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THE ENVIRONMENTAL KUZNETS CURVE: EXPLORING A FRESH SPECIFICATION

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ABSTRACT

Using a new specification, we reanalyze the data on worldwide environmental quality investigated by Gene Grossman and Alan Krueger in a well-known paper on the environmental Kuznets curve (which postulates an inverse U shaped relationship between income level and pollution). The new specification enables us to draw conclusions from fixed effects estimation. In general, we find support for the environmental Kuznets curve for some pollutants and for its rejection in other cases. The fresh specification offers some promise for analysis of such phenomena.

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Introduction

Since most phenomena understood as pollution tend to be related either to industrial production or consumption that come with high levels of material prosperity, one might expect a generally positive link between a country's income level and environmental pollution. This would be true even if environmental externalities were continually accounted for optimally in the usual economist's sense of balancing marginal benefit of regulation with marginal cost in non-environmental benefits foregone. At least two offsetting effects on the demand side of the system might be posited as people get richer. First, they may be prepared to pay more for environmental quality (environmental amenity is a normal good). Second, the composition of the consumption bundle might shift in the direction of less pollution-intensive goods, such as digitally recorded entertainment. There may also be offsetting effects on the supply side. The

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high wages associated with high income might make pollution-intensive goods relatively expensive to produce. The technological change that generates higher incomes might be biased in favor of less pollution-intensive goods (like software services). General equilibrium effects in the world trading system might also give rise to systematic effects on the location of pollution-intensive production activities in countries at different stages of development.

A priori theory thus gives us no particularly clear prediction about the association between differences in income levels and pollution, either across countries or over time. The idea that, as an empirical matter, there is a tendency on balance for pollution to worsen as economies develop and then to improve as economies become rich, has come to be known as the environmental Kuznets curve (EKC) hypothesis. The term refers by analogy to the "inverted U" relationship between the level of economic development and the degree of income inequality pointed out by Simon Kuznets (1955) in his 1954 presidential address to the American Economic Association. Brought to prominence by the World Bank's 1992 World Development Report and papers prepared in connection with that report, a substantial literature has developed, debating the theoretical basis for such a regularity in environmental quality and the merits of the evidence relating thereto.[1]

This paper aims to add to the list an exploration that uses a new model specification and approach to estimation. The approach seems rather well adapted to the investigation of the environmental Kuznets curve, with regard to which the available evidence consists of a relatively

[1] See, in addition to Grossman and Krueger (1993, 1995), Andreoni and Levinson (1998), Antweiler, Copeland and Taylor, (1998), Arrow et al (1995), Beckerman (1992), Cropper and Griffiths (1994), Ekins (1997), Harbaught, Levinson and Wilson (2000), Hilton and Levinson (1998), Kahn (1998), Selden and Song (1994, 1995), Shafic and Bandyopadhyay (1992), Stern, Common and Barbier (1996), Torras and Boyce (1998).

short panel of observations from economies at widely diverse levels of development and with idiosyncratic features that may be expected to have a significant influence on the environmental variables of interest.

These are the characteristics of the data used in an influential paper (1995) by Princeton's Gene Grossman and Alan Krueger (hereinafter GK).[2] In their pioneering study they analyzed readings over a period of at most twelve years (water pollutants within the span 1979-1990 and air pollutants within the span 1977-1988) from instruments measuring levels of fourteen different water and air pollutants at multiple locations in sixty-six countries. Although they found considerable variation among different pollutants, GK concluded there was a detectable inverted U relationship between a country's income and the levels of most of the pollutants they examined. Relatively low and high levels of income tend to be associated with relatively low levels of pollution. Pollution tends to be highest at intermediate income levels.

GK made no claim to have tested a structural model of the determinants of pollution. Their finding is, however, most easily understood and described in structural, dynamic terms: A poor country does not have enough industrial activity to cause significant pollution. As the country develops economically, pollution grows. Furthermore, as its industrial potential improves, it becomes an attractive location for high-polluting industrial production. At some point, the opposing forces mentioned increase in importance. The pollution problem becomes bad enough to stir collective action to control it; at the same time, incomes rise enough for the country's residents to be prepared to pay for it. Simultaneously, there is a shift toward low-polluting products, so that, beyond that point, pollution falls as income grows.

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[2] Grossman and Krueger (1993) applied a similar method to data confined to air pollution.

The GK finding attracted widespread interest and controversy.[3] The immediate impetus for this paper is a somewhat serendipitous development of a novel specification of the Kuznets curve that we think has some attractive properties. Using the data and programs kindly provided by GK, we have applied the new specification to a reanalysis of the relationship between income and pollution. Our specification augments theirs in data description. The question is whether, or rather, for which pollutants, there is a signal in the data of some sort of inverted U. The spirit of our analysis, then, is to draw a weight-of-the-evidence conclusion from the data examined by GK. While we use the tools of hypothesis testing along the way, our approach is rather that of exploratory data analysis.

The data consist of observations of a variety of pollution indicators at several locations in each of several countries over several years. The countries differ in their levels of economic development, presenting the key variation of interest. The straight cross-sectional evidence poses, however, a long-standing econometric problem (recalling the cross section vs. time series studies of the consumption-income relationship). That is, the countries located at different levels of income might have inherently different, unobserved, characteristics. If presently rich countries happened to have the property of low pollution, a positive true relationship between income growth and pollution would be masked in the cross section. The same goes for presently poor or middle-income countries.

The basic ways to deal with this problem are to use fixed effects or random effects methods to analyze the relationship between pollution and income found in the panel data. The

[3] See the special issue of Environment and Development Economics, February 1996; see also Antweiler, Copeland and Taylor (1998), Torras and Boyce (1998), Stern, Common and Barbier (1996).

fixed effects approach amounts to running a separate regression for each location on the relationship between income and pollution, with the requirement that the relationship be the same, up to the location-specific constant term, everywhere. (In principle, similar logic can be extended to the slopes or higher-order terms.) Because it effectively adds a parameter for each measurement station, fixed effects estimation imposes a severe cost in degrees of freedom. If the location-specific influence can be itself assumed to be appropriately random, degrees of freedom are saved and are exploited by random effects methods.[4]

In terms of the notation used in the present paper, the specification used by GK (1995) is given by

(1) $$P_{it} = y_{it}\beta_1 + y_{it}^2\beta_2 + y_{it}^3\beta_4 + \overline{y}_{it-}\beta_4 + \overline{y}_{it-}^2\beta_5 + \overline{y}_{it-}^3\beta_6 + X_{it}^{'}\beta_7 + \varepsilon_{it}$$

where

$i =$ measurement station
$P_{it} =$ measure of pollution level at that station
$y_{it} =$ per capita GDP in the country in which the station is located
$\overline{y}_{it-} =$ average GDP per capita over the prior three years
$X_{it} =$ a vector of covariates

Our reanalysis of the data brings to the estimation a fresh specification, whereby each country's income level (*y*) and growth rate (*g*) are reduced to single numbers (fixed cross-sectionally). The trend rate of increase in pollution is assumed to depend on these two characteristics of an economy.

[4] In their work on air pollution Grossman and Krueger (1993) used both methods. The relevant coefficients indicating the EKC were significant by standard measures only for the random effects estimation.

The Basic BSS Specification

What we refer to as the GK functional form expresses the level of pollutant in a country as a function of a cubic of the country's current and lagged per capita real GDP ("income"), plus time and various controls. (Particular interest attaches to the quadratic term in income, which gives rise potentially to the characteristic inverted U shape.)

We arrived at the alternative functional form, which we call the BSS form, from the thought that the Kuznets curve phenomenon, if it exists, might relate more to the long-term growth trends in countries at different levels of development than to year-to-year variations in income. This led us to the following schematic model (2):

(2) $$\frac{dP}{dt} = \alpha(y - y^*)g\,,$$

where

- *P* refers to the level of pollutant registered at a particular location (mean concentration (in water) or median concentration (in air)), [5]
- *y* and *g* are the level and rate of growth, respectively, of income in the country in question over the reference period,
- *t* is time measured in years during the reference period and
- α and *y** are constants (to be estimated in the empirical application) specific to the pollutant.

Note that the schematic omits an exogenous time trend and other controls that one might add.

[5] Henceforth, we use "mean" to refer to both these measures.

For the cross-sectional estimation of the parameters of (2), we, in effect integrate it to obtain (3)

(3) $$P = \alpha(y - y^*)gt + \beta \text{ ,}$$

where β is a constant of integration of (2).

Equation (2) describes a locally linear relationship between pollution and time at the location in question. The trend rate of increase in pollution depends upon the level of development (measured by y) of the country in which the measuring station is located and the rate of growth, g, of that country's economy. If α is less than zero, then for y less than y^*, the more rapidly a country is growing, the more rapidly is pollution increasing. For y greater than y^*, more rapidly a country is growing, the more rapidly is pollution decreasing. (If a country's rate of growth is negative, pollution will be trending down if the country is poor, trending up if the country is rich.) Thus, y^* in this formulation indicates the location (in terms of development) of the top of the inverted U. A cross section snapshot of otherwise identical countries growing at the same positive rate (but having started at different times, so as to reach the various income levels at the time of the snapshot) would look like the graph shown in Figure 1. Alternatively, it could be thought of as the pollution path of a country with constant growth as it gets richer through time.

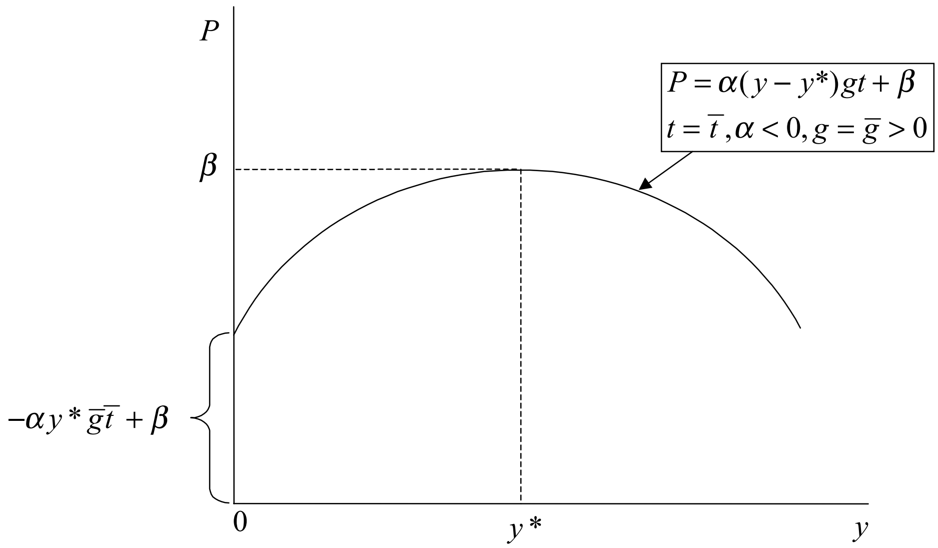

Figure 1. Cross Section at Time $\bar{t}$ of Economies Growing Constantly at the Same Rate, $\bar{g}$, with Different Starting Dates

Taking the GK specification as the more typical approach, we would note two features that distinguish the BSS approach:

- The income data are captured in two aggregates (average level and average growth rate); the GK specification uses actual year-by-year income (albeit while including lagged income variables that do some of the same smoothing as do our aggregates).
- The GK structure is a cubic in income (or more generally a polynomial); the BSS structure maps into a function of the logarithm of income and the product of income and its log.

To explain the latter point, suppose an economy were growing at a constant rate, $y = y_0 e^{gt}$. We could then invert the growth function to express time as a function of income, $t = (\ln y - \ln y_0)/g$. Substituting in to the BSS form yields $P = \alpha(y - y^*)(\ln y - \ln y_0) + \beta$. Differences in conclusions we may reach about the Kuznets curve from those of GK presumably trace to these differences in the approaches.

The Cubic BSS Specification

Although our very parsimonious functional form does seem to give us the ability to detect the presence or absence of the inverted U phenomenon in the empirical record, we follow GK in looking as well at the somewhat more flexible cubic formulation (4) (expressed in its integrated form),

(4) $$P = \alpha(y - y^*)(y - y^{**})gt + \beta .$$

GK concluded that for some pollutants concentration reached a peak at some level of income but then at higher levels the concentration appeared to trend up again. In specification (4), this pattern would be implied by a positive estimated value of α, with y^* indicating the top of the U and y^{**} indicating the income level at which pollution would tend up again.

Anticipating the Empirical Results

In spite of the heavy information requirements imposed by fixed effects estimation, perhaps because the BSS specification of the U-curve is so simple, we obtain coefficient estimates with sufficient statistical significance to draw conclusions about the Kuznets curve hypothesis by standard hypothesis testing standards. For the basic model, coefficients on *ygt* and *yt* as regressors together imply the position of the turning-point income value and whether the implied curve is inverted or not. In a very general sense, the inverted U-curve hypothesis can be tested by examining the properties of these coefficients. Assessing the coefficients derived from fixed effects estimation for statistical significance in the usual way, our results suggest that for some pollutants (arsenic, COD, dissolved oxygen, lead, smoke, SO_2), the effect is there; for others (coliform, nickel, nitrates) there exists and effect but not in the expected direction. (For still others, the hypothesis of no relationship cannot be rejected).

As another way to assess the evidence in the regression relating to the environmental Kuznets curve we have explored the question whether the implied pollution-income relationship reaches a peak in the framework of income and growth levels within the span of historical experience. If the inverted U hypothesis held, one would expect the time derivative of pollution predicted by our formulation to be positive for a country at a low level of income and negative for one at a high level of income, assuming both countries are growing at positive rate. On a bar graph with income categories on the horizontal axis, we would expect to see the bars march down from left to right, from positive to more and more negative (with the possibility of turning positive at high levels of income for the cubic version of the hypothesis). Using values of the income levels ($1000, $5000, $10,000 and $20,000) ranging from very low to a bit beyond the top level in the sample distribution, a growth rate of 3% (fairly high but arbitrarily chosen for illustrative purposes) and point estimates of the coefficients, BOD is added to the list of winners. The details of these and other inferences are spelled out in the section on empirical results.

Empirical Results

The Data

Environmental Data

Since our main objective is to see what the data tell us using various approaches, we use exactly the same data employed by GK (1995). Their paper includes an excellent description of those data; we summarize the discussion here for purposes of a reasonably self-contained exposition.

Collected through the Global Environmental Monitoring System (GEMS), sponsored by a consortium of United Nations agencies, the environmental data set includes annual statistical summaries for the years 1977-88 for the air pollutants and 1979-90 for the water contaminants. [6] The aim of GEMS is "to improve the validity and comparability of environmental data globally and to provide for the collection and assessment of environmental data," and the wide use of the GEMS data in similar studies indicates that it is one of the most comprehensive sources of international environmental data available. Still, one should note some concerns about them:

- Because few stations have consistently reported data throughout the time period they do not comprise a balanced panel.
- Because countries do not send reports to the organization within a regulated time period, the most recent years have fewer observations. If countries that report conditions more promptly are those with stricter environmental laws and less pollution the environmental data in these years may be biased downward. On the other hand, if countries with more severe environmental problems inform GEMS sooner, we may witness an upward bias in overall environmental concentrations.
- There is also some concern that the selection of stations included in the sample is biased, for two different reasons. First, one might expect that since democratic countries value access to information more highly than non-democratic nations, stations located in democratic countries report data more frequently. Second, it seems possible that specific station sites are selected because of observed adverse environmental effects in the area. Therefore, when another station is added, one might anticipate that overall pollution as measured would

[6] The water pollution data are from "GEMS/WATER DATA SUMMARY 1988-90" <http://www.cciw.ca/gems/summary/ intro.html> (26 March 1997). For the air pollutants, GK (1995, footnote 2) report "The GEMS data for 1977-1984 are published by the WHO in the series 'Air Quality in Selected Urban Areas.' We obtained unpublished data for 1985-1988 from the U.S. EPA."

increase. GEMS has tried to avoid this selection bias by establishing stations at major sources of water supply for municipalities, irrigation, livestock, and selected industries. They also include baseline stations where it is believed that humans have not polluted the area at all.

The pollutants studied by GK and in this paper are arsenic, biological oxygen demand (BOD), cadmium, chemical oxygen demand (COD), total coliform ("coliform" in our tables and charts), fecal coliform, dissolved oxygen (a "good," rather than a "bad"), lead, mercury, nickel, and nitrate in water, and smoke, suspended particles and sulphur dioxide (SO_2) in air in urban areas. The number of countries with data in each category ranges from 10 (nickel) to 52 (dissolved oxygen). These countries are listed in Table 1. Typically, a country has several monitoring stations; by 1990 the GEMS program included 287 river stations. The yearly statistics are derived from readings taken as frequently as biweekly for water and daily for air. GK discarded observations from lake and groundwater stations and focused on river basins, the category for which the most data are available.

There is a slight difference in the measures used by GK for the water pollutants and the air pollutants. For the former, the environmental indicator used is the arithmetic mean of the year’s readings, for the latter, the annual median. The mean value is the preferred measure because it evaluates more stations. Medians are only reported if a station has four or more values during the year. However, the median must be used for the air data because GEMS/AIR did not provide mean values.

Table 2 provides a summary of the environmental data. It includes the mean level of each pollutant and the standard deviation, both of which are calculated across all stations over the entire time period. For several pollutants, we note large standard deviations relative to the mean. From this relationship we infer that the distributions are not all necessarily bell-shaped.

Income and Growth Data

The GDP per capita data used by GK are from Summers and Heston's (1991) Penn World Tables Mark 5.6. All values are expressed in 1985 U.S. dollars. All references made herein to income and GDP are in per capita terms.

Controls

GK's estimation incorporated a variety of controls for factors, other than level of development, that would be expected to influence pollution levels. For air pollutants these include population density and dummy variables indicating proximity to a coast or desert, and location in a central city or residential or industrial area. The mean water temperature is included for water pollutants because warmer water will dissolve a greater quantity and variety of chemicals, releasing them into the aquatic environment. Because methods of measurement may vary, regressions for some types of pollutants also include dummy variables for the type of measuring device used.

Econometric Specification

For estimation, we expand the specification of the relationship for each pollutant as

$$P_{i,t} = \alpha(y_i - y_i^*)g_i t + \beta' Z_{i,t} + \lambda t + \varepsilon_{i,t}, \quad (5)$$

where

- i indicates the measurement station,
- $Z_{i,t}$ is a vector of station control variables and
- t is the year of the observation.

As has been discussed, the pollution variables are annual means of the measured levels. (In the cases of fecal and total coliform the log of the annual means is used because the levels of these pollutants display exponential growth and highly skewed distributions. In order to allow for readings of zero, the variables used for the regressions are log(1+ *P*).)

We discuss below alternative assumptions about the error term, $\varepsilon_{i,t}$.

<u>Income and Growth Variables</u>

The variable y_i is a level indicator of the GDP per capita of the country in which the station is located and g_i is an indicator of the country's rate of economic growth. All stations within the same country are assigned the same values of y_i and g_i. Consistent with GK, whose income variables are all in per capita terms, the basic version of our model takes as the measure of the rate of growth an average of the rate of increase in per capita GDP over a reference period. Specifically, the variable *g* was calculated by first taking a four-year average (to minimize the effect of short-term cyclical influences) of GDP per capita at the start of the period of observations and a four-year average at the end of this period. The first average was of 1979-82 for all stations,[7] and the second of 1989-92 for most stations. In the small number of cases where the Summers and Heston data for a country do not extend to 1992, an earlier four-year period is used. The rate of growth for a country is that exponential rate that takes the average in the first period to the average in the second period; i.e., the difference between the natural logs of the two

[7] Because we study more water pollutants than air pollutants, we used 1979 as the first observation year instead of 1977, when air pollution observations began. Also, Summers and Heston provided no income data for Kuwait until 1980, so the period 1980-83 was substituted for Kuwait's first average.

values divided by the time span (measured from the midpoints of the early income values and later income values, usually equal to 1990.5-1980.5).

The value of y_i is obtained by taking the same four-year average of GDP per capita from the start of the period of observations (1979-82) and using the rate of growth just described to extrapolate to 1985.5, the midpoint of the years for which income data were available for most countries. Using a level indicator for income de-emphasizes year-to-year fluctuations -- GK used lagged income in their model with a similar objective. Table 3 provides a list of the calculated income and growth values for the individual countries.

Interpretation of the Parameters

The parameter y^* is the income level at which the concentration levels begin to fall under the Kuznets curve inverted U hypothesis (or rise in the case of a U-shape). Because the coefficients to be estimated on *ygt* and *gt* are α and αy^*, respectively, the estimate of y^* is found implicitly by calculating the ratio of the coefficients, $\frac{\alpha y^*}{\alpha}$. The other coefficient of critical interest is α itself. A negative value indicates the inverted U shape of the Kuznets curve.

The coefficient of t is intended to capture a possible exogenous worldwide trend in the level of the pollutant in question.

Error Structure

To address the problem of locationally idiosyncratic but unobservable variation in conditions, we use a fixed effects estimator of the coefficients in (5) and for the econometric analogue of (4).

GK used random effects estimation in their analysis. The general model is

(16) $$P_{i,t} = \gamma + \delta' x_{i,t} + u_i + \varepsilon_{i,t},$$

where P is pollution, x_{it} is a vector of all regressors over stations over time, u_i is a station-specific error, and $\varepsilon_{i,t}$ is a random disturbance over time and across stations. The applicability of random effects methods depends, however, upon the regressors being uncorrelated with the country-specific error term, u_i. We note that this condition is not especially plausible *a priori*. We would not expect the controls such as proximity to a desert to be uncorrelated with the station. For our specification a Hausman test rejects the random effects assumptions for most cases. Some would, however, question relying on the Hausman test[8] and so we also report the random effects results.

<u>Econometric Results</u>

<u>The Basic Fixed Effects Model</u>

Table 4 displays the coefficients on *ygt*, *gt*, *t* and the implied *y** values from the fixed effects estimation. The usual conventions have been followed to indicate the level of statistical significance. Because many of the variables used as regressors are time invariant -- such as those relating to location -- these fall out of the fixed effects estimation. Only the mean temperature of the water and the type of measuring instrument vary over time and remain in the estimation.

By examining the signs of α we can determine whether the implied shape is a U or an inverted-U. A positive α indicates a U-shape, and a negative α, an inverted-U. As indicated in Table 4, the estimates for arsenic, COD, dissolved oxygen (as a direct measure of environmental quality), lead, smoke, and sulphur dioxide indicate the inverted-U shape at a ninety percent confidence level or better. For total coliform, nickel and nitrates the estimates indicate a U-shaped relationship between income and pollution, the opposite of the environmental Kuznets curve hypothesis. (By contrast, GK find support for an inverted-U shape for all pollutants, except for suspended particles, which decrease monotonically.)

The shape of the pollution-income relationship in the relevant range is not completely determined by the sign of the coefficient, α, however. The location of y^* is also important. For COD, the point estimate of the turning point is negative and for dissolved oxygen it is at a low level of income. For these pollutants the estimated path falls continuously, which might, however, be taken as in keeping with the spirit of the Kuznets hypothesis.

Random Effects Estimates of the Basic Model

Table 5 presents the results of the random effects estimation for the basic BSS specification. Compared with the fixed effects estimates, COD and smoke drop from the list for which there is support for the Kuznets curve; nickel is added; coliform joins the list with the wrong shape. The last column of the table also shows the results of the Hausman specification test of the null hypothesis that the regressors in a random effects estimation are uncorrelated with the station-specific residuals. In only two cases is the probability more than 10% that the assumptions needed for random effects estimation hold.

Cubic Specification

Table 6 presents the result of estimating the cubic version of the BSS model. The environmental Kuznets Curve would imply a positive value for alpha. BOD, COD, lead, and sulphur dioxide stay on the list with significant support in this regard. For COD and lead,

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[8] See Antweiler, Copeland and Taylor (1998).

however, the estimated turning points are negative or very low. Although the sign of the alpha for dissolved oxygen is "wrong," (since it is a good, the sign of alpha should be negative) and in that sense does not support the environmental Kuznets curve, the estimates imply a peak level at y^{**} at a level comparable to that of sulphur dioxide. We therefore regard the cubic estimate as favoring the Kuznets curve for dissolved oxygen.

Table 7 presents random effects estimates of the coefficients of the cubic BSS model, along with the Hausman test statistics.

Graphical Display of Model Results

The graphs presented in Figure 2 through Figure 15 show the implications of three estimated relationships for the rate of change of the level of pollution for countries ranging from very low to very high income levels, each growing at the same rate. The idea is to visualize the validity of the environmental Kuznets curve hypothesis over (and slightly beyond) the range of historical experience. If the income level of the low-income country is below the peak of the inverted U, and the income level of the high-income country is above the peak, then the bars on the left of the graphs should be positive and those on the right, negative, marching down from left to right.

To facilitate comparison across the pollutants in the strength of any effect, we carry over to the graphs the measurement of pollution in units of standard deviation in the entire sample of observations. This choice of units allows the reader to get a sense for whether effects are "large" with respect to the different pollutants. In each case, we show the value of dP/dt implied by the standard BSS model, the cubic BSS model, and the GK model. The two BSS models are estimated using fixed effects; the GK model is estimated using random effects, employing the program provided to us by GK. The error bars show the 95% confidence intervals.

The confidence intervals on the time derivatives serve their usual function of indicating the strength of the evidence in the data for the signs and we include them in the pictures for that reason. At the same time, it should be recognized that they do not directly inform us about the evidence relating to the environmental Kuznets curve. For that purpose we would need a test of the hypothesis that the derivatives go from positive to negative as the income levels increase.[9]

Looking just at the point estimates of the time derivatives to draw conclusions about the environmental Kuznets curve, the GK results support the environmental Kuznets curve hypothesis for all pollutants, although for seven out of the fourteen pollutants the evidence implies the curve turns up again at high incomes, suspended particles decline with income throughout the range (arguably consistently with the EKC view) and for coliform the inverted U appears only very early and very weakly. GK support for nitrates and cadmium are fairly muted, as the initial derivative is negative. The BSS specifications reject an EKC for coliform fecal coliform, nickel, nitrates and suspended particles; they agree in supporting an EKC finding BOD, COD (which, however, declines with income throughout), dissolved oxygen, and sulphur dioxide. For the rest, the picture is mixed.

Conclusions

Table 8 summarizes the interpretations we draw from the fresh analysis. As a crude device to pull together the signal in the evidence as explored here, to each pollutant we assign a score of 1 for an entry of Y (supports a straight EKC) or YN (supports an EKC with an upturn at high incomes; a score of .5 for an entry of "?" (the relevant coefficient is statistically insignificant). On the basis of this *ad hoc* device, and in the spirit of exploratory analysis, arsenic, BOD, COD, dissolved oxygen, lead and sulphur dioxide would seem to invite for further investigation as to the validity of the EKC hypothesis. Coming in close are cadmium, mercury, and smoke. Pretty definitely not: (total) coliform, fecal coliform, nickel, nitrates, and suspended particles. Whether or not readers agree with this jury's verdict, we hope to have persuaded them of the utility of our addition to the bag of specification/estimation tricks for thinking about the Kuznets curve phenomenon.

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[9] The cubic specifications would allow for the curve to turn up again for high incomes.

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Tables

Countries Reporting Pollutant Levels

Arsenic	BOD	Cadmium	COD	Coliform (total)	Dissolved Oxygen	Fecal Coliform	Lead	Mercury	Nickel	Nitrate	Smoke	Suspended Particles
AUSTRALIA	ARGENTINA	AUSTRALIA	BELGIUM	ARGENTINA	ARGENTINA	ARGENTINA	AUSTRALIA	ARGENTINA	AUSTRALIA	ARGENTINA	ARGENTINA	ARGENTINA
BELGIUM	BANGLADESH	BELGIUM	BRAZIL	BELGIUM	AUSTRALIA	AUSTRALIA	BELGIUM	AUSTRALIA	BELGIUM	AUSTRALIA	BELGIUM	AUSTRALIA
BRAZIL	BELGIUM	BRAZIL	CHILE	BRAZIL	BANGLADESH	BANGLADESH	BRAZIL	BELGIUM	BRAZIL	BANGLADESH	BRAZIL	BELGIUM
CANADA	BRAZIL	CANADA	COLOMBIA	CHILE	BELGIUM	BELGIUM	CANADA	BRAZIL	CANADA	CANADA	CHILE	BRAZIL
CHILE	CANADA	COLOMBIA	DENMARK	CHINA	BRAZIL	BRAZIL	FINLAND	CANADA	JAPAN	CHILE	COLOMBIA	CANADA
CHINA	CHILE	DENMARK	FINLAND	COLOMBIA	CANADA	CANADA	HUNGARY	CHINA	MALAYSIA	CHINA	DENMARK	CHINA
FINLAND	CHINA	FINLAND	FRANCE	FIJI	CHILE	CHILE	INDONESIA	DENMARK	NETHERLANDS	COLOMBIA	EGYPT	COLOMBIA
INDONESIA	COLOMBIA	HUNGARY	HUNGARY	FINLAND	CHINA	CHINA	JAPAN	FINLAND	PHILIPPINES	ECUADOR	FRANCE	DENMARK
JAPAN	DENMARK	INDONESIA	INDIA	HUNGARY	COLOMBIA	COLOMBIA	KENYA	FRANCE	UNITED KINGDOM	EGYPT	GREECE	FINLAND
MALAYSIA	ECUADOR	IRELAND	INDONESIA	INDIA	DENMARK	DENMARK	MALAYSIA	HUNGARY	UNITED STATES	FIJI	HONG KONG	GHANA
NETHERLANDS	EGYPT	ITALY	IRELAND	JAPAN	ECUADOR	ECUADOR	MEXICO	INDONESIA		FINLAND	IRAN	GREECE
NEW ZEALAND	FIJI	JAPAN	ITALY	KENYA	EGYPT	FIJI	NETHERLANDS	IRELAND		GUATEMALA	IRELAND	HONG KONG
PORTUGAL	FRANCE	KENYA	JAPAN	MALAYSIA	FIJI	FRANCE	NORWAY	ITALY		HUNGARY	NEW ZEALAND	INDIA
THAILAND	GUATEMALA	LUXEMBOURG	KENYA	MEXICO	FINLAND	GUATEMALA	PORTUGAL	JAPAN		INDIA	PERU	INDONESIA
TURKEY	HUNGARY	MALAYSIA	LUXEMBOURG	NEW ZEALAND	FRANCE	HUNGARY	REP. OF KOREA	LUXEMBOURG		INDONESIA	POLAND	IRAN
UNITED KINGDOM	INDIA	MEXICO	MALAYSIA	PAKISTAN	GUATEMALA	INDIA	THAILAND	MALAYSIA		IRAN	PORTUGAL	IRAQ
UNITED STATES	INDONESIA	NETHERLANDS	MEXICO	PHILIPPINES	HUNGARY	INDONESIA	TURKEY	MEXICO		IRELAND	SPAIN	ISRAEL
	IRAN	NORWAY	NETHERLANDS	PORTUGAL	INDIA	IRAN	UNITED KINGDOM	NETHERLANDS		JAPAN	UNITED KINGDOM	JAPAN
	IRELAND	PAKISTAN	NEW ZEALAND	TANZANIA	INDONESIA	IRELAND	UNITED STATES	NEW ZEALAND		KENYA	VENEZUELA	KENYA
	ITALY	PHILIPPINES	PAKISTAN	THAILAND	IRAN	ITALY	URUGUAY	PHILIPPINES		MALAYSIA		KUWAIT
	JAPAN	PORTUGAL	PHILIPPINES	TURKEY	IRELAND	JAPAN		PORTUGAL		MEXICO		MALAYSIA
	KENYA	REP. OF KOREA	PORTUGAL	URUGUAY	ITALY	LUXEMBOURG		REP. OF KOREA		NETHERLANDS		NEW ZEALAND
	LUXEMBOURG	THAILAND	REP. OF KOREA		JAPAN	MALAYSIA		THAILAND		NEW ZEALAND		PAKISTAN
	MALAYSIA	UNITED KINGDOM	SRILANKA		KENYA	MEXICO		TURKEY		NORWAY		PHILIPPINES
	MALI	UNITED STATES	THAILAND		LUXEMBOURG	NETHERLANDS		UNITED KINGDOM		PAKISTAN		PORTUGAL
	MAROC	URUGUAY	TURKEY		MALAYSIA	NEW ZEALAND		UNITED STATES		PANAMA		THAILAND
	MEXICO	W. GERMANY	UGANDA		MALI	NORWAY		URUGUAY		PERU		UNITED STATES
	NETHERLANDS		UNITED KINGDOM		MAROC	PAKISTAN		W. GERMANY		PORTUGAL		VENEZUELA
	NEW ZEALAND		UNITED STATES		MEXICO	PANAMA				SENEGAL		W. GERMANY
	PAKISTAN		W. GERMANY		NETHERLANDS	PERU				SPAIN		YUGOSLAVIA
	PANAMA		ZAIRE		NEW ZEALAND	PHILIPPINES				SUDAN		
	PHILIPPINES				NORWAY	PORTUGAL				SWEDEN		
	PORTUGAL				PAKISTAN	REP. OF KOREA				TANZANIA		
	REP. OF KOREA				PANAMA	SPAIN				THAILAND		
	SPAIN				PERU	SRILANKA				TUNISIE		
	SRILANKA				PHILIPPINES	TANZANIA				TURKEY		
	SUDAN				PORTUGAL	THAILAND				UNITED KINGDOM		
	TANZANIA				REP. OF KOREA	TUNISIE				UNITED STATES		
	THAILAND				SENEGAL	TURKEY				URUGUAY		
	TUNISIE				SPAIN	UNITED KINGDOM				W. GERMANY		
	TURKEY				SRILANKA	UNITED STATES						
	UNITED KINGDOM				SUDAN	URUGUAY						
	UNITED STATES				TANZANIA							
	URUGUAY				THAILAND							
	W. GERMANY				TUNISIE							
	ZAIRE				TURKEY							
					UNITED KINGDOM							
					UNITED STATES							
					URUGUAY							
					W. GERMANY							
					ZAIRE							

Descriptive Statistics

Pollutant	Mean	Standard deviation	Units
Mercury	0.285	0.785	µg/L
Arsenic	0.00594	0.00947	mg/L
Cadmium	0.0435	0.165	mg/L
Dissolved Oxygen	8.12	3.25	mg/L
Lead	0.0314	0.293	mg/L
Nickel	0.00883	0.0111	mg/L
Nitrate	1.53	3.88	mg Nitrogen/L
BOD	6.63	22.6	mg Oxygen/L
COD	48.4	119.434	mg Oxygen/L
Coliform (total)	178000	943000	No./100mL
Fecal coliform	103000	599000	No./100mL
Smoke*	53.3	53.2	ug/cubic m
Suspended particles*	151	129	ug/cubic m
Sulphur dioxide*	34.3	38.9	ug/cubic m

*based on annual median concentration
Source: GEMS/WATER and GEMS/AIR databases

Table 2. Summary of Environmental Data

Country Income and Growth
(sorted by income)

Country	Income	Growth		Income	Growth
ZAIRE	460	-0.01	REPUBLIC OF KOREA	4,742	0.08
TANZANIA	515	0.01	URUGUAY	4,869	0
MALI	527	0	HUNGARY	5,106	0
UGANDA	641	-0.03	YUGOSLAVIA	5,142	-0.02
SUDAN	808	-0.01	ARGENTINA	5,498	-0.02
KENYA	902	0	PORTUGAL	5,848	0.03
GHANA	906	0	MEXICO	5,968	0
INDIA	1,059	0.03	GREECE	6,333	0.01
CHINA	1,145	0.04	VENEZUELA	6,886	-0.01
SENEGAL	1,152	0	U.S.S.R.	7,077	0.03
PAKISTAN	1,242	0.02	IRELAND	7,977	0.03
BANGLADESH	1,263	0.03	SPAIN	8,382	0.03
INDONESIA	1,644	0.04	ISRAEL	8,635	0.02
EGYPT	1,774	0.01	E. GERMANY	9,505	0.04
PHILIPPINES	1,798	-0.01	NEW ZEALAND	11,006	0.01
BOLIVIA	1,825	-0.02	ITALY	11,284	0.02
SRI LANKA	1,877	0.03	UNITED KINGDOM	11,521	0.02
GUATEMALA	2,331	-0.01	HONG KONG	11,650	0.05
PERU	2,523	-0.03	FINLAND	11,963	0.02
TUNISIE	2,718	0.01	BELGIUM	12,010	0.02
THAILAND	2,818	0.05	NETHERLANDS	12,040	0.02
ECUADOR	2,990	-0.01	JAPAN	12,176	0.04
COLOMBIA	3,119	0.01	DENMARK	12,584	0.02
PANAMA	3,201	-0.01	FRANCE	12,768	0.02
TURKEY	3,250	0.02	W. GERMANY	13,050	0.02
JORDAN	3,377	-0.01	KUWAIT	13,065	-0.05
IRAN	3,618	-0.01	SWEDEN	13,380	0.02
FIJI	3,634	0	AUSTRALIA	13,406	0.02
IRAQ	4,042	-0.09	NORWAY	13,461	0.02
BRAZIL	4,068	0	LUXEMBOURG	13,968	0.03
POLAND	4,095	-0.01	SWITZERLAND	15,126	0.01
CHILE	4,138	0.02	CANADA	15,436	0.02
MALAYSIA	4,520	0.03	U.S.A.	16,577	0.02

Source: Authors' calculation; see text for details

Table 3. Country Income and Growth Data

Basic BSS Model
Fixed Effects Estimates

Model Specification P=alpha(y-y*)gt+beta*t+(temperature controls)+C
Implemented as P=a1*(ygt)+a2*(gt)+a3*t+(temperature controls)+C

(Pollutants are scaled in percent of the standard deviation of the observations in the sample.)

Pollutant	ygt coeff	ygt z-stat	gt coeff	gt z-stat	t coeff	t z-stat	alpha	y*
arsenic	-0.02740754 (***)	-2.812	363.07195 (***)	2.633	-1.08187641	-0.377	-0.02740754	13247
BOD	-0.00664293	-1.601	7.55860	0.213	0.42558436	0.525	-0.00664293	1138
cadmium	-0.00026747	-0.018	-4.14508	-0.023	3.66637735	1.142	-0.00026747	-15497
COD	-0.01215113 (*)	-1.805	-114.55787 (**)	-2.359	4.42480853 (***)	3.444	-0.01215113	-9428
coliform	0.03738792 (***)	4.459	-336.48291 (***)	-4.139	11.68690520 (***)	4.544	0.03738792	9000
dissolved O2	0.01009395 (***)	4.134	-12.04056	-0.684	-1.20243041 (**)	-2.26	0.01009395	1193
fecal coliform	0.00000003	0.994	0.00003	0.134	0.00001382 (***)	2.586	0.00000003	-1263
lead	-0.01059726 (***)	-3.861	109.05392 (***)	3.392	0.29839077	0.487	-0.01059726	10291
mercury	0.01174342	0.675	83.18447	0.422	-8.02615632 (**)	-2.483	0.01174342	-7083
nickel	0.15985613 (**)	2.343	-2019.78855 (**)	-2.532	-4.89468569	-1.184	0.15985613	12635
nitrates	0.01297263 (**)	2.053	-137.14704 (***)	-2.682	-0.04296918	-0.035	0.01297263	10572
smoke	-0.03471547 (***)	-3.613	415.63746 (***)	4.253	-3.89550901 (***)	-4.491	-0.03471547	11973
so2	-0.03096669 (***)	-7.927	94.60559 (**)	2.397	0.05695148	0.065	-0.03096669	3055
suspended particles	-0.00364225	-1.157	103.02904 (***)	4.309	-2.30705971 (***)	-2.939	-0.00364225	28287

Table 4. BSS Model: Fixed Effects Estimates

Basic BSS Model
Random Effects Estimates

Model Specification ?
Implemented as ?

(Pollutants are scaled in percent of the standard deviation of the observations in the sample.)

Pollutant	ygt coeff	ygt z-stat	gt coeff	gt z-stat	t coeff	t z-stat	alpha	y*	Hausman prob accept RE
arsenic	-0.00016445 (***)	-3.359	0.78472102	2.633	0.81645606	-0.377	-0.00016445	4772	0.0814
BOD	0.00002063	0.703	-0.23131150	0.213	-0.17969241	0.525	0.00002063	11212	0.4452
cadmium	-0.00001364	-0.400	0.29201394	-0.023	1.92841191 (*)	1.142	-0.00001364	21406	0.0143
COD	0.00002744	0.747	-0.38575963 (*)	-2.359	0.92375841	3.444	0.00002744	14060	0.0104
coliform	0.00008390 (*)	1.772	-0.19142061	-4.139	8.29134546 (***)	4.544	0.00008390	2282	0
dissolved O2	0.00013296 (***)	4.511	-0.67185709	-0.684	-0.59902412 (**)	-2.26	0.00013296	5053	0
fecal coliform	-1.74050831E-10	-0.947	0.00000118	0.134	0.00001658 (***)	2.586	0.00000000	6794	0.0014
lead	-0.00003320 (***)	-3.203	0.04161093	3.392	0.08978031	0.487	-0.00003320	1253	0.0006
mercury	-0.00001173	-0.186	-0.60323802	0.422	-2.56545285 (**)	-2.483	-0.00001173	-51428	0.3761
nickel	-0.00015531 (*)	-1.840	0.77839036	-2.532	-4.79659216 (***)	-1.184	-0.00015531	5012	0.0029
nitrates	0.00007869 (**)	2.540	-0.10497520	-2.682	-1.88535599 (**)	-0.035	0.00007869	1334	0.0004
smoke	-0.00012069	-1.501	0.72849685	4.253	-2.45861170 (***)	-4.491	-0.00012069	6036	0.0003
so2	-0.00004554 (**)	-1.962	0.68753953 (***)	2.397	-3.68298861 (***)	0.065	-0.00004554	15097	0
suspended particles	-0.00020979	-10.517	1.78878670	4.309	-0.82008412 (**)	-2.939	-0.00020979	8527	0

Table 5. BSS Model: Random Effects Estimate

BSS Cubic Model
Fixed Effects Estimates

Model Specification P=alpha(y-y*)(y-y**)gt+beta*t+(temperature controls)+C
Implemented as P=a1*(y^2gt)+a2*(ygt)+a3*(gt)+a4*t+(temperature controls)+C

(Pollutants are scaled in percent of the standard deviation of the observations in the sample.)

Pollutant	y2gt	y2gt z-stat	ygt coeff	ygt z-stat	gt coeff	gt z-stat	t coeff	t z-stat	alpha	y*	y**
arsenic	7.90E-09	0.464	-3.07E-02 (*)	-1.627	1.98E+02	0.961	3.71E+00	0.879	7.90E-09	6442	3880419
BOD	3.15E-08 (**)	2.127	-2.51E-02 (***)	-2.639	8.22E+01 (*)	1.925	-1.17E+00	-1.234	3.15E-08	3286	794499
cadmium	3.11E-08	1.349	-3.53E-02	-1.219	1.66E+02	0.572	7.26E+00 (*)	1.656	3.11E-08	4729	1129371
COD	4.47E-08 (*)	1.775	-3.44E-02 (***)	-3.099	-1.55E+02 (***)	-2.807	6.90E+00 (***)	4.586	4.47E-08	-4469	774123
coliform	-1.89E-08	-0.53	5.59E-02 (***)	3.624	-2.08E+02 (**)	-2.201	6.17E+00 (**)	1.965	-1.89E-08	3725	2956411
dissolved O2	1.70E-08 (**)	1.967	7.03E-03	1.604	-8.59E+00	-0.419	-1.21E+00 (**)	-1.979	1.70E-08	-416068	1218
fecal coliform	-2.91E-13 (***)	-4.321	1.90E-07 (***)	3.933	-4.13E-06	-0.015	1.02E-05	1.621	-2.91E-13	22	653289
lead	4.78E-09 (*)	1.744	4.45E-03	1.381	-8.98E+01 (***)	-2.87	9.26E-03	0.018	4.78E-09	-949998	19766
mercury	3.18E-08	1.299	-1.34E-02	-0.432	1.35E+02	0.453	-6.07E+00	-1.353	3.18E-08	10341	410260
nickel	3.39E-08	1.347	1.56E-01 (**)	2.278	-2.18E+03 (***)	-2.664	-3.73E+00	-0.794	3.39E-08	-4625173	13913
nitrates	-8.51E-09	-0.429	1.80E-02 (*)	1.552	-1.59E+02 (***)	-2.798	8.09E-02	0.057	-8.51E-09	8875	2110825
smoke	-8.93E-09	-1.116	-2.52E-02 (*)	-1.955	3.71E+02 (***)	3.52	-4.14E+00 (***)	-4.629	-8.93E-09	-2831988	14682
so2	3.65E-08 (***)	5.607	-5.60E-02 (***)	-9.496	1.06E+02 (***)	2.714	1.09E+00	1.233	3.65E-08	1891	1531250
suspended particles	-2.89E-10	-0.058	-3.46E-03	-0.778	1.03E+02 (***)	4.259	-2.31E+00 (***)	-2.937	-2.89E-10	-11999007	29652

Table 6. BSS Cubic Model: Fixed Effects Estimates

BSS Cubic Model
Random Effects Estimates

Model Specification ?
Implemented as ?

(Pollutants are scaled in percent of the standard deviation of the observations in the sample.)

Pollutant	y2gt	y2gt z-stat	ygt coeff	ygt z-stat	gt coeff	gt z-stat	t coeff	t z-stat	alpha	y*	y**	Hausman prob accept RE
arsenic	-1.64E-08 (***)	-2.631	8.28E-05	0.797	-1.17E-01	-0.21	2.90E+00 (**)	2.019	-1.64E-08	*imaginary*	*imaginary*	0.4781
BOD	-2.34E-09	-0.404	5.33E-05	0.704	-2.86E-01	-1.173	-7.81E-01	-1.202	-2.34E-09	8597	14217	0.1427
cadmium	-8.58E-09	-1.52	1.24E-04	1.264	-1.43E-01	-0.323	4.16E+00 (***)	2.77	-8.58E-09	1266	13178	0.019
COD	-3.35E-09	-0.375	6.39E-05	0.569	-4.50E-01	-1.549	1.27E+00 (*)	1.727	-3.35E-09	*imaginary*	*imaginary*	0.0001
coliform	1.46E-08	0.958	-1.10E-04	-0.568	2.06E-01	0.494	6.05E+00 (***)	5.571	1.46E-08	*imaginary*	*imaginary*	0
dissolved O2	2.73E-08 (***)	5.856	-1.98E-04 (***)	-3.095	-5.60E-02	-0.233	-1.13E+00 (***)	-3.8	2.73E-08	-272	7545	0
fecal coliform	-1.22E-13 (***)	-4.2	1.40E-09 (***)	3.279	-2.33E-06	-1.518	2.32E-05 (**)	5.511	-1.22E-13	2007	9491	0
lead	7.60E-10	0.567	-4.11E-05 (*)	-1.775	2.02E-02	0.181	-3.70E-01	-1.579	7.60E-10	495	53652	0.0032
mercury	8.48E-09	0.83	-1.42E-04	-0.804	-1.06E-01	-0.134	-3.60E+00 (**)	-1.97	8.48E-09	-718	17438	0.5455
nickel	-1.51E-08	-1.475	1.63E-04	0.705	-1.08E+00	-0.691	-3.53E+00	-1.998	-1.51E-08	*imaginary*	*imaginary*	0.0494
nitrates	-1.46E-08 (***)	-2.561	2.69E-04 (***)	3.267	-4.99E-01 (*)	-1.809	-1.58E+00 (*)	-1.886	-1.46E-08	2087	16345	0.0044
smoke	-6.94E-09	-1.414	-3.42E-05	-0.337	4.84E-01	0.667	-2.12E+00 (***)	-3.299	-6.94E-09	-11178	6246	0.0001
so2	-1.32E-08 (***)	-4.164	1.27E-04 (***)	2.691	2.72E-01	1.393	-2.54E+00 (***)	-4.437	-1.32E-08	-1799	11429	0
suspended particles	9.63E-10	0.31	-2.24E-04 (***)	-4.627	1.81E+00 (***)	8.479	-9.06E-01 (*)	-1.936	9.63E-10	8406	224094	0

Table 7. BSS Cubic Model: Random Effects Estimates

Environmental Kuznets Curve

	Evidence from the Coefficients*		*Model* Interpreting the Charts**			
Estimation Method:	BSS FE	BSS Cubic FE	BSS FE	BSS Cubic FE	GK RE	Score
Pollutant:						
arsenic	Y	?	Y	Y	YN	4.5
BOD	?	Y	Y	Y	Y	4.5
cadmium	?	?	N	Y	Y	3.0
COD	Y	Y	Y	Y	Y	5.0
coliform	N	?	NN	NN	N	0.5
dissolved O2	Y	Y	Y	Y	Y	5.0
fecal coliform	?	N	N	N	Y	1.5
lead	Y	Y	Y	N	YN	4.0
mercury	?	?	N	Y	YN	3.0
nickel	N	?	NN	N	YN	1.5
nitrates	N	?	NN	NN	Y	1.5
smoke	Y	?	Y	N	YN	3.5
so2	Y	Y	Y	Y	YN	5.0
suspended particles	?	?	N	N	Y	2.0

* Y means the key coefficient is significant at at least the 10% level and of the right sign; N means significant and of the wrong sign; ? means insignificant.

** For the charts, Y=graphs start positive, end negative; NN=graphs start negative and end positive; N=graphs don't clearly or monotonically move up or down; YN=graphs start positive, go negative, then go positive again.

Source: Author's calculations and Grossman and Krueger (1995); see text.

Table 8. Interpreting the Evidence for the Environmental Kuznets Curve

Figures

Arsenic:

	Slopes L	M	H	VH	Error bars L	M	H	VH
BSS	0.03357	0.02260	0.00890	-0.01851	0.02558	0.020872	0.018104	0.025758
cubic	0.01669	0.00442	-0.01089	-0.04137	0.039567	0.040027	0.047541	0.074821
GK	0.00473	-0.00045	-0.02090	0.14671	0.001761	0.002033	0.003463	0.072184

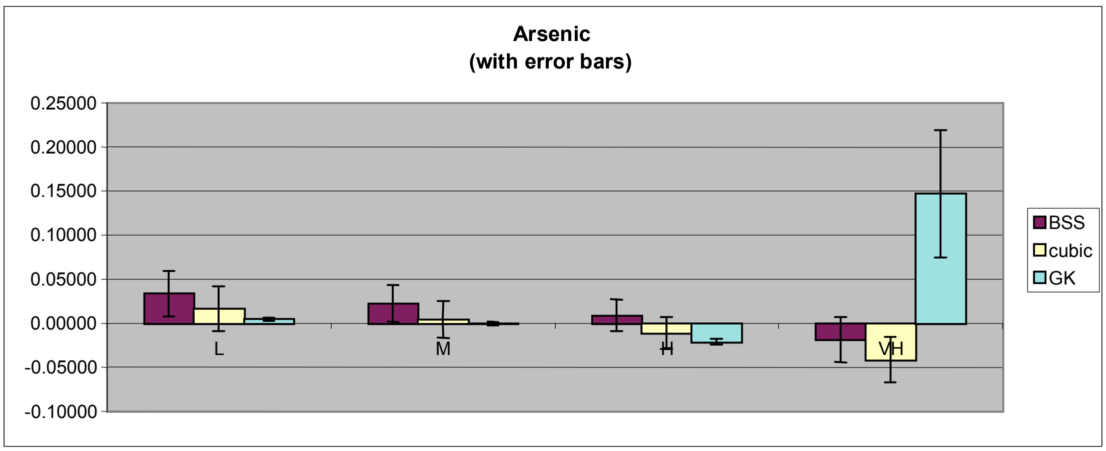

Figure 2. Arsenic

BOD

	Slopes L	M	H	VH	Error bars L	M	H	VH
BSS	0.0000916	-0.0025656	-0.0058871	-0.0125300	0.0065423	0.0058011	0.0071996	0.0136721
cubic	0.0057124	-0.0042619	-0.0165880	-0.0407679	0.0081151	0.0108710	0.0183663	0.0357184
GK	0.0006769	0.0013177	-0.0022337	-0.0219535	0.0006482	0.0010812	0.0024302	0.0553990

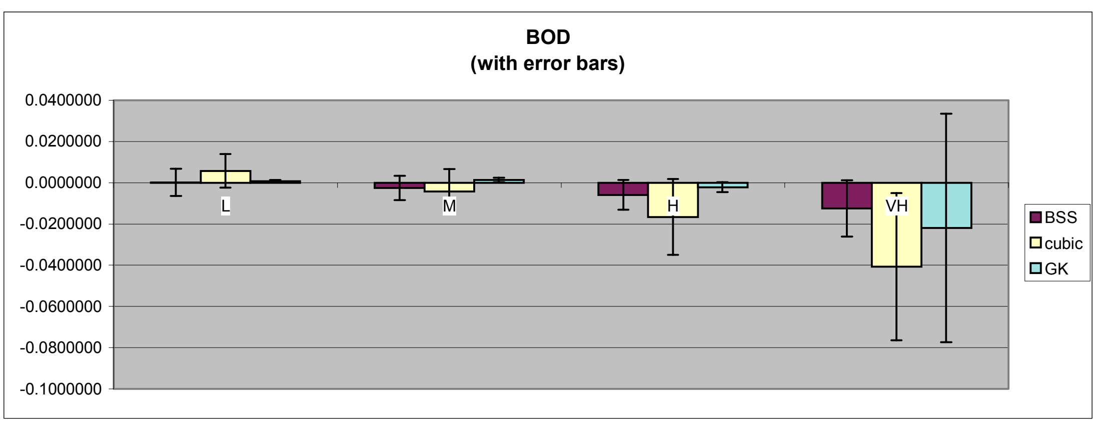

Figure 3. Biological Oxygen Demand

Cadmium

	Slopes				Error bars			
	L	M	H	VH	L	M	H	VH
BSS	-0.0004413	-0.0005482	-0.0006820	-0.0009495	0.0326334	0.0257604	0.0235487	0.0405602
cubic	0.0130827	-0.0009490	-0.0183486	-0.0526814	0.0552398	0.0542074	0.0650806	0.1076517
GK	-0.0012574	0.0010004	0.0028970	-0.1061043	0.0013937	0.0017380	0.0036435	0.0580979

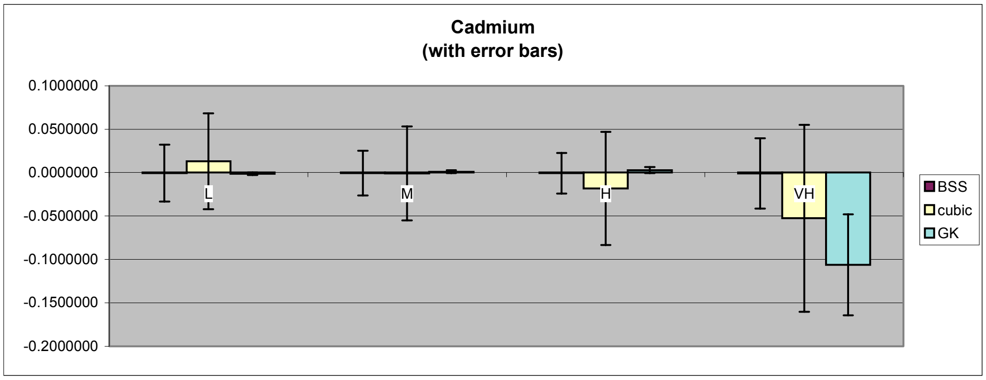

Figure 4. Cadmium

COD

	Slopes				Error bars			
	L	M	H	VH	L	M	H	VH
BSS	-0.01267	-0.01753	-0.02361	-0.03576	0.009353	0.010469	0.014666	0.026182
cubic	-0.01891	-0.03257	-0.04945	-0.08253	0.010772	0.014399	0.023019	0.043018
GK	0.00082	0.001902	-0.00291	-0.04085	0.000754	0.001249	0.003094	0.065809

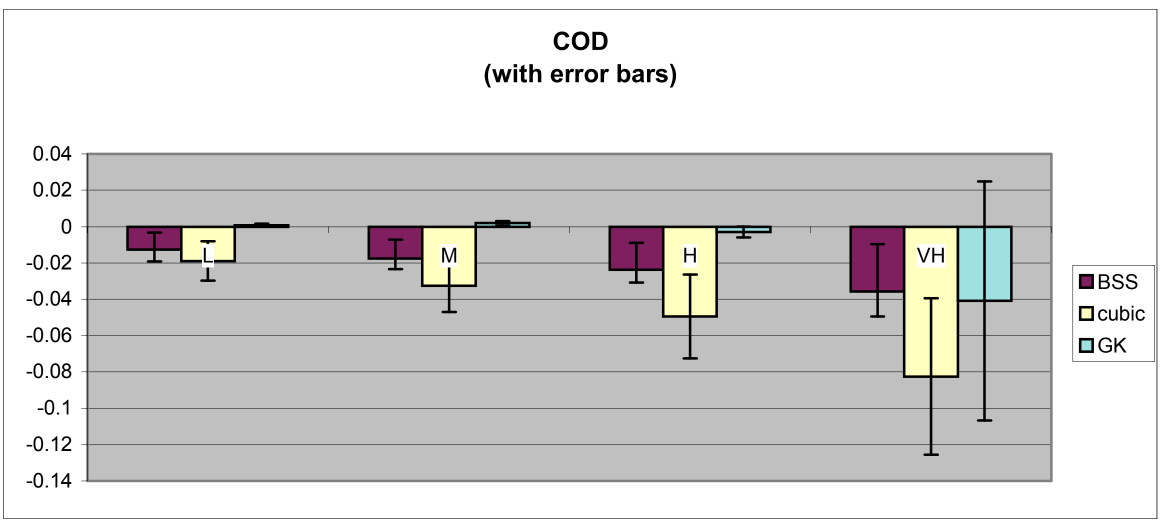

Figure 5. Chemical Oxygen Demand

Coliform

	Slopes L	M	H	VH	Error bars L	M	H	VH
BSS	-0.029909499	-0.014954332	0.003739628	0.04112755	0.01629305	0.01911795	0.02473873	0.03885763
cubic	-0.015198309	0.007098507	0.034884615	0.0901738	0.0190347	0.02493802	0.03669513	0.06396293
GK	0.003957005	-0.007928295	0.033815354	1.05935347	0.00136245	0.00393835	0.0100038	0.34462411

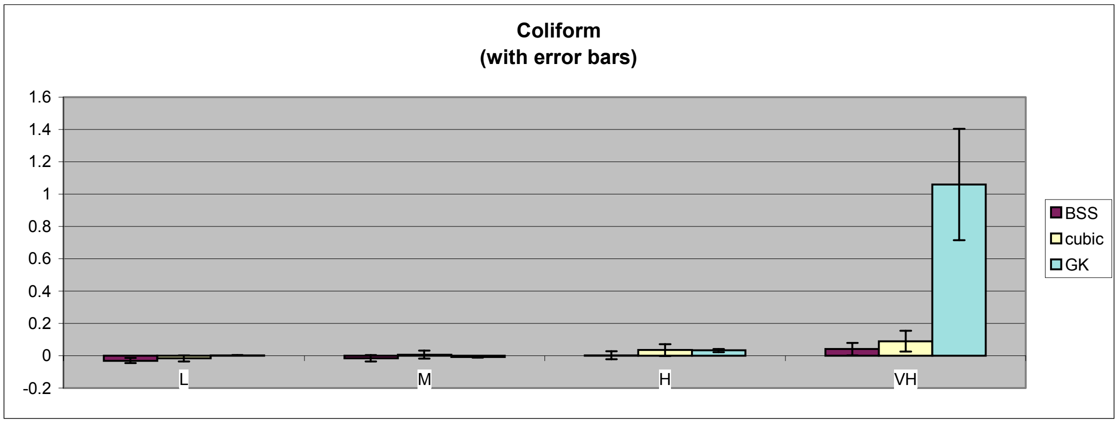

Figure 6. Coliform

DisO2

	Slopes L	M	H	VH	Error bars L	M	H	VH
BSS	-0.000194662	0.003842916	0.008889889	0.018984	0.003458	0.0041	0.005771	0.010054
cubic	-0.000154395	0.002699698	0.006343608	0.013886	0.003994	0.005461	0.008928	0.01688
GK	-5.35715E-05	0.00085653	0.007587862	0.059101	0.000761	0.001262	0.002691	0.051897

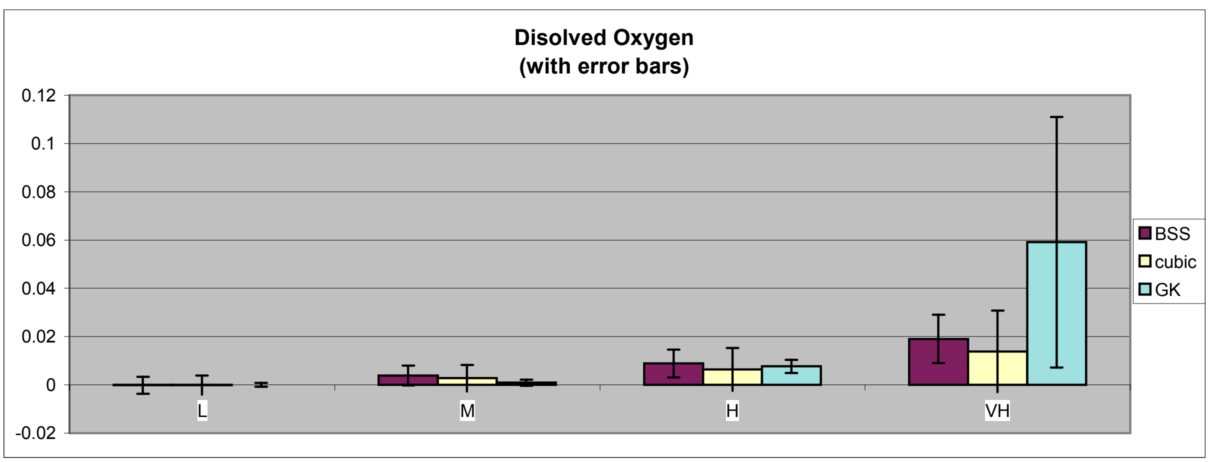

Figure 7. Dissolved Oxygen

Fecal coliform

	Slopes L	M	H	VH	Error bars L	M	H	VH
BSS	5.75632E-09	1.59298E-08	2.86467E-08	5.41E-08	4.43E-08	3.94E-08	4.68E-08	8.56E-08
cubic	1.8551E-08	9.38272E-08	1.86614E-07	3.68E-07	5.34E-08	6.4E-08	9.81E-08	1.83E-07
GK	5.74078E-10	1.19182E-08	-2.96828E-08	-7.8E-07	3.89E-09	6.55E-09	1.45E-08	2.55E-07

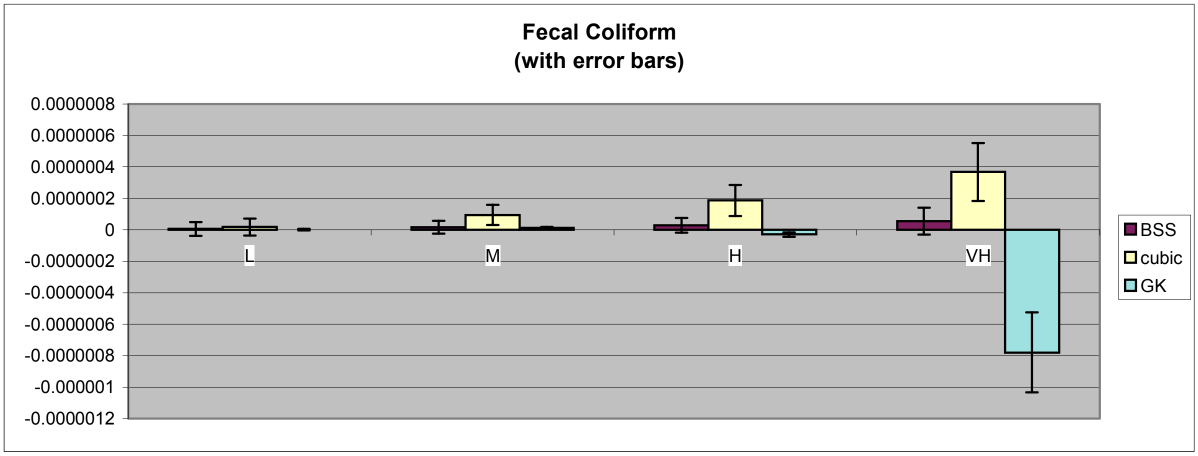

Figure 8. Fecal Coliform

Lead

	Slopes L	M	H	VH	Error bars L	M	H	VH
BSS	0.009845665	0.00560676	0.000308128	-0.01029	0.005929	0.004765	0.004495	0.007662
cubic	-0.008530182	-0.006740148	-0.004481097	0.000109	0.005961	0.005946	0.007283	0.01215
GK	7.40852E-05	-0.001077859	-0.002426865	0.016392	0.000338	0.000438	0.000834	0.014555

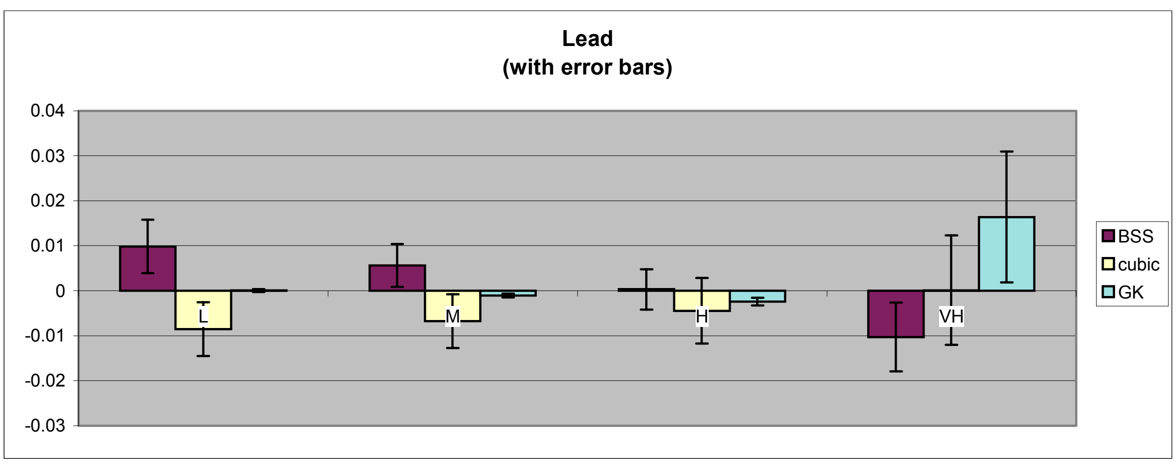

Figure 9. Lead

Mercury

	Slopes L	M	H	VH	Error bars L	M	H	VH
BSS	0.009493	0.01419	0.020062	0.031805	0.0359971	0.0269086	0.0228904	0.04288274
cubic	0.012149	0.006879	0.000434	-0.01198	0.0565416	0.0556784	0.067986	0.11446133
GK	0.003025	-8.3E-05	-0.00755	0.159621	0.0057809	0.0167106	0.0424465	1.46225405

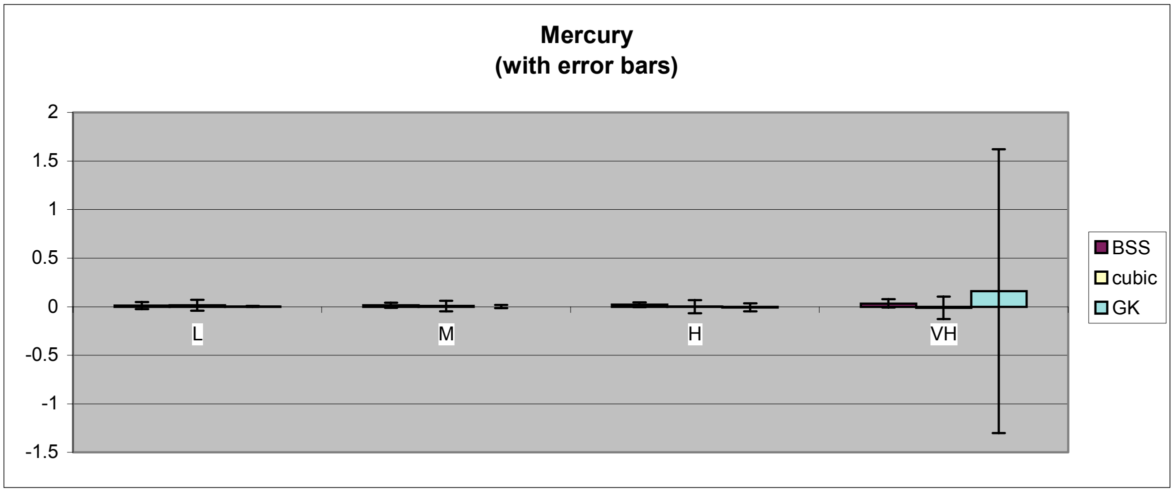

Figure 10. Mercury

Nickel

	Slopes L	M	H	VH	Error bars L	M	H	VH
BSS	-0.18599	-0.12205	-0.04212	0.117733	0.143437	0.092776	0.040439	0.119633
cubic	-0.20238	-0.13981	-0.06145	0.095794	0.154507	0.141584	0.153059	0.239586
GK	0.001359	-0.00111	-0.00925	0.038387	0.004258	0.004754	0.003438	0.125988

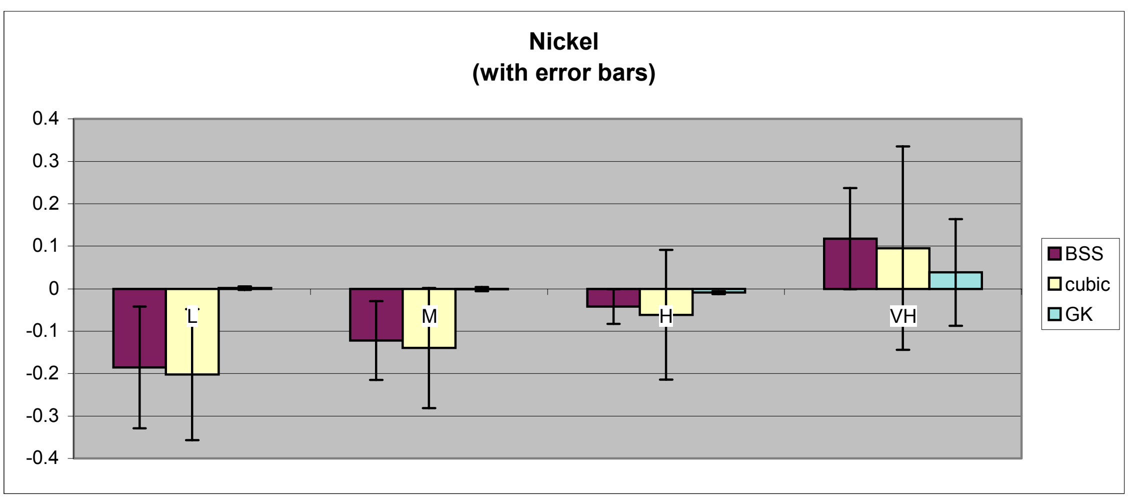

Figure 11. Nickel

Nitrates

	Slopes				Error bars			
	L	M	H	VH	L	M	H	VH
BSS	-0.012417442	-0.00722839	-0.000742076	0.01223055	0.00966026	0.00978117	0.01295492	0.02329986
cubic	-0.014132824	-0.006941508	0.002009362	0.01978352	0.01094586	0.01426961	0.02317559	0.04412702
GK	-0.000336574	0.005123009	0.002625	-0.1894721	0.00069625	0.00117284	0.00247519	0.05085072

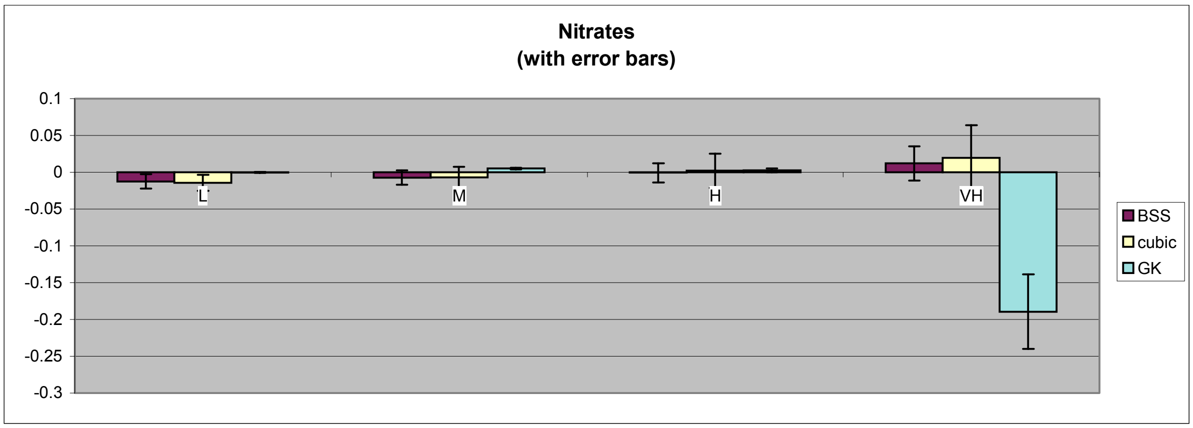

Figure 12. Nitrates

Smoke

	Slopes				Error bars			
	L	M	H	VH	L	M	H	VH
BSS	0.0380922	0.02420601	0.00684827	-0.0278672	0.01746513	0.01131428	0.00809789	0.02168299
cubic	0.03461147	0.0245274	0.01188213	-0.01354234	0.0196971	0.01890954	0.02458803	0.04518124
GK	0.00541896	0.00407772	-0.0104472	0.16429572	0.00177781	0.00174022	0.00613318	0.20091071

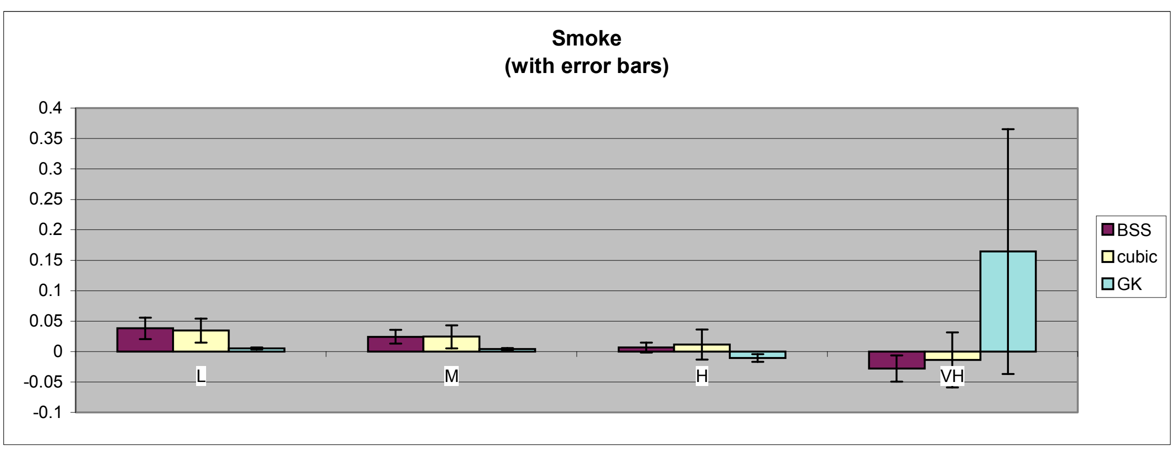

Figure 13. Smoke

Sulphur Dioxide

	Slopes				Error bars			
	L	M	H	VH	L	M	H	VH
BSS	0.006364	-0.00602	-0.02151	-0.05247	0.007341	0.006462	0.007274	0.012766
cubic	0.004981	-0.01734	-0.04507	-0.09999	0.007495	0.008605	0.01248	0.022674
GK	0.002379	-0.00251	-0.01339	0.123991	0.000592	0.000838	0.001946	0.032552

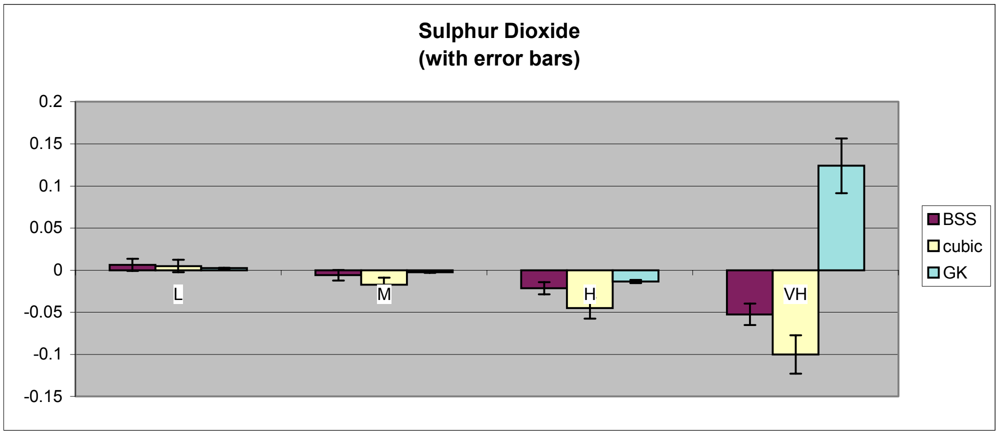

Figure 14. Sulphur Dioxide

Suspended Particles

	Slopes				Error bars			
	L	M	H	VH	L	M	H	VH
BSS	0.00993868	0.00848178	0.00666066	0.00301841	0.00464811	0.00525385	0.00719716	0.01248414
cubic	0.009938	0.00855344	0.00682145	0.00335312	0.00473277	0.00612894	0.00950505	0.01752286
GK	-0.00281062	-0.00642937	-0.00411498	-0.0420257	0.0005279	0.00071401	0.00174005	0.02523966

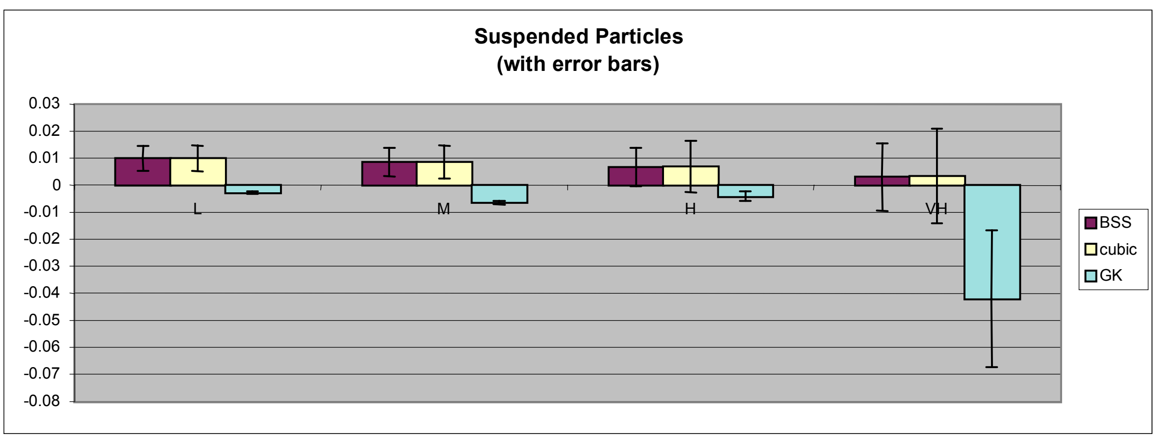

Figure 15. Suspended Particles