high correlation against the per capita GDP income variable.

Summary statistics of the data used are presented in Table 1. Most pollutants exhibit a large range in values and a high standard deviation. According to exploratory plots of the data (Lin and Liscow, 2013), the concentrations of the majority of the pollutants (chemical oxygen demand, total arsenic, dissolved oxygen, total lead, total nickel, and fecal coliform) are decreasing functions of per capita income, political rights, and civil liberties. The concentrations of only two pollutants (total cadmium and nitrate) exhibit increasing functions of per capita income, political rights, and civil liberties. The concentrations of three pollutants (biological oxygen demand, total mercury, and total coliform) show no relationship with the income or political variables. Several of these trends are largely dependent upon the observations from only one or a few countries; for example, total cadmium's curve is dependent upon 1980s UK and 1990s France data. This suggests that water quality generally improves as countries develop.

Exploratory plots of the data also show that only a few of the pollutants (chemical oxygen demand, total arsenic, total mercury, and total cadmium) potentially have an inverted- U form for concentration with respect to income. Interestingly, a few of the pollutants (biological oxygen demand, chemical oxygen demand, total lead, fecal coliform) appear to have an inverted-U shape for the political variables as well. The high amounts of pollution and mid-range political variables for Mexico, India, and Colombia cause this phenomenon for both chemical and biological oxygen demand; this is also reflected in the

OECD versus non-OECD plots, in which concentrations decrease for OECD countries with improving political institutions, while they increase for non-OECD countries with improving political institutions. These exploratory plots suggest that, to the extent that there is an EKC, it may be as much caused by political as income factors (Lin and Liscow, 2013).

Results

In Figure 1, we present the graphical results of the estimated relationships between water quality and per capita GDP, political rights and civil liberties resulting from our nonparametric instrumental variable estimation. The left column of the figure represents the relationship between per capita GDP and pollution, the middle column represents the relationship between political liberties and pollutant concentration and the last column represents the relationship between pollutant concentration and civil liberties. We describe the results for each pollutant below.

Nickel

We find a cubic relationship or N-shaped curve between nickel concentration and per capita GDP. We do not find political rights or civil liberties impacting the nickel concentration.

Mercury

Per capita GDP and mercury concentration seem to have a cubic relationship. However we do not see any relationship between political rights and GDP or civil liberties and per capita GDP.

Arsenic

Per capita GDP and arsenic pollution seem to have a cubic relationship. The lower humps of the curve reaches first before getting to the upper hump. Arsenic pollution also declines if there are no political rights. Civil liberties do not have any impact on the arsenic pollution.

Cadmium

Cadmium concentration seems to have declined with increase in per capita GDP especially after per capita GDP hits $6,000 level. However, we do not find any definitive relationships between cadmium concentration and per capita GDP level.

Lead

We found that an inverted U-shaped relationship exists between per capita GDP and lead concentration. There is no distinct pattern on the relationship between civil liberties and lead pollution or political rights and lead pollution although it looks like the highest amount of when political rights has the value equal to 5.

Fecal coliform

For fecal coliform we found almost a cubic relationship between pollution and income. The lower turning points occurred around $4000 whereas the upper turning point is around $10,000. Variations in political rights or civil liberties do not seem to have any impact on the fecal coliform concentration in water bodies.

Total coliform

The relationship between total coliform and per capita GDP seem to follow almost a polynomial of 4^{th} degree type of relationship. The pollution level seems to reduce substantially after the income level reaches the $11,000 level. When the level of political rights is lower (and the political rights index is higher), total coliform concentration is lower.

Dissolved oxygen

At lower levels of GDP, the relationship between GDP and dissolved oxygen looks flat but once the GDP level is $8000 or higher the dissolved oxygen level starts declining. We do see a clear quadratic relationship between political rights and GDP. There is no unique shape observed between civil liberties and dissolved oxygen concentration.

Chemical oxygen demand

The relationship between GDP and chemical oxygen demand concentration looks like an N-shape.   We also see that higher civil liberties are associated with higher levels of chemical oxygen demand and lower civil liberties are associated with lower levels of chemical oxygen demand. The relationship with political rights is flat.

Biological oxygen demand

The biological oxygen demand curve shows 5th degree of polynomial relationship with per capita GDP. We see a clear relationship between civil liberties and biological oxygen demand with higher civil liberties associated with low biological oxygen demand levels and lower civil liberties associated with higher levels of pollution. We do not find political rights affecting the level of biological oxygen demand.

Nitrate

We did not see any distinct shape on the relationship between nitrate pollution and per capita GDP. Higher civil liberties contribute to less amount of nitrate pollution but political rights have no impact on the nitrate pollution. Many studies (Paudel et al. 2005 and 2009) have shown an existence of EKC curve for nitrate pollution. For the global level water pollutants, others have shown the quadratic relationship between income and pollution.

Conclusion

This study contributes to a better understanding of the relationships between water pollution and per capita GDP, civil liberties, and political rights at the global level. We use recent advances in econometric techniques to address the inclusion of continuous and discrete variables in nonparametric instrumental variable regression models.

According to our results, we find an inverted U-shape relationship for one pollutant (lead), and a cubic relationship for three pollutants (nickel, arsenic and fecal coliform). In contrast, according to the results of Lin and Liscow (2013), whose model uses instrumental variables but, unlike the model in this paper, is neither nonparametric nor accounts for the discrete nature of the political variables, evidence for an inverted-U relationship between income and environmental degradation were found for at least two out of the four IV specifications for seven out of eleven water pollutants (biological oxygen demand, chemical oxygen demand, arsenic, cadmium, lead, nickel, and fecal coliform), and for each of these seven pollutants there is both a peak and a trough. By using a nonparametric model that accounts for the discrete nature of the political variables, we find that fewer pollutants exhibit an environmental Kuznets curve than were previously found in Lin and Liscow (2013).

In terms of the political variables, we found that the arsenic and total coliform levels decline as the level of political rights declines (and as the political rights index increases), but lead and dissolved oxygen have an inverted U-shaped curve with political rights. For lead and dissolved oxygen, results suggest that as countries progress towards political rights, water pollution increases at first but then decreases after certain levels of political rights have been attained. Our results indicate that higher biological oxygen demand and nitrate pollution levels are associated with lower levels of civil liberties (higher civil liberties index) but that lower chemical oxygen demand levels are associated with lower levels of civil liberties (higher civil liberties index). Thus, factors affecting political rights such as the fairness of the electoral process, the degree of political pluralism and participation, and the presence of a non-corrupt and transparent government are beneficial for water quality to some extent.

By estimating a nonparametric relationship between political variables and pollution and by accounting for the categorical nature of the political variables, we are able to detect a nonlinear relationship between political variables and pollution, which for some pollutants is an inverted U-shaped curve. In contrast, Lin and Liscow (2013), whose model uses instrumental variables but, unlike the model in this paper, is neither nonparametric nor accounts for the discrete nature of the political variables, are unable to tease out the nonlinear nature of some of the relationships; they instead find that the effect of political variables on pollution can be either positive or negative depending on pollutant and political variable.

The relationships between environmental degradation, income and political institutions found in this study suggest that there are nonlinear relationships between water pollution and income and between water pollution and political institutions, and that those in the field and in academia should be open to relationships between these key components of sustainable development.

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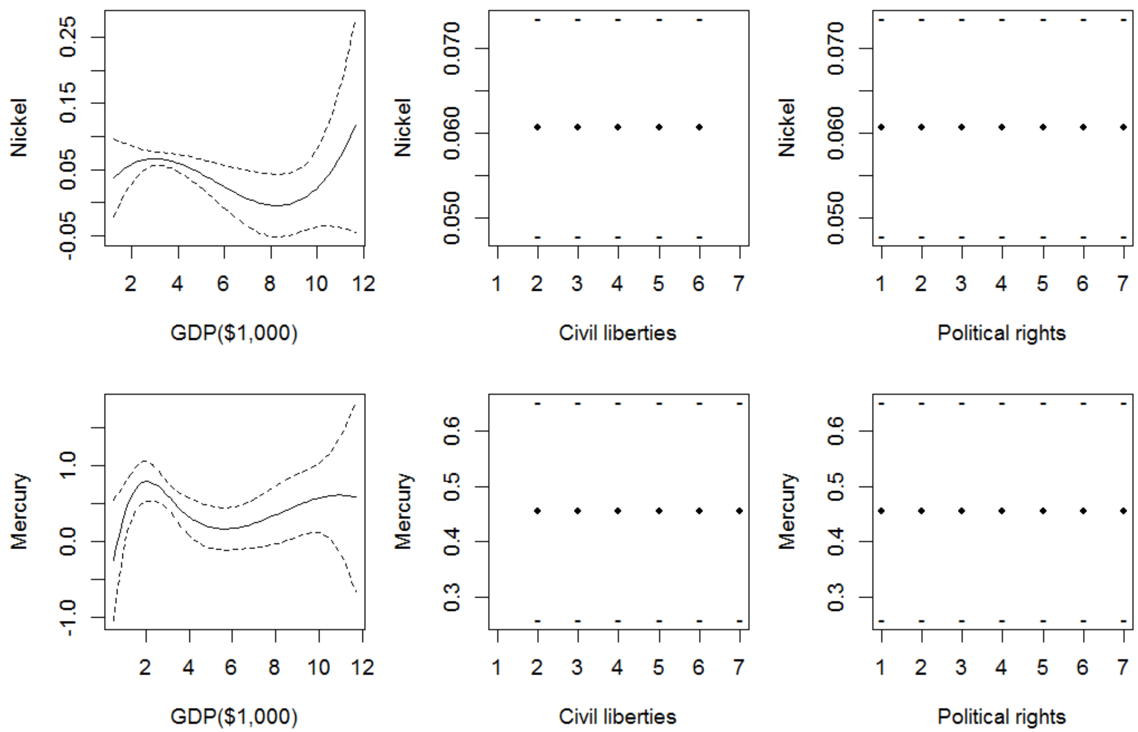
Table 1: Summary Statistics

Variable Name.	M. type	Mean	SD	Min	Max	Observation	
Nickel	overall	0.014	0.030	0.000	0.326	N	246.00
	between		0.015	0.000	0.067	n	30.00
	within		0.024	-0.041	0.325	T-bar	8.20
Mercury	overall	0.336	0.713	0.000	7.900	N	447.00
	between		0.459	0.000	2.468	n	44.00
	within		0.617	-2.133	6.937	T-bar	10.16
Arsenic	overall	0.017	0.068	0.000	0.785	N	309.00
	between		0.084	0.000	0.518	n	38.00
	within		0.051	-0.250	0.516	T-bar	8.13
Cadmium	overall	0.023	0.097	0.000	1.000	N	475.00
	between		0.061	0.000	0.257	n	45.00
	within		0.081	-0.222	0.857	T-bar	10.56
Lead	overall	0.030	0.106	0.000	1.067	N	500.00
	between		0.127	0.000	0.500	n	50.00
	within		0.079	-0.440	0.860	T-bar	10.00
Fecal coliform	overall	47982.37	229659.500	0.000	3681414.000	N	467.00
	between		96137.040	0.000	515869.100	n	42.00
	within		201667.600	-411961.200	3383963.000	T-bar	11.12
Total coliform	overall	134726.9	660444.300	0.000	10400000.000	N	431.00
	between		421087.000	0.000	2593846.000	n	47.00
	within		541430.600	-2456222.000	7985642.000	T-bar	9.17
Dissolved oxygen	overall	8.389	2.497	0.000	42.500	N	914.00

	between		1.943	3.556	11.586	n	70.00
	within		1.584	3.983	41.169	T-bar	13.06
Chemical oxygen demand	overall	24.740	31.787	0.873	393.400	N	531.00
	between		23.420	2.011	96.650	n	52.00
	within		22.680	-52.046	331.192	T-bar	10.21
Biological oxygen demand	overall	4.189	9.658	0.348	192.400	N	688.00
	between		6.456	0.831	33.465	n	56.00
	within		8.134	-27.394	163.506	T-bar	12.29
Nitrate	overall	1.281	2.302	0.010	18.565	N	294.00
	between		2.957	0.067	15.283	n	41.00
	within		1.300	-4.069	11.908	T-bar	7.17

Table 1. Contd.

Variable Name.	M. type	Mean	SD	Min	Max	Observation	
Political Rights	overall	3.660	2.228	1.000	7.000	N	6017.00
	between		2.006	1.000	7.000	n	203.00
	within		1.006	-0.109	8.751	T-bar	29.64
Civil Liberties	overall	3.665	1.935	1.000	7.000	N	6017.00
	between		1.756	1.000	7.000	n	203.00
	within		0.839	0.588	7.635	T-bar	29.64
Per Capita GDP	overall	10.362	12.506	0.102	123.433	N	5447.00
	between		12.265	0.482	70.805	n	182.00
	within		3.600	-23.051	62.990	T-bar	29.93
Debt	overall	5.184	5.942	0.000	135.376	N	3478.00
	between		3.317	0.084	17.891	n	127.00
	within		4.946	-11.697	128.428	T	27.39


Nickel
GDP($1,000)
Civil liberties
Political rights
Mercury
GDP($1,000)
Civil liberties
Political rights

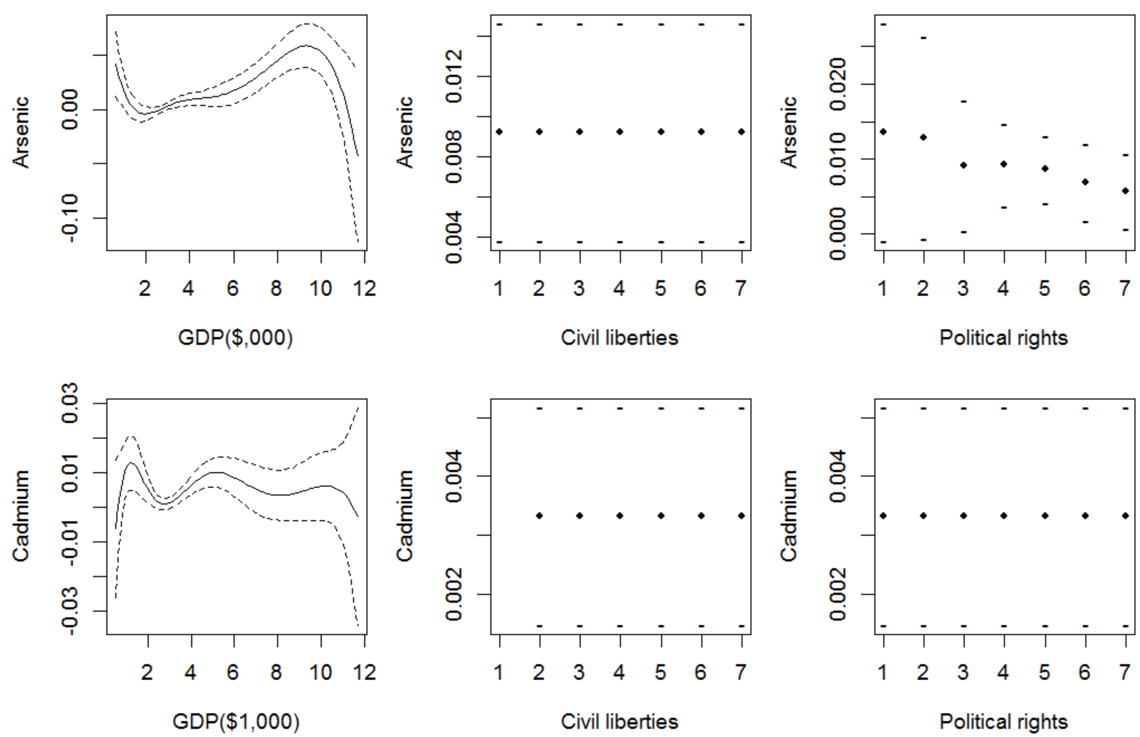
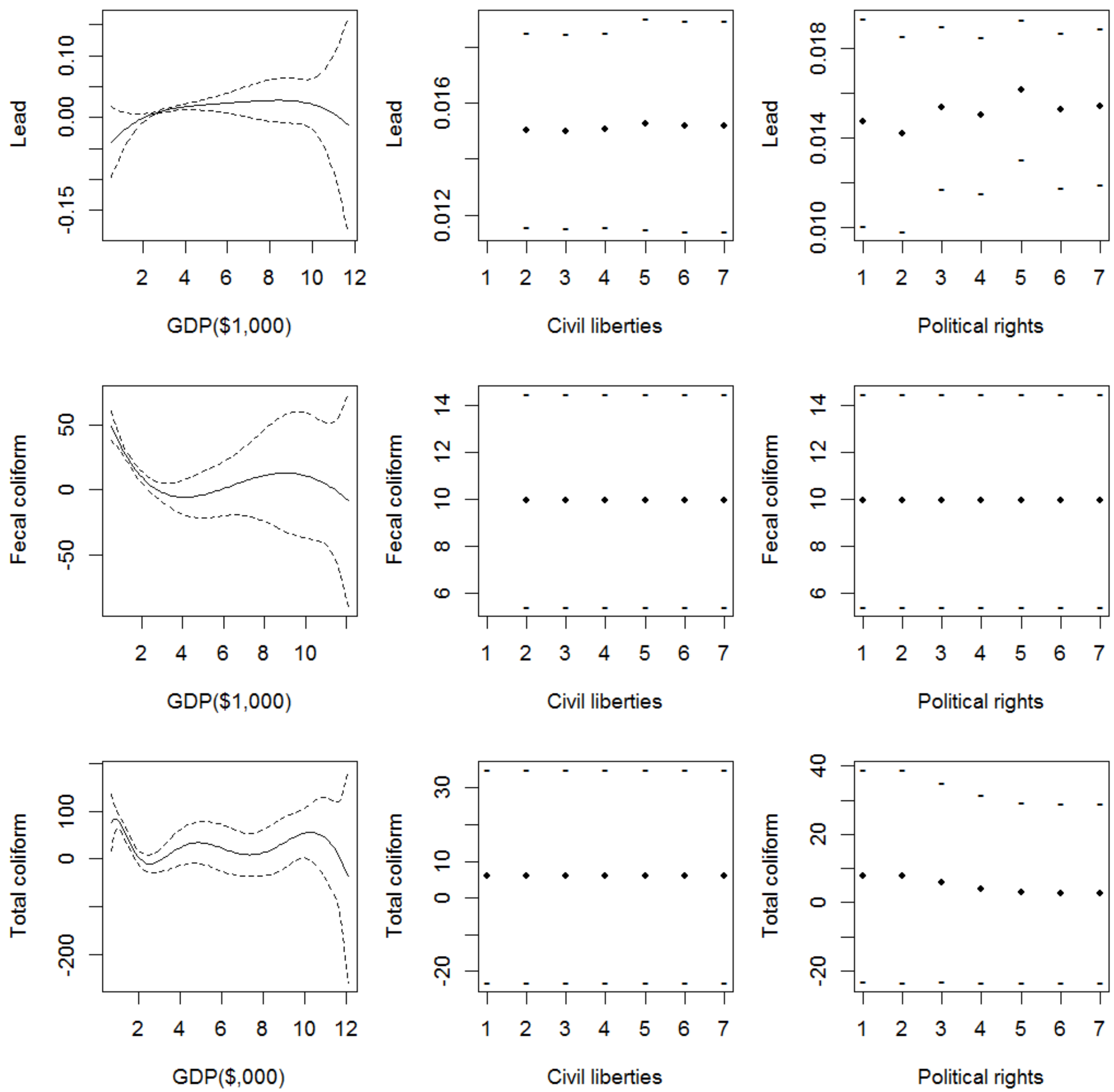


Figure 1. Relationship between pollution and per capita GDP; pollution and civil liberties; and pollution and political rights obtained from using a nonparametric instrumental variable estimation. (Note: Dotted lines in the GDP-pollutant relationship are confidence interval bands. The lightly dotted points in civil liberties and political rights are confidence interval bands.)


Lead
GDP($1,000)
Civil liberties
Political rights
Fecal coliform
Total coliform
GDP($,000)

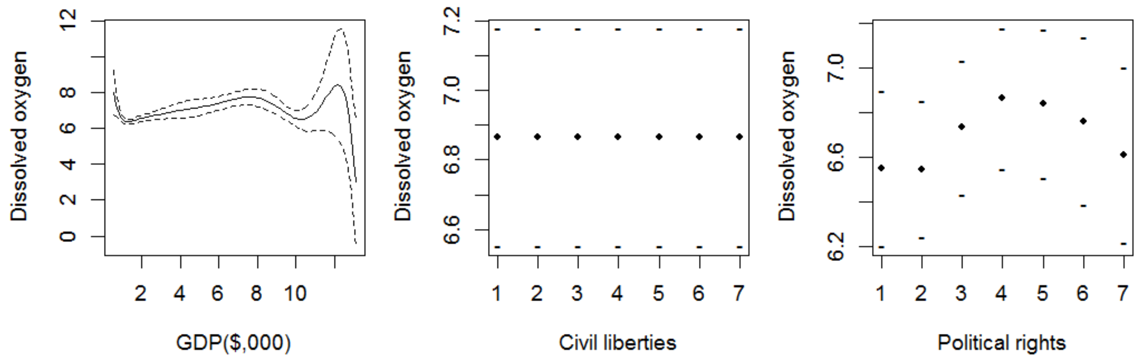
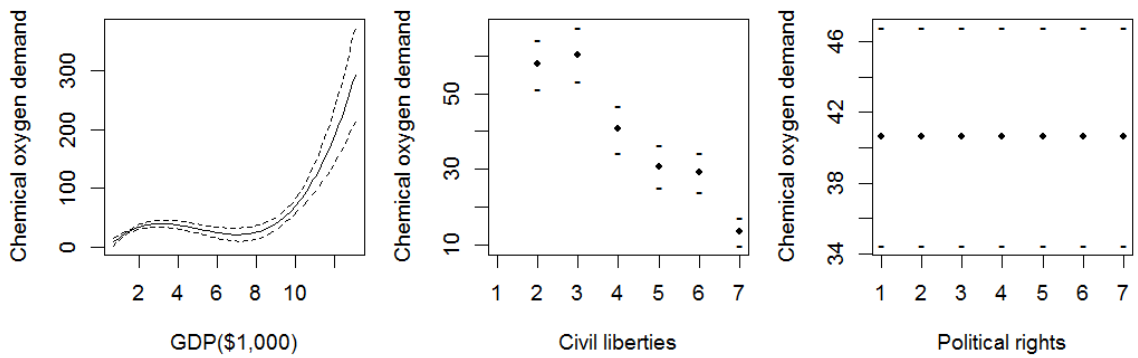


Figure 1 (Cont.)



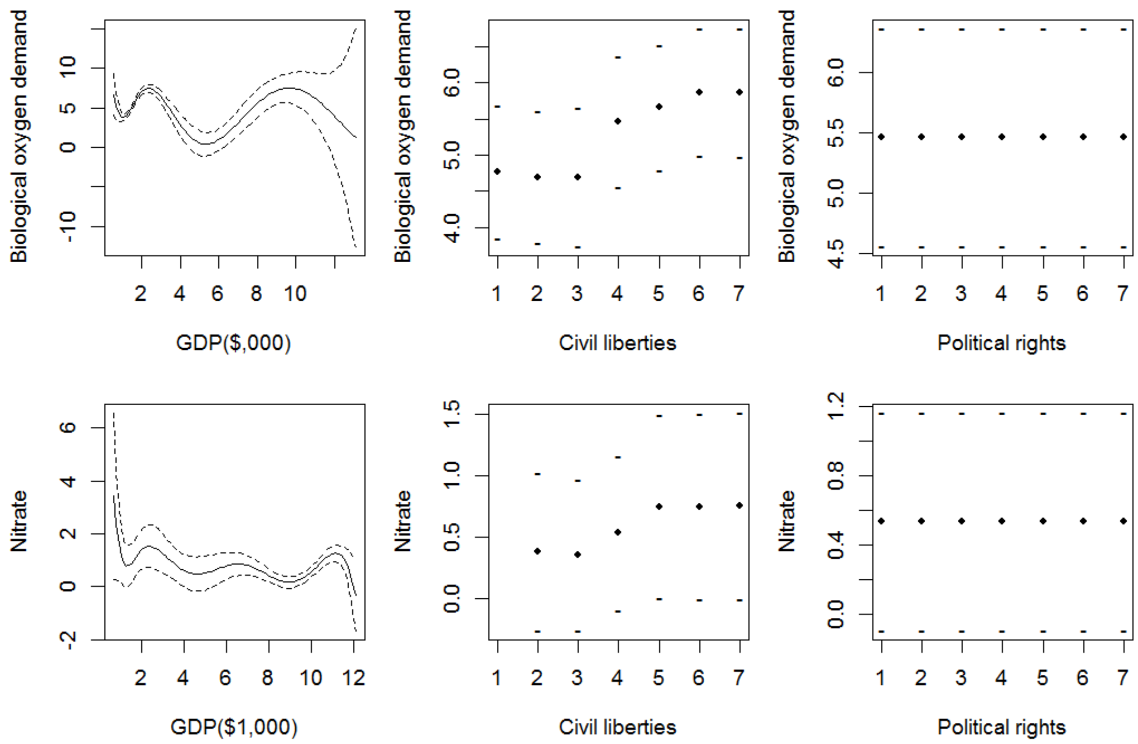


Figure 1 (Cont.).