Title

Is the environmental Kuznets curve an empirical regularity?

Authors
Deacon, Robert
Norman, Catherine S

Publication Date
2004-07-13

Is the environmental Kuznets curve an empirical regularity?

Robert T. Deacon and Catherine S. Norman

Department of Economics

University of California, Santa Barbara 93106

Deacon@econ.ucsb.edu Norman@econ.ucsb.edu

July 13, 2004

Abstract

The empirical literature on the environmental Kuznets curve (EKC) purports to describe how a nation's environmental quality will evolve if it makes the transition from poverty to wealth. The popular generalization is that pollution will first increase and then, if income becomes sufficiently high, decline. Empirical support for this proposition is based primarily on cross-country variations in income and pollution rather than evidence on the behavior of individual countries over time. We examine a recently available data set on SO_2, smoke, and particulate air pollution to look for examples of countries following the EKC process. For most pollutants the income-pollution pattern does not differ from what would be expected to occur by chance. According to the EKC hypothesis, the driving force in the worldwide decline in air pollution is growth in income. To check the plausibility of this explanation, we estimate country-specific income elasticities for clean air that are implied by the EKC framework. We find them to be implausibly large relative to other estimates in the literature. We suggest an alternative hypothesis, that public support for environmental protection increased dramatically around 1970, sparking increased efforts to improve environmental quality. Cleanup was faster in rich countries than in poor, however. The record of within-country air pollution trends is broadly consistent with this story.

1 Introduction

The environmental Kuznets curve (EKC) hypothesis describes the time path of pollution a country will follow as economic development proceeds. When growth occurs in an extremely poor country, pollution initially grows because the increased production generates pollution emissions and because the country, given its poverty, places a low priority on pollution control. Once a country gains a sufficient degree of affluence, however, its priorities shift to protecting air quality. If this income effect is strong enough, it will cause pollution to decline. To some, this reasoning suggests that environmental improvement cannot come without economic growth. The World Bank, in its 1992 World Development Report, reported that "economic growth is essential for environmental stewardship" and GATT (1992) offered a similarly positive policy message from the EKC literature. The EKC hypothesis is intuitively appealing. Moreover, it seems in general agreement with the experiences and casual empiricism of those who lived through last half of the 20th century in North America and Western Europe. To date, however, no carefully documented examples of specific countries following the EKC path as economic growth proceeds have been offered.

In what follows we examine data on air pollution and GDP growth for individual nations to see if clear examples of the EKC phenomenon can be found. We make use of a recently available extension and revision of the GEMS database on air pollution around the world. This update was compiled by the EPA's Aerometric Information Retrieval System (AIRS) and in what follows we refer to this data set as GEMS/AIRS. Harbaugh, Levinson, and Wilson (2002) (HLW) studied these data thoroughly to check the robustness of results in the EKC literature. HLW also explain differences between the GEMS/AIRS data and the earlier GEMS data set. They point out that many observations that were missing in the original data set have been filled in, duplicate entries have been eliminated, and some original entries have been amended.[1] Overall, the new series contains many more observations and is more accurate than the original GEMS data.

Our main reason for relying on the GEMS/AIRS data is its extensive temporal coverage. Data are available as early as 1971 for some countries and the last observations are for 1992. This is a long enough period to observe significant economic growth and it includes the time span when nations around the world initiated substantive environmental policy. If the EKC phenomenon is an important empirical regularity, we should see it operating in data from individual nations over this period. A second advantage is that its country coverage—46 individual nations—is extensive. Finally, the primary factual basis for the now-famous inverted-U is the GEMS data set. To have the best chance for success, it makes sense to base our search for EKC behavior on this vehicle.

[1] Thanks are due to Arik Levinson for making these data available to us. As Harbaugh, Levinson, and Wilson (2002, p. 542) point out, the simple correlation between average pollution observations in the original GEMS data set and observations in the revised AIRS data set is disturbingly low for SO_2 and for smoke, .75 and .77, respectively.

Our approach is simple: we plot air pollution against income in as many countries as possible, to see whether or not the EKC hypothesis is an empirical regularity. Looking only within countries permits simple tests of the EKC hypothesis—we literally look at plots of pollution against income. Looking only within-countries also mitigates observable and unobservable cross-country heterogeneity in economic, political, and climatic factors. Assuming we can measure air pollution and income accurately, the only attributes that might be of concern are those that clearly changed within countries during the sample period.

While this simplifies the empirical approach somewhat, it highlights the importance of measuring air pollution and income accurately. Surprisingly, this is less straightforward than it might first seem. Consider measurement of the dependent variable in an EKC model, air pollution. The GEMS/AIRS data consist are annual observations from hundreds of individual monitoring sites around the world. Many sites opened and closed sporadically, while others operated more or less continuously. Contemporaneous readings from different monitoring sites in the same city clearly show that some sites were located in dirtier neighborhoods than others. Simply averaging across sites within a city or country, given that sites come and go, will introduce measurement errors[2]. Our approach is to compile within-country air pollution series from a consistent set of monitoring sites, which necessitates dropping observations from sites that do not report consistently.

Accurately measuring income, the most important *independent* variable in an EKC model, is arguably even more crucial because measurement error here will lead to biased estimates. The most common income measure in the empirical literature is national level per capita GDP, used apparently for reasons of data availability.[3] On theoretical grounds, however, a local income measure is arguably more appropriate. The main driving force in the upward sloping portion of the hypothesized EKC is the pollution generation that accompanies an increase in production. Because air pollution is generally experienced near the source, the appropriate measure of the production driving it is local GDP. The downward sloping portion of the EKC is expected to occur because higher incomes may lead to more stringent pollution controls.[4] National level GDP would be the right income measure for this pollution control effect if air pollution policies were set only by national governments. Sub-national governments also control air quality

[2] It is common in panel data EKC studies to include site-specific fixed effects. This clearly is a sensible approach if baseline pollution differences across sites are additive and constant. It is not if they are proportional or if the individual effects should be interacted with other variables.

[3] Two studies on income-pollution relationships within U.S. jurisdictions have used pollution and income data at the county and census tract level. See, respectively, Carson et al (1997) and Khanna (2002).

[4] Antwiler, Copeland, and Taylor (2000) call this the 'technique effect'. They also point out that the air quality will be affected if the composition of output changes.

through land use controls and environmental permitting, however.[5] Accordingly, local income, i.e., income near the monitoring site, should be a determining factor in an EKC model. Summarizing, a failure to include local income, either in addition to or instead of national income, will lead to biased income coefficients. This is particularly unfortunate because the key point of the EKC exercise is accurate estimation of the income coefficient(s) and the turning point.[6]

Our approach to this problem is to take care to use income and air pollution data that are matched to one another. The starting point is the income data available to us and to other researchers—national level GDP per capita. The air pollution measures we seek are, accordingly, series that indicate the time pattern of national level air pollution in each country. We construct these by averaging readings from a consistent set of monitoring sites in each country. Readings at individual sites within a country generally differ from one another, perhaps due to variations in community income or climatic conditions. If these differences were stable over time they would not pose a problem. In that case readings from any of the individual monitoring sites would serve as a national air pollution series. Of course they are not stable over time, due to the effect of transitory idiosyncratic factors. We average the yearly readings across a stable set of sites in each country, with the thought that positive and negative idiosyncrasies will tend to cancel out in the process, reducing measurement error.

2 Literature Review

The EKC literature began with two papers in the early 1990s. Shafik and Bandyopadhyay (1992) examined the empirical relationship between per capita income and ambient concentrations of air pollution, rates of deforestation, access to clean water, and production of solid wastes. Grossman and Krueger (1993, 1995) used a similar empirical approach to estimate the likely effects of increased income, attributed to NAFTA, on air pollution. In both studies, the authors found that airborne sulfur dioxide and smoke concentrations rose with per capita income, up to $3,000-$4,000 in the former study and $4,000-$6,000 in the latter, beyond which they declined. Although these authors cautioned that their results

[5] This is evident in the common observation that affluent communities tend to have better air quality than poor communities.

[6] Including fixed effects for communities or monitoring sites, along with national level income, will not fix this problem. Consider the seemingly advantageous case where income in each community differs from national income by a fixed proportion. The confounding problem is that the proportionality factors should be different for each community, which necessitates community-specific coefficients for the national income term. That is, one would need to interact the fixed effects with national level income.

did not necessarily imply an automatic reduction in pollution as income rose, some observers drew this interpretation.[7]

The intriguing idea that greening might follow automatically from economic growth led to a large empirical literature on the subject. Other researchers attempted to control for the influence on pollution of determining factors that might be correlated with income. Panayotou (1997) considered the industrial and institutional structure of countries and used GDP per unit area to separate the effect of production on pollution generation from the effect of income on pollution control. Toras and Boyce (1998) examined the effects of literacy, inequality, and civil freedoms on the turning point and significance of the EKC coefficients. Barrett and Grady (2000) re-estimated the Grossman and Krueger equations after adding measures of political and civil liberties. Significantly, all of these papers relied on the GEMS air pollution data, and all found the inverted-U relationship.[8]

Some authors questioned the methodology of estimating a single regression model with panel data from many different countries, i.e., trying to identify a 'global' EKC. Stern et al (1996) advised against including countries at different stages of development in a single equation, arguing that factors other than differences in income might affect the relationship between pollution and income. Coondoo and Dinda (2002) cautioned that the pattern of causality between pollution and income might differ from one group of countries to another. De Bruyn (1997) estimated the pollution-income relationship for emissions in four OECD nations separately, highlighting the importance of structural changes within countries.[9]

Interpretation of early empirical findings on the EKC was clouded by the absence of a clear theoretical model (Thompson and Strohm, 1996, and Stern, 1998). More emphasis on theory was needed to inform the methodology and to allow empirical tests to distinguish the relationships behind the observed inverted-

---

[7] Bartlett (1994) argued that this implied a perverse effect of environmental regulation—that it might inhibit growth and thereby stall environmental improvement.

[8] Subsequent work examined emissions rather than concentrations. Hilton and Levinson (1997) separated emissions of lead from leaded gasoline into lead intensity per gallon, which reflects pollution control policy, and total gasoline consumption, which reflects the scale of activity. Selden and Song (1994) looked at emissions data for mostly OECD nations and found a turning point between $8-10,000 of per capita income for sulfur dioxide and suspended particulate matter. Selden and Holtz-Eakin (1995) found no turning point at all for carbon dioxide. Stern and Common's (2001) EKC for sulfur dioxide did not begin to slope down until per capita income reached $100,000, a level that is irrelevant to any actual economy.

[9] De Bruyn (1997) pointed out that only 13 percent of the variation in SO_2 emission targets could be explained by variations in income; hence the emphasis on income as a determining factor seemed misplaced. Carson et al, estimated EKCs for air quality within the United States, using state level panel data.

U. Antweiler, Copeland and Taylor (2001) developed a theoretical model of pollution generation and abatement to study the pollution effects of opening trade. As with many others before, they used the GEMS air pollution data as a vehicle for estimation.[10]

An important feature of this empirical literature is its heavy reliance on the GEMS air pollution data. As noted earlier, Harbaugh, Levinson and Wilson (2002) examined the properties of an expanded and corrected air pollution data set. Using these revised data, they compared pollution-income relationships between the old and new data sets and studied the sensitivity of EKC findings to functional forms, samples, and estimation methods. They found that the original GEMS data set contained significant inaccuracies. They also found that results from the new data set are not robust to rather slight changes in the sample, empirical specification, and estimation technique. Overall, they found little support for the inverted-U, the icon of the EKC hypothesis.

This review leads to three generalizations that are important for our purposes. First, the air pollution data reported in the GEMS and subsequent GEMS/AIRS data sets forms the primary foundation for the now familiar EKC generalization—the inverted-U. Second, despite a decade of concerted empirical work, there is still significant skepticism in the profession that the inverted-U is an empirical regularity.[11]

Third, and most important for our purposes, the empirical support offered for the EKC story—which purports to show how a country's pollution will change as its income increases—is drawn from cross-country panel data on pollution and income. Most of the variation in pollution in these data is across countries or monitoring sites, rather than over time. In the GEMS/AIRS data for SO_2 and particulates, the within-site (across years) standard deviation in air pollution is less than one-third as great as the across-sites (within years) standard deviation. For smoke the within-site standard deviation is about half as large as the across-sites standard deviation. The EKC hypothesis is a story about how a country's pollution will change as that country's economy grows. Support for that story has come mainly from variations in income and pollution across countries, however,

[10] Andreoni and Levinson (2001) showed that sufficiently strong increasing returns to scale in abatement can generate a theoretical EKC. Copeland and Taylor (forthcoming) present four theoretical mechanisms that could yield an EKC. In their treatment, the source of economic growth and the nature of abatement costs are key factors determining the resulting relationship between pollution and income.

[11] See, for example, HLW. Vincent (1997) tested some of the cross-country panel predictions on a panel of detailed data from Malaysian states. Not only did the parameters fail to predict the pattern of changes in Malaysian air and water pollution, none of the measures of environmental quality exhibited an EKC.

rather than direct examination of how pollution within a country changes as its income increases.[12]

3 Data

We use the GEMS/AIRS data set on air quality because of its extensive coverage and its prominence in the EKC literature. The measures used are median ambient air concentrations of sulfur dioxide, suspended particulates (TSP), and smoke (fine particulates). The income measure used is per capita real GDP in 1985 dollars from the 1991 Penn World Tables.[13]

For non-parametric, within-country estimation, we need to observe one concentration per country per year for each pollutant. The GEMS/AIRS data set generally includes observations from several cities in a country and often from multiple sites within a particular city. If a country adds a monitoring site in a relatively dirty region toward the end of the sample period, the average pollution readings for that country may indicate declining air quality simply due to the addition of the new site. Even within a city there can be considerable variation in pollution concentrations across sites.[14]

To avoid composition bias in the final series, we collect data only from monitoring sites that operated throughout all or most years covered by the GEMS/AIRS data. Observations from sites that report only sporadically are dropped. In most countries the selection of which sites to include and which to drop is a straightforward matter of choosing the longest-active site and all the other sites that are active over the same time period. Observations tend to be confined to a few major cities in each country. In a few cases where the longest-active site had *n* observations and there were quite a few sites with *n-1* observations, we dropped the extra year in the interest of having a broader data base for annual pollution readings in the country. In the sulfur dioxide data set, the largest of the three, some cases were less clear cut. Data for the US data include at least some observations for 23 locations. There were a few sites with 20

---

[12] Researchers have generally been careful to use empirical methods that allow for unobserved additive heterogeneity across countries or monitoring sites. Apart from country- or site-specific constant terms, however, a single empirical model is assumed to apply to all countries.

[13] Later in this section we compare results obtained from the GEMS/AIRS data set with results from the unmodified GEMS data set used in earlier studies.

[14] For example, the data we use for Brussels, Belgium are from a monitoring site in the city that collected TSP observations from 1976 to 1986. Also in the data set is TSP information from a different monitoring site in Brussels that collected observations only in 1985 and 1986. Observations from the second site are about 25 percent higher than readings from the first. To aggregate them would indicate an upward trend in pollution in Brussels that may not exist in reality. For estimation of a parametric model with panel data, a sensible way to deal with this composition problem is to include fixed effects for sites.

observations, but the available years were often different and confining the sample to these cities would have excluded some of the largest US cities. By including a consistent set of fifteen years we were able to include ten US cities, with multiple observation sites for a few of the largest.[15]

We excluded any country that did not have at least ten years of data after processing for consistent composition over time. The average number of monitoring sites in each country-year observation is 2.3 for smoke, 2.6 for TSP, and 3.1 for sulfur dioxide. For some larger countries, a significant share of the available data is from sites that report only sporadically. Eliminating data from sporadically reporting sites and from sites that fail to report data for at least 10 years reduces the overall sample of site observations from 687 to 409 for smoke, from 1,085 to 484 for particulates, and from 2,381 to 1,113 for sulfur dioxide.[16]

4 Within-country Relationships Between Pollution and GDP

We examine the relationship between income and pollution within countries to see if the overall pattern accords with predictions from the EKC theory. We use a simple, non-parametric approach. For each country, observations on pollution and per capita GDP are ordered by per capita GDP and tritiles are formed. The tritiles are three subsets of observations that contain, respectively, the lowest one-third of income observations, the middle one-third, and the highest one-third. We then compute mean pollution and mean per capita GDP for each tritile and plot the results—mean pollution against mean GDP for each country. We perform this analysis twice for each country and pollutant, once using current per capita GDP as the income measure and once using a three year average of lagged per capita GDP.

Our intent is to see whether these plots of pollution against income, each with three data points, are consistent or inconsistent with the EKC hypothesis. With only three data points, there are only four possible ways the data could be ordered: monotone increasing, monotone decreasing, a single peak (inverted-U,) and a single trough (U-shaped). We regard the following patterns as *consistent* with the EKC story: monotone increasing for a ‘poor’ country, monotone decreasing for a ‘rich’ country, and single peaked for a country of any income. We regard the following patterns as *inconsistent* with EKC behavior: monotone decreasing for a ‘poor’ country, monotone increasing for a ‘rich country’, and a

[15] We tested the sensitivity of the results reported in the next section to the choice of monitoring sites by considering two alternative data sets for the US, one for Japan, one for Australia, and one for New Zealand. The pattern of the relationship between income (or lagged income) and pollution did not change in any of the alternate cases.
[16] Details about the procedure for eliminating observations and the final data set actually used are available on request.

single trough (U-shaped) for any country. The criteria used for identifying 'rich' and 'poor' countries are explained later.

We begin by simply identifying countries displaying each pattern, counting their numbers, and giving summary information on their income levels. Later we examine the consistency of these results with the EKC hypothesis more formally. Using lagged income is consistent with previous EKC analysis and seems a more appropriate measure because it allows the policy response to be gradual. For this reason we place more emphasis on these estimates in discussions.

Tables 1 and 2 show results for sulfur dioxide using lagged and current per capita GDP, respectively. There are 23 countries in the sample overall. When *lagged* GDP is used as an income measure, 6 countries exhibit a trough while only 4 display the predicted single peak. On the positive side, the average income of countries for which SO_2 decreases as income increases exceeds average income for countries with a monotone increasing relationship. Japan is present in the former group and Brazil and Iran are in the latter, however, which does not accord well with the EKC hypothesis.

For the estimates based on *current* GDP per capita, 7 exhibit the classic inverted-U associated with the EKC hypothesis while 4 exhibit a trough. Again, the increasing relationship between income and SO_2 in relatively rich Japan and the decreasing relationships in relatively poor Brazil and Iran do not support the EKC paradigm. Neither does the fact that the midrange of GDP for the one country showing an increasing relationship between pollution and income exceeds the midrange of GDP for countries showing a decreasing relationship.

European Union policies on pollution control affected the behavior of some countries in our sample and this fact bears on the interpretation of results. EU regulation of ambient air quality began in 1980 with Directive 80/779/EEC, requiring member nations to harmonize standards for SO_2 and suspended particulates. EU members and prospective members were required to adhere to the 'environmental acquis', the EU's body of environmental standards and laws. The deadline for compliance was 1983, which is right in the middle of the sample period. Adherence to this directive is an environmental policy response, of course, and policy responses are part of the EKC story. A single policy response was required of all EU members, however, rich and poor alike, which is not in keeping with the EKC hypothesis. Furthermore, Portugal and Spain entered the EU after this environmental legislation went into force, so their pollution control efforts may have represented a preference for admission to the Union rather than clean air, per se. It is also significant that the EU heavily subsidized the pollution control costs of four relatively poor EU members, Ireland, Spain, Greece, and Portugal. The EU Structural Fund and Cohesion Fund provided assistance so that these countries "could build the public sector infrastructure needed to comply with the environmental acquis" (DEPA 2001) when they were unable to meet EU pollution targets. To summarize, all four of these poorer EU members may have pursued relatively vigorous pollution control simply due to EU policy. These considerations may account for certain results in Tables 1 and 2. Spain experienced decreasing in SO_2 as income rose, while Ireland's pollution decreased with income at relatively high income levels, i.e., on the right-hand side of the peak.

Tables 3 and 4 give results for suspended particulates. Overall, the number of cases displaying a trough, 10, slightly exceeds the number displaying a peak, 9. Judging from these cases alone, the predictive power of the EKC hypothesis is poor for particulates. Among the 7 cases of monotone behavior, two are anomalous (Brazil in Table 3 and Yugoslavia in Table 4). Ignoring countries exhibiting a single trough, which are clearly inconsistent with EKC, the ordering of mean income for groups in Tables 3 and 4 broadly agrees with the EKC hypothesis.[17]

Our results for smoke, shown in Tables 5 and 6, are the most problematic for the EKC hypothesis. Looking across results for lagged and current GDP, more countries exhibit a U-shaped relationship (6), than an inverted-U shape (4). The cases of monotone relationships also contain contrary evidence. The countries for which pollution increases as income increases are relatively rich, Denmark and Ireland. The group for which pollution decreases as income increases includes such relatively impoverished nations as Brazil, Chile, Egypt, Poland, and Venezuela. Overall, the smoke data are the least consistent with the EKC hypothesis.

When considered across all three pollutants, are the pollution-income relationships in Tables 1-6 generally consistent with the EKC prediction? Figure 1 shows the four possible shapes for relationships among three data points, our tritiles. Each cell, corresponding to a given income level and pollution-income relationship, is labeled consistent, inconsistent, or inconclusive to indicate whether or not it agrees or disagrees with the EKC hypothesis. We count a single peak as consistent with the hypothesis regardless of the country's income level, and regard this as a generous interpretation of the EKC prediction. A trough is considered inconsistent with EKC behavior for any level of income. An increasing relationship between pollution and GDP is consistent for a poor country but not a rich country, and vice versa for a decreasing relationship. We characterize the EKC's prediction for the remaining two cases as inconclusive.

Countries were divided into low, middle and high income groups according to their 1983 per capita GDP. Cutoff points for each income category were set to be

[17] The average income for cases exhibiting a single peak is higher than average income for those with an increasing relationship between pollution and GDP and lower than those with a declining relationship between pollution and GDP.

consistent with the estimated turning points in the EKC literature. For example, the income range for countries classified as poor was set purposely to correspond to the left side of the EKC peak for air pollutants, as reported in the empirical EKC literature. Specifically, a country was classified as low income if its 1983 was below $3,500 (1986 dollars), as middle income if its income was between $3,500 and 7,000, and as high income if its income exceeded $7,000. To judge what fraction of observations would be expected to fall into each cell in Figure 1 under random assignment, we start by observing the fraction of countries that fall into each of the three income ranges. For a given income category, we then assume (under random assignment) that each of the four income-pollution relationships is equally likely. This is the pattern expected under random assignment, and a simple X^2 test can be used to determine if the observed pattern is significantly different.

The test was performed for three pollutants (SO_2, smoke, and suspended particles) and two income measures (current and lagged GDP per capita,) so 6 tests were performed in all. The $X^2(11)$ statistics and significance levels for these tests are as follows:

Pollutant:	Income measure:	X^2	(signif.)
SO_2	lagged GDP	18.40	(7.28%)
SO_2	current GDP	23.10	(1.71%)
Particulates	lagged GDP	8.50	(66.79%)
Particulates	current GDP	14.33	(21.53%)
Smoke	lagged GDP	4.60	(94.9%)
Smoke	current GDP	9.93	(53.67%)

Only one of the 6 cases, for SO_2 and current GDP, beats random assignment with 95% confidence.[18] The SO_2 with lagged GDP case beats random assignment with a bit more than 90**%** confidence. The income-pollution relationships for particulates and smoke are not significantly different than what one would get by throwing (poorly aimed) darts at Figure 1.

We replicated this analysis with the original, smaller GEMS data set used by Grossman and Krueger (1995), Shafik and Bandyopadhyay (1992), Toras and Boyce (1998), Antweiler, Copeland and Taylor (2001) and others. The intent was

[18] If we test the number of observations falling into *any* of the EKC-consistent vs. EKC-inconsistent or inconclusive categories, the resulting $X^2(2)$ statistic differed from random assignment only at the 90**%** confidence level.

to see if this earlier data set, which consistently yielded a single peaked EKC in cross-country analysis, would also produce within-country patterns that agree with the EKC hypothesis. We used all countries for which we had at least nine years of observations to construct country-year pollution data and tritiles and followed the procedure explained earlier.

Sulfur dioxide is the only pollutant for which the EKC outperforms random assignment, however, it does so with a high degree of confidence. Only 4 of 20 nations in the SO_2 sample exhibit the inverted-U within the sample period, however. Three of these nations – Ireland, Greece, and Spain—were being brought into compliance with European Union environmental standards during the sample period as discussed earlier. Thus it would be unwise to place much emphasis on an SO_2 'turning point' estimate from these data.

For particulates, within-country results from the original GEMS data set show little if any correspondence with the EKC hypothesis. Contrary to the EKC story, countries exhibiting a negative relationship between pollution and income tend to be poor (e.g., Greece and Thailand) and those with a positive relationship between pollution and income tend to be rich (e.g., Germany and Denmark). Two countries exhibit a trough-shaped relationship. The level of agreement is even worse for smoke. For this pollutant the troughs outnumber the peaks, 3 to 2, countries with increasing pollution-income relationships tend to be rich (e.g., Denmark and Ireland), and countries with decreasing pollution-income relationships tend to be poor (e.g., Chile and Egypt).

To summarize results from the GEMS/AIRS data, we observe significant agreement with EKC predictions for SO_2 when current GDP is used as an income measure, and near significant agreement when the preferred income measure, lagged GDP, is used. Overall, however, the famous inverted-U is not prominent in any of these results. Scanning across all three pollutants and two income measures, the reverse of the inverted-U, a trough, is actually more common. For the best behaved pollutant, SO_2, peaks beat troughs by only 11 to 10. It is worth reiterating that most of the evidence we count as supporting the EKC prediction for SO_2 is simply observations on rich countries exhibiting a negative relationship between pollution and GDP. For smoke and particulates, the EKC hypothesis does no better at predicting pollution-income patterns than random assignment.

5 Are Implied Income Elasticities of Pollution Plausible?

Average GDP in nations covered by the GEMS/AIRS data grew by 45 percent between the early 1970s and late 1980s, clearly creating a *potential* for increased pollution. Actual pollution levels fell over this period, however. Average SO_2 concentrations in the GEMS/AIRS data set used to construct our tritiles dropped by 22 percent.[19] Average concentrations of smoke and suspended particulates also fell, but less dramatically. The EKC hypothesis attributes declining pollution in the face of growing income to an increase in the demand for pollution control.[20] In what follows, we examine whether or not such an income effect could plausibly account for the observed combination of reductions in air pollution and increases in income.

Figure 2 illustrates our approach. For a given country, S denotes pollution (SO_2, smoke, suspended particulates), X denotes output (real national GDP), and the subscripts L and H indicate years of low and high GDP in our sample.[21] Thus, S_L and X_L are the country's observed pollution and GDP in the low output year. Absent a change in pollution control policy, technology, or the composition of output, the pollution generated per unit output will be constant. Hence, 'pollution generation' in the high output year, S_E, is calculated as:

$$S_E = (S_L/X_L) \cdot X_H \quad (1)$$

where X_H is GDP in the high output year.

If observed pollution in the high output year falls short of the pollution generated, S_E , we regard the difference as pollution control. In keeping with the EKC hypothesis, we attribute this reduction in pollution to an increase in income and compute an implied income elasticity. To do this we simply calculate the percentage difference between S_E and S_H and then divide it by the corresponding percent change in *per capita* GDP.[22] The result is an income elasticity of pollution and is expected to be negative because pollution is a 'bad'. Per capita income is used because a policy response seems most likely to follow from a change in individual income. We also compute income elasticities with respect to the percent change in total GDP, however, to see how sensitive the results are to this choice.

[19] The coverage of countries is somewhat different in our sample. The percentages in the text are only meant to indicate general trends.
[20] Other causes would include the development of new technologies for controlling pollution and increased knowledge regarding the effects of air pollution on health. These causes do not figure prominently in the EKC literature, however. Another potential cause is the 'composition effect', which occurs if an economy's output shifts toward production of cleaner goods either over time or as income rises.
[21] The estimate of pollution generation is based on total GDP rather than per capita GDP because total output is the pollution source.
[22] We compute arc elasticities, so the percent change in pollution is calculated as: $(S_E - S_H)/(5*(S_E+S_H))$. It is negative if actual pollution is lower than estimated pollution generation. Percent changes in income are computed similarly.

Table 7 reports implied income elasticities for SO_2, smoke, and suspended particulates for countries in the sample.[23] Results for SO_2 are highlighted in the following discussion since the country coverage is most extensive for this pollutant. The elasticities computed from percent changes in *per capita* GDP, which seems the more appropriate definition, average –3.71 over the entire sample. If one regards income growth as the driving force behind the reductions in observed SO_2 pollution (relative to levels that would be expected based on growth in output) then a 10 percent increase in per capita income will induce a 37 percent reduction in pollution in the average country. Average elasticities for smoke and particulates are smaller, but still large relative to our expectations. They imply that a 10 percent increase in per capita income will reduce smoke and particulate pollution by 20 percent and 24 percent, respectively.

In some cases a country experienced a drop in output late in the sample period, causing the years of maximum and minimum GDP per capita to be close to one another. In some cases minimum GDP actually occurred after maximum GDP, as in Iran and Poland. Because the pollution experienced in these cases may be atypical, we recomputed the averages for countries in which the minimum and maximum GDP were separated by more than 10 years and more than 15 years. These results are in the last two rows. Restricting the sample in this way typically increases the elasticity in absolute value.

Elasticities computed from the percentage change in total GDP, shown in the last three columns, are smaller in absolute value because most countries experienced population growth. Thus total GDP increased at a faster rate than per capita GDP and the resulting income elasticities are smaller. Even these elasticities are large in absolute value, particularly for SO_2.[24]

The implied elasticities in Table 7 relate to the response of *environmental quality levels* to changes in income, which corresponds to a conventional income elasticity of demand for a market commodity.[25] Valuation studies generally estimate the determinants of *willingness-to-pay* for environmental improvement,

[23] The criterion for including countries in samples was explained earlier.

[24] The elasticities with respect to per capita income for Venezuela are positive and relatively large, but are negative with respect to national GDP, which deserves explanation. Between its years of low and high total GDP, Venezuela's change in pollution indicated that some abatement took place. This implies a negative income elasticity of pollution with respect to national GDP. Venezuela's *per capita* GDP actually fell over the same period, however, resulting in a positive elasticity of pollution with respect to per capita income. The positive elasticities for smoke in Denmark and other countries result from the fact that actual smoke pollution increased faster than national GDP, which our approach interprets as 'negative abatement'. Since this occurred while national and per capita GDP were rising, the result is a positive implied income elasticity of pollution.

[25] The demand response comes about as a result of a political process in this case, which suggests interpreting the implied elasticities as pertaining to the median voter.

rather than determinants of 'demand', and this renders comparisons somewhat ambiguous. Flores and Carson (1997) point out that the income elasticity of willingness-to-pay for a quantity constrained good is less than the ordinary income elasticity of demand under plausible circumstances, though there are exceptions. Regarding the income elasticity of willingness-to-pay, the valuation literature generally concludes that it is no greater than unity. Kristrom and Riera (1996) survey a group of contingent valuation studies from Europe and conclude that the income elasticity is less than one in each case.[26] In a hedonic property value study, Harrison and Rubinfeld (1978) concluded that the income elasticity of willingness-to-pay for reductions in one type of air pollution is roughly 0.8 to 1.0. Nelson (1978) uses a hedonic approach to estimate a conventional income elasticity of *demand for air quality* in the Washington DC area, where air quality is measured as the reciprocal of particulate air pollution. His income elasticity is comparable to ours and he finds it is approximately unity. Khanna (2002) examined U.S. census tract data on pollution and income, controlling for factors that should determine scale and composition effects, in order to identify the technique, or abatement, effect. Khanna (2002) found a significant income elasticity only for particulates, and its absolute value is less than unity. Overall, the valuation literature gives some evidence (Nelson, 1978 and Khanna, 2002) that the demand for clean air is approximately unity, and no clear evidence that the income elasticity of demand for clean air or other environmental amenities exceeds unity.

For purposes of comparison, focus on the first three columns and last two rows of Table 7. These are implied elasticities that use per capita GDP as an income measure, which we regard as more appropriate, and exclude countries for which minimum and maximum GDP are separated by less than 10 years. These income elasticities are between 3.5 and 4.1 (in absolute value) for SO_2, between 3.2 and 3.4 for smoke, and 2.2 for particulates. We are unaware of *any* valuation-based income elasticity estimates in this range; indeed, income elasticities for market goods are seldom if ever this large. Accordingly, it appears implausible to us that the pollution control observed in these countries could be due to an income effect operating through the demand for clean air.

6 Downward Trends in SO_2: Does EKC Theory Add any Insight?

The preceding income elasticity estimates attribute *all* shifts in the demand for clean air to changes in income. They also assume that pollution control costs remained constant over the period. It seems clear, however, that increased knowledge of the health effects of air pollution and the general increase in public support for environmental protection caused the desired level of air quality to rise

[26] Unfortunately, these studies examine land use amenities rather than clean air.

independent of income effects, certainly in the U.S. and other wealthy nations. In addition, pollution control technology almost surely improved during the sample period. Both factors should account for some of the pollution reduction observed in the data, reductions that, in keeping with the EKC hypothesis, we attributed to an income effect. In what follows we examine this possibility.

Although pollution control regulations clearly were on the books earlier, air quality became a prominent public policy issue in the late 1960s and the 1970s, particularly in wealthy countries.[27] The close correlation in time with events such as Earth Day, highly publicized oil spills, initiatives to protect endangered species, and efforts to eliminate pesticides suggests that more stringent air quality regulations arose partly from a broad shift in public attitudes toward better environmental protection. An alternative to the EKC income effect is to view these events as signals of a shift in the equilibrium level of pollution, particularly in wealthier nations, brought about by education and by better information on environmental problems. Such a shift cannot be achieved instantly, however, but only gradually as more stringent regulations are adopted, as enforcement strategies are devised, and as old heavily polluting capital wears out and is replaced.

This is a story about a shift in the desired level of pollution control from an old 1960s equilibrium, where environmental health risks are not widely publicized, environmental education is largely non-existent, and pollution control technologies are primitive, to a new 1990s equilibrium where each of these gaps has been filled to some degree. It does not highlight income growth as a factor that drives environmental protection. Of course, income may well be an important factor in this process; wealthy nations may have made the transition from the old to the new equilibrium more quickly than poorer nations, and they may have adopted more ambitious pollution control targets. This does not imply that an inverted-U should describe the relationship between income and pollution over this period, however, either in cross-country or time series data.

In what follows we examine the explanatory power of this alternative 'trend model' for SO_2. Sulfur dioxide is emphasized because the available data are most extensive for this pollutant. Also, SO_2 is the only pollutant for which our within-country analysis found any support for the EKC hypothesis. First, we estimate individual, within-country time trends for SO_2. Next, to see if rates of pollution reduction were more rapid in richer countries, we compute the correlation between the country-specific pollution trends and country income. Finally, we add

[27] Portney (1990, p. 28-30) reviews pre-1970 air pollution policy in the U.S. Portney (1990, p. 48) also presents data for the U.S. showing that emissions of particulates dropped rapidly after 1970 and sulfur dioxide emissions, which had peaked in 1970, fell steadily thereafter. He also cites EPA data from a limited number of monitoring sites, however, indicating that ambient concentrations of both pollutants had begun to decline during the 1960s (Portney, 1990, pp. 50-51.)

income and income squared to the simple trend model for each country, test the significance of the income terms, and see whether or not they correspond to EKC behavior.

Results are presented in Table 9. The dependent variable is the country-specific average SO_2 concentration in a given year, in micrograms per cubic meter. Column (1) shows the trend coefficients and their significance levels. Fifteen of the 23 are significant, and all but one of these is negative. Only Japan experienced a significant, positive trend in sulfur dioxide over the sample period. The simple correlation between the within-country trends and country income, measured as per capita GDP in 1980, is indeed negative, -.36, and significant at 10 percent. We carried out the same procedure with exponential trends, i.e., trends from regressing the log of SO_2 pollution against time. The results were generally similar; 13 of the 23 countries had significant trends, all of which were negative. The correlation between the exponential trends and per capita GDP was also negative, and stronger; -.56, which is significant at 0.5 percent.[28] Using either linear or exponential trends, higher income countries reduced SO_2 pollution at a more rapid rate than poorer countries.[29]

Can the EKC hypothesis enhance our understanding of the within-country behavior of pollution over 1970-1992, beyond what the trends show? This was checked by adding lagged per capita GDP and its square to the trend model. Column (2) reports whether the income terms describe a peak (P) or trough (T) and their significance levels.[30] Cases where the income terms are not jointly significant at 10 percent or better, 8 of the 23, are not reported. Of the 15 significant income terms, the troughs outnumber the peaks, by 9 to 6. Column (4) provides summary information for models that use current per capita GDP as the income measure. Here, the income terms are jointly significant in 10 of the 23 cases. Of these 10 significant cases, 7 are troughs and only 3 are peaks.

An estimated trough need not be inconsistent with the EKC hypothesis. If the country involved is wealthy and if the trough bottoms out at an income level above the income range of the sample, the country might just be on the downward sloping portion of an EKC. According to the data in columns (3), (5), and (6), however, this is not the case. Some of the countries exhibiting troughs are poor

[28] These results are available on request.

[29] It might be thought that high-income countries started with higher SO_2 concentrations in the early years, as a consequence of greater output, so they had more cleanup to undertake. This might, then, account for their more rapid rates of decrease. This possibility was checked by regressing SO_2 levels against per capita GDP for years prior to 1975. While the coefficient was positive, it was small and did not approach significance (t=0.46) so this hypothesis is not supported.

[30] None of the estimates implied monotone relations between pollution and income.

(Iran, Poland, and Yugoslavia) and where troughs do occur they tend to hit bottom at an income level close to the country's sample mean.

On balance, the EKC hypothesis adds little if any insight over a simple 'trend model' for SO_2, one that posits that countries generally tried to reduce pollution during the 1970-1992 period and rich countries cleaned up faster than poor ones.

7 Conclusions

The preceding analysis of trends is clearly not intended as a serious model of pollution control, or as a thorough econometric analysis of the available time series data. We view it mainly as a vehicle for questioning whether the EKC hypothesis can add to our understanding of pollution control worldwide, beyond what is obvious. The vast majority of countries experienced growth in per capita GDP during the 1970-1992 period, and average worldwide pollution levels fell during this same period. The EKC hypothesis attributes the pollution decline to the increase in income. Our intent was simply to point out that any other determining factor that is trended over time, e.g., better information and education on the benefits of environmental protection, would have the same effect. Most of the data points from Tables 1 and 2 that we classified as supporting the EKC hypothesis for SO_2 are simply within-country observations of increasing income and decreasing pollution. Once we allow for the effects of trended variables, as in Table 8, income remains a significant determining factor in some countries, but the way it affects pollution generally does not agree with the EKC hypothesis. Indeed, the oddly shaped pollution-income relationships summarized in Table 8 have no ready explanation.

We have not attempted to formulate a model of what causes the pollution level to be what it is in a given country at a given time, so our empirical results may be open to several interpretations. This is a valid criticism, especially with respect to the income elasticity estimates, though it is one we share with the most of the empirical literature on the EKC. In defense, it was not our aim to develop a framework for understanding why pollution behaves as it does in individual countries. Rather, our aim was to see if the inverted-U is a useful stylized fact about the way pollution and income are related within individual countries. On balance, and given the data presently available, we are not convinced that it is.

References

Antweiler, Werner, Brian R. Copeland, and M. Scott Taylor, 2001. "Is Free Trade Good for the Environment?" *American Economic Review,* 91 (4) 877-908.

Bartlett, Bruce, 1994. "The high cost of turning green." *The Wall Street Journal,* September 14.

Barrett, Scott, and Kathryn Graddy, 2000. "Freedom, Growth, and the Environment" *Environment and Development Economics* 5(4) 433-56.

Carson, Richard T., Y. Jeon, and D.R. McCubbin, 1997. "The Relationship Between Air Pollution and Income: US Data", *Environment and Development Economics,* 2, 433-450.

Coondoo, D. and S. Dinda, 2002. "Causality between income and emissions: a country group-specific econometric analysis." *Ecological Economics*, 40 (3) 351-367.

Copeland, Brian R., and M. Scott Taylor, forthcoming. *Trade and the Environment: Theory and Evidence*, Department of Economics, University of British Columbia, Vancouver Canada.

Dasgupta, Susmita, Benoit Laplante, Hua Wong, and David Wheeler. 2002. "Confronting the Environmental Kuznets Curve." *Journal of Economic Perspectives*. 16(1) 147-168.

Flores, Nicholas E., and Richard T. Carson, 1997. "The Relationship between the Income Elasticities of Demand and Willingness to Pay." *Journal of Environmental Economics and Management* 33(3) 287-295.

General Agreement on Tariffs and Trade, 1992. *International Trade 1990-1991*. Volume 1. Geneva.

Grossman, Gene and Alan B Krueger. 1993. "Environmental Impacts of a North American Free Trade Agreement," in Peter Garber, ed., *The Mexico-U.S. Free Trade Agreement*, M.I.T Press.

Grossman, Gene M., and Alan B. Krueger, 1995. "Economic Growth and the Environment." *Quarterly Journal of Economics,* 112 (2) 353-378.

Harbaugh, Willima T., Arik Levinson, and David Molloy Wilson, 2002. "Reexamining the Empirical Evidence for an Environmental Kuznets Curve." *Review of Economics and Statistics*, 83(3) 541-551.

Harrison, David, and Daniel L. Rubinfeld, 1978. "Hedonic Housing Prices and the Demand for Clean Air." *Journal of Environmental Economics and Management* 5(2) 81-102.

Hilton, F. G. Hank, and Arik Levinson, 1998. "Factoring the Environmental Kuznets Curve: Evidence from Automotive Lead Emissions." *Journal of Environmental Economics and Management*. 35(2) 126-41.

Holtz-Eakin, D. and T. M. Selden, 1995. "Stoking the Fires? CO_2 Emissions and Economic Growth." *Journal of Public Economics* 57(1) 85-101.

Khanna, Neha, 2002. "Is Air Quality Income Elastic? Revisiting the Environmental Kuznets Curve Hypothesis." Working Paper WP0207, Department of Economics, Binghampton University, Binghampton NY.

Kristrom, Bengt, and Pere Riera, 1996. "Is the Income Elasticity of Environmental Improvements Less Than One?" *Environmental and Resource Economics* 7 45-55.

Nelson, Jon P., 1978. "Residential Choice, Hedonic Prices, and the Demand for Urban Air Quality." *Journal of Urban Economics* 5 357-369.

Panayotou, T., 1997. "Demystifying the Environmental Kuznets Curve: Turning a Black Box into a Policy Tool." *Environment and Development Economics,* 2: 383-399.

Portney, Paul R., 1990. "Air Pollution Policy." In Paul R. Portney, ed., *Public Policies for Environmental Protection*., Washington DC: Resources for the Future.

Selden, T. M. and D. Song, 1994. "Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions?" *Journal of Environmental Economics and Management*, 27 (2) 147-162.

Shafik, N. and S. Bandyopadhyay, 1992. "Economic Growth and Environmental Quality: Time Series and Cross-Country Evidence." Policy Research Working Paper No. WPS 904, Washington, D.C.: The World Bank.

Stern, David I., 1998. "Progress on the Environmental Kuznets Curve?" *Environment and Development Economics*, 3 173-96.

Stern, David I., Michael S. Common, and Edward B. Barbier, 1996. "Economic Growth and Environmental Degradation: The Environmental Kuznets Curve and Sustainable Development." *World Development*, 24 (7) 1151-1160.

Thompson, P., and L. A. Strohm, 1996. "Trade and Environmental Quality: A Review of the Evidence." *Journal of Envir. and Development*, 5 (4) 363-389.

Torras, M. and James K. Boyce, 1998. "Income, Inequality, and Pollution: A Reassessment of the Environmental Kuznets Curve," *Ecological Economics*, 25 147-60.

World Bank, 1992. *World Development Report: 1992*, New York: Oxford University Press.

Table 1. The Shape of the Pollution-GDP Relationship: SO_2 vs. Lagged Real GDP

SO_2	*N*	Countries
Single peak	4	China, Ireland, Hong Kong,
Mean lagged GDP at peak	4,240	Thailand
Single trough	6	Chile, India, Israel, Poland,
Mean lagged GDP at trough	5,905	Yugoslavia, Canada
Increasing	2	Japan, Venezuela
Mean center of lagged GDP range	8,977	
Decreasing	11	Australia, Belgium, Brazil, Finland,
Mean center of lagged GDP range	9,861	W. Germany, Iran, Netherlands,
		New Zealand, Spain, U.K., U.S.

Table 2. The Shape of the Pollution-GDP Relationship: SO_2 vs. Current Real GDP

SO_2	*N*	Countries
Single peak	7	China, Chile, Ireland, Poland, H.K.,
Mean GDP at peak	4,804	Thailand, Venezuela
Single trough	4	Brazil, India, Israel, Netherlands
Mean GDP at trough	5,904	
Increasing	1	Japan
Mean center of GDP range	11,562	
Decreasing	11	Australia, Belgium, Canada, Finland
Mean center of GDP range	10,686	W. Germany, Iran, N.Z., Spain, U.K., U.S.
		Yugoslavia

Table 3. The Shape of the Pollution-GDP Relationship:
Particulates vs. Lagged Real GDP

Total Suspended Particles	*N*	Countries
Single peak	4	China, Finland, Japan, Thailand
Mean lagged GDP at peak	6,674	
Single trough	6	W. Germany, India, Iran, Malaysia
Mean lagged GDP at trough	6,005	Yugoslavia, Belgium
Increasing	0	
Mean center of lagged GDP range	-	
Decreasing	3	Australia, Brazil, Canada
Mean center of lagged GDP range	10,242	

Table 4. The Shape of the Pollution-GDP Relationship:
Particulates vs. Current Real GDP

Total Suspended Particles	*N*	Countries
Single peak	5	China, India, Thailand, Finland, Japan
Mean GDP at peak	8,045	
Single trough	4	Belgium, Brazil, W. Germany, Malaysia
Mean GDP at trough	7,759	
Increasing	1	Iran
Mean center of GDP range	4,853	
Decreasing	3	Australia, Canada, Yugoslavia
Mean center of GDP range	10,793	

Table 5. The Shape of the Pollution-GDP Relationship:
Smoke vs. Lagged Real GDP

Smoke	*N*	Countries
Single peak	3	Egypt, Venezuela
Mean lagged GDP at peak	6,549	New Zealand
Single trough	3	Belgium, Chile, Iran
Mean lagged GDP at trough	5,798	
Increasing	2	Denmark, Ireland
Mean center of lagged GDP range	9,069	
Decreasing	5	Brazil, H.K., Poland,
Mean center of lagged GDP range	6,634	Spain, United Kingdom

Table 6. The Shape of the Pollution-GDP Relationship:
Smoke vs. Current Real GDP

Smoke	*N*	Countries
Single peak	1	Poland
Mean GDP at peak	4,218	
Single trough	3	Belgium, Iran, U.K.
Mean GDP at trough	8,092	
Increasing	2	Denmark, Ireland
Mean center of GDP range	9,826	
Decreasing	7	Brazil, Chile, Egypt, H.K.,
Mean center of GDP range	6,203	N.Z., Spain, Venezuela

Table 7. Implied income elasticities of pollution

Pollutant:	SO_2	Smoke	Partic.	SO_2	Smoke	Partic.
GDP measure	Per cap.	Per cap.	Per cap.	Total	Total	Total
Australia	-7.92		-4.15	-4.52		-2.37
Belgium	-5.47	-4.52	-3.59	-5.15	-4.24	-3.45
Brazil	-8.98	-10.80	-4.68	-2.75	-3.31	-2.43
Canada	-1.84		-3.44	-1.30		-2.42
China	-1.06		-1.99	-0.76		-1.43
Chile	-1.00	0.94		-0.82	0.77	
Denmark		0.94			0.77	
Egypt		-2.79			-1.45	
Ireland	-2.89	0.22		-2.36	0.18	
Finland	-2.42		-0.86	-2.20		-0.78
W. Germany	-3.93		-1.62	-3.46		-1.43
Hong Kong	-2.27	-1.51		-1.75	-1.16	
India	-2.47		-3.20	-1.26		-1.63
Iran	-1.45	0.11	0.41	-1.87	0.14	0.54
Israel	-3.26			-1.49		
Japan	-2.37		-0.56	-1.95		-0.50
Malaysia			-3.12			-1.65
Netherlands	-6.30			-4.36		
New Zealand	-10.31	-3.62		-7.34	-2.57	
Poland	-0.87	-1.14		-0.97	-1.27	
Spain	-4.45	-4.06		-3.44	-3.14	
Thailand	-1.56		-2.10	-1.15		-1.56
U. K.	-6.09	-3.97		-5.87	-3.83	
U. S.	-6.78			-3.58		
Venezuela	1.23	2.91		-0.82	-1.95	
Yugoslavia	-2.91		-2.99	-2.57		-2.64
Avg. elasticity	-3.71	-2.01	-2.45	-2.68	-1.52	-1.67
Avg. >10 years	-4.12	-3.23	-2.24	-2.84	-2.35	-1.56
Avg. >15 years	-3.58	-3.42	*	-2.95	-2.29	*

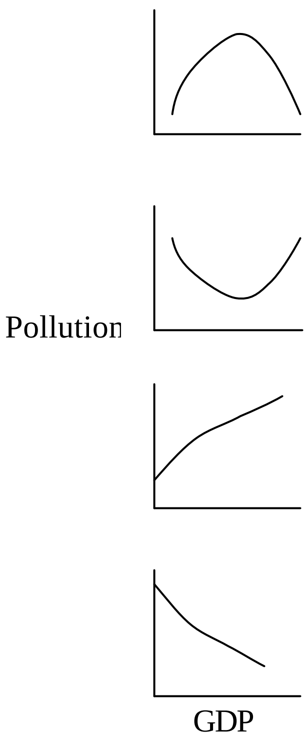
Excludes countries with fewer than 10 observations on pollution and GDP. Avg.>10 years is an average elasticity for countries with more than 10 years between minimum and maximum GDP, etc.
*Insufficient observations..

Table 8. Country-specific Trends in SO_2 and Shapes of Country-specific EKCs.

Country	Trend (1)	Lagged GDP: Peak or Trough? (2)	Lagged GDP: Turning Point (3)	Current GDP: Peak or Trough? (4)	Current GDP: Turning Point (5)	GDP in 1980 (6)
Australia	-3.69***	--		--		$12,520
Belgium	-6.75***	T**	$11,347	T***	$10,102	$11,109
Brazil	-5.23***	P**	$4,139	--		$4,303
Canada	-0.79***	T*	$8,450	--		$14,133
China	-0.01	P**	$983	P*	$1,096	$966
Chile	1.73	--		--		$3,892
Ireland	-1.17*	--		--		$6,823
Finland	-1.36***	--		P*	$13,641	$10,851
W. Germany	-4.60***	--		--		$11,920
Hong Kong	-0.18***	P**	$10,578	--		$8,719
India	1.32	--		--		$882
Iran	1.46	P**	$1,913	T**	$5,572	$3,434
Israel	-0.71	--		--		$7,895
Japan	2.86***	P**	$9,593	P*	$14,749	$10,072
Netherlands	-3.00***	T***	$10,519	T***	$10,980	$11,284
New Zealand	-1.50***	T***	$10,941	T***	$12,445	$10,362
Poland	-0.11	T***	$4,500	--	$4,319	$4,419
Spain	-5.95***	T***	$8,297	T**	$8,431	$7,390
Thailand	-0.13	--		--		$2,178
U.K.	-9.77***	T***	$10,010	--		$10,167
U.S.	-1.87***	T***	$15,755	T***	$14,795	$15,295
Venezuela	-0.21	P***	$7,952	--		$7,401
Yugoslavia	-2.12**	T***	$4,980	T***	$5,459	$5,565

Significance: *** 1% or better, ** 5% or better, * 10% or better.
Notation: P indicates peak, T indicates trough, -- indicates no significant relationship.

Income Level:



Shape of relationship:	Low	Middle	High
	Consistent	Consistent	Consistent
	Inconsistent	Inconsistent	Inconsistent
	Consistent	Inconclusive	Inconsistent
	Inconsistent	Inconclusive	Consistent

Figure 1. Expected Relationships Under the EKC Hypothesis

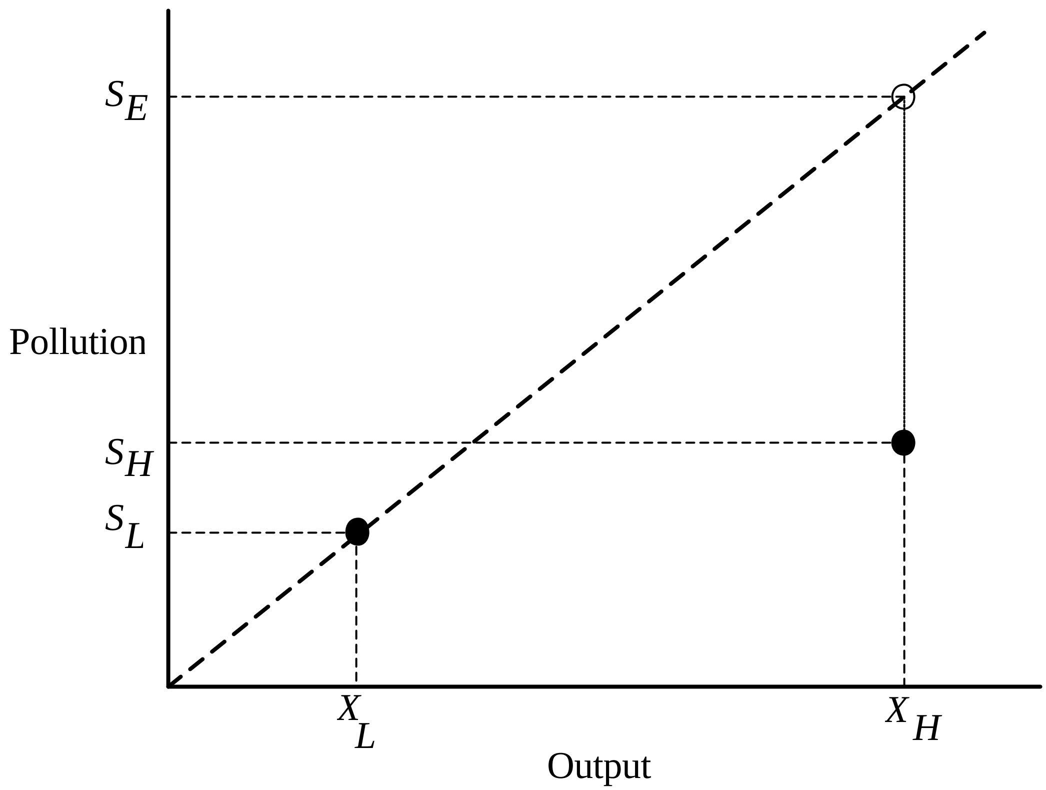


Figure 2. Income growth, pollution generation, and abatement