On the Political Mechanisms of the Environmental Kuznets Curve for Global Water Quality[1]

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Abstract

This paper examines the effects of poverty and political institutions on environmental quality, using country-level global water quality panel data from 1979 to 1999. The key innovation is the use of instrumental variables and country-specific fixed effects in our econometric methodology. Evidence for an inverted-U relationship between income and environmental degradation were found for seven out of eleven water pollutants. Political institutions have a significant effect on environmental quality for five of the eleven pollutants.

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1 Introduction

The effects of increasing income on environmental quality is an issue that has long puzzled economists. For over a decade, economists have theorized that a graph of environmental degradation versus income often looks something approximating an inverted-U shape, dubbed the environmental Kuznets curve (EKC) after Simon Kuznets' work in the 1950s and 1960s on income equality (Kuznets 1955, 1965). Among the reasons why economists have found the effects of increasing income on environmental quality so intriguing is that the answers to this question would help resolve fundamental issues concerning humanity's ability to develop economically, while still preserving the environment.

Some economists hypothesize that there is a causal relationship between income and environmental degradation, and that the relation is in the shape of an inverted U: as countries "get rich, … first [environmental] problems increase, and then they decrease" (Lomborg and Pope 2003, p.9). According to this theory, the solution to environmental problems is to alleviate poverty.

Other economists agree with the shape of the relationship between income and environmental degradation but disagree with the claim of causality and, more importantly, with the conclusion that by mitigating poverty, one would also improve environmental quality. Instead, they suggest that there are very important omitted variables, and that what cleaned up the environment was not rising income, but rather political institutions responding to public demand (Lomborg and Pope 2003). As Dasgupta and Maler (1995, p. 2412) state: "The connection between environmental protection and civil and political rights is a close one. As a general rule, political and civil liberties are instrumentally powerful in protecting the environmental resource base, at least when compared with the absence of such liberties in countries run by authoritarian regimes."

In this paper, we examine two issues regarding the relationships among poverty, politics and environmental degradation. First, *what is the relationship between income and water pollution?* Does it tend to be an inverted U? Or is there some other relationship? And, second, *what role do political institutions play?* Are they peripheral or essential?

To examine the relationship between environmental quality, income, and political institutions, we use a multivariate regression analysis of water pollution on income and institutional variables.

According to the results, evidence for an inverted-U relationship between income and environmental degradation were found for seven out of eleven water pollutants. Political institutions have a significant effect on environmental quality for five of the eleven pollutants.

The key innovation of this study is to use instrumental variables to mitigate the problems caused by simultaneity bias and omitted variable bias. For example, it is entirely plausible that water pollution harms economic development. Likewise, an omitted variable such as a cultural or geographic factor may affect both environmental quality and income.

Our study is important not only because of its methodology, but also because its results will expand the state of knowledge regarding the consequences—especially on environmental quality—of income, civil liberties and political institutions.

The balance of our paper proceeds as follows. In the next section we survey the relevant literature and highlight our contributions to it. We describe our data in Section 3 and conduct a graphical analysis of relationships among environmental quality, income and political mechanisms in Section 4. Section 5 describes our identification strategy and Section 6 presents our regression results. Section 7 concludes.

2 Previous Literature

Empirical work to test for the existence of the EKC has been conducted on various measures of environmental quality since the early 1990s. Grossman and Krueger (1995) conducted perhaps the most important study, using global air and water quality data, and found that much of their data did, indeed, conform to the model of the EKC with a turning point generally before a country reaches a per capita income of $8000. Since this point, several economists have studied carbon dioxide emissions (Panayotou 1997), deforestation (Bhattarai and Hammig 2000), and a variety of other pollutants, using global and national datasets. The preponderance of these studies seem to support the existence of an environmental Kuznets curve across a wide range of countries and pollutants.

The vast majority of the empirical environmental Kuznets curve literature, however, has essentially put into a black box the mechanisms through which the EKC occurs. Some have mistaken the existence of the EKC to mean that economic development *per se* eventually decreases environmental degradation. However, most economists have generally assumed that there is a political mechanism behind the EKC: economic development induces a policy response, in which a country's more wealthy and empowered citizens demand environmental protection and their government responds. According to their 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.

Does an induced policy response underlie the EKC? If so, then the presence of those democratic institutions that facilitate citizens' expression of their wills should have a significant impact on environmental quality, since their absence would hinder citizens' ability to express their desire for a cleaner environment. NGO’s like the Sierra Club should be important. If democratic institutions really do help mitigate a country's impact on the environment, then this study may be suggestive of methods that international aid groups can take to best foster environmental preservation.

If no such induced policy response exists, then many of the mechanistic assumptions underlying the theory on the environmental Kuznets curve may be untrue. For example, perhaps the poor really do not place less emphasis on the environment than the richer citizens on the other side of the EKC "hump".

Barrett and Grady (2000) were among the first to explore the political mechanisms of the EKC by exploring the significance of political rights and civil liberties, using the same data as Grossman and Krueger (1995). They found 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.

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 were inadequate.

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. They obtain empirical support for their hypothesis that democracy and its associated freedoms provide the conduit through which agents can exercise their preferences for environmental quality more effectively than under an autocratic regime, thus leading to decreased concentrations or emissions of pollution.

This study makes several improvements upon the existing literature.[2] First, we look at what is perhaps the most political of environmental issues—water—in greater depth and with more abundant and updated data than any previous study we have seen. Second, we instrument for income in order to prevent the problems of omitted variable bias and simultaneity bias. Third, we also use country fixed effects to capture any unobserved characteristics of the countries. Fourth, we add political variables to the pollution regression. Fifth, so that we can best assess how our use of instrumental variables, country fixed effects and political variables improves upon the existing literature, we use data similar to that used by Grossman and Kreuger (1995) and Barrett and Graddy (2000) to provide useful benchmarks against which to compare our own results.

Some recent literature has applied semiparametric techniques to EKC estimation. Zapata, Paudel and Moss (2008) provide a discussion of EKC research questions that can be addressed

[2] It is important to distinguish between two strains of research into the EKC—the empirical strain, which generally uses reduced-form equations, and the theoretical strain, which generally uses more structural formulas. This study is fully in the former category. Israel and Levinson (2004) combine the two strains. Andreoni and Levinson (2000) also make a significant contribution combining empirics with theoretical structural models.

via advances in semiparametric econometric methods. Paudel, Zapata and Susanto (2005) use parametric and semiparametric models to study nonpoint source water pollutants in Louisiana watersheds. Millimet, List and Stengos (2003) propose that the appropriateness of a parametric pecification of the EKC should be based on the formulation of an alternative hypothesis of a semiparametric partial linear model. We do not use semiparametric techniques in our paper, however, but instead focus on addressing the endogeneity of income. Semiparametric techniques will be the subject of future work.

There are drawbacks to using aggregate country-level data. Political rights, civil liberties, and income level affect pollution heterogeneously within countries, and, as a consequence, country-level aggregation may average out the factors driving the EKC identification. In the context of air pollution in the United States, Auffhammer, Bento and Lowe (2007) find that special attention may be paid to the dirtiest air quality monitors in non-attainment counties, which may lead to a heterogeneous treatment effect across monitors within non-attainment counties. As a consequence, studies that do not account for the heteorogeneity may have failed to identify the effects of the regulations if the effects experienced in single monitor counties are partially offset by those experienced in multiple monitor counties. Similarly, Plassmann and Khanna (2006) assert that country-level analyses of global environmental Kuznets curve relationships that use multi-country panel data sets are likely to suffer from several types of aggregation bias that may explain why previous studies have yielded conflicting results. To address these aggregation biases, both studies use disaggregated air quality data in the United States.

Despite its drawbacks, we use country-level data for two reasons. First, disaggregate data on water pollution and political institutions is not available for most countries. Disaggregate data may be available for air pollution in the U.S., but there is little variability in political rights and civil liberties within the U.S. Second, we want to be able to compare our results with previous cross-country studies that do not instrument for income, since the use of instruments and is our primary innovation. We hope to use disaggregated data in future work when such data becomes more available.

3 Data

For our measure of environmental quality, we choose to focus on water. We choose water because it seems the environmental variable most likely to show the importance of political institutions. Since water is probably the most important and fought-over public good, it is also the most politicized. Indeed, since ancient times, civilizations have fought over the possession of water. The environmental movement in the United States was started largely through Rachel Carson's statements about the impact of DDT entering the water, and thus the food supply. As the ever-expanding human population continues to place increasing demands on the global water supply, the issue of water quality is becoming even more crucial.

We use data from the Global Environmental Monitory System GEMS/Water dataset, which consists of triennial surveys of water quality statistics from 1979 to 1999 from across the developed and developing world. This study updates the data set used by Grossman and Krueger (1995) and by Barrett and Graddy (2000) to include the years from 1991 to 2000.

The data set consists 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 the three years of one or more data point from one of GEMS/water's hundreds of sites around the world.[3]

Following Grossman and Krueger (1995), we use the data on biological oxygen demand, chemical oxygen demand, dissolved oxygen, nitrate, arsenic, cadmium, lead, mercury, nickel, total coliforms, and fecal coliform. All data is 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. The data set also includes water temperature (in degrees Celsius), which we use a control. The year assigned to each data point is the middle of the three years.

To this data, we add data on gross domestic product (GDP) per capita at purchaser's prices in constant 2000 international dollars from the World Development Indicators (WDI). We also add GDP squared and GDP cubed.

For data on political mechanisms, we use the indices on political rights and civil liberties 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 a 7 in both categories for most years. Freedom House attempts to use a methodology not bound by culture, but rather using standards drawn from the Universal Declaration of Human Rights (Freedom House 2004). Political rights measures factors like the fairness of the electoral process, the degree of political pluralism and participation, and the presence of a non-corrupt and transparent government (Freedom House

[3] This dataset also has several drawbacks, which we have tried to mitigate. First, the very variety of measures seems conducive to a study that fails to appreciate the unique dynamics that govern each different pollutant and takes data as numbers without a great deal of meaning. As such, we have tried to look at the qualities of each pollutant individually, turning this drawback into an advantage that we can use to inform patterns that we see. Second, the data can be rather spotty; in few cases are there countries with observations in all seven triennial surveys. The biases that this introduces may be difficult to discern. We have tried to mitigate this problem by choosing the pollutants with the best data from the dozens in the GEMS/Water dataset. Our use of exploratory plots broken down by year, country, and development level (OECD versus non-OECD) helps mitigate both of these factors because it allows easy perusal of the reasons for plots' shapes.

2004). Civil liberties measures the freedom of expression and belief, the ability to associate, the rule of law, and the degree of individual autonomy.

Also from the World Development Indicators (WDI), we add data on the percentage of GDP that comes from manufacturing as a control.[4] Also from the WDI dataset, we add the age dependency ratio (dependents—the population under age 15 and above age 65—as a proportion of the working age population) and total debt service (% of GNI) [5] as instruments.

Tables 1a and 1b present summary statistics for our data set.

4 Graphical analysis

In this section we examine the relationships among environmental quality, income and political institutions by graphical analysis. To assess these relationships at an aggregate level, we first pool the data over all years and all countries to plot each of the eleven water quality variables versus income, political rights, and civil liberties. There are thus 33 relationships in total. The plots are available in an online appendix (URL TBA). Representative graphs for chemical oxygen demand and cadmium are presented in Figure 1. In order to see the nuances of the data, we also subdivided the plots by country, by year, and by development level (OECD versus non-OECD) for each of these 33 relationships. For example, the plots by country allow easy understanding of which countries lead to an inverted-U shape.

We had two hypotheses for the results the graphical analysis. First, we thought that pollutants classified as inorganic contaminants would be most likely to improve with

[4] "Manufacturing refers to industries belonging to ISIC divisions 15-37. Value added is the net output of a sector after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources. The origin of value added is determined by the International Standard Industrial Classification (ISIC), revision 3." (World Bank)

[5] "Total debt service is the sum of principal repayments and interest actually paid in foreign currency, goods, or services on long-term debt, interest paid on short-term debt, and repayments (repurchases and charges) to the IMF." (World Bank)

development, since they are most likely to come from point sources, such as large chemical factories instead of more dispersed farms, and thus be easier to regulate. Second, we thought that those pollutants that occur naturally in moderate amounts would be most likely to show no relationship with political or economic development.

As seen from a summary of the patterns gleaned from the exploratory plots presented in Table 2, the data bears out neither of these hypotheses. There seems to be no connection between the type of pollutant and the relationship between the pollution's concentration and the state of political or economic development. However, there are still several interesting trends.

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.

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 results suggest that, to the extent that there is an EKC, it may be as much caused by political as income factors.

In order to see the nuances of the data, we also subdivided the plots in the online appendix by country. As evidenced by these plots, the shape of the relationships of each pollutant with GDP, political rights and civil liberties in the pooled plots is governed primarily by the cross-sectional variation between countries. They thus reflect cross-sectional variation in pollution levels between countries at different points in their development paths, rather than time series variation in pollution levels within countries developing over time either politically or economically. With few exceptions (i.e. Ireland), the countries in this dataset do not vary substantially in their GDP or institutional indicators over the 20-year time horizon of this dataset. Given that this study uses a dataset over a longer period of time than those used in many studies in the EKC literature, these results suggest that the EKC may not truly reflect individual countries' trajectory over time, but instead perhaps other factors not traditionally captured in the EKC literature.

5 Econometric Methodology

Our regression model is the following:

$$pollution_{it} = \alpha_0 + \alpha_1 y_{it} + \alpha_2 y_{it}^2 + \alpha_3 y_{it}^3 + \alpha_4 pr_{it} + \alpha_5 cl_{it} + x_{it}^{'}\beta + \varepsilon_{it},$$

where $pollution_{it}$ is the water pollutant concentration for country i at time t, y_{it} is country i's per capita GDP at time t, pr_{it} the political rights index in country i at time t, cl_{it} is the civil liberties index in country i at time t, and x_{it} is a vector of controls including population density, water temperature, year, and manufacturing value added. The cubic trend in income is consistent with previous studies (see e.g., List and Gallet, 1999), while the addition of political variables is less common. Allowing for the possibility that a country's political institutions may have a lagged effect on pollution concentrations, we also run a model lagging the political variables:

$$pollution_{it} = \alpha_0 + \alpha_1 y_{it} + \alpha_2 y_{it}^{\,2} + \alpha_3 y_{it}^{\,3} + \alpha_4 pr_{i,t-1} + \alpha_5 cl_{i,t-1} + x_{it}{}^{'}\beta + \varepsilon_{it}.$$

Finally, to control for any time-invariant unobservables that vary by country, we also run the following fixed effects model:

$$pollution_{it} = \alpha_0 + \alpha_1 y_{it} + \alpha_2 y_{it}^{\,2} + \alpha_3 y_{it}^{\,3} + \alpha_4 pr_{it} + \alpha_5 cl_{it} + x_{it}{}^{'}\beta + \mu_i + \varepsilon_{it},$$

where μ_i is a country-specific fixed effect. A fixed effects model is more appropriate than a random effects model because the unobservables captured by the fixed effect are likely to be correlated with the regressors.[6]

In all the models above, a negative second derivative of pollution with respect to income for some range of income would be consistent with an inverted-U shape:

$$\frac{\partial pollution_{it}}{\partial y_{it}^{\,2}} = 2\beta_2 + 6\beta_3 y_{it} < 0.$$

If political institutions facilitate environmental improvement, we would expect a positive coefficient on the political rights and civil liberties indices, where lower values of the indices indicate a stronger political institution.

There are two types of endogeneity problems that plague regressions of environmental quality on institutional and income variables and that have been largely ignored by previous literature on the subject. One type is the simultaneity bias introduced by the reverse causality of

[6] Because we use instruments in the fixed effects regression, the regression models for some of the pollutants do not fit the asymptotic assumptions of the Hausman test so a Hausman test between fixed effects and random effects could not be conducted.

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.

A second type of endogeneity problem arises from omitted variable bias. While including policy variables helps reduce the problem of the endogeneity of GDP, it is still quite plausible that a third variable jointly causes both economic growth and environmental degradation—perhaps cultural or geographic factors not now in the regression formula.

In order to mitigate the problems of endogeneity, we innovate upon the previous literature by employing an instrumental variables approach for the regressions both with and without the fixed effects in order to identify the coefficient on income. The instruments are debt service and age dependency ratio. These instruments are reasonably credible instruments for GDP; while they are correlated with GDP, they do not have an effect on environmental quality, except through their effect on GDP. 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. Countries with a higher age dependency ratio will have lower rates of growth and GDPs, both because countries with large populations of young are likely to be less productive on average and because poorer countries tend to have this demographic profile.[7]

For each of the 11 water pollutants, we run five regressions. The first regression is OLS where standard errors are clustered by country. The second and third regressions are

[7] It should be noted that the age dependency ratio also includes dependents over the age of 65, but the change in the number of youths likely dwarfs the change in the number of elderly. Moreover, the proportion of elderly people during this time period (1979-1999) was small even in industrialized countries.

instrumental variables (IV) generalized method of moments (GMM) regressions; the second regression uses the contemporaneous political variables and the third regression uses the lagged political variables. In both IV GMM regressions, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used.

To address any potential weak instruments problem, the fourth regression is a limited information maximum likelihood (LIML) regression using age dependency ratio and total debt service as instruments for per capita GDP. We report the LIML estimate and a coverage-corrected standard error for the coefficient on per capita GDP based on the conditional likelihood ratio (CLR) approach developed by Moreira (2003). Computation of the conditional p-value for the CLR test uses the algorithm of Andrews, Moreira, and Stock (forthcoming). Andrews, Moreira, and Stock (2004) showed that the CLR test is approximately optimal. In particular, it dominates the Anderson and Rubin (1949) test and the Lagrange multiplier (score) test proposed independently by Kleibergen (2002) and Moreira (2001).

To capture any country-specific unobservables that are invariant over time, the fifth regression is a fixed effects regression where per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed.

6 Regression Results

Before adjusting the standard errors, we test for heteroskedasticity using a Breusch-Pagan / Cook-Weisberg test. For all pollutants, as reported in Table 4, we reject the null of constant variance. We therefore need to adjust the standard errors for heteroskedasticity. Thus, with OLS, standard errors are clustered by country. With IV GMM, we use a robust weighting matrix that is optimal when the error term is heteroskedastic.

To compare the instrumental variables result with OLS, we first run an OLS model for each of the pollutants. The results are reported as specification (1) in Tables 4a-4k. According to the OLS results, the only two pollutants for which the coefficient on per capita GDP is significant are nickel and total coliforms, and for these pollutants only the linear term is significant. For these two pollutants, the linear term is positive. The OLS results show no evidence for an inverted-U shaped relationship. The coefficient on political rights is significant and positive for cadmium and nickel, and the coefficient on civil liberties is significant and negative for dissolved oxygen and cadmium.

For each pollutant, we conduct a Durbin-Wu-Hausman test to test for the endogeneity of income. This is a test of whether the residual from a regression of income on all the exogenous variables has a significant coefficient when added to the original model. The null hypothesis is that income is exogenous. According to the results, income is endogenous for the regressions of chemical oxygen demand, dissolved oxygen, arsenic, and fecal coliform. Thus, at least for these pollutants, instrumental variables are needed to overcome endogeneity.[8]

[8] In the presence of heterogeneous treatment effects (with income as the treatment in this case), however, Hausman tests for exogeneity are called into question. There is no reason the OLS estimate should equal the IV estimate (Angrist, Imbens and Rubin, 1996). Thus, the results of the Hausman test are suggestive of endogeneity, but are not definitive.

Table 3 presents the results of the first stage regression of per capita GDP on the instruments and on the other exogenous variables. The F-statistic for the joint test of the instruments is 39.11 when the exogenous variables include the contemporaneous political variables and 41.12 when the exogenous variables include the lagged political variables. The instruments are thus correlated with the endogenous variable.

We use a Hansen overidentification test to test whether the instruments are uncorrelated with the error term. As reported in Table 4, for all the pollutants for which we reject exogeneity of per capita GDP (chemical oxygen demand, dissolved oxygen, arsenic, and fecal coliform) and therefore for which instruments are needed, we cannot reject the null hypothesis that the instruments are uncorrelated with the error term, so the instruments are admissible.

The results from the IV GMM specifications in Tables 4a-4k are robust to whether the political variables are lagged (specification 3) or not (specification 2). In contrast with the OLS results, some pollutants show an inverted-U relationship under the IV GMM specifications. Pollutants exhibiting an inverted-U relationship have a cubic relationship with income, which leads to both a peak and a trough. These pollutants are (per capita income at peak in constant international dollars in parentheses): biological oxygen demand (peak at $8362-8434), chemical oxygen demand (peak at $7228-7234), arsenic (peak at $9055-10883), cadmium (peak at $8937-10,000), lead (peak at $7932-8104), and fecal coliform (peak at $4253-4298). Political rights has a significant negative effect on chemical oxygen demand (lagged specification), and a significant positive effect on cadmium (both specifications) and lead (both specifications). Civil liberties has a significant negative effect on mercury (lagged specification).

To address any potential weak instruments problem, we run a conditional IV LIML regression using age dependency ratio and total debt service as instruments for per capita GDP, and report the LIML estimate and a coverage-corrected standard error for the coefficient on per capita GDP. As with IV GMM, pollutants exhibiting an inverted-U relationship have a cubic relationship with income, which leads to both a peak and a trough. These pollutants are (per capita income at peak in constant international dollars in parentheses): biological oxygen demand (peak at $8194), chemical oxygen demand (peak at $8170), cadmium (peak at $7927)[9], lead (peak at $8242), nickel (peak at $6667), and fecal coliform (peak at $4446).   For arsenic, which had an inverted-U shape under the GMM IV results, there is no peak under the conditional IV results. Political rights has a significant negative coefficient for nitrate and a significant positive coefficient for cadmium. Civil liberties has a significant negative coefficient for arsenic, cadmium and mercury, and a significant positive coefficient for nitrate.

When country fixed effects are included with the IV estimation, some of the environmental Kuznets relationships go away. As with the other IV results, pollutants exhibiting an inverted-U relationship have a cubic relationship with income, which leads to both a peak and a trough. These pollutants are (per capita income at peak in constant international dollars in parentheses): arsenic (peak at $12,468), nickel (peak at $9000), and total coliforms (peak at $12,861). Chemical oxygen demand has a significant positive cubic term. Nitrate and fecal coliform have significant linear terms. The linear, quadratic and cubic terms are all significant for cadmium, which had an inverted-U shape under all the other IV specifications, but there is no peak under the IV fixed effects specification. Political rights has a significant negative effect on nitrate and mercury and a significant positive effect on arsenic. Civil liberties has a significant negative effect on cadmium and mercury.

Thus, according to the results, evidence for an inverted-U relationship between income and environmental degradation were found for at least two out of the four IV specifications for

[9] For chemical oxygen demand, only the cubic term has a significant coefficient out of all the GDP terms.

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. The 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.

The results also provide some evidence for the importance of political institutions. The political indicators have a statistically significant effect on water pollution in at least two IV specifications for five out of eleven pollutants. The direction of the effect varies by pollutant and political variable. For some pollutants, political institutions have a positive effect on water pollution; for others, political institutions have a negative effect. For some pollutants, the two political variables have opposite effects on water pollution.

7 Conclusions

This study is suggestive of a likely shape of the water quality-income relationship and also of the importance of political institutions. The key innovation is the use of instrumental variables and country-specific fixed effects in our econometric methodology. Evidence for an inverted-U relationship between income and environmental degradation were found for seven out of eleven water pollutants. Political institutions have a significant effect on environmental degradation for five out of eleven water pollutants.

For international donors trying to improve the lives of the world's poor, while improving the environment they inhabit, this study offers a few implications. First, at least with some of the water pollutants, political institutions matter. Second, this study suggests that water quality may affect income to a significant extent, as evidenced by the Durbin-Wu-Hausman tests and the instrumental variables regressions. If accurate, then this study provides more evidence for why water supplies should be protected and cleaned—it may help countries gain more income. Finally, the relationships between environmental degradation, income and political institutions found in this study suggest that those in the field and academia should be open to relationships between these key components of sustainable development.

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TABLE 1a. Summary statistics for water pollutants

Variable	# obs	# countries	mean	s.d.	min	max
Biological Oxygen Demand (mg/l)	2422	55	3.96	12.01	0.00	240.16
Chemical Oxygen Demand (mg/l)	1883	51	24.37	57.19	0.00	948.39
Dissolved Oxygen (mg/l)	2890	67	8.42	2.97	0.00	84.67
Nitrate (mg/l)	1214	38	1.13	2.59	0.00	22.60
Total Arsenic (mg/l)	957	27	0.01	0.03	0.00	0.43
Total Cadmium (mg/l)	1248	39	0.02	0.09	0.00	1.00
Total Lead (mg/l)	1053	29	0.03	0.09	0.00	1.60
Total Mercury (μg/l)	1230	39	0.30	0.81	0.00	16.17
Total Nickel (mg/l)	661	18	0.01	0.03	0.00	0.22
Total Coliforms (mg/l)	2075	41	3.58E4	1.12E5	0.00	1.00E6
Fecal Coliform (count/100 ml)	2075	56	2.58E4	1.14E5	0.00	1.00E6

Note: The data span the years 1979 to 1999.

TABLE 1b. Summary statistics for explanatory, control and instrumental variables

Variable	# obs	mean	s.d.	min	max
Explanatory variables					
Political rights (1 = best to 7 = worst)	2674	2.58	2.04	1	7
Civil liberties (1 = best to 7 = worst)	2674	2.83	1.91	1	7
GDP per capita, PPP (1000 constant 2000 international $)	2724	12.50	9.18	0.50	40.17
Control variables					
Water temperature (degrees Celsius)	2838	16.77	8.15	0.00	44.67
Manufacturing, value added (% of GDP)	1896	18.95	4.96	4.28	40.48
Population density (people per sq km)					
Instruments					
Age dependency ratio (dependents to working-age population)	2851	0.61	0.15	0.42	1.12
Total debt service (% of GNI)	1290	4.83	3.61	0.05	18.37

Note: The data span the years 1979 to 1999.

Figure 1.

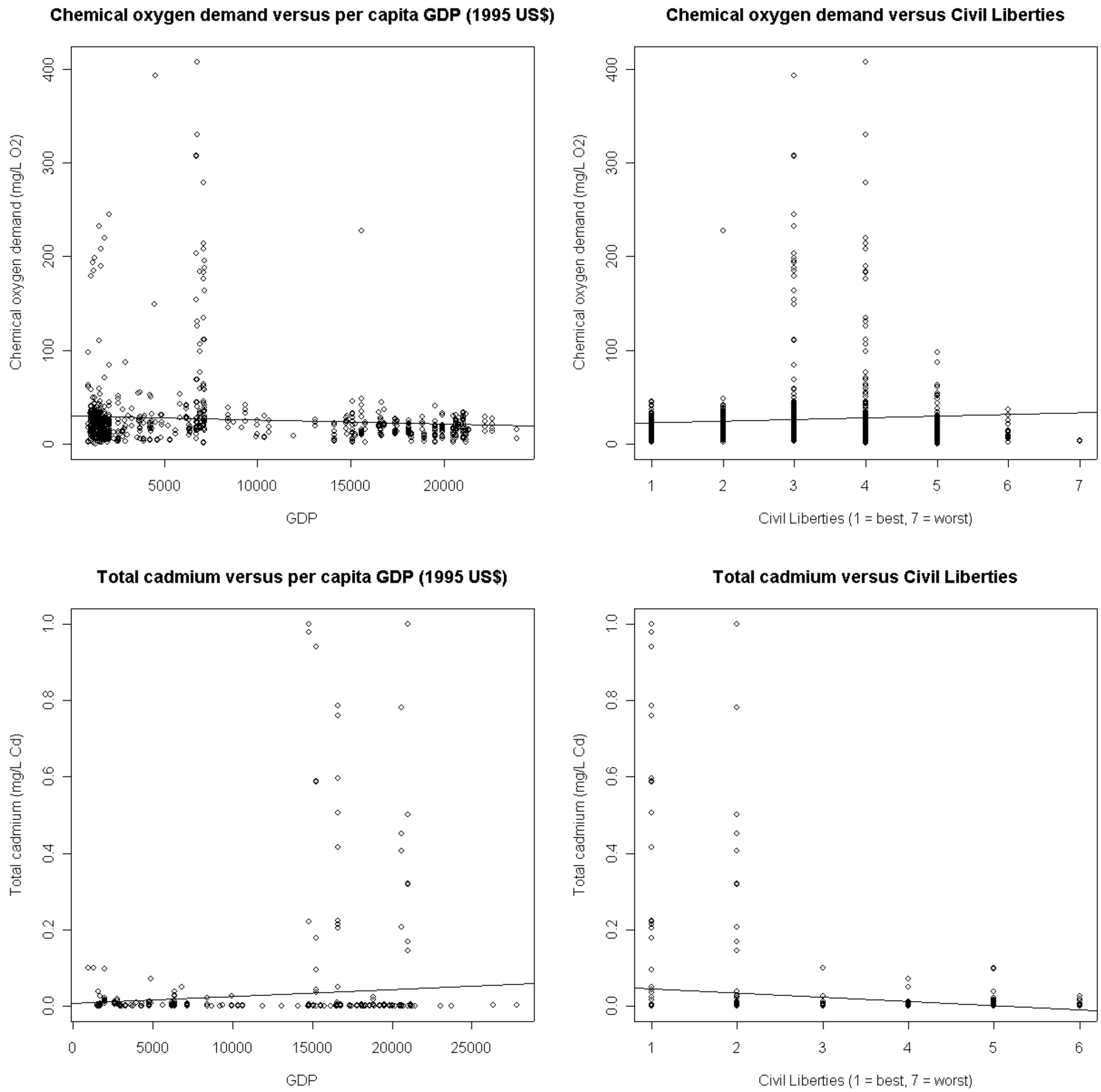
Chemical oxygen demand versus per capita GDP (1995 US$)
Chemical oxygen demand (mg/L O2)
GDP
Chemical oxygen demand versus Civil Liberties
Chemical oxygen demand (mg/L O2)
Civil Liberties (1 = best, 7 = worst)
Total cadmium versus per capita GDP (1995 US$)
Total cadmium (mg/L Cd)
GDP
Total cadmium versus Civil Liberties
Total cadmium (mg/L Cd)
Civil Liberties (1 = best, 7 = worst)

Table 2. Graphical relationships and characteristics of pollutants

	Relationship with			Characteristics		
	Political Rights	**Civil Liberties**	**Per Capita GDP**	**Classification**	**Natural Occurrence**	**Source of Pollution**
	Decreasing					
Chemical Oxygen Demand	decreasing	inverted-U	decreasing/inverted-U	Organic Matter	N/A	Waste-water effluent
Total Arsenic	decreasing	decreasing	decreasing/inverted-U	Inorganic contaminants	Not uncommon	Industrial discharge or insecticide application
Dissolved Oxygen	decreasing	decreasing	decreasing	Organic Matter	From atmosphere eand photosynthetic activity	Measure of waste-treatment process and generally surface-water quality
Total Lead	decreasing	decreasing	decreasing	Inorganic contaminants	1 to 50 ug/l	Atmospheric input from use in leaded gasoline or smelting; industria and mine or smelte roperations; lead salts; printing and dyeing; explosives; lead pipes
Total Nickel	decreasing	decreasing	decreasing	Inorganic contaminants	Normally a few ug/l	Burning fossil fuels and mining
Fecal Coliform	decreasing	decreasing	decreasing	Microbial Pollution	Very low	Fecal matter
	Increasing					
Total Cadmium	increasing	increasing	increasing/inverted-U	Inorganic contaminants	Below 1 ug/l	Mining, smelting; wastes fro melectroplating plants, pigment works, textile and ehcmical industries; metal and plastic pipes
Nitrate	increasing	increasing	increasing	Nutrients	Minute amounts	Chemical fertilizers from cultivated land, drainage from livestock feed lots
	None					
Biological Oxygen Demand	none	none	none	Organic Matter	N/A	Waste-water effluent
Total Mercury	none	none	none	Inorganic contaminants	Generally low	Chlora-alkali plants using electrolytic cells; electronics and electrical, explosives, photography, pesticide and preservative, chemical and petrochemical catalysis, and ussers of the above indutrial products
Total Coliform	none	none	none	Microbial Pollution	Very low	Fecal matter, as well as other contaminants

Table 3: First stage regressions

Dependent variable is per capita GDP, PPP (constant 2000 international $ / 10E3)	(1)	(2)
age dependency ratio (dependents to working-age population)	-0.01	0.00
	(0.61)	(0.61)
total debt service (% of GNI)	0.17 ***	0.18 ***
	(0.02)	(0.02)
political rights (1 = best to 7 = worst)	0.09	
	(0.08)	
civil liberties (1 = best to 7 = worst)	-0.80 ***	
	(0.10)	
political rights lagged (1 = best to 7 = worst)		0.07
		(0.07)
civil liberties lagged (1 = best to 7 = worst)		-0.78 ***
		(0.10)
population density (people per sq km)	-0.004 ***	-0.003 ***
	(0.000)	(0.000)
temperature (degrees Celsius)	-0.07 ***	-0.07 ***
	(0.01)	(0.01)
year	0.03 *	0.03 **
	(0.01)	(0.01)
manufacturing, value added (% of GDP)	0.19 ***	0.19 ***
	(0.01)	(0.01)
constant	-52.08 *	-55.29*
	(22.78)	(22.82)
p-value (Pr > F)	0.00 ***	0.00 ***
Adjusted R^2	0.57	0.57
# observations	1107	1107
joint test of instruments		
F statistic	39.11	41.12
p-value	0.00 ***	0.00 ***

Note: Standard errors are in parentheses.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4a. Regression Results: Biological oxygen demand

Dependent variable is biological oxygen demand	OLS (1)	IV GMM (2)	IV GMM (3)	COND IV (4)	IV FE (5)
per capita GDP (/ 10E3)	1.00	-12.51 ***	-12.52 ***	-16.24 ***	-2.75
	(1.06)	(2.39)	(2.40)	(4.36)	(20.93)
per capita GDP squared (/10E7)	-0.86	29.87 ***	29.89 ***	31.48 ***	15.70
	(0.70)	(5.48)	(5.50)	(8.33)	(50.58)
per capita GDP cubed (/10E11)	0.18	-17.85 ***	-17.76 ***	-17.55 ***	-8.98
	(0.13)	(3.31)	(0.46)	(4.42)	(30.45)
political rights	-0.55	-0.49		-0.27	0.02
(1 = best to 7 = worst)	(0.55)	(0.46)		(0.52)	(0.71)
civil liberties	0.81	1.32		0.54	-0.36
(1 = best to 7 = worst)	(0.86)	(0.79)		(0.77)	(2.53)
political rights lagged			-0.54		
(1 = best to 7 = worst)			(0.46)		
civil liberties lagged			1.43		
(1 = best to 7 = worst)			(0.80)		
p-value (Pr > F or Pr > χ^2)	0.19	0.00 ***	0.00 ***	0.00 ***	0.00 ***
# observations	1483	925	925	925	925
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.93				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.01 *	0.01 *		
Turning points					
Peak (constant 2000 international $)	7652	8362	8434	8194	10702
Trough (constant 2000 international $)	24199	2794	2786	3764	954

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4b. Regression Results: Chemical oxygen demand

	Dependent variable is chemical oxygen demand				
	OLS	IV GMM	IV GMM	COND IV	IV FE
	(1)	(2)	(3)	(4)	(5)
per capita GDP (/ 10E3)	13.57	-40.02 **	-38.55 **	1.31	89.14
	(8.13)	(14.83)	(14.73)	(14.70)	(81.39)
per capita GDP squared (/10E7)	-10.10	150.62 ***	147.42 ***	31.87	-226.43
	(5.68)	(32.94)	(32.71)	(25.14)	(135.59)
per capita GDP cubed (/10E11)	1.91	-113.37 ***	-111.30 ***	-26.66 *	123.82 *
	(1.01)	(21.49)	(21.31)	(12.78)	(59.38)
political rights	-0.82	-4.85		1.14	0.60
(1 = best to 7 = worst)	(3.19)	(2.67)		(2.16)	(2.88)
civil liberties	1.01	-1.81		-4.63	-9.42
(1 = best to 7 = worst)	(1.01)	(3.25)		(2.83)	(5.59)
political rights lagged			-5.79 *		
(1 = best to 7 = worst)			(2.88)		
civil liberties lagged			-0.35		
(1 = best to 7 = worst)			(3.38)		
p-value (Pr > F or Pr > χ^2)	0.01 **	0.00 ***	0.00 ***	0.00 ***	0.00 ***
# observations	1270	912	912	912	912
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.00 **				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.17	0.14		
Turning points					
Peak (constant 2000 international $)	9032	7228	7234	8170	2468
Trough (constant 2000 international $)	26221	1629	1596	-200	9723

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4c. Regression Results: Dissolved oxygen

	Dependent variable is dissolved oxygen				
	OLS	IV GMM	IV GMM	COND IV	IV FE
	(1)	(2)	(3)	(4)	(5)
per capita GDP (/ 10E3)	0.13	-0.87	-0.88	-0.47	-2.21
	(0.26)	(0.77)	(0.77)	(0.72)	(4.31)
per capita GDP squared (/10E7)	0.06	0.84	0.84	0.97	12.13
	(0.18)	(1.69)	(1.69)	(1.38)	(8.78)
per capita GDP cubed (/10E11)	-0.02	0.66	0.67	-0.48	-9.89
	(0.03)	(1.04)	(1.04)	(0.72)	(5.20)
political rights	-0.05	-0.16		-0.08	0.20
(1 = best to 7 = worst)	(0.16)	(0.16)		(0.13)	(0.26)
civil liberties	-0.30 *	0.27		-0.22	0.83
(1 = best to 7 = worst)	(0.17)	(0.27)		(0.18)	(0.46)
political rights lagged			-0.16		
(1 = best to 7 = worst)			(0.17)		
civil liberties lagged			0.28		
(1 = best to 7 = worst)			(0.27)		
p-value (Pr > F or Pr > χ^2)	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***
# observations	1786	1089	1089	1089	1089
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.00 ***				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.16	0.16		
Turning points					
Peak (constant 2000 international $)	27795	-12112	-12005	10305	7132
Trough (constant 2000 international $)	-7795	3628	3647	3167	1044

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4d. Regression Results: Nitrate

	Dependent variable is nitrate				
	OLS	IV GMM	IV GMM	COND IV	IV FE
	(1)	(2)	(3)	(4)	(5)
per capita GDP (/ 10E3)	-0.07	-3.84	-3.91	-0.30	-7.60 **
	(0.14)	(3.97)	(4.29)	(0.76)	(2.97)
per capita GDP squared (/10E7)	0.02	8.21	8.34	0.34	7.56
	(0.13)	(8.59)	(9.28)	(1.38)	(4.79)
per capita GDP cubed (/10E11)	-0.00	-4.38	-4.44	-0.23	-1.68
	(0.03)	(4.53)	(4.89)	(0.69)	(1.91)
political rights	-0.31	-0.57		-0.38 *	-1.44 **
(1 = best to 7 = worst)	(0.24)	(0.44)		(0.17)	(0.53)
civil liberties	0.34	1.01		0.49 *	0.07
(1 = best to 7 = worst)	(0.29)	(0.83)		(0.20)	(0.35)
political rights lagged			-0.52		
(1 = best to 7 = worst)			(0.46)		
civil liberties lagged			0.98		
(1 = best to 7 = worst)			(0.88)		
p-value (Pr > F or Pr > χ^2)	0.00 ***	0.08	0.10	0.00 ***	0.00 ***
# observations	671	297	297	297	297
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.12				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.21	0.26		
Turning points					
Peak (constant 2000 international $)		9381	9400		23614
Trough (constant 2000 international $)	17500	3115	3123		6386

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4e. Regression Results: Arsenic

	Dependent variable is arsenic				
	OLS	IV GMM	IV GMM	COND IV	IV FE
	(1)	(2)	(3)	(4)	(5)
per capita GDP (/ 10E3)	-0.01	-0.04 **	-0.04 **	-0.31 ***	-0.17 *
	(0.02)	(0.02)	(0.02)	(0.05)	(0.07)
per capita GDP squared (/10E7)	0.01	0.09 **	0.10 **	0.42 ***	0.33 **
	(0.01)	(0.03)	(0.04)	(0.08)	(0.11)
per capita GDP cubed (/10E11)	-0.00	-0.05 **	-0.05 **	-0.20 ***	-0.14 ***
	(0.00)	(0.02)	(0.02)	(0.04)	(0.04)
political rights	0.01	0.00		-0.00	0.03 ***
(1 = best to 7 = worst)	(0.01)	(0.00)		(0.01)	(0.01)
civil liberties	-0.02	0.00		-0.02 *	-0.01
(1 = best to 7 = worst)	(0.02)	(0.00)		(0.01)	(0.01)
political rights lagged			0.01		
(1 = best to 7 = worst)			(0.01)		
civil liberties lagged			0.00		
(1 = best to 7 = worst)			(0.00)		
p-value (Pr > F or Pr > χ^2)	0.00 ***	0.00 ***	0.00 **	0.00 ***	0.00 ***
# observations	512	209	209	209	209
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.00 ***				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.08	0.12		
Turning points					
Peak (constant 2000 international $)		9055	10883		12468
Trough (constant 2000 international $)	5000	2945	2450		3246

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4f. Regression Results: Cadmium

	Dependent variable is cadmium				
	OLS (1)	IV GMM (2)	IV GMM (3)	COND IV (4)	IV FE (5)
per capita GDP (/ 10E3)	0.02	-0.10 ***	-0.10 ***	-0.09 ***	-0.04 *
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
per capita GDP squared (/10E7)	-0.01	0.20 ***	0.19 ***	0.14 ***	0.04 *
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
per capita GDP cubed (/10E11)	0.00	-0.10 ***	-0.10 ***	-0.07 ***	-0.02 *
	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
political rights	0.04 **	0.01 ***		0.01 ***	0.00
(1 = best to 7 = worst)	(0.01)	(0.00)		(0.00)	(0.00)
civil liberties	-0.05 *	-0.00		-0.01 ***	-0.01 **
(1 = best to 7 = worst)	(0.02)	(0.00)		(0.00)	(0.00)
political rights lagged			0.01 ***		
(1 = best to 7 = worst)			(0.00)		
civil liberties lagged			-0.00		
(1 = best to 7 = worst)			(0.00)		
p-value (Pr > F or Pr > χ^2)	0.29	0.00 ***	0.00 ***	0.00 ***	0.00 ***
# observations	610	261	261	261	261
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.10				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.00 ***	0.00 ***		
Turning points					
Peak (constant 2000 international $)	10000	10000	8937	7927	
Trough (constant 2000 international $)		3333	3730	5407	

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4g. Regression Results: Lead

	Dependent variable is lead				
	OLS	IV GMM	IV GMM	COND IV	IV FE
	(1)	(2)	(3)	(4)	(5)
per capita GDP (/ 10E3)	0.03	-0.19	-0.24 **	-0.55 ***	-0.17
	(0.06)	(0.10)	(0.09)	(0.08)	(0.14)
per capita GDP squared (/10E7)	-0.02	0.56 ***	0.61 ***	0.89 ***	0.24
	(0.03)	(0.16)	(0.16)	(0.14)	(0.20)
per capita GDP cubed (/10E11)	0.00	-0.37 ***	-0.38 ***	-0.45 ***	-0.09
	(0.00)	(0.09)	(0.08)	(0.07)	(0.08)
political rights	0.06	0.04 *		0.04	-0.01
(1 = best to 7 = worst)	(0.04)	(0.02)		(0.02)	(0.02)
civil liberties	-0.03	-0.00		0.02	-0.03
(1 = best to 7 = worst)	(0.04)	(0.03)		(0.03)	(0.02)
political rights lagged			0.04 *		
(1 = best to 7 = worst)			(0.02)		
civil liberties lagged			-0.01		
(1 = best to 7 = worst)			(0.02)		
p-value (Pr > F or Pr > χ^2)	0.02 *	0.00 ***	0.00 ***	0.00 ***	0.00 ***
# observations	500	247	247	247	247
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.13				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.00 ***	0.00 ***		
Turning points					
Peak (constant 2000 international $)	7500	7932	8104	8242	12895
Trough (constant 2000 international $)		2158	2598	4943	4883

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4h. Regression Results: Mercury

	Dependent variable is mercury				
	OLS	IV GMM	IV GMM	COND IV	IV FE
	(1)	(2)	(3)	(4)	(5)
per capita GDP (/ 10E3)	0.22	0.02	0.08	-0.21	-1.46
	(0.15)	(0.47)	(0.47)	(1.44)	(0.90)
per capita GDP squared (/10E7)	-0.13	-0.63	-0.79	0.50	1.49
	(0.10)	(0.89)	(0.88)	(1.55)	(1.21)
per capita GDP cubed (/10E11)	0.02	0.48	0.59	-0.12	-0.46
	(0.02)	(0.52)	(0.50)	(0.75)	(0.49)
political rights	0.11	-0.02		0.19	-0.37 ***
(1 = best to 7 = worst)	(0.12)	(0.18)		(0.10)	(0.12)
civil liberties	-0.10	-0.34		-0.28 **	-0.24 **
(1 = best to 7 = worst)	(0.14)	(0.19)		(0.10)	(0.10)
political rights lagged			0.07		
(1 = best to 7 = worst)			(0.16)		
civil liberties lagged			-0.44 *		
(1 = best to 7 = worst)			(0.17)		
p-value (Pr > F or Pr > χ^2)	0.24	0.00 ***	0.00 ***	0.00 ***	0.00 ***
# observations	597	255	255	255	255
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.44				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.88	0.97		
Turning points					
Peak (constant 2000 international $)	11529	162	539	25489	14080
Trough (constant 2000 international $)	31805	8588	8388	2289	7514

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4i. Regression Results: Nickel

	Dependent variable is nickel				
	OLS (1)	IV GMM (2)	IV GMM (3)	COND IV (4)	IV FE (5)
per capita GDP (/ 10E3)	0.01 *	0.04	0.07	0.16 ***	---
	(0.006)	(0.05)	(0.05)	(0.06)	
per capita GDP squared (/10E7)	-0.01	-0.14	-0.18	-0.22 *	0.27 ***
	(0.00)	(0.15)	(0.15)	(0.09)	(0.03)
per capita GDP cubed (/10E11)	0.00	0.10	0.12	0.10 *	-0.20 ***
	(0.00)	(0.09)	(0.08)	(0.05)	(0.02)
political rights	0.01 *	0.01		0.00	0.02
(1 = best to 7 = worst)	(0.005)	(0.01)		(0.01)	(0.01)
civil liberties	-0.00	-0.01		0.01	0.00
(1 = best to 7 = worst)	(0.01)	(0.02)		(0.01)	(0.01)
political rights lagged			0.00		
(1 = best to 7 = worst)			(0.02)		
civil liberties lagged			-0.01		
(1 = best to 7 = worst)			(0.02)		
p-value (Pr > F or Pr > χ^2)	0.00 ***	0.00 ***	0.00 ***	0.00 ***	0.00 ***
# observations	323	111	111	111	111
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.32				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.00 ***	0.00 ***		
Turning points					
Peak (constant 2000 international $)	5000	1761	2643	6667	9000
Trough (constant 2000 international $)		7573	7357	8000	0

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4j. Regression Results: Total coliforms

	Dependent variable is total coliforms				
	OLS	IV GMM	IV GMM	COND IV	IV FE
	(1)	(2)	(3)	(4)	(5)
per capita GDP (/ 10E3)	1.86E4 *	9.19E4 *	8.52E4	-3.03E4	-3.05E5
	(0.83E4)	(4.26E4)	(4.66E4)	(3.52E4)	(1.60E5)
per capita GDP squared (/10E7)	-9.74E3	-1.40E5	-1.21E5	1.09E5	5.79E5 *
	(4.85E3)	(0.90E5)	(0.96E5)	(0.66E5)	(2.61E5)
per capita GDP cubed (/10E11)	1.48E3	5.57E4	4.35E4	-7.13E4 *	-2.48E5 *
	(0.78E3)	(4.47E4)	(4.64E4)	(3.40E4)	(1.02E5)
political rights	3.23E3	-1.25E4		-3.73E3	-1.43E3
(1 = best to 7 = worst)	(12.16E3)	(0.90E4)		(7.30E3)	(13.34E3)
civil liberties	7.87E3	1.40E4		1.88E4	-3.19E3
(1 = best to 7 = worst)	(14.66E3)	(1.97E4)		(1.05E4)	(14.67E3)
political rights lagged			-1.55E4		
(1 = best to 7 = worst)			(0.93E4)		
civil liberties lagged			1.77E4		
(1 = best to 7 = worst)			(2.00E4)		
p-value (Pr > F or Pr > χ^2)	0.11	0.00 ***	0.00 ***	0.00 ***	0.00 ***
# observations	856	665	665	665	665
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.08				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.05 *	0.11		
Turning points					
Peak (constant 2000 international $)	14043	4480	4724	8531	12861
Trough (constant 2000 international $)	29831	12277	13820	1660	3188

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.

Table 4k. Regression Results: Fecal coliform

	Dependent variable is fecal coliform				
	OLS (1)	IV GMM (2)	IV GMM (3)	COND IV (4)	IV FE (5)
per capita GDP (/ 10E3)	5.34E3	1.43E5 ***	1.43E5 ***	1.47E5 **	-2.57E5 *
	(9.51E3)	(0.31E5)	(0.30E5)	(0.49E5)	(1.21E5)
per capita GDP squared (/10E7)	-1.36E3	-2.28E5 ***	-2.30E5 ***	-2.40E5 **	3.49E5
	(8.05E3)	(0.61E5)	(0.61E5)	(0.87E5)	(2.34E5)
per capita GDP cubed (/10E11)	72.83	9.56E4 *	9.70E4 *	1.12E5 *	-1.26E5
	(1610.78)	(3.85E4)	(3.80E4)	(0.45E5)	(1.45E5)
political rights	2.33E3	484.79		-870.68	1.22E4
(1 = best to 7 = worst)	(13.10E3)	(8512.03)		(7132.25)	(0.98E4)
civil liberties	1.47E4	360.52		1.22E4	-1.27E3
(1 = best to 7 = worst)	(1.31E4)	(15942.28)		(1.04E4)	(18.23E3)
political rights lagged			734.75		
(1 = best to 7 = worst)			(8013.30)		
civil liberties lagged			530.22		
(1 = best to 7 = worst)			(15279.77)		
p-value (Pr > F or Pr > χ^2)	0.00 **	0.00 ***	0.00 ***	0.00 ***	0.00 ***
# observations	1383	906	906	906	906
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity before clustering (H0: constant variance)					
p-value	0.00 ***				
Durbin-Wu-Hausman test of endogeneity of per capita GDP (H0: per capita GDP is exogenous)					
p-value	0.02 *				
Hansen overidentification test (H0: instruments are uncorrelated with error term)					
p-value		0.07	0.07		
Turning points					
Peak (constant 2000 international $)	24424	4298	4253	4446	13387
Trough (constant 2000 international $)	100067	11602	11555	9839	5079

Notes: Standard errors are in parentheses. Controls include population density, water temperature, year and manufacturing. For the OLS specification, standard errors are clustered by country. For the IV GMM and IV FE specifications, per capita GDP, per capita GDP squared and per capita GDP cubed are instrumented with age dependency ratio, total debt service, age dependency ratio squared, total debt service squared, age dependency ratio cubed and total debt service cubed. For the IV GMM specifications, a robust weighting matrix that is optimal when the error term is heteroskedastic is used. For the COND IV specification, per capita GDP is instrumented with age dependency ratio and total debt service, the LIML estimate and a coverage-corrected standard error is reported for the coefficient on per capita GDP. For the IV FE specification, country-level fixed effects are included.
Significance codes: * 5% level, ** 1% level, and *** 0.1% level.