The Environmental Kuznets Curve
A Primer

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Introduction

Since 1991, when economists first reported a systematic relationship between income changes and environmental quality, the relationship known as the Environmental Kuznets Curve (EKC) has become standard fare in technical conversations about environmental policy (Grossman and Krueger 1991). When first unveiled, EKCs revealed a surprising outcome. The early estimates showed that some important indicators of environmental quality such as the levels of sulfur dioxide and particulates in the air actually improved as incomes and levels of consumption went up.

Prior to the advent of EKCs, many well-informed people believed that richer economies damaged and even destroyed their natural resource endowments at a faster pace than poorer ones. They thought that environmental quality could only be achieved by escaping the clutches of industrialization and the desire for higher incomes. The EKC's paradoxical outcome inspired a large amount of research. We now know far more about linkages between an economy and its environment than we did before 1991.

EKCs are statistical artifacts that summarize a few important aspects of collective human behavior in two-dimensional space. A chart showing an Environmental Kuznets Curve reveals how a technically specified measurement of environmental quality changes as the fortunes of a nation or other large human community change.

The advent of EKCs raise many questions: Where did the name "Environmental Kuznets Curve" come from? Why Kuznets? What have we learned about the statistical relationships between various measures of environmental quality and income? Do all aspects of environmental quality deteriorate or improve systematically with economic development? Does the degree of property rights and contract enforcement make a difference?

This primer addresses each of these questions. The following section explains how the EKC got its name, describes the general form of the first Kuznets Curve, and shows how the original concept was modified for environmental use. Some brief theoretical considerations are offered in this section to lay groundwork for more details that come later.

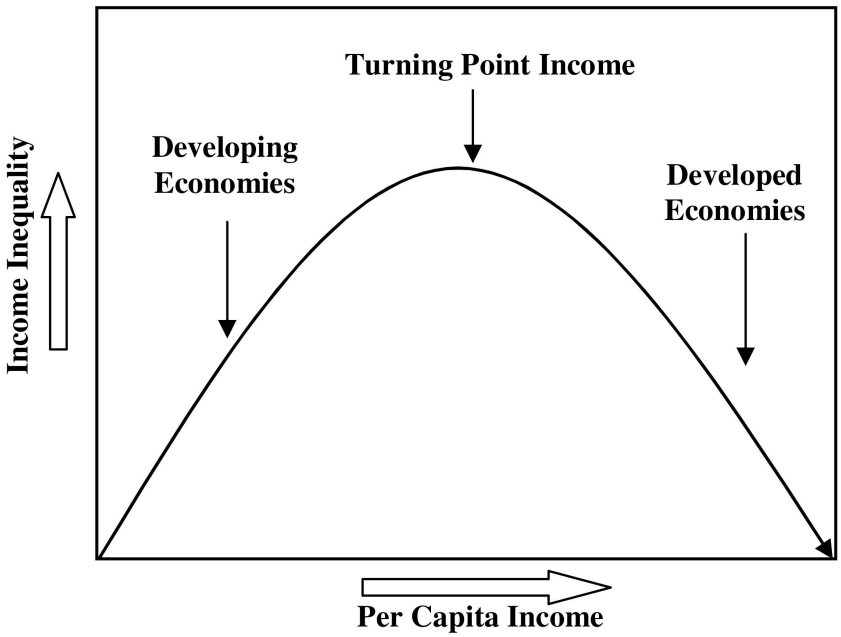
The next section reviews the EKC literature and summarizes major EKC

studies. This discussion shows how EKC measurement has progressed since 1991 and explains how different aspects of environmental quality are affected when economic development occurs. The primer's third major section focuses on studies that relate political and economic institutions to the EKC relationship. These studies show how property rights and contract enforcement affect environmental conditions, thereby suggesting that higher incomes alone will not generate environmental improvements. Finally, the primer concludes with a brief summary.

How the EKC Got its Name

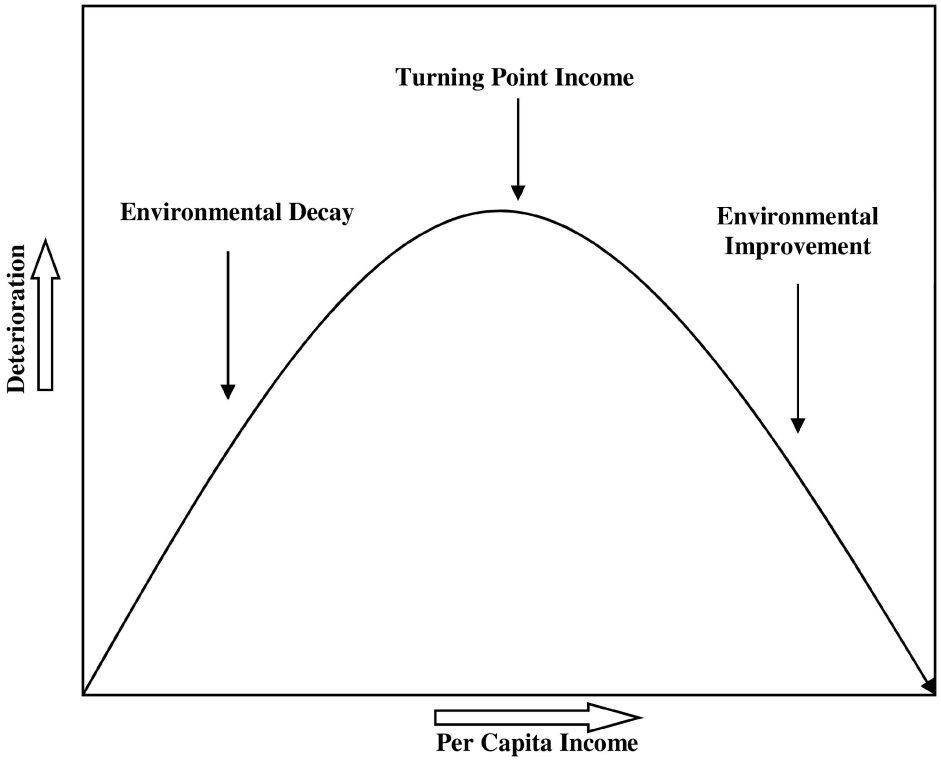
At the sixty-seventh annual meeting of the American Economic Association in December 1954, Simon Kuznets delivered the presidential address, entitled "Economic Growth and Income Inequality." He suggested that as per capita income increases, income inequality also increases at first but then, after some turning point, starts declining (Kuznets 1955, 23–24.) Kuznets believed that the distribution of income becomes more unequal at early stages of income growth but that the distribution eventually moves back toward greater equality as economic growth continues. This changing relationship between per capita income and income inequality, now observed empirically, can be represented by a bell-shaped curve now known as the Kuznets Curve. The general form of the original Kuznets Curve is shown in figure 1.

Figure 1
The Kuznets Curve



In 1991, the Kuznets Curve took on a new existence. It became a vehicle for describing the relationship between measured levels of environmental quality, such as the concentration of sulfur dioxide emissions, and related measures of per capita income, across time. As economists were able to marshal data on the environment for larger samples of countries and income levels, evidence began to mount that as countries develop, certain measures of the quality of life might initially deteriorate but then improve. Specifically, there is evidence that the level of environmental degradation and conventionally measured per capita income follows the same inverted-U-shaped relationship as does income inequality and per capita income in the original Kuznets curve. With only slight modification, the original Kuznets Curve figure can be converted to the Environmental Kuznets Curve shown here.

Figure 2
Environmental Kuznets Curve



The logic of the EKC relationship is intuitively appealing. At the low levels of per capita income found in pre-industrial and agrarian economies, where most economic activity is subsistence farming, one might expect rather pristine environmental conditions, relatively unaffected by economic activities—at least

for those pollutants associated with industrial activity. The EKC statistical relationship suggests that as development and industrialization progress, environmental damage increases due to greater use of natural resources, more emission of pollutants, the operation of less efficient and relatively dirty technologies, the high priority given to increases in material output, and disregard for—or ignorance of—the environmental consequences of growth. However, as economic growth continues and life expectancies increase, cleaner water, improved air quality, and a generally cleaner habitat become more valuable as people make choices at the margin about how to spend their incomes. Much later, in the post-industrial stage, cleaner technologies and a shift to information and service-based activities combine with a growing ability and willingness to enhance environmental quality (Munasinghe, 1999).[1]

Generally speaking, the transition from lower to higher levels of per capita income occurs over a long period of time, perhaps as much as a century, if not more. But the transition from destruction to enhancement of the environment may take place in a much briefer time period. For example, a population may be just at the enhancement threshold when rising incomes from trade expansion generate the necessary demand for environmental improvement.

Saying all this may tempt one to think that higher incomes alone will solve most environmental problems. Unfortunately, life is not that simple. If it were, transfers of income from richer to poorer societies—through foreign aid, for example—would enable the recipients to avoid environmental destruction. The movement along an environmental Kuznets curve is also a movement through a well-known set of property rights stations.

In primitive societies managed by tradition or tribal rule, part of the resource base may be treated as a commons. The cost of defining and enforcing transferable private property rights is simply too large to do otherwise; the net gains are too small. With growing scarcity, however, a time comes when some aspects of the commons become defined as public or private property. As "propertyness" expands—and private property is the most incentive-enriched form[2]—individuals have a greater incentive to manage, to conserve, and to accumulate wealth that can be traded or passed on to future generations. Under such circumstances, what might be viewed as a waste stream affecting the commons, or no-man's-land, is seen as an invasion of property. Those who impose uninvited costs are held accountable.

Eventually, when most aspects of the environment are defined as property, the community moves rapidly in the race to improve environmental life. The pace of this progress is determined partly by the extent to which environmental assets are protected by private property rights. Thus, the Environmental Kuznets Curve is a proxy for a property rights model that begins with a commons and ends with private property rights.

Early EKC Theory

According to Barbier (1997), the origins of the EKC hypothesis are somewhat cloudy and appear to be the product of numerous studies conducted simultaneously in the early 1990s. Most sources point to the analysis by Grossman and Krueger (1991) of air quality measures in a cross-section of countries for different years. Their study was part of a wider investigation into the claim that the economic growth accompanying the North American Free Trade Agreement (NAFTA) would foster environmental degradation. Grossman and Krueger identified the turning point where higher incomes yield improved air quality. At the time of the study, per capita income in Mexico fell into the zone where air quality improves.

An early EKC study by Shafik (1994) reported similar findings. This paper was originally a background paper (Shafik and Bandyopadhyay 1992) for the World Bank's inquiry into growth and environment relationships for the bank's 1992 *World Development Report*. Then, Panayotou (1995) offered perhaps the earliest and most detailed explanation of a possible Kuznets-type U-shape relationship between the rate of environmental degradation and the level of economic development in an analysis conducted for the World Employment Program of the International Labor Office in 1992.

Although there is empirical evidence verifying the existence of the EKC relationship for select environmental indicators, the theoretical framework for the Environmental Kuznets Curve is still in its early stages. Studying the effect of trade liberalization, Lopez (1994) derived a theoretical model showing that under certain conditions the inverted U-shaped relationship between pollution and income holds. Munasinghe (1999) presents both a theoretical model and results from empirical case studies. He focused on the marginal benefits and marginal costs of pollution reduction. He concluded that in the early stages of development the perceived marginal benefits of environmental protection are simply too small for decision makers to forgo the benefits of added economic development.

Environmental Quality—A Luxury Good?

The recognition that pollution may decline as incomes grows goes back at least as far as 1971. Vernon Ruttan, in his presidential address to the American Agricultural Economics Association, hypothesized the luxury nature of environmental quality when he said:

> In relatively high-income economies the income elasticity of demand for commodities and services related to sustenance is low and declines as income continues to rise, while the income elasticity of demand for more

> effective disposal of residuals and for environmental amenities is high and continues to rise. This is in sharp contrast to the situation in poor countries where the income elasticity of demand is high for sustenance and low for environmental amenities. (Ruttan 1971, 707–708)

Based on Ruttan's hypothesis, Antle and Heidebrink (1995) developed an environmental transition hypothesis reflecting the trade-off between the environment and economic development. They agreed that the demand for environmental quality rises once an income threshold is reached, but they assumed that the inputs that form environmental quality, such as water and air quality, are generally unpriced common-access resources until then. Giving only implicit recognition to the evolution of property rights, Antle and Heidebrink (1995, 605) concluded: "Economic growth is likely to be accompanied by environmental degradation at low income levels, but as income grows the demand for environmental protection also tends to increase, leading to a development path characterized by both economic growth and environmental quality improvements."

The authors developed a theoretical model that assigned prices to environmental and market goods. In the early stage of development, the price of environmental goods is low, and lots are used. With continued resource use and rising scarcity, the price of environmental use rises. Deterioration ends and improvement follows. Antle and Heidebrink did not explicitly recognize that the rising price of environmental quality or services can stem from the emergence of markets, property rights and other fundamental changes in institutions, but their model is consistent with this possibility.

Thus, one component of EKC theory is that environmental quality becomes a luxury good at higher levels of income. Stated more formally, this means that the income elasticity of demand for environmental resources varies with the level of income. At the threshold where further income increases yield environmental improvement, income elasticity of demand is greater than one; environmental quality is a luxury good. However, some form of exclusive property rights must exist if environmental quality is to be preserved or improved (Anderson and Leal 2001). This means there is a story about evolving property rights embedded in the classic EKC relationship (Yandle and Morriss 2001).[3]

The Accumulated Empirical Evidence

Empirical analyses of the EKC have focused on two critical topics: whether a given indicator of environmental degradation displays an inverted-U relationship with levels of per capita income; and the calculation of the threshold where environmental quality improves with rising per capita income (Barbier 1997).

Grossman and Krueger (1991) were the first to model the relationship between environmental quality and economic growth, and their methodology is worth further description. They analyzed the EKC relationship in the context of the much-debated North American Free Trade Agreement. At the time, many people feared that opening markets with Mexico would invite a race to the bottom—companies would try to find the lowest environmental standards they could get away with. Environmentally intensive factories, it was said, would rush across the border to escape the stricter environmental standards of Canada and the United States.

Grossman and Krueger had a different hypothesis. They proposed that rising incomes from trade would lead to stricter environmental control. In other words, free trade would protect the environment. To address the hypothesis, they developed a cross-country panel of comparable measures of air pollution in various urban areas and explored the relationship between economic growth and air quality. The data for their statistical experiments came from a joint project of the World Health Organization and the United Nations Environment Program that began in 1976 called the Global Environmental Monitoring System (GEMS). GEMS has as its goal the improvement of air quality monitoring in urban areas worldwide. It monitors air quality in cities around the world on a daily, weekly, or less frequent basis.[4]

In all, forty-two countries are represented in Grossman and Krueger's sample for sulfur dioxide, nineteen countries for smoke or dark matter, and twenty-nine for suspended particulates. The participating cities are located in a variety of developing and developed countries and were chosen to roughly represent the world's different geographic conditions. In most of the cities, air quality measurements are taken at two or three different sites, which are classified either as center city or suburban and as commercial, industrial, or residential. Multiple sites in the same city are monitored because pollutant concentrations can vary dramatically with local conditions and land use.

Grossman and Krueger held constant the identifiable geographic characteristics of different cities, a common global time trend in the levels of pollution, and the location and type of the pollution measurement device. With these constant, they found that ambient levels of both sulfur dioxide and dark matter (smoke) suspended in the air increase with per capita GDP (gross domestic product) at low levels of national income but decrease with per capita GDP at higher levels of income. These findings provided statistical evidence for the existence of an EKC relationship for these two indicators of environmental quality. The turning point came when per capita GDP was in the range of $4,000 to $5,000 measured in 1985 U.S. dollars (or about $6,200 to $8,200 in 2001 U.S. dollars). Unlike the relationship found for sulfur dioxide and smoke, no turning point was found for the mass of suspended particulate matter in a given volume of air. In this case, the relationship between pollution and GDP was monotonically increasing.[5]

Following closely on the heels of the Grossman and Krueger study, Shafik and Bandopadhyay (1992) estimated the relationship between economic growth and several key indicators of environmental quality reported in the World Bank's cross-country time-series data sets.[6] They found a consistently significant relationship between income and all indicators of environmental quality they examined. As income increases from low levels, quantities of sulfur dioxide, suspended particulate matter, and fecal coliform increase initially and then decrease once the economy reaches a certain level of income. The turning-point incomes in 1985 U.S. dollars for these pollutants are $3,700, $3,300 and $1,400 respectively.[7] (In 2001 U. S. dollars, the turning points would be about $6,100, $5,400, and $2,300).

A study by Hettige, Lucas, and Wheeler (1992) explored the EKC phenomenon further. They developed a production toxic intensity index for 37 manufacturing sectors in 80 countries over the period from 1960 to 1988.[8] Their goal was to avoid focusing on individual measures of environmental quality such as air quality, but rather to generalize the environmental impact of manufacturing by determining if manufacturing became more or less "toxic" in relation to income. The index, based on information from the U.S. Environmental Protection Agency and the U. S. Census of Manufacturers, attempted to measure a country's toxicity or pollution intensity. The researchers could then identify the extent to which polluting production did or did not shift from higher- to lower-income countries when incomes rose faster in one than the other location.

The results of the study indicate the existence of an EKC relationship for toxic intensity per unit of GDP. No evidence, however, was found for toxic intensity measured per unit of manufacturing output. When the mix of manufacturing was held constant, Hettige et al. found that manufacturing in low-income countries was not more toxic, nor manufacturing in high-income ones less toxic. Manufacturing, which is just one part of GDP, did not become cleaner or dirtier as income changed. Instead, manufacturing became smaller relative to services and trade in expanding economies. This suggests that higher income leads to a demand for a cleaner environment regardless of whether the environment has been damaged by a toxic producing manufacturing sector. They conclude that the GDP-based intensity result is due solely to a broad shift from industry toward lower-polluting services as development proceeds.

This could mean that dirty production shifts elsewhere. To examine whether this happened, the authors divided the pooled data into subsets for each decade beginning with 1960. They find the estimated pattern for the 1960s to be quite different from that of the latter decades. For the 1960s, toxic intensity grew most quickly in high-income economies. This pattern is sharply reversed during the 1970s and 1980s, when toxic intensity in manufacturing in less developed countries grew most quickly. What might explain the shift to these countries?

The authors extended their analysis to investigate the possibility that toxic

displacement has been affected by the trade policies of less developed countries. Their investigation indicates that the toxic intensity of manufacturing output in these countries rises when the governments protect their chemical manufacturing sector with tariffs and non-tariff trade barriers. They also find that outward-oriented, high-growth less developed countries have slow-growing or even declining toxic intensities of manufacturing, while toxic intensity increases more rapidly in inward-oriented economies—those with less trade.

Their findings on trade policy and toxic-intensity suggest a revised view of the displacement phenomenon or "pollution-haven" theory. Rapidly increasing toxic intensity does not seem to characterize all manufacturing in less developed countries in the 1970s, when environmental regulation in industrialized countries became more strict. Rather, toxic intensity in manufacturing has grown much more rapidly in economies that are relatively closed to international trade.

Goklany (2001) emphasizes this point, which Grossman and Krueger (1991) also note: Open economies improve their environments. More open economies have had higher growth rates of labor-intensive assembly activities that are also relatively low in toxic intensity. Highly protected economies have had more rapid growth of capital-intensive smokestack sectors.

There is yet another development/trade issue to consider. Suri and Chapman (1998) focused on energy consumption. Specifically, they showed that as industrialized economies matured, they moved to services and then imported more manufactured goods from developing countries. The Suri-Chapman findings suggest that the global diffusion of manufacturing contributes to environmental improvements as incomes rise and development continues.

Deforestation

An EKC study by Cropper and Griffiths (1994) moved away from pollution to study deforestation. Cropper and Griffiths examined the effect of population pressures on deforestation in 64 developing countries. Income and population growth are the factors underlying the rate of deforestation in this study. Since deforestation is primarily a problem of developing countries, the authors restricted their study to non-OECD countries in Africa, Asia, and Latin America roughly in the tropical belt and containing forest area of over 1,000,000 hectares. They found that per capita income levels in most countries in Latin America and Africa are to the left of (lower than) the respective peaks of their estimated EKCs ($5,420 and $4,760 in 1985 U.S. dollars), or about $8,900 and $7,800 in 2001 U.S. dollars. In other words, they haven't reached their turning points. However, for countries in these two continents, as income increases, the rate of deforestation levels off.

In another study, Panayotou (1995) investigated the EKC relationship for deforestation, sulfur dioxide, oxides of nitrogen, and suspended particulate matter.

He used mid-to-late 1980s data from 41 tropical, mostly developing countries for deforestation, and late-1980s data for 55 countries (both developed and developing) for emissions of sulfur dioxide and oxides of nitrogen. By this time, national data on emissions of sulfur dioxide, oxides of nitrogen, and suspended particulate matter for developed countries were available in the OECD's *State of the Environment*.[9] For developing countries, as a rough approximation, the author constructed emission data from data on the consumption of petroleum, coal, and natural gas, which account for over 90 per cent of man-made emissions. He found that the turning-point income for deforestation occurs much earlier (around $800 per capita or $1,300 in 2001 dollars) than for emissions ($3,000 or about $4,900 in 2001 dollars for sulfur dioxide, $4,500 or $7,400 in 2001 dollars for suspended particulates and $5,500 or $9,000 for oxides of nitrogen.) According to Panayotou, this is because deforestation for either agricultural expansion or logging takes place at an earlier stage of development than heavy industrialization.

On the basis of his empirical work, Panayotou argued that environmental degradation overall (combined resource depletion and pollution) is worse at levels of income per capita under $1,000 (or about $1,600 in 2001 dollars). Between $1,000 and $3,000 (or about $4,900), both the economy and environmental degradation undergo dramatic structural change from rural to urban and from the principal pursuit of agricultural production to industrial production. A second structural transformation begins to take place, he said, as countries surpass a per capita income of $10,000 (about $16, 400) and begin to shift from energy-intensive heavy industry into services and information-intensive industry.

In her approach to EKC modeling, Shafik (1994) expanded the variables considered. She hypothesized that there are four determinants of environmental quality in any country: 1) endowment such as climate or location; 2) per capita income, which reflects the structure of production, urbanization, and consumption patterns of private goods, including private environmental goods and services; 3) exogenous factors such as technology that are available to all countries but change over time; and 4) policies that reflect social decisions about the provision of environmental public goods depending on institutions and the sum of individual benefits relative to the sum of individuals' willingness to pay. Shafik then focused on the availability of clean water, access to urban sanitation, ambient levels of suspended particulate matter, ambient levels of sulfur oxides, changes in forest area between 1961–86, the annual rate of deforestation between 1962–86, dissolved oxygen in rivers, fecal coliforms in rivers, municipal waste per capita, and carbon emissions per capita.[10]

Shafik's results were truly mixed. She found an EKC relationship between per capita income and sulfur dioxide and suspended particulate concentrations. However, the general EKC shape did not hold for carbon emissions per capita, dissolved oxygen in rivers, or forestation/deforestation.

Consolidating the Turning-Point Data

By the mid-1990s, investigations of EKC relationships had generated enough consistent findings to give assurance that for many pollutants, richer is definitely cleaner. With more and more environmental data sets gathered, researchers could probe even deeper. Grossman and Krueger (1995) went back to the drawing board and conducted a more extensive empirical project. Once again, they modeled the relationship between per capita income and environmental quality using GEMS data sets. Only this time, while repeating an analysis of air quality, they focused heavily on water quality. The GEMS/Water project monitors various dimensions of water quality in river basins, lakes, and groundwater aquifers, but the data on lakes and groundwater are quite limited. Because of this, Grossman and Krueger focused their attention on river basins.[11]

Their 1995 study makes use of all variables that can be considered indicators of water quality, provided that they have anthropogenic constituents (not just "natural" pollutants) and that at least ten countries are represented in the sample. They found an EKC relationship for eleven of the fourteen indicators selected for the analysis. The estimated turning-point incomes (in 1985 and 2001 U.S. dollars) are shown in Table 1.

Table 1
Water Pollution and Income

Pollutant	EKC Turning Point	
	1985 US$	2001 US$
Arsenic	$ 4,900	$ 8,000
Biological oxygen demand	7,600	12,500
Cadmium	5,000	8,200
Chemical oxygen demand	7,900	13,000
Dissolved oxygen	2,700	4,400
Fecal coliform	8,000	13,100
Nitrates	2,000	3,300
Lead	10,500	17,200
Smoke	6,200	10,200
Sulfur dioxide	4,100	6,700
Total coliform	3,000	4,900

Note: The values for 2001 U.S. dollars are approximate.
Source: Grossman and Krueger (1995).

At this point in EKC research, it became clear that human communities

assign a higher priority to improving certain dimensions of water quality than to improving air quality. The evidence is that the income turning points for levels of dissolved oxygen and total coliform in water are lower than for sulfur dioxide, smoke, and suspended particulates in the air. Most likely, the behavior reflects the fact that harms from contaminated water occur much more swiftly and therefore are more clearly visible than those associated with air pollution.

Selden and Song (1994) examined the two air pollutants studied by Grossman and Krueger, along with oxides of nitrogen and carbon monoxide. They used GEMS data across countries and across time to model the relationship between per capita GDP and the air pollutants.[12] Broadly speaking, their results lend support to the existence of an EKC relationship for all four air pollutants. The EKC turning point (in 1985 U.S. dollars) for sulfur dioxide was nearly $9,000, and in the vicinity of $10,000 for suspended particulate matter. (In 2001 dollars, the figures would be about $14,500 and $16,400.) Both the figures are significantly higher than the estimates from Grossman and Krueger.

Seldon and Song attribute the higher turning points in their results to their use of aggregate air-quality data, which includes readings from both rural and urban areas, rather than the urban data used by Grossman and Krueger. They expect urban air quality to improve before aggregate data reveal improvement. The turning-point income they found for oxides of nitrogen was over $10,000, while carbon monoxide peaked when income levels were a little over $15,000 (or approximately $16,400 and $24,600 in 2001 U.S. dollars.)

Cole, Rayner, and Bates (1997) examined the relationship between per capita income and a wide range of environmental indicators using cross-country panel data sets. The environmental indicators used in this analysis are: carbon dioxide, carbonated fluorocarbons (CFCs) and halons, methane, nitrogen dioxide, sulfur dioxide, suspended particulates, carbon monoxide, nitrates, municipal waste, energy consumption and traffic volumes. Data for the years 1970–92 cover ten OECD countries for nitrogen dioxide, eleven for sulfur dioxide, seven for suspended particulate matter and carbon monoxide, nine for nitrogen dioxide and sulfur dioxide from transport, seven for suspended particulate matter from transport, and twenty-four for traffic volumes. Data for concentration of nitrates covers the years 1975–90 for 30 rivers in fifteen OECD countries. Carbon dioxide data are for seven regions between the years 1960 and 1991.

Data on global emissions and total energy use are for 22 OECD countries between 1980 and 1992. CFCs and halons data include 1986 data for 38 countries, and 1990 data for 39 countries. Late 1980s data for methane emissions in 88 countries were used, while data for municipal waste came from 13 OECD countries. Energy use from transport covered 24 OECD countries from 1970–90. Emissions of nitrogen dioxide, sulfur dioxide and suspended particulates from the transport sector are considered separately. The range of meaningful turning points estimated by Cole, Rayner, and Bates (1997) is shown in Table 2.

Table 2
Selected Pollutants and Income

Pollutant	EKC Turning Point	
	1985 US$	2001 US$
Carbon Dioxide	$ 22,500 – $ 34,700	$ 37,000 – 57,000
Carbon Monoxide	9,900 – 10,100	16,300 – 16,600
Nitrates	15,600 – 25,000	25,600 – 41,000
Nitrogen Oxide (industrial)	14,700 – 15,100	24,100 – 24,800
Nitrogen Oxide (transport)	15,100 – 17,600	24,800 – 28,900
Sulfur dioxide	5,700 – 6,900	9,400 – 11,300
Sulfur dioxide (transport)	9,400 – 9,800	15,400 – 16,100
Suspended particulates (non-transport)	7,300 – 8,100	12,000 – 13,000
Suspended particulates (transport)	15,000 – 18,000	24,600 – 29,600

Note: The values in 2001 U.S. dollars are approximate.
Source: Cole, Rayner, and Bates (1997).

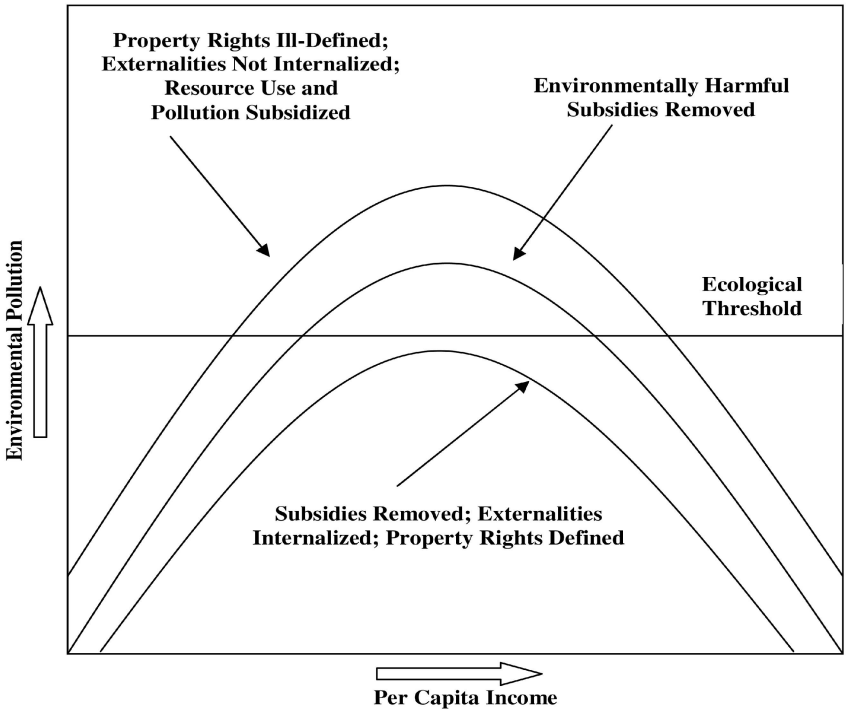
Introducing Property Rights and the Rule of Law

In 1997, a new approach to the EKC relationship was adopted—an attempt to incorporate explicit policy considerations. Panayotou (1997) studied the EKC relationship for sulfur dioxide both to gain a better understanding of the income-environment relationship and as a basis for conscious policy intervention. Panayotou found that faster economic growth and higher population density do increase moderately the environmental price of economic growth, but better policies can offset these effects and make economic growth more environmentally friendly and sustainable (see figure 3).

The sample used in the study includes 30 developed and developing countries for the period 1982–94. The country median of annual sulfur dioxide concentrations was the average of all daily observations obtained from the GEMS air quality monitoring project.The policy variables used in the study are proxies for the quality of institutions. The author experimented with a set of five indicators of the quality of institutions in general: respect/enforcement of contracts, efficiency of the bureaucracy, the efficacy of the rule of law, the extent of government corruption, and the risk of appropriation, all obtained from Knack and Keefer (1995). Since all these variables were highly correlated, the author chose to use an index for the respect/enforcement of contracts. Panayatou's main finding is that the quality of policies and institutions in a country can significantly reduce environmental degradation at low-income levels and speed up

improvements at higher-income levels. Policies such as more secure property rights under a rule of law and better enforcement of contracts and effective environmental regulations can help flatten the EKC and reduce the environmental price of higher economic growth, as illustrated in Figure 3.

Figure 3
Income-Environment Relationship under Different Policy and Institutional Scenarios



Source: Panayotou (1997).

The results that show a strong relationship between property rights enforcement and environmental quality are consistent with findings by Norton (2002) that document a related linkage between property rights and income. Norton's survey of literature and his own work show that strong property rights institutions support markets, which expand incomes and wealth. This means that there are two major forces at play in a process that yields environmental protection. Property rights enforcement leads to higher income levels, which in turn generate demand for environmental quality. Strong property rights institutions also provide a legal basis for taking action against those who generate pollution that degrade property values. They also provide incentives for investing in natural resource management where payoffs generally do not come for many years.

Following in the footsteps of Panayotou, Qin (1998) included property rights considerations when he estimated EKCs for two common measures of environmental quality, sulfur dioxide emissions and levels of dissolved oxygen in rivers. Along with the two traditionally shaped EKCs, Qin also derived a monotonically increasing EKC for carbon emissions.[13] The proxy variables Qin used for the quality of institutions is the index of property rights obtained from Business Environmental Risk Intelligence data. These data are provided by the Institutional Reform and the Informal Sector, and Knack and Keefer (1995) and range continuously from 0 to 4, with a higher score for greater enforceability of laws governing property rights. Contract enforceability measures the relative degree to which contractual agreements are honored and complications presented by language and mentality differences are mitigated.

Qin found the point estimate for turning-point income for sulfur dioxide to be $7,798 in 1985 purchasing-power-parity-adjusted dollars (about $12,800 in 2001 dollars.) The property rights variable was significant, and corresponded to a flatter EKC as the index rose. The turning-point income for dissolved oxygen in rivers was estimated at $3,249 per capita GDP in 1985 purchasing power parity adjusted dollars (about $5,300 in 2001 dollars). The results for the property rights variable were similar to that of sulfur dioxide. The evidence again says that property rights enforcement matters.

Using the annual percentage change in forest area between the years 1972 to 1991 as an indicator of environmental quality, Bhattarai (2000) analyzed the EKC relationship for tropical deforestation across 66 countries in Latin America, Asia, and Africa. The study quantifies the relationship between deforestation and income, controlling for political and governing institutions, macroeconomic policy, and demographic factors. The results from his empirical analysis suggest that underlying political and civil liberties and governing institutional factors (the rule of law, quality of the bureaucracy, level of corruption in government, enforcement of property rights) are relatively more important in explaining the process of tropical deforestation in the recent past than other frequently cited factors in the literature—for example, population growth and shifting cultivation. The study suggests that improvements in political institutions and governance, and establishment of the rule of law significantly reduce deforestation. In a related way, macroeconomic policies that lead to increased indebtedness and higher black market premiums on foreign exchange (measures of trade and exchange rate policies) will increase the process of deforestation.

Goklany (1999) was also interested in the forces underlying changes in pollution but he took a more direct policy analysis approach rather than engaging in statistical analysis for the purpose of estimating an EKC. He examined long-term air quality and emissions data for each of the original five traditional "criteria" air pollutants or their precursors in the United States—sulfur dioxide, particulate matter, carbon monoxide, nitrogen oxides, and ozone or one of its

precursors, volatile organic compounds, and to a lesser extent, lead. His data covered the period before and after major environmental laws shifted control of air pollution to the federal government.

Specifically, Goklany examined three separate sets of indicators for each air pollutant. The first set consists of national emissions estimates, which are available from 1900 onward for sulfur dioxide, nitrogen oxides, and volatile organic compounds; from 1940 for particulate matter and carbon monoxide; and from 1970 for lead. The second set of indicators is composed of outdoor air quality measurements. These include ambient concentrations in the outdoor air, which are usually better indicators for the environmental, health, social, and economic impacts of air pollution than are total emissions. Based upon available data, Goklany developed qualitative trends in national air quality for the various pollutants. These were established from 1957 forward for particulate matter, from the 1960s for sulfur dioxide and carbon monoxide, and from the 1970s for ozone/volatile organic compounds and nitrogen oxides.

The final set of indicators consisted of estimates from 1940 to 1990 of residential combustion emissions per occupied household. Those estimates served as crude proxies for indoor air pollutants, which should serve as a better indicator of the public health impact of various air pollutants than outdoor air quality.

Goklany's findings indicate that before society reaches an environmental transition for a specific pollutant—that is, during the early phases of economic and technological development—"the race to the top of the quality of life" may superficially resemble a "race to the bottom"—or a race to relax environmental standards. But once a society gets past the transition, the race to the top of the quality of life begins to look more like a race to top environmental quality.

This could, in fact, create a not-in-my-backyard (NIMBY) situation. Goklany suggests that the apparent race to the bottom and the NIMBY effect are two aspects of the same effort to improve the quality of life. During the apparent "race to the bottom," people are improving their lives in ways not clearly "environmental"; during the NIMBY phase, they are improving their lives by keeping out polluters since they are unwilling to pay the costs of controlling the pollution. The former occurs before the turning point while the latter occurs after. Goklany also examines whether the data support the contention that, prior to the national control effected by the Clean Air Act Amendments of 1970, there had been little progress in improving air quality and that states had been engaged in a race to the bottom. His findings do not support those claims, which were used to justify the 1970 nationalization.

Conclusion

As this primer indicates, there is no single EKC relationship that fits all pollutants for all places and times. There are families of relationships, and in many cases the inverted-U EKC best approximates the link between environmental change and income growth. The indicators for which the EKC relationship seems most plausible are local air pollutants such as oxides of nitrogen, sulfur dioxide, and particulate matter.

By way of contrast, there is no evidence to support the EKC hypothesis for gases such as carbon dioxide, which cause no harm locally but may affect the global climate as they accumulate in the atmosphere. The very nature of the potential harm—impact on global climate—makes unilateral action fruitless. It is impossible for people in a single nation or community to make a difference in upper atmospheric conditions.

The EKC evidence for water pollution is mixed. There is evidence of an inverted U-shaped curve for biological oxygen demand (BOD), chemical oxygen demand (COD), nitrates, and some heavy metals (arsenic and cadmium). In most cases, the income threshold for improving water quality is much lower than that for the air pollution improvement threshold.

The acceptance of the EKC hypothesis for select pollutants has important policy implications. First, the relationship implies a certain inevitability of environmental degradation along a country's development path, especially during the take-off process of industrialization. Second, the normal EKC suggests that as the development process picks up, when a certain level of per capita income is reached, economic growth helps to undo the damage done in earlier years. If economic growth is good for the environment, policies that stimulate growth (trade liberalization, economic restructuring and price reform) ought to be good for the environment. However, income growth without institutional reform is not likely to be enough. As we have shown, the improvement of the environment with income growth is not automatic but depends on policies and institutions. GDP growth creates the conditions for environmental improvement by raising the demand for improved environmental quality and makes the resources available for supplying it. Whether environmental quality improvements materializes or not, when and how, depends critically on government policies, social institutions and the completeness and functioning of markets. It is for this reason, among others, that Arrow et al. (1995) emphasize the importance of getting the institutions right in rich and poor countries. Along these lines, Torras and Boyce (1998) argue and show empirically that, all else equal, when ordinary people have political power, civil rights as well as economic rights, air and water quality improves in richer and poorer countries.

Better policies, such as the removal of distorting subsidies, and the introduction of more secure property rights over resources, and the imposition of

pollution taxes to connect actions taken to prices paid will flatten the underlying EKC and perhaps achieve an earlier turning point. Because market forces will ultimately determine the price of environmental quality, policies that allow market forces to operate are expected to be unambiguously positive. The search for meaningful environmental protection is a search for ways to enhance property rights and markets.

Notes

1. A major motivation for examining the linkages between income and the environment is the search for better policies for developing countries. If the EKC hypothesis is empirically verified, the early stages of economic development could be even more onerous for low-income groups than Kuznets originally predicted for inequality alone if the poor are more adversely affected by environmental degradation. This finding would require appropriate policy responses, especially on the social side (Munasinghe 1999.) Second, if environmental damage is a structurally determined and inevitable result of initial growth, then attempts to avoid such damage in the early stages of development may be futile (Munasinghe 1999.)

2. Property can be owned by families, clans, or other groups and still provide some incentive effects similar to those of private property.

3. The concept of environmental quality as a luxury good is also deeply embedded in the post-materialist thesis in environmental sociology (Martinez-Alier 1995). According to this view, the modern environmental movement is explained by the decreasing marginal utility of material goods and services (relative to environmental amenities) due to a relative abundant supply of materials goods. This approach is not limited to environmental quality; increasing emphasis on issues such as human rights, animal rights, and feminism has appeared in industrial economies only when societal income rose to a certain level. Hence, when poverty vanishes, people (or society) will start to worry about quality of life and environmental amenities, eventually producing the EKC relationship. However, the transition to the environmental stage is much more complex than this. Similarly, the notion of "too poor to be green" suggests that the poor either lack awareness (no preference for environmental amenities), have other more immediate necessities, or do not have enough income to invest in environmental improvement. It is possible that all these conditions occur simultaneously. Hence, the changes in the socio-political factors underlying the EKC may be too complex to be captured by a simple analytical model.

4. The Global Environmental Monitoring System is part of the United Nations Environment Program. Information on the data and directions to the data are found at http://www.wri.org/wri/statistics/unep-gle.html. Daily (or, in some cases, weekly or less frequent) measurements are taken of the concentrations of sulfur dioxide and suspended particulate matter. Data on particulates are collected

by different methods, either measuring the mass of materials in a given volume of air or the concentration of finer, darker matter (smoke). The GEMS sample of cities has changed over time. Sulfur dioxide was monitored in 47 cities spread over 28 different countries in 1977, 52 cities in 32 countries in 1982, and 27 cities in 14 countries in 1988. Measurements of suspended particulates were taken in 21 cities in 11 countries in 1977, 36 cities in 17 countries in 1982, and 26 cities in 13 countries in 1988, while data for dark matter (smoke) are available for 18 cities in 13 countries for 1977, 13 cities in nine countries for 1982, and seven cities in four countries for 1988.

5. Discovering turning points requires a data set that contains per capita income or GDP that ranges from very low to high levels. Without this range of incomes, one might observe a monotonically rising or falling relationship between pollution concentrations and income rather than a curve. The appropriate range of incomes is not always available for higher-income countries, such as the United States. If an EKC relationship is observed, it will likely be for the rightmost part of the curve, that portion where rising income levels are associated with environmental improvement. This result is found in work by Carson, Jeon, and McCubbin (1997). They used U.S. state-level emissions for seven major air pollutants: greenhouse gases, air toxics, carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic carbon, and particulate matter less than ten microns in diameter. In their initial analysis, the authors examined the 1990 state-level per capita emissions for greenhouse gases converted to pounds of equivalent carbon dioxide, air toxics, and point-source emissions of carbon monoxide, oxides of nitrogen, sulfur dioxide, volatile organic carbon, and particulate matter. They found that emissions per capita decrease with increasing per capita income for all seven major classes of air pollutants. In this respect, their results are consistent with those from country studies that find an EKC. Hilton and Levinson (1998) found a more complete EKC in their work on auto lead oxide emissions across the developed world. There is a related EKC identification problem when data are examined for all countries worldwide. The heterogeneity of the sample makes it extraordinarily difficult to account for institutional differences. (See Stern and Common, 2001).

6. Most of the variables cited in this paper are included in the environmental data appendix to the *World Development Report, 1992* (World Bank 1992). The sample size varied depending on availability of data. Data on lack of safe water were available only for two years, 1975 and 1985 for 44 and 43 countries respectively, while data on lack of urban sanitation were available for 1980 and 1985 for 55 and 70 countries respectively. Annual deforestation reflected the yearly change in the forest area for 66 countries between 1962 and 1986. Total deforestation was the change in forest area between the earliest date for which substantial data was available, 1961, and the latest date, 1986. Total deforestation data were available for 77 countries. Data on dissolved oxygen were available for 57 rivers distributed in 27 countries for intermittent years between 1979 and 1988. Data on fecal coliform were available for 52 rivers distributed in

25 countries for intermittent years between 1979 and 1988. Data on ambient levels of sulfur dioxide were available for 47 cities distributed in 31 countries for the years 1972 to 1988, while data on ambient levels of suspended particulate matter were available for 48 cities in 31 countries for 1972 to 1988. Data on municipal solid waste per capita were computed in kilograms, on the basis of available city level information for 39 countries compiled for the year 1985. Data on carbon emissions per capita were available for 118–153 countries between 1960 and 1989.

7. Shafik and Bandyopadhyay (1992) also explore the impact of political and civil liberties on environmental quality. They use Gastil indexes that measure the level of political and civil liberties their study. The political rights index measures rights to participate meaningfully in the political process for 108–119 countries for 1973 and 1975–86 on a scale of one to seven where lower numbers indicate greater political rights. A high-ranking country must have a fully operating electoral procedure, usually with a significant opposition vote. It is likely to have had a recent change of government from one party to another, an absence of foreign domination, decentralized political power and a consensus that allows all segments of the population some power. The index of civil liberties measures the extent to which people are able to express their opinion openly without fears of reprisals and are protected in doing so by an independent judiciary. Though this index reflects rights to organize and demonstrate as well as freedom of religion, education, travel, and other personal rights, more weight is given to the expression of political rights. The results indicate that political and civil liberties have insignificant effects on access to clean water and sanitation. Greater political and civil liberties are associated with increases in the annual rate of deforestation, but total deforestation over the period 1961–86 was unaffected. River quality (measured by dissolved oxygen) improves with increased political liberties, but other measures are insignificant. In the case of local air pollution, more democratic countries have higher levels of sulfur dioxides. Particulates and municipal solid wastes were not affected by political or civil liberties. Carbon emissions are ambiguous—with a positive sign in the case of civil liberties and a negative sign for political rights. The results for political and civil liberties therefore indicate no clear pattern.

8. For each country and year, Hettige, Lucas, and Wheeler (1992) have used UN industrial data to calculate shares of total manufactured output for 37 sectors defined on the international standard industrial classification (ISIC). To obtain country-specific toxic-intensity indexes, they have multiplied these shares by U.S. sectoral toxic intensities, estimated as total pounds of toxic release per dollar's worth of output. The sectoral intensities have been calculated from a sample of 15,000 U.S. plants which they have obtained by merging data from two sources: the U.S. Environmental Protection Agency's (EPA's) 1987 Toxic Release Inventory, which provides plant-level release estimates for 320 toxic substances, and the 1987 Census of Manufacturers, which provides plant-level data on output value. They pool the country-specific toxic-intensity indexes with

time-series estimates of income per capita to test two broad hypotheses: 1) industrial pollution intensity follows an inverse U-shaped pattern as development proceeds; and 2) OECD environmental regulation has significantly displaced toxic industrial production toward less-regulated LDC's. The rationale for the latter hypothesis is founded on relative production cost. The former is based on the general notion of three stages of industrial development dominated by 1) agroprocessing and light assembly, which are (relatively) low in toxic intensity, 2) heavy industry (e.g., metals, chemicals, paper), which has high toxic intensity, and 3) high-technology industry (e.g., microelectronics, pharmaceuticals), which is again lower in toxic intensity. In part this is perceived as a natural evolution and in part a response to growing pressure for environmental regulation at higher incomes.

9. This periodic report issued by the Organization for Economic Cooperation and Development discusses environmental conditions in its member nations.

10. Data and countries covered are the same as in Shafik and Bandopadhyay (1992).

11. In choosing where to locate its monitoring stations, GEMS/Water has given priority to rivers that are major sources of water supply to municipalities, irrigation, livestock, and selected industries. A number of stations were included to monitor international rivers and rivers discharging into oceans and seas. Again, the project aimed for representative global coverage. The available water data cover the period from 1979 to 1990. By January 1990 the project had the active participation of 287 river stations in 58 different countries. Each such station reports thirteen basic chemical, physical, and microbiological variables, several globally significant pollutants including various heavy metals and pesticides, and a number of site-specific optional variables.

12. The GEMS data used in the paper are obtained from the World Resources Institute. There are 22 high-income, six middle-income and two low-income countries in the sample. Clearly, less-developed countries are underrepresented in the sample.

13. The data for sulfur dioxide emissions were from GEMS, and the sample included data from 1981–86 for 14 countries. From GEMS/Water stations, three three-year-aggregated annual median dissolved oxygen levels in 15 countries for 1979–81, 1982–85 and 1986–88 were computed. The data for carbon dioxide was taken from World Resources Institute (1990). It is the cross-country annual carbon dioxide emissions from fossil fuel consumption and cement industries in 41 countries in 1987.

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