Sustainability, growth and development

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Abstract *The Brundtland Report (WCED, 1987) encouraged the view that the main threats to the environmental sustainability of development are poverty-driven depletion of environmental resources in the developing world, and consumption-driven pollution of the biosphere by the developed world. Recent work on the empirical relationship between per capita GDP growth and certain indicators of environmental quality seems to contradict this view. Some indicators of local air and water quality first worsen and then improve as per capita incomes rise. This paper reconsiders both these findings, and the empirical relation between environmental quality and measures of poverty, consumption and human development. It finds that deepening poverty at one end of the scale and increasing affluence at the other both have implications for the environment. But these implications are different. Deepening poverty is associated with environmental effects that tend to have immediate and local implications for the health and welfare of the communities concerned. Increasing affluence is associated with environmental effects which are much more widespread and much longer-lasting. The environmental consequences of growth increasingly tend to be displaced on to others – either geographically distant members of the present generation or members of future generations. The paper argues that the relevant question is not whether economic growth has environmental consequences: it is whether those consequences threaten the resilience of the ecological systems on which economic activities depend. Since loss of ecological resilience implies that the economic activities concerned are environmentally unsustainable, it should be a major focus of strategies for sustainable development.*

Introduction

The Brundtland Report (WCED, 1987) advanced the notion that the main threats to environmentally unsustainable development are poverty-driven depletion of environmental resources in the developing world, and consumption-driven pollution of the biosphere by the developed world. By this view, the poor are responsible for degradation of forests, wetlands, rangelands and coastal zones in order to meet their basic needs, while the rich discharge disproportionate quantities of waste as emissions to air and water. The implication is that environmentally sustainable development is threatened by extremes of poverty and affluence alike. More recently, environmental economists have identified an empirical relationship between per capita income and certain indicators of environmental quality that, on the surface at least, seems to tell the opposite story. The relationship was first observed in work undertaken by Grossman and Krueger on the environmental implications of Mexico's inclusion in the North American Free Trade Area (NAFTA) (Grossman and Krueger, 1993). It showed that certain indicators of environmental quality first deteriorate and then improve as per capita incomes rise: that economic growth is initially associated a deterioration of environmental quality and later an improvement. The relationship was called

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"the environmental Kuznets curve" (EKC) (Panayotou, 1995) after the Kuznets relation between income inequality and per capita income (Kuznets, 1955).

Subsequently, a relationship of this sort has been found between per capita income and emissions of sulphur dioxide (Grossman and Krueger, 1993; 1995; Seldon and Song, 1994; Shafik, 1994; Panayotou, 1995; 1997), particulates and dark matter (Grossman and Krueger, 1993), nitrogen oxides and carbon monoxide (Seldon and Song, 1994), carbon dioxide and CFCs (Cole *et al.,* 1997). Grossman and Krueger (1995) have also found a Kuznets relation involving various indicators of water quality, including faecal coliform, biological and chemical oxygen demand and arsenic. Panayotou (1995) and Antle and Heidebrink (1995) have found the same general relationship between deforestation rates and per capita income, while Cole *et al.* (1997) have extended it to include energy use and traffic volumes. The evidence does not all run in the same direction. Volumes of municipal waste have been found to be a strictly increasing function of per capita income (Shafik, 1994; Cole *et al.,* 1997) and there are conflicting results on solid particulates (Grossman and Krueger, 1995) and carbon dioxide (Shafik, 1994). Nevertheless, the broad direction of the evidence to date favours the EKC.

Not only does the existence of the EKC appear to suggest that the post-Brundtland view on the environmental consequences of growth are wrong about the effects of poverty and affluence, it also appears to suggest that growth may be environmentally beneficial. While there may be negative environmental effects during the early stages of growth, these will be counteracted by later environmental quality improvements. To the proponents of market-led development strategies, the EKC hypothesis has been interpreted as both a rationale for growth and an argument against growth-inhibiting environmental protection measures (Beckerman, 1992). This is particularly important for developing countries given the trend towards the liberalisation of both domestic and international markets as a means of stimulating market-led growth. If economic growth does "take care" of the environment – if there is some level of per capita income at which growth becomes environmentally sustainable – the short-term diversion of resources from environmental protection to investment may be welfare-enhancing. For these reasons we need to understand what can and cannot be inferred from the EKC for the development process, and for the wellbeing of people at different levels of consumption.

This paper has three aims:

(1) to reconsider the evidence on the EKC in the light of recent assessments;

(2) to consider the relationship between environmental quality and alternative measures of performance including consumption, the human development index, and an index of poverty devised for the International Fund for Agricultural Development;

(3) to reassess the linkage between sustainability, growth and development in the light of these findings.

The first aim is therefore to clarify just what relationship has been established between economic growth and environmental change. The second is to consider what the available data tell us about the relationship between development – as distinct from growth – and environmental change. The linkages identified by the Brundtland Report and subsequently embodied in the report of the 1992 United Nations Conference on Environment and Development: Agenda 21 (UNCED, 1993) suggest a different relationship between measures of human development, poverty or consumption and environmental quality. The paper tests the hypotheses implicit in the Brundtland Report. The third aim is to draw out the policy implications of the observed relationship between environmental sustainability, economic growth and development.

Growth and the environment: the evidence for the EKC

Most studies of the EKC estimate a basic model of the general form

$$E_{it} = f(Y_{it}, C_i, X_{it})$$

where E_{it} denotes either total or per capita environmental quality in country i and year t; Y_{it} denotes per capita income in country i at time t; C_i denotes country specific effects; X_{it} denotes "external" factors which may include such things as the level of technology, and i and t are country and time indices. This model assumes no feedbacks between the environment and the economy. To test the EKC hypothesis the functional forms employed for estimating the basic model from cross-country data tend to be quadratic in either levels or logarithms. A number of studies involve cross-sectional data only. Some use panel data for a more restricted set of countries, but either way the data are sparse (Stern, 1998).

A summary of the main findings of this research is offered in Barbier (1997). While an inverted U-shaped relationship between per capita income and a range of air pollution indicators appears to be reasonably robust, the evidence on water pollutants and resource depletion indicators, such as deforestation, is much less clear. In general, the results show that well-defined EKCs exist only for local air pollutants. The relationship between income and environmental quality is dependent on whether there are significant externalities and "stock feedback effects" – typically where the environmental effect is cumulative. The kinds of pollutants for which the inverted U relationship has been estimated do not have strong stock feedback effects. They also tend to be very localised. Environmental effects that are more dispersed in time and space (that are global or occur in the far future) tend to increase with income (Arrow *et al.*, 1995). Where EKCs have been found for emissions that involve distant or long-term effects, such as carbon dioxide, the turning points estimated for such emissions involve such large standard errors that they cannot be considered reliable (Cole *et al.*, 1997).

The turning points define the levels of per capita income at which emissions start to fall as incomes rise further. If an EKC does exist, and if the turning point can be identified with confidence, then its location may predict the trend in emissions for countries at different levels of per capita income. At present, estimates of the turning points associated with given pollutants vary widely. Although there is considerable evidence to support the general form of the relationship between sulphur dioxide and per capita income, for example, estimates of the turning points for that pollutant range from $3,000 (Panayotou, 1995) to $10,700 (Seldon and Song, 1994). The range of estimates for other pollutants is even wider (see Table I). Even if we take the most optimistic estimate for sulphur dioxide, this indicates that some 90 of the world's low and middle income economies still have a long way to go before we would expect to see any improvement in per capita emissions. Global income distribution is highly skewed, with median per capita income well below the mean. Hence, even though global per capita income may exceed that turning point, emissions will still be increasing in a majority of countries for the foreseeable future (Stern *et al.,* 1996). A similar story can be told at the national level, urban emissions being expected to fall before national emissions.

Attempts to predict emissions on the basis of the EKC results illustrate just how far there is to go. Stern *et al.* (1996) predict emissions of sulphur dioxide based on individual country projections. They find that aggregate emissions of sulphur dioxide are expected to rise from 383 million tonnes in 1990 to 1,181

Table I. "Turning points" for pollutants with a "Kuznets" relation to GDP per capita

Air pollution						
SO_2	SPM	NO_x	CO	CO_2	CFCs	Source of estimates
6,900	7,300	14,700	9,900		12,600	Cole *et al.* (1997)
4,107						Grossman and Krueger (1993)
4,053						Grossman and Krueger (1995)
3,000	4,500	5,500				Panayotou (1995)
5,000						Panayotou (1997)
10,700	9,600	21,800	19,100			Seldon and Song (1994)
3,670	3,280					Shafik (1994)
				35,428		Holtz-Eakin and Seldon (1995)
				12,800		Moomaw and Unruh (1997)
Other effects						
Faecal coliform	BOD	COD	Arsenic	Nitrates	Deforestation	
7,955	7,623	7,853	4,900			Grossman and Krueger (1995)
				15,600		Cole *et al.* (1997)
					2,049	Antle and Heidebrink (1995)
					823	Panayotou (1995)
					4,760/5,420	Cropper and Griffiths (1994)

Source: Adapted from Barbier (1997)

million tons in 2025. This implies a doubling of per capita emissions. Seldon and Song (1994) similarly predict increasing aggregate emissions of sulphur and carbon monoxide through 2025, and of solid particulates and nitrogen oxides through 2050.

While the EKC findings do not themselves imply any causality between economic growth and environmental change, four main causal explanations have been conjectured. These are:

(1) income-related changes in the sectoral composition of economies (Panayotou, 1997; de Bruyn, 1997);

(2) income related changes in technology (de Bruyn, 1997);

(3) the link between income and the demand for environmental quality (McConnell, 1997); and

(4) the impact of environmental constraints to growth (Arrow *et al.,* 1995).

The first two are quite intuitive. Local air and water quality may be expected to deteriorate in the first stages of industrialisation in countries at the dirty end of the product cycle. Nor is it surprising that local air and water quality should improve with the expansion of the service sector and the relocation of "smokestack industries". This reflects the nature of industrialisation. Industrial growth in the developing countries is frequently based on highly polluting industries. Developing countries account for a steadily increasing proportion of world output in many of the most highly polluting industries: pulp and paper, iron, steel and non-ferrous metals, petroleum refining and chemical products (Table II).

This partly reflects the fact that industrial growth in the developing countries depends to a considerable extent on the activities of small and medium-scale enterprises (SMEs). SMEs tend to be concentrated in the most environmentally damaging activities – chemicals, textiles, leather and fur products, food processing, non-ferrous metal work, charcoal and fuelwood supply. Moreover, although large firms dominate the capital intensive industries like pulp and paper, industrial chemicals, petroleum refineries, and

Table II. Average annual growth of polluting industries

	Developed countries		Developing countries	
Branch of industry	1975-85	1985-92	1975-85	1985-92
Textiles	0.2	0.0	2.8	3.9
Leather and fur products	–0.3	–0.2	4.4	5.3
Pulp and paper products	1.7	3.4	5.0	5.1
Industrial chemicals	1.6	3.5	6.7	7.4
Petroleum refineries	0.7	1.2	7.8	5.3
Misc. petroleum and coal products	2.0	1.7	8.1	4.1
Iron and steel	–1.5	1.0	6.4	4.2
Non-ferrous metals	0.9	3.2	7.2	5.4

Source: UNIDO (1992)

iron and steel, many of the environmentally more harmful tasks and processes are sub-contracted to SMEs. SMEs also tend to rely on older technologies, are difficult to regulate and face fewer incentives not to pollute. As a result, growth based on the encouragement of SMEs tends to increase environmental risks. The problem here is that the disposal of acids, various heavy metals, solvents, cadmium, chromium, inks and dyes, catalysts and oil residues is largely unregulated. Indeed, most hazardous waste is simply dumped in landfills or disposed of in drains, both options resulting in the contamination of surface and ground water (Tolba *et al.,* 1992).

The relative impact of structural and technological factors tends to differ with the time horizon over which the problem is evaluated. Decomposition studies of the explanations for emissions reduction over a relatively short horizon, for example, typically find technological change to be more significant than structural change (de Bruyn, 1997).

The third explanation considers the link between income and the demand for environmental quality. If environmental quality is in the nature of a luxury good then people will demand higher environmental quality as per capita incomes rise. McConnell (1997) shows that income-related changes in the demand for environmental amenity are neither necessary nor sufficient to generate an EKC, but they are consistent with the EKC. The luxury good hypothesis is not, however, directly testable. Given that environmental quality cannot be bought and sold in markets, changes in demand may be captured only indirectly in changes in technology, policy, regulation and consumption of marketed goods with greater or less environmental impacts.

The last explanation focuses on the nature of the environmental constraints to growth. It is argued that what matters is not the absolute level of per capita emissions or depletion, but aggregate emissions or depletion relative to the assimilative or carrying capacity of the environment (Arrow *et al.,* 1995). The general policy problem implicit in the EKC is the degree to which pollution and other forms of environmental deterioration can be delinked from consumption growth. If they cannot, then at some point consumption growth will be halted by the environment's limited capacity to absorb the impacts of consumption. The point made by Arrow *et al.* (1995) is that growth in consumption is constrained by the assimilative or carrying capacity of the environment. Environmental constraints may be relieved by changes in technology, the structure of production or the pattern of consumption. Where environmental constraints are not binding there is little incentive to reduce emissions or the depletion of environmental resources. Where environmental constraints are binding, however, there may be little option but to do so. Moreover, where environmental constraints are binding and the population is growing, there may be little option but to reduce per capita emissions or rates of depletion. At low levels of income, the environmental impacts of consumption may be within the assimilative or carrying capacity of the environment. As income rises, however, the constraints imposed by the environment tighten. Growth in consumption, whether induced by growth in the level of economic activity or growth in population, may be expected to close on environmental constraints in various ways, and hence to stimulate environmentally conserving responses.

Development and the environment: environmental quality, consumption and human development

Most of the empirical research in this area focuses on the relationship between growth in per capita income and environmental change. This may not be appropriate if we are interested in the link between human development and environmental sustainability, or in the Brundtland conjectures. This section accordingly identifies other measures that may be used to analyse the linkage between environmental change and economic performance. These include

- consumption of marketed goods and services,
- poverty, and
- human development.

Specifically, it identifies four measures of environmental change and the same number of performance measures.

Indicators of environmental change

The four measures of environmental change reflect qualitatively different impacts of the development process. They comprise:

(1) a measure of water pollution – lack of access to safe water supplies;

(2) a measure of industrial pollution – emissions of sulphur dioxide (SO_2);

(3) a measure of the depletion of environmental resources – deforestation; and

(4) a measure of greenhouse gas emissions – carbon dioxide (CO_2).

Of the four environmental indicators selected for analysis, two currently attract most attention in low-income countries. The pollution and depletion of local water supplies is one. Deforestation and the allied problem of desertification is the other. Emissions of SO_2 and CO_2, being primarily by-products of industrialisation, attract more attention in middle and upper income countries. The problems are, however, all linked. Water pollution and depletion are of concern for many reasons, not least being the immediate effects on human health and productivity. But from an environmental perspective the main significance of water depletion lies in its impact on plant-available moisture and so the structure and productivity of ecological and agro-ecological systems. Because deforestation and desertification affect the hydrological cycle, they are linked with the depletion and pollution of water supplies. Deforestation and desertification are also linked with the carbon cycle both through emissions due to land use change, and through their effect on the capacity of forests to sequestrate carbon.

The proxy for water pollution used here is the percentage of the total population without access to safe water supplies as reported in both the *World Development* and *Human Development Reports.* This indicator is useful in capturing both the quantitative and qualitative aspects of water supplies. The indicator of deforestation used is the percentage change in forest cover during the 1980s. The sources are World Resources Institute (1994). This indicator is highly sensitive to the environmental reference point – the proportion of forest cover remaining. The data set is that used by Panayotou (1993; 1995). The indicators of sulphur dioxide and carbon dioxide used here are 1990 per capita kg of SO_2 and CO_2 reported in UNEP (1994). SO_2 data are government estimates except for Asian country estimates which derive from Kato and Akimoto (1992). CO_2 data are based on UNSO consumption data for gas, liquid and solid fuels, and cement manufacture (CDIAC, 1992).

Indicators of economic performance

The first of the performance measures is PPP adjusted income per capita. This provides a direct point of comparison with the EKC literature, and makes it possible to identify and analyse the differences that use of alternative measures implies. The alternative performance measures are:

- a measure of consumption – private and government consumption per capita;
- a measure of development – the human development index;
- a measure of poverty – an IFAD index of rural poverty in the developing countries.

The alternative performance indicators selected all involve some modification to the per capita income. Consumption is measured by the sum of private and general government consumption in 1990 as reported in the *Human Development* and the *World Development Reports* (UNDP, 1992; World Bank, 1992). Private consumption is the market value of goods and services received by households and non-profit organisations, including imputed rents on owner-occupied dwellings. Government consumption is current expenditures on goods and services by national, state, provincial and local governments, but excluding state-owned enterprises. The measure of consumption used accordingly excludes any non-marketed environmental goods and services.

The measure of poverty selected is IFAD's Integrated Poverty Index (IPI) for 114 developing countries. Use of this measure truncates the sample of countries, and this needs to be borne in mind in interpreting the results. The IPI is based on Sen's composite poverty index (Sen, 1976). It has been adjusted for purposes of this exercise to take values between 0 and 100, and is increasing in poverty. That is, the closer to 100 the more impoverished is the country.

The IPI is calculated by combining a head count index of poverty, the income gap ratio, life expectancy at birth, and the annual rate of growth of per capita GNP. The head count index is simply the percentage of the population below the poverty line. The income gap ratio is the difference between the highest per capita GNP in the sample and the per capita GNP of the country concerned, expressed as a percentage of the former. Life expectancy at birth is included as a proxy for income distribution below the poverty line. Using this measure it is possible to classify countries into three broad groups. An IPI of 40 or more indicates severe poverty; an IPI between 40 and 20 indicates moderate poverty; while an IPI of less than 20 indicates little poverty. The IPI used here was developed on the basis of data for a number of different years, but notionally describes the situation in 1988.

Finally, the HDI has been selected as the most general and widely accepted index of development. The version used here is not adjusted for income distribution, and so combines GDP per capita in PPP$; life expectancy at birth; and educational attainment – the latter measured by a combination of adult literacy and primary, secondary and tertiary education enrolment ratios. Once again, for comparability, the HDI used is for 1990.

Country-specific variables

The country-specific variables selected reflect the stylized facts that lie behind the propositions of the Brundtland Report and Agenda 21. The first of these relate to the role of population growth, rural employment, agriculture and deforestation. The conversion of land to agriculture and the intensification of agriculture in developing countries – the proximate causes of deforestation and carbon emissions in many developing countries – are widely argued to be driven by population growth, landlessness, and rural poverty. The IFAD review of the position as it was in the late 1980s is described in Table III. Inspection reveals an obvious linkage between the proportion of the population in agriculture, the level of rural poverty, and the existence of non-farm rural employment opportunities. The country-specific variables evaluated accordingly include population growth; the proportion of the population in the rural areas; and agriculture's share of GDP.

To capture the effect of dependence on world commodity markets the country-specific variables include a measure of the openness of the economy: exports as a proportion of GDP. This is measured by the ratio of the value of exports of goods and services to GDP in 1990 (UNDP, 1992; World Bank, 1992). Exports of goods and services is the market value of goods and services provided to the rest of the world. It includes the value of merchandise, freight, insurance, travel and other non-factor services, but excludes transfer payments, investment income, interest and labour income. It also excludes transboundary environmental externalities.

The data used in this analysis are described and reported in Appendix 1. The environmental performance indicators are denoted ACH_2O (safe water), SO_2 (emissions of sulphur), CO_2 (emissions of carbon dioxide), and DEF (deforestation). The economic/social performance indicators are denoted INCOME (real gross domestic product per capita in purchasing power parity terms), CONSUMPTION (per capita consumption), HDI (the human development index) or DHDI (the distribution-adjusted human development

Table III.
Profile of rural population in developing countries, 1988

	Rural population (millions)	Per cent of total population	Agricultural population per cent of rural population	Population below the poverty line per cent of rural population	Landless population per cent of rural population	Refugee population per cent of rural population
Asia	2,019	74	83	31	26	5
Asia (excluding China and India)	567	70	74	46	20	5
Sub-Saharan Africa	337	73	98	60	11	6
Near East and N. Africa	106	51	73	26	23	13
L. America and Caribbean	123	29	96	61	31	1
Least developed countries	368	80	89	69	18	7

Source: Jazairy *et al.* (1992)

index), and IPI (the integrated poverty index). The country specific variables are denoted POPG (the rate of population growth), RUPOP (rural population as a percentage of total population), AGSHARE (agricultural GDP as a percentage of total GDP), and EXPSHA (exports of goods and non-factor services as a percentage of GDP).

The relationship between environmental change, poverty, consumption and human development

Since the aim is to consider the relation between environmental change and these performance measures in comparison with the existing literature it employs the most common approach in the literature so far – an OLS treatment of cross-sectional data. This means that the results are subject to all the limitations of this approach noted in the existing literature (see, for example, Stern *et al.,* 1996; Stern, 1998). The estimated results for all models are given in Appendix 2. The results for each of the four environmental indicators are summarised below.

Polluted water supplies (lack of access to clean water supplies)

Lack of access to clean water supplies is shown to decline monotonically with growth in income, the HDI and consumption. The best fit is given by linear models including the country-specific variables, population growth and the share of rural population. That is, rapidly growing rural populations are most closely associated with lack of access to safe water. Differences in the coefficients on income, consumption and the HDI show that the latter has the weaker effect, although it is in the same direction as the first two. This reflects the fact that where per capita GDP and educational attainment – both elements of the HDI – may be expected to vary directly with lack of access to safe water, the life expectancy element in the HDI will do the opposite.

The relationship between access to safe water and the IFAD poverty index, IPI, is less significant. The poverty index involves a truncated sample since it was calculated for low and middle-income countries only. While the IPI model has less explanatory power than the others, it does indicate that lack of access to safe water is an increasing function of poverty. In addition to the IPI, the model includes the effects of population growth and rural population share. Both effects are positive and significant. Population growth is, however, the more important explanator of the two. As with GDP, CONSUMPTION and INCOME, a linear model gives the best fit. The implication is that access to clean water does not involve a Kuznets relation with any of the criteria of human development. While the factors assessed may not explain a great deal of the variation in access to safe water, some models perform better than others.

Sulphur dioxide

Sulphur dioxide emissions have been the most studied pollutant in the EKC literature. It is already well understood that SO_2 bears a Kuznets type relationship with per capita income. It turns out that SO_2 bears the same relation to consumption. The best fit is offered by a quadratic specification of the model in both cases. As with lack of access to clean water supplies, the consumption model has less explanatory power than the income model. It may be inferred that the inclusion of information on savings/investment improves the explanatory power of the model. This is consistent with the fact that the primary sources of emissions are industrial activities, and especially power generation, ferrous and non-ferrous metals and petrochemicals.

The turning points for income are in the range \$7,359-\$9,563 while those for consumption are \$6,391-\$7,239. Given the distribution of income and consumption (see Appendix 1) this puts a country like Portugal at the turning point. It also makes it easy to see how many countries are below the turning point. For all such countries, growth in either income or consumption will be associated with rising per capita sulphur emissions, and hence an increasing burden on the assimilative capacity of the environment.

Although quadratic models are reported for HDI and NHDI, they do not clearly dominate the linear models. That is, although the relationship between sulphur emissions and the two human development indicators is consistent with at least a segment of the inverted U, a linear model performs just as well. One limitation of the sulphur models is that the sample size is smaller than for the other environmental indicators. There are data for about 60 countries for the income and HDI models, and only 43 for the consumption model. Part of the difference in the explanatory power of the models may be due to this. The sample size for the IPI model is only 18. The results from that model have not therefore been reported.

Deforestation

Of all the environmental indicators investigated to date, we have most difficulty in fitting deforestation and income data to quadratic models. Although Panayotou (1995) reports a Kuznets relationship between deforestation and per capita income, the relationship is much weaker than for SO_2. It is also clear that there is less obvious sense in taking the rate of deforestation as the relevant indicator, since it is so sensitive to the proportion of the forest remaining.

Using the same data set as Panayotou, there is no evidence for a Kuznets relationship when the whole sample is considered. There is some limited support for a Kuznets relationship between deforestation and three measures of performance – income, consumption, and the HDI – when only tropical countries are considered. But none of the models has much explanatory power. The turning points – between \$1,888 and \$2,816 – for the two models reported are closer to those estimated by Antle and Heidebrink (1995) than those estimated by Panayotou (1995). There is no statistically significant relation between the poverty index, IPI, and deforestation. The only country-specific variable that is significant in any of the models is the rural population as a proportion of the total population.

Carbon dioxide

Carbon emissions increase monotonically with per capita GDP, consumption and the measures of human development used, and decrease monotonically with poverty. The best fit in all cases is offered by a linear model. In all cases CO_2 emissions increase with the three development measures over the whole income range. This is exactly opposite to the case of water pollution. Water pollution was found to decrease over the whole of the income range.

The most significant of the country-specific variables is the share of agriculture in GDP, the coefficients reflecting the fact that CO_2 emissions increase with manufacturing and industrial activity and fall with agricultural activity. The higher the agricultural share in GDP, the lower the share of manufacturing and industrial activities that generate carbon emissions. The results of a model including our index of the openness of the economy, the share of exports in GDP, are also reported though they are not significant in all cases; and do not add much explanatory power to the regressions. In one case – when the economic performance indicator is consumption – the openness of the economy does turn out to be significant. Carbon emissions are an increasing function of both consumption and the share of exports in GDP.

Since the poverty model excludes many of the major sources of carbon emissions, it is weaker than the other models. It indicates a negative relation between poverty and carbon emissions that is statistically significant, but not very strong. This reflects the negative correlation between poverty and the industrial and manufacturing activities that are the main sources of carbon emissions. Since the role of land use conversion in generating carbon emissions in low-income countries is dominated by the effect of industrial emissions in middle and high-income countries, it merely weakens the relationship with the IPI.

Discussion

There is little strong evidence in support of the hypothesis that environmental degradation is driven by poverty in the developing world and by overconsumption in the developed world if environmental degradation is proxied by indicators of the type used in the EKC literature. Since an inverted-U shaped relation holds for at least some such environmental indicators and measures of consumption, poverty and human development, as well as for per capita income, there is reason to doubt the Brundtland hypothesis. Measured in per capita terms, some of the environmental impacts of economic activities appear to be least severe at either end of the income range, and most severe in the middle.

It is, however, worth recalling that the results have been developed for single equation models based on cross-sectional data that assume away any feedbacks between environment and economy; and that the measure of environmental quality tends to be a per capita measure of outputs (emissions). In no case is the indicator of environmental quality used a measure of the volume of emissions relative to the assimilative or carrying capacity of the ecosystem concerned. In some cases it is a measure of ambient concentrations, but this is still unrelated to the carrying or assimilative capacity of the affected system. Recall, in addition, that the EKC is well defined for one environmental indicator only – sulphur dioxide. There is no EKC for the lack of access to clean water at one end or CO_2 at the other; the best fit in the deforestation models is quadratic, but the models do not have much explanatory power.

Poverty, myopia and parochialism

The most compelling explanation for the differences found in both the shape of the curve relating environmental and development indicators is that the four classes of environmental problem evaluated typically impose costs at very different temporal and spatial scales. The lack of access to clean water imposes costs that are immediate and very local in their effect. People who do not have access to clean water suffer an increased incidence in a range of gastro-intestinal and skin diseases. Infant mortality tends to be much higher, and life expectancy is much lower. Productivity, and hence consumption, are also much lower. Put another way, the pollution of local water supplies reduces the quality of life of the people who use those supplies as they use it. Emissions of SO_2, by contrast, have more diffuse effects. In Europe, for example, acidic deposition due to SO_2 emissions is recognised to be a European-wide problem. Emissions from thermal power generating plants in the UK, for instance, lead to "acid rain" in Scandinavia, Germany, Poland, the Czech Republic and other countries. Nor are the effects as immediate. Increasing acidification of soils and water reduces their productivity – eventually. Acidic deposition on buildings increases the rate at which stone and metal corrodes, and so reduces their working life. Both impose very real costs on society, but the costs are delayed.

Deforestation and CO_2 emissions are at the other end of the spectrum from pollution of local water supplies. They are linked in the sense that land conversion (the burning of forests) is one source of CO_2. But they are also linked in that both involve long-term global effects. Deforestation is recognised to be a major factor in biodiversity loss. The destruction of habitats in areas of high species richness and high levels of endemism is the main proximate cause of species extinctions (Heywood, 1995). All of humanity loses from the loss of information and the evolutionary potential which that implies (Perrings *et al.,* 1995). Similarly, CO_2 is the main proximate cause of global climate change. Climate change is a process fraught with uncertainty, but is expected to impose very significant adjustment costs on societies and ecosystems alike across the globe (see Bruce *et al.,* 1996). Of course, deforestation has other more localised effects. It involves loss of watershed protection and hence increased soil erosion and siltation of rivers and reservoirs. But these effects are still imposed on people other than those engaged in land conversion.

People are more concerned about the short-term environmental impacts of economic activity in their own neighbourhood than they are about long-term impacts occurring at geographically distant locations. The measure of their concern for the wellbeing of future generations or those who live far away – the rate at which they discount future and distant costs – appears to be a function of per capita income. That is, the rate at which people discount the wider and future environmental costs of their actions appears to fall with income. Poverty induces people to behave as if they are myopic, while affluence allows people the luxury of "caring" more about both future generations and distant members of the present generation.

The common intuition behind this is straightforward. If people are impoverished by the imposition of charges for environmental resources, they will focus their attention on "free" or open access resources, and their decisions will become increasingly myopic. The economic intuition is equally plain. A change in the relative prices involves both substitution and income effects. For the poor, the income effects of price changes tend to be very strong. They may also be perverse. An increase in the price of a resource reduces the real income of the user. For a large class of resources (inferior goods) a reduction in the real income of users induces an increased demand for the resource. In the extreme case (Giffen goods) an increase in the price of the good induces people to buy more of that good. The existence of Giffen goods is evidence of a form of poverty trap.

One implication of this is that where income effects come close to dominating substitution effects, as is likely for many marginal environmental resources, there is a real risk that market-based incentives may not work or may work in the "wrong" direction. Price changes that cause farmer incomes to fall are a case in point. If farmers increase output to compensate for the reduction in their income, the environmental consequences of the price change may be perverse. Put another way, the effectiveness of economic incentives designed to assure the environmentally sustainable use of resources in developing countries will be weakened by any policy that deepens and widens poverty in those countries.

More generally, the Brundtland perception of the relationship between poverty, affluence and the environment has been illuminated by the hunt for a Kuznets relationship between per capita income and environmental quality. The EKC studies have shown that deepening poverty at one end of the scale, and increasing affluence at the other, both have implications for the environment. But these implications are different. Deepening poverty is associated with environmental effects that tend to have immediate and local implications for the health and welfare of the communities concerned. Increasing affluence is associated with environmental effects which are much more widespread and much longer-lasting.

In the light of this, we might ask what is learned by looking at the relationship between environmental indicators and other measures of economic and social performance. Except in the case of lack of access to safe water supplies, both consumption and the two variants of the HDI have less explanatory power than GDP per capita. In all cases, however, the difference in the explanatory power of the income and consumption models is marginal. The results of the models for the two variants of the HDI – the HDI and the income distribution-adjusted HDI – show that addition of an implicit distribution variable slightly improves the explanatory power of the models for sulphur, carbon and deforestation (bearing in mind the weakness of the latter model). On the other hand, it slightly worsens the explanatory power of the model for access to safe water.

The only substantial difference is between the models using alternative development indicators and the models using the IPI. This measure of performance turns out to have much weaker explanatory power than the others. Poverty is not as good a predictor of environmental quality as the other measures of performance. The poverty data set is, of course, truncated, but even if the same sample of countries is used in the models for the other performance indicators, the poverty models have least explanatory power. This is true even for lack of access to safe water, which we might expect to be closely correlated with an index that includes the proportion of the rural population below the poverty line. Bearing in mind, however, that the environmental indicators tested are associated with particular patterns of consumption or particular productive activities, all this indicates is that the IPI is a weaker predictor of consumption or production activities in low and middle income countries than the other performance measures.

Environmental sustainability, growth and development

Arrow *et al.* (1995) argue that the interesting question about the link between growth, development and the environment is not whether economic growth does have environmental consequences. It is whether its environmental consequences threaten the resilience of the ecological systems on which economic activities depend. To answer that question requires more than an index of the level of pollution or depletion, it requires an index of the level of pollution or depletion relative to the assimilative or carrying capacity of the ecological system concerned. The EKC is evidence that environmental improvements have occurred in some cases. It is not evidence either that they will occur in all cases, or that they will occur in time to avert the potentially irreversible environmental effects of economic or human development.

The central point made by Arrow *et al.* (1995) is that reductions in the emission of pollutants has, in almost every case, been induced by regulation or policy to satisfy some environmental constraint. The explanation is simple. The environmental effects of production or consumption are mediated by the market in only a few cases. In the vast majority of cases, these effects are external to the market and so are not registered in the transactions between consumers and producers. This may be because of ignorance or uncertainty about the nature and extent of the environmental effects of consumption; because consumers are "authorised" to ignore the effects of their actions on others by the structure of rights in a society; or because the environment concerned is in the nature of a public good – of benefit to all but the responsibility of none. Where market prices are unable to signal convergence on some environmental constraint, adjustments tend to be made in the political arena as a belated response to evidence of environmental degradation.

Historically, environmental improvement has followed specific institutional reforms, environmental legislation and market-based incentives designed to internalise harmful external effects. It has also been limited to cases where societies have a direct incentive to internalise the environmental costs of their own activity. Where the environmental costs of economic activity have been borne by the poor, by future generations, or by people in other countries, the incentive to address environmental questions has been much weaker.

Two observations follow. First, the assumption implicit in the basic model that there are no feedback effects from the environment to the economy is unhelpful. There are no market prices attaching to environmental effects, but the development of environmental laws and regulations responds to evidence of the consequences of environmental change. In terms of the econometrics of the problem, estimation of single equation relationships where there are feedback effects necessarily introduces biases, and may result in inconsistent estimates (Stern *et al.,* 1996; Stern, 1998). Moreover, the interpretation given to the inverted-U shaped relation that countries can grow out of environmental problems without appropriate environmental policies is misleading.

Second, the severity of the environmental consequences of economic activity at different levels of income is sensitive to the nature and effectiveness of environmental policy. Panayotou (1997) uses a panel of data from 30 developed and developing countries over the period 1982-1994 to test the sensitivity of the relationship between sulphur dioxide emissions, GDP per capita, a set of country effects including the rate of growth, the sectoral structure of the economy, and its population density together with a policy variable – the enforcement of contracts. He concludes that the effectiveness of policy can help to flatten the EKC, or to lower the turning point. He notes that where there are environmental thresholds this can contribute to the sustainability of growth by preventing the economy from overshooting those thresholds.

This last point is important. If there are significant irreversibilities, or effects are very expensive to reverse, future increases in current national income may offer no protection against environmental degradation. Effects in this category include national environmental issues such as soil erosion, depletion of ground water reservoirs, and desertification. They also include global issues such as climate change and biodiversity loss. Arrow *et al.* (1995) conclude that economic growth is not a panacea for improving environmental quality. They emphasise, however, that this is not an argument against economic growth *per se,* but against the presumption that growth will automatically resolve the problem of environmental degradation; and that growth is automatically environmentally sustainable.

The environmental consequences of economic activity are usually quite specific to the nature of the activity, and the type of economic activity tends to be correlated with income. It is not at all surprising, therefore, that the distribution of environmental effects associated with given activities may be mapped into the income range associated with those activities. The optimistic conclusion drawn from this by at least some – that economic growth will “take care" of the environment – is, however, unwarranted. The environmental consequences of economic growth may be expected to change as the activities supporting growth changes. Each new wave of activities will have its own set of effects. There is not much that can be said about general trends, except that results of the EKC studies lend some support to the view that more affluent societies will avoid activities with significant local or short-term effects. Hence the environmental consequences of growth in higher income countries will tend to be displaced on to others – either geographically distant members of the present generation or members of future generations.

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Appendix 1

Table AI. Environmental quality indicators

Country	CO_2	ACH_2O	DEF	SO_2
Afghanistan	0.10	21		3.9
Albania	0.82	97	0	
Algeria	0.74	71	0.8	
Angola	0.14	40	0.7	
Antigua and Barbuda	1.08			
Argentina	0.93	64	0.1	
Australia	4.32	100	0	
Austria	1.95	100	0.4	13.1
Bahamas	1.44			
Bahrain	6.93			
Bangladesh	0.04	78	4.1	0.5
Barbados	1.08	100		
Belgium	2.87	100	–0.3	42.3
Belize	0.37			
Benin	0.04	55	1.3	
Bhutan	0.02	34		
Bolivia	0.30	53	1.2	
Botswana	0.36	90	0.5	
Brazil	0.13	87	0.6	
Brunei	5.34			4.4
Bulgaria	2.76	99	–0.2	114.6
Burkina Faso	0.02	70	0.7	
Burundi	0.01	46	0.6	
Cambodia	0.01		1.0	0.3
Cameroon	0.13	44	0.6	
Canada	4.35	100	–1.1	143.3
Cape Verde	0.06			
C.African Rep.	0.02	24	0.4	
Chad	0.01	57	0.7	
Chile	0.71	87	-0.1	
China	1.86	72	0.7	17.7
Colombia	0.44	86	0.7	
Comoros	0.03			
Congo	0.24	38	0.2	
Costa Rica	0.30	92	3.0	
Côte d'Ivoire	0.19	69	1.0	
Cuba	0.90			
Cyprus	1.70	100		
Czechoslovakia	3.62		0.1	177.1
Denmark	2.71	100	0	52
Djibouti	0.25			
Dominica	0.24	68	2.9	
Ecuador	0.44	54	1.8	
Egypt	0.42	90	0	
El Salvador	0.13	47	2.3	
Eq.Guinea	0.09			
Ethiopia	0.02	18	0.3	
Fiji	0.27	80		
Finland	2.82	96	0	51.5
France	1.74	100	-0.1	21.5
Gabon	1.45	66	0.6	
Gambia	0.06	77	0.8	
German DR	5.05			314.9
German FR	2.94	100	–0.4	16.6
Ghana	0.07	57	1.4	
Greece	1.88	98	0	50.3
Grenada	0.38			
Guatemala	0.12	62	1.8	
Guinea	0.05	52	1.2	
Guinea-Bissau	0.06	25	0.8	
Haiti	0.03	41	5.1	
Honduras	0.10	64	2.2	
Hong Kong	1.26	98	–0.5	25.9
Hungary	1.49	98	–0.5	95.7
Iceland	0.15	100		24.8
India	0.22	73	0.6	3.7
Indonesia	0.21	34	1.1	2.7
Iran	0.90	89		
Iraq	0.75	77		
Ireland	2.27	100	–1.2	45.2
Israel	2.08	100	–0.3	58.6
Italy	1.82	100	0	42.0
Jamaica	0.52	72	7.8	
Japan	2.34	96	0	9.2
Jordan	0.69	99	–1.0	
Kenya	0.07	49	0.6	
Korea	1.54	93	0.1	7.9
Korea Dem.	1.96			59.3
Kuwait	3.45		0	222.5
Laos	0.01	28	0.9	0.4
Lebanon	0.93		0.6	
Lesotho		47	0	
Liberia	0.05	50		
Libya	2.57			
Madagascar	0.02	21	0.8	
Malawi	0.02	51	1.4	
Malaysia	0.90	78	2.1	14.7
Maldives				1.5
Mali	0.01	11	0.8	
Malta	1.29	100		
Mauritania	0.35	66	0	
Mauritius	0.29	95	0.2	
Mexico	1.01	89	1.3	
Mongolia	1.26	80	0.9	49.4
Morocco	0.25	56	–1.4	
Mozambique	0.02	22	0.8	
Myanmar	0.03	74		0.7
Namibia			0.3	

(*continued*)

Country	CO_2	ACH_2O	DEF	SO_2	Country	CO_2	ACH_2O	DEF	SO_2
Nepal	0.01	37	1.0	0.6	Tanzania	0.02	52	1.2	
(The) Netherlands	2.54	100	–0.3	16.1	Thailand	0.46	77	3.5	11.2
New Zealand	2.07	97	0		Togo	0.05	70	1.5	
Nicaragua	0.15	54	1.9		Trinidad	3.19	96	–2.1	
Niger	0.04	53	0.4		Tunisia	0.34	70	–1.9	
Nigeria	0.21	42	0.7		Turkey	0.69	84	0	7.2
Norway	2.48	100	–1.4	1.5	UAE	9.05	100	0	
Oman	2.24	46	0		Uganda	0.08	33	1.0	
Pakistan	0.14	55	3.5		UK	2.65	100	–1.1	66.3
Panama	0.30	84	1.9		USSR	3.66			57.3
Paraguay	0.09	35	2.8		Armenia			3.9	20.9
Peru	0.27	53	0.4		Azerbaijan			1.3	12.4
Philippines	0.19	81	3.4	6.0	Belarus			–0.4	54.6
PNG	0.16	33	0.3		Estonia			–1.2	121.3
Poland	2.60	89	–0.1	83.5	Georgia			0.7	13.9
Portugal	1.09	92	–0.5	20.6	Kazakhstan			0	87.0
Qatar	10.47			430.8	Kyrgyzstan			1.2	12.4
Romania	2.12	95	0	45.6	Latvia			–0.2	20.0
Rwanda	0.02	69	0.2		Lithuania			0	38.0
St Kitts	0.40				Moldova			–6.7	52.9
St Lucia	0.30				Russia			0.2	68.2
St Vincent	0.19				Tajikistan				3.0
Sao Tome	0.15				Turkmenistan				5.8
Saudi Arabia	3.64	93	0	99.2	Ukraine			–0.3	53.3
Senegal	0.10	44	0.7		Uzbekistan			5.5	25.2
Seychelles	0.66				Uruguay	0.35	95	–0.6	
Sierra Leone	0.04	39	0.6		USA	5.26		0.1	84.7
Singapore	3.77	100	2.3	51.7	Vanuatu	0.12			
Somalia	0.03	36			Venezuela	1.40	92	1.2	
South Africa	2.15		–0.8		Vietnam	0.10		1.5	0.6
Spain	1.41	100	0	56.7	Yemen	0.11		0	
Sri Lanka	0.06	60	1.4	1.7	Yemen Pdr	0.64			
Sudan	0.04	34			Yugoslavia	1.50			62.1
Surinam	1.24	68			Zaire	0.03	39		
Swaziland	1.80	31			Zambia	0.08	59	1.1	
Sweden	1.60	100	0	24.5	Zimbabwe	0.71	84	1.7	
Switzerland	1.72	100	–0.6	9.5					
Syria	0.66	79	–4.3						

Notes: Values for carbon dioxide (CO_2) give emissions from industrial sources in per capita 1990 kg CO_2, as reported in the UNEP's *Environmental Data Report 1993-94*. They are based on UN consumption data for gas, liquid and solid fuels plus cement manufacturing statistics to which appropriate emission factors have been applied. Per capita emissions are based on UN population statistics. Emissions of SO_2 are measured in per capita 1990 kg of SO_2 and they are also reported in the UNEP's *Environmental Data Report 1993-94*.
Access to drinking water (ACH_2O) is measured by access to water supplies through either standpost or home connections. Safe water is defined as treated surface waters or untreated but uncontaminated waters. These data are reported in the *Human Development Report 1994*.
Annual deforestation rates during the 1980s (DEF) refers to the permanent conversion of forestland to other uses. Estimates of forest area are derived from country statistics assembled by the FAO and the UNECE. The data are reported in the *Human Development Report 1997*

Table AI.

Table AII. Performance and country-specific indicators

Country	INC	HDI	DHDI	IPI	CONS	POPG	AG SHARE	RUPOP	EXP SHA
Afghanistan	714	0.066		0.570		2.63	45.0	81.8	
Albania	3,000	0.699				1.83		64.8	
Algeria	3,011	0.528		0.166	1,866	2.72	13.0	48.3	25
Angola	840	0.143		0.596		2.70	13.0	71.7	
Antigua	4,000	0.785		0.216		0.30	4.0	69.0	78
Argentina	4,295	0.832	0.812	0.125	3,607	1.27	13.0	13.7	14
Australia	16,051	0.972	0.935		12,680	1.37	4.0	14.5	17
Austria	16,504	0.952			12,047	0.07	3.0	41.6	41
Bahamas	11,235	0.875				1.80	2.0	35.7	59
Bahrain	10,706	0.790			7,173	3.67	1.2	17.1	89
Bangladesh	872	0.189	0.170	0.841	854	2.67	38.0	83.6	8
Barbados	8,304	0.928		0.017	7,307	0.16	6.6	55.3	50
Belgium	16,381	0.952	0.951		12,449	0.03	2.0	3.1	74
Belize	3,000	0.689		0.503	2,400	2.39	22.7	50.0	55
Benin	1,043	0.113		0.622	1,022	3.00	37.0	62.3	20
Bhutan	800	0.150		0.848	624	2.15	43.0	94.7	29
Bolivia	1,572	0.398		0.801	1,446	2.76	24.0	48.8	21
Botswana	3,419	0.552		0.434	2,153	3.71	3.0	72.5	64
Brazil	4,718	0.730	0.652	0.449	3,632	2.07	10.0	25.1	7
Brunei	14,000	0.847				3.60			
Bulgaria	4,700	0.854			3,384	0.11	18.0	32.3	40
Burkina Faso	618	0.074		0.871	593	2.66	32.0	91.0	11
Burundi	625	0.167		0.805	618	2.91	56.0	94.5	8
Cambodia	1,100	0.186				2.48		88.4	
Cameroon	1,646	0.310		0.304	1,349	3.27	27.0	58.8	21
Canada	19,232	0.982	0.948		15,193	0.88	3.3	22.9	25
Cape Verde	1,769	0.479		0.360	1,645	2.65	14.4	71.4	17
C.African Rep.	768	0.159		0.878	783	2.77	42.0	53.3	17
Chad	559	0.088		0.563	642	2.47	38.0	70.5	25
Chile	5,099	0.864	0.831	0.432	3,926	1.66	8.0	14.1	37
China	1,990	0.566		0.126	1,134	1.43	27.0	66.6	18
Colombia	4,237	0.770	0.720	0.365	3,135	1.97	17.0	30.0	20
Comoros	721	0.269		0.472	764	3.45	35.8	72.2	41
Congo	2,362	0.372		0.695	1,653	3.16	13.0	59.5	49
Costa Rica	4,542	0.852	0.852	0.217	3,542	2.64	16.0	59.6	37
Côte d'Ivoire	1,324	0.286	0.268	0.236	1,138	3.78	47.0	59.6	37
Cuba	2,200	0.711		0.256		1.03	15.0	25.1	
Cyprus	9,953	0.890		0.002	7,663	1.04	7.1	47.2	52
Czechoslovakia	7,300	0.925			5,256	0.21	8.0	22.5	33
Denmark	16,781	0.955	0.936		12,921	0.08	5.0	13.0	35
Djibouti	1,000	0.104		0.613	1,040	2.88	4.0	19.3	47
Dominica	2,404	0.586		0.377	2,139	2.22	17.0	39.6	3
Ecuador	3,074	0.646		0.533	2,397	2.56	13.0	44.0	31
Egypt	1,988	0.389	0.383	0.220	1,789	2.39	17.0	53.3	20
El Salvador	1,950	0.503	0.508	0.279	1,930	1.93	11.0	55.6	16
Eq Guinea	700	0.164		0.666	742	2.42	58.7	71.3	28
Ethiopia	369	0.172		0.643	346	2.67	41	87.1	13
Fiji	4,427	0.730		0.156	3,674	1.78	23.7	60.7	63

(continued)

Country	INC	HDI	DHDI	IPI	CONS	POPG	AG SHARE	RUPOP	EXP SHA
Finland	16,446	0.954	0.941		12,170	0.30	6.0	40.3	23
France	17,405	0.503	0.938		13,575	0.35	4.0	25.7	23
Gabon	4,147	0.503		0.166	2,612	3.47	9.0	54.4	56
Gambia	913	0.086		0.826	830	2.89	34.1	76.8	68
German DR						0.48		22.8	
German FR	18,213	0.957			13,113	0.10	1.5	12.6	32
Ghana	1,016	0.311		0.524	914	3.15	48.0	67.0	21
Greece	7,366	0.902			6,776	0.23	17.0	37.5	22
Grenada	4,081	0.787			3,917		15.0	41.0	44
Guatemala	2,576	0.489		0.647	2,369	2.88	26.0	60.6	21
Guinea	501	0.045		0.672	395	2.86	28.0	74.4	30
Guinea-Bissau	841	0.090		0.753	933	1.99	47.0	80.2	8
Haiti	933	0.275		0.762	923	2.01	31.3	71.7	12
Honduras	1,470	0.472	0.436	0.483	1,396	3.18	23.0	56.3	40
Hong Kong	15,595	0.913	0.891		10,448	2.20	0.0	6.0	137
Hungary	6,116	0.887	0.896		4,464	0.18	12.0	38.7	33
Iceland	16,496	0.960			13,196	0.97	12.0	9.5	37
India	1,072	0.309	0.288	0.48	857	2.07	31.0	73.0	8
Indonesia	2,181	0.515	0.503	0.398	1,374	1.93	22.0	69.5	26
Iran	3,253	0.557	0.538	0.475	2,602	2.74	21.0	43.3	15
Iraq	3,508	0.589		0.501		3.48	18.0	28.7	
Ireland	10,589	0.925	0.928		7,518	0.92	9.9	42.9	62
Israel	10,840	0.938			9,539	1.66		8.4	32
Italy	15,890	0.924	0.923		12,553	0.03	4.0	31.1	21
Jamaica	2,979	0.736	0.665	0.679	2,115	1.21	5.0	47.7	59
Japan	17,616	0.983	0.990		11,626	0.43	3.0	23.0	11
Jordan	2,345	0.582		0.131	2,556	3.25	5.9	32.0	65
Kenya	1,058	0.369	0.372	0.515	856	3.58	29.0	76.4	25
Korea	6,733	0.872	0.897	0.048	4,241	0.95	9.0	28.0	32
Korea Dem.	2,000	0.640		0.158		1.81	24.0	40.2	
Kuwait	15,178	0.815			10,472	3.40	1.0	4.4	56
Laos	1,100	0.246		0.811	1,111	2.82	59.0	81.4	10
Lebanon	2,300	0.565		0.119		0.25	9.0	16.3	
Lesotho	1,743	0.431		0.497	2,457	2.85	24.0	79.8	14
Liberia	857	0.222		0.212	702	3.16	37.0	54.1	43
Libya	7,000	0.568				3.65		29.8	
Madagascar	704	0.327		0.499	647	3.18	33.0	76.2	15
Malawi	640	0.168		0.827	576	3.52	33.0	88.2	24
Malaysia	6,140	0.790	0.743	0.261	4,113	2.64	21.0	57.0	79
Maldives	1,200	0.497		0.373		3.20	31.0	80.0	
Mali	572	0.082		0.462	514	3.04	46.0	80.8	18
Malta	8,732	0.885		0.009	7,072	0.49	4.0	15.0	81
Mauritania	1,057	0.140		0.766	1,035	2.73	26.0	53.2	47
Mauritius	5,750	0.794	0.779	0.087	4,485	1.17	12.0	59.5	67
Mexico	5,918	0.805	0.767	0.371	4,793	2.20	9.0	27.4	16
Mongolia	2,100	0.578			2,037	2.74	17.0	47.7	23
Morocco	2,348	0.433		0.393	1,901	2.58	16.0	52.0	25
Mozambique	1,072	0.154		0.675	1,200	2.65	65.0	73.2	16

(continued)

Table AII.

Country	INC	HDI	DHDI	IPI	CONS	POPG	AG SHARE	RUPOP	EXP SHA
Myanmar	659	0.390		0.384		2.09	59.0	75.2	
Namibia	1,400	0.289			1,190	3.19	11.0	72.2	55
Nepal	920	0.170	0.128	0.593	846	2.48	60.0	90.4	12
(The) Netherlands	15,695	0.970	0.972		11,614	0.63	4.0	11.5	57
New Zealand	13,481	0.947	0.921		10,784	0.87	9.0	16.0	28
Nicaragua	1,497	0.500		0.173	1,526	3.36	21.0	40.2	23
Niger	645	0.080		0.348	632	3.14	36.0	80.5	16
Nigeria	1,215	0.246		0.490	850	3.30	36.0	64.8	39
Norway	16,028	0.979	0.956		11,379	0.28	3.0	25.0	44
Oman	9,972	0.598		0.188	7,179	3.79	3.0	89.4	38
Pakistan	1,862	0.311	0.304	0.271	1,638	3.44	26.0	68.0	16
Panama	3,317	0.738	0.705	0.199	2,786	2.07	10.0	46.6	38
Paraguay	2,790	0.641		0.404	2,120	2.93	28.0	52.5	34
Peru	2,622	0.592		0.597	2,018	2.08	7.0	29.8	11
Philippines	2,303	0.603	0.584	0.577	1,934	2.49	22.0	57.4	28
PNG	1,786	0.318		0.678	1,607	2.26	29.0	84.6	37
Poland	4,237	0.831			2,669	0.65	14.0	38.2	26
Portugal	8,770	0.853	0.827		6,928	0.25	8.7	66.4	35
Qatar	11,400	0.802				4.16		11.0	
Romania	2,800	0.709			2,044	0.48	18.0	47.3	17
Rwanda	657	0.186		0.857	630	3.41	38.0	92.3	9
St Kitts	3,300	0.697		0.312		0.10	12.0	59.0	59
St Lucia	3,470	0.720		0.377		1.90	12.0	55.0	90
St Vincent	3,647	0.709		0.405		1.20	16.0	73.0	61
Sao Tome	600	0.374		0.467	498	2.40	22.0	67.0	25
Saudi Arabia	10,989	0.688			7,802	3.96	8.0	22.7	46
Senegal	1,248	0.182		0.659	1,135	2.78	21.0	61.6	26
Seychelles	4,191	0.761		0.085	3,688	0.60	6.0	43.0	48
Sierra Leone	1,086	0.065		0.633	1,031	2.49	32.0	67.8	17
Singapore	15,880	0.849	0.865		8,892	1.25	0.0	0.0	190
Somalia	836	0.087		0.685	652	3.26	65.0	63.6	10
South Africa	4,865	0.673			3,648	2.22	5.0	40.5	26
Spain	11,723	0.923	0.928		9,261	0.30	6.2	21.6	17
Sri Lanka	2,405	0.663	0.636	0.419	2,044	1.33	26.0	78.6	30
Sudan	949	0.152		0.807	930	2.88	36.0	78.0	8
Surinam	3,927	0.751		0.371	3,612	1.94	11.0	52.6	37
Swaziland	2,384	0.458		0.444	2,026	3.44	23.2	66.9	90
Sweden	5,047	0.977	0.963		3,987	0.22	3.0	16.0	30
Switzerland	20,874	0.978	0.961		14,611	0.42		40.1	37
Syria	4,756	0.694	0.631	0.404	4,090	3.61	28.0	49.6	27
Tanzania	572	0.270		0.592	600	3.66	59.0	67.2	18
Thailand	3,986	0.715	0.670	0.282	2,670	1.53	12.0	77.4	38
Togo	734	0.218		0.288	653	3.07	33.0	74.3	41
Trinidad	6,604	0.877		0.193	4,490	1.68	3.0	30.9	46
Tunisia	3,579	0.600	0.572	0.120	2,863	2.38	16.0	45.7	42
Turkey	4,652	0.717	0.629	0.113	3,814	2.08	18.0	38.7	19
UAE	16,753	0.738			10,051	3.26	2.0	22.2	55
Uganda	524	0.194		0.802	529	3.67	67.0	89.6	7

(continued)

Table AII.

Country	INC	HDI	DHDI	IPI	CONS	POPG	AG SHARE	RUPOP	EXP SHA
UK	15,804	0.964	0.948		13,117	0.22	1.8	10.9	25
USSR						0.78		34.2	
Armenia	4,741	0.831				1.40	20.0		
Azerbajan	3,977	0.770				1.50	31.0		
Belarus	5,727	0.861				0.60	21.0		
Estonia	6,438	0.872				0.60	17.0		
Georgia	4,572	0.829				0.70	27.0		
Kazakhstan	4,716	0.802				1.20	28.0		
Kyrgyzstan	3,114	0.689				1.90	28.0		
Latvia	6,457	0.868				0.50	24.0		
Lithuania	4,913	0.868				0.90	21.0		
Moldova	3,896	0.758				0.90	34.0		
Russia	7,968	0.862				0.60	13.0		
Tajikistan	2,558	0.657					33.0		
Turkmenistan	4,230	0.746							
Ukraine	5,433	0.844				0.40	23.0		
Uzbekistan	3,115	0.695				2.50	33.0		
Uruguay	5,916	0.881		0.179	4,732	0.56	11.0	14.5	27
USA	21,449	0.976	0.944		18,231	0.81	2.0	25.0	10
Vanuatu	2,005	0.533			1,824	3.10	24.0	79.0	37
Venezuela	6,169	0.824	0.793	0.221	4,379	2.61	6.0	9.5	39
Vietnam	1,100	0.472		0.586		2.15	40.0	78.1	
Yemen	1,562	0.233		0.272	1,437	3.76	20.0	88.0	23
Yemen Pdr				0.279		3.07	16.0	56.7	
Yugoslavia			0.868			0.58	12.0	43.9	24
Zaire	367	0.262		0.802	322	3.14	30.0	60.5	25
Zambia	744	0.314	0.325	0.791	617	3.75	17.0	50.1	32
Zimbabwe	1,484	0.398		0.543	1,172	3.16	13.0	72.4	32

Notes: Values for INCOME are real GDP per capita (PPP$)1990 reported in the UNDP's *Human Development Report 1993*. Values for CONSUMPTION are obtained multiplying INCOME by the share of consumption (both private and public consumption) on GDP. Data on the share of consumption are from the World Tables 1992.These data refer to 1990. For some countries these are for the closest year to 1990. Values for HDI and DHDI are obtained from the UNDP's *Human Development Report* 1993 and 1991 respectively. Values for IPI are from Jazairy *et al.* (1992). Data on population growth (POPG) are from the UN population statistics. Data on agricultural share of GDP (AGSHARE) are from the World Bank's World Tables 1992. Data on rural population as percentage of total population are obtained from the *Human Development Report 1994*. Data on the export of goods and non-factor services' share of GDP are obtained from the World Bank's World Tables 1992

Table AII.

Appendix 2. Results

All models use cross-sectional data. Regression coefficients are estimated using OLS, the residuals being tested for heteroscedasticity using a Lagrange multiplier test. If the hypothesis that the error term is homoscedastic is rejected, White's heteroscedasticity consistent variances and standard errors are used to make statistical inferences about the true parameter values. The results are presented for each indicator below.

1. Lack of safe water

The data set consists of observations on percentage of population with access to safe water (ACH_2O) on 123 countries for 1990. However, the size of the sample in each regression depends on the number of observations of the independent variables that are available (see Tables for details). To obtain a measure of "lack of safe water" (LACKW), the data are transformed in the following way: LACKW = 100 – ACH_2O. Note that there are several countries in the sample with 100 per cent access to safe water in terms of population. This means that LACKW = 0 for such countries. To be able to take the logarithm of LACKW without having to reject any observation, we define LNLACKW as LOG(1 + LACKW).

The best fit models are linear. Model 1(a) does not include country specific variables. LNLACKW is regressed on a constant term and the logarithm of per capita GDP (INCOME). Access to safe water increases with income. Model 1(b) adds the logarithm of population growth (POPG) and the logarithm of rural population's share of total population (RUPOP) to the set of independent variables. This seems to suggest that, income level given, rapidly growing populations and populations that do not gather on urban concentrations will find it more difficult to provide access to safe water to all their components. The coefficients are individually and jointly significant. However, the Breusch-Pagan statistic in model 1(a) is 5.22782 and the 95 per cent critical value for chi-squared[1] is 3.84. The Breusch-Pagan statistic in Model 1(b) is 11.2627 and the 95 per cent critical value for chi-squared[3] is 7.82. Both indicate heteroscedasticity and, therefore, reduced efficiency of the estimates. As the problem appears to lie with outliers, observations 34,43,44,75 and 106 (Congo, Ecuador, Egypt, Jordan and Oman) have been dropped. The new sample is formed by 118 countries. The results are reported as Models 1(a)* and 1(b)*. After dropping these five observations it is easier to maintain the assumption of homoscedasticity (at least for the regressions on income and consumption). A similar procedure is carried out for the rest of the economic/social performance indicators.

Models 2(a), 2(b), 2(a)* and 2(b)* correspond to the regressions having the logarithm of consumption (CONSUMPTION) as the main independent variable. The results are almost identical to those for INCOME. Models 3(a), 3(b), 3(a)* and 3(b)* correspond to the regression having HDI as the main independent variable. Models 5(a), 5(b),5(a)* and 5(b)* give the estimates for the regressions when IPI is the main independent variable. Here we have not been as lucky as before correcting the heteroscedastic estimates. The computed B-P statistics still exceed the critical chi-squared value at the 5 per cent level of significance. White's heteroscedasticity-corrected t ratios are reported in bold. On the basis of White's estimators the OLS regressors are statistically significant. For DHDI, only Models 4(a) and 4(b) are reported since the Breusch-Pagan test fails to reject the null hypothesis of homoscedasticity. (Note: there are no data on DHDI for four out of the five outliers in the sample.)

Note: All variables are in logs. t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold.

Variable	1(a)	1(b)	1(a)*	1(b)*
Constant	11.849	6.2676	12.038	7.2937
	(22.015)	(5.580)	(24.262)	(6.652)
	(25.501)	**(4.473)**	**(27.582)**	**(5.594)**
INCOME	–1.1495	–0.67034	–1.1757	–0.74985
	(–17.181)	(–7.090)	(–19.056)	(–8.125)
	(–18.959)	**(–5.709)**	**(–20.906)**	**(–6.768)**
RUPOP		0.41489		0.31319
		(3.272)		(2.576)
		(2.870)		**(2.339)**
POPG		0.46513		0.44045
		(5.882)		(5.840)
		(5.375)		**(5.485)**
Adjusted R^2	0.70	0.78	0.75	0.81
F	295.17	149	363	174.18
B-P chi-squared	5.22782[1]	11.2627[3]	2.81732[1]	9.05542[3]
N	123	123	118	118

Note: Dependent variable: lack of safe water (in logs)

Table AIII. Relationship between lack of safe water and income

Variable	2(a)	2(b)	2(a)*	2(b)*
Constant	12.503	6.5881	2.646	7.3951
	(21.881)	(5.714)	(23.745)	(6.529)
	(25.051)	**(4.637)**	**(26.721)**	**(5.466)**
CONSUMPTION	–1.2607	–0.73741	–1.2816	–0.80130
	(–17.365)	(–7.196)	(–18.937)	(–7.957)
	(–19.131)	**(–5.802)**	**(–20.805)**	**(–6.577)**
RUPOP		0.43951		0.35892
		(3.530)		(2.988)
		(3.207)		**(2.752)**
POPG		0.44296		0.42524
		(5.577)		(5.552)
		(4.932)		**(5.031)**
Adjusted R^2	0.71	0.79	0.76	0.82
F	301.52	152.09	358.60	172.43
B-P chi-squared	3.62807[1]	11.2660[3]	1.43765[1]	7.83460[3]
N	118	118	113	113

Note: Dependent variable: lack of safe water (in logs)

Table AIV. Relationship between lack of safe water and consumption

Variable	3(a)	3(b)	3(a)*	3(b)*
Constant	4.9335	1.4607	4.9349	1.6328
	(28.749)	(2.317)	(29.311)	(2.654)
	(39.601)	**(2.185)**	**(39.968)**	**(2.431)**
HDI	–0.040418	–0.019705	–0.040577	–0.020255
	(–14.896)	(–5.530)	(–15.339)	(–5.811)
	(–16.847)	**(–5.142)**	**(–16.996)**	**(–5.188)**
RUPOP		0.55804		0.52216
		(4.308)		(4.138)
		(4.176)		**(3.912)**
POPG		0.51025		0.51636
		(6.046)		(6.253)
		(5.557)		**(5.691)**
Adjusted R^2	0.64	0.75	0.66	0.77
F	221.9	127.73	235.29	136.17
B-P chi-squared	8.12902[1]	16.2745[3]	8.47418[1]	16.1600[3]
N	123	123	118	118

Note: Dependent variable: Lack of safe water (in logs)

Table AV. Relationship between lack of safe water and HDI

Variable	4(a)	4(b)
Constant	5.5507	2.4947
	(13.992)	(2.761)
	(14.092)	**(3.009)**
DHDI	–0.048997	–0.026169
	(–9.323)	(–3.812)
	(–9.255)	**(–3.812)**
RUPOP		0.40528
		(2.573)
		(3.043)
POPG		0.43621
		(3.607)
		(4.395)
Adjusted R^2	0.63	0.73
F	91.58	46.03
B-P chi-squared	0.0403805[1]	1.41257[3]
N	50	50

Note: Dependent variable: lack of safe water (in logs)

Table AVI. Relationship between lack of safe water and distribution-adjusted HDI

Variable	5(a)	5(b)	5(a)*	5(b)*
Constant	2.2933 (13.106) **(8.783)**	0.16834 (0.264) **(0.264)**	2.3425 (13.204) **(8.717)**	0.44610 (0.734) **(0.628)**
IPI	0.023865 (7.152) **(5.418)**	0.012441 (3.736) **(3.596)**	0.022968 (6.861) **(5.074)**	0.010210 (3.114) **(3.146)**
RUPOP		0.48117 (2.744) **(2.507)**		0.42287 (2.526) **(2.270)**
POPG		0.82855 (5.078) **(4.470)**		0.92998 (5.940) **(6.152)**
Adjusted R^2	0.35	0.55	0.35	0.58
F	51	38	47	41
B-P chi-squared	29.5936[1]	16.2754[3]	28.2021[1]	11.1919[3]
N	91	91	86	86

Note: Dependent variable: lack of safe water (in logs)

Table AVII. Relationship between lack of safe water and IPI

2. Sulphur emissions

Testing for heteroscedasticity fails to reject the null hypothesis of spherical disturbances for all our regressions. As regards country-specific factors, RUPOP proves to be the only significant variable. Models are numbered in the same way as the previous section. In general, the best fit is given by a quadratic function in CONSUMPTION and INCOME. We do not take IPI into account as the sample is reduced to only 17 countries.

The best fit for HDI and DHDI may be linear. On the basis of the OLS t statistics in Ta#ble 2.4 $DHDI^2$ and RUPOP are not significant. However, the sample size has been reduced considerably and, even though the B-P chi-squared statistics are not above critical values, they are close. White's heteroscedasticity consistent standard errors are much larger than the OLS standard errors and so estimated t values are much larger than those obtained by OLS.The RUPOP regressor is significant, whereas the $DHDI^2$ regressor's statistic improves but not enough as to consider it significant at any sensible level.

Tables also report turning points for quadratic forms. As regards INCOME, the turning point is close to 8,000PPP$. The sample ranges from 659 to 21,450 PPP$. For CONSUMPTION the turning point is in the neighbourhood of 6,500 PPP$. The sample ranges from 1,111 to 18,231PPP$ and, again, countries such as Portugal would be at the inflexion point. For HDI and DHDI the quadratic form is not significant.

Variable	1(a)	1(b)
Constant	–53.494	–52.091
	(–5.036)	(–4.120)
	(–5.036)	**(–4.105)**
INCOME	12.484	12.933
	(4.887)	(4.221)
	(4.858)	**(4.166)**
INCOME^2	–0.68106	–0.72627
	(–4.481)	(–3.954)
	(–4.480)	**(–3.895)**
RUPOP		–0.52563
		(–2.074)
		(–2.460)
Turning point	9,562.83	7,359.25
Adjusted R^2	0.51	0.57
F	35.98	23.42
B-P chi-squared	0.878784[2]	0.333612[3]
N	66	50

Note: Dependent variable: sulphur emissions (in logs)

Table AVIII. Relationship between sulphur emissions and income

Variable	2(a)	2(b)
Constant	–59.718	–55.315
	(–3.438)	(–3.169)
	(–3.642)	**(–3.399)**
CONSUMPTION	14.281	13.729
	(3.376)	(3.269)
	(3.568)	**(3.445)**
CONSUMPTION^2	–0.80346	–0.78338
	(–3.154)	(–3.106)
	(–3.324)	**(–3.244)**
RUPOP		–0.34787
		(–1.394)
		(–1.950)
Turning point	7,238.64	6,391.15
Adjusted R^2	0.42	0.44
F	16.76	12.08
B-P chi-squared	0.441957[2]	0.657053[3]
N	43	43

Note: Dependent variable: sulphur emissions (in logs)

Table AIX. Relationship between sulphur emissions and consumption

Variable	3(a)	3(b)	3(c)	3(d)
Constant	–1.8370 (–2.026) **(–1.468)**	0.54961 (0.375) **(0.337)**	–0.85428 (–1.628) **(–1.563)**	1.6624 (1.234) **(1.385)**
HDI	0.090694 (2.838) **(2.110)**	0.097118 (2.770) **(2.009)**	0.049286 (7.402) **(7.195)**	0.037851 (4.310) **(4.546)**
HDI^2	–0.00034464 (–1.325) **(–1.022)**	–0.00050258 (–1.743) **(–1.373)**		
RUPOP		–0.54731 (–2.260) **(–2.493)**		–0.49265 (–2.008) **(–2.400)**
Turning point		1.315 (ERR)		0.966
Adjusted R^2	0.45	0.52	0.45	0.50
F	328.59	18.88	54.79	25.69
B-P chi-squared	1.14857[2]	0.918947[3]	0.138158[1]	0.0549220[2]
N	66	50	66	50

Note: Dependent variable: sulphur emissions (in logs)

Table AX. Relationship between sulphur emissions and HDI

Variable	4(a)	4(b)	4(c)	4(d)
Constant	–1.4112 (–1.260) **(–2.626)**	–0.45537 (–0.303) **(–0.645)**	–0.99655 (–1.566) **(–2.482)**	–0.011141 (–0.009) **(–0.015)**
DHDI	0.065646 (1.572) **(2.499)**	0.068300 (1.629) **(2.626)**	0.047066 (6.132) **(8.126)**	0.042825 (4.682) **(6.069)**
$DHDI^2$	–0.00015442 (–0.453) **(–0.620)**	–0.00021663 (–0.623) **(–0.875)**		
RUPOP		–0.21973 (–0.954) **(1.975)**		–0.19283 (–0.862) **(–1.717)**
Turning point	2.125 ERR	1.576 ERR		
Adjusted R^2	0.54	0.54	0.55	0.55
F	18.36	12.5	37.6	18.99
B-P chi-squared	2.75084[2]	5.22124[3]	2.30768[1]	4.05908[3]
N	30	30	30	30

Note: Dependent variable: sulphur emissions (in logs)

Table AXI. Relationship between sulphur emissions and distribution-adjusted HDI

3. Deforestation

Table AXII.
Relationship between deforestation and income

Variable	1(a)	1(b)
Constant	–12.143	–11.713
	(–2.775)	(–2.727)
	(–4.193)	**(–4.223)**
INCOME	3.4554	2.8363
	(2.967)	(2.388)
	(4.408)	**(3.810)**
$INCOME^2$	–0.22903	–0.17854
	(–2.980)	(–2.234)
	(–4.354)	**(–3.538)**
RUPOP		0.33465
		(1.887)
		(1.466)
Turning point	1,888.52	2,815.90
Adjusted R^2	0.09	0.13
F	4.44	4.27
B-P chi-squared	10.5324[2]	8.80976[3]
N	65	65

Note: Dependent variable: deforestation (in logs)

Table AXIII.
Relationship between deforestation and consumption

Variable	2(a)	2(b)
Constant	–13.133	–12.677
	(–2.759)	(–2.718)
	(–3.886)	**(–4.223)**
CONSUMPTION	3.7966	3.1137
	(2.940)	(2.370)
	(4.071)	**(–2.205)**
$CONSUMPTION^2$	–0.25720	–0.19939
	(–2.955)	(–2.205)
	(–4.026)	**(–3.398)**
RUPOP		0.35359
		(1.899)
		(1.525)
Turning point	1,604.61	2,482.67
Adjusted R^2	0.09	0.12
F	4.37	4.25
B-P chi-squared	8.32347[2]	6.86583[3]
N	62	62

Note: Dependent variable: deforestation (in logs)

Variable	4(a)	4(b)
Constant	0.38737	–1.2971
	(0.648)	(–1.146)
	(0.717)	**(–1.255)**
HDI	0.032155	0.025698
	(1.282)	(1.059)
	(1.455)	**(1.288)**
HDI^2	–0.00035094	–0.00022386
	(–1.496)	(–0.948)
	(–1.714)	**(–1.186)**
RUPOP		0.40991
		(1.724)
		(1.849)
Turning point	0.046	0.098
Adjusted R^2	0.04	0.13
F	1.59	5.38
B-P chi-squared	0.181439[2]	0.368943[3]
N	24	24

Note: Dependent variable: deforestation (in logs)

Table AXIV. Relationship between deforestation and HDI

Variable	4(a)	4(b)
Constant	0.25596	–1.7882
	(1.370)	(–2.281)
	(1.962)	**(–1.849)**
DHDI	0.027845	0.023952
	(2.858)	(2.547)
	(3.280)	**(3.229)**
$DHDI^2$	–0.00028458	–0.00017242
	(–2.980)	(–1.636)
	(–4.354)	**(–1.904)**
RUPOP		0.33465
		(2.678)
		(2.195)
Turning point	0.046	0.058
Adjusted R^2	0.08	0.17
F	4.09	5.38
B-P chi-squared	13.5996[2]	7.33021[3]
N	65	65

Note: Dependent variable: deforestation (in logs)

Table AXV. Relationship between deforestation and distribution-adjusted HDI

Variable	5(a)	5(b)	5(c)
Constant	0.76108	0.55193	–0.57263
	(4.624)	(1.789)	(–0.626)
	(3.876)	**(2.011)**	**(–0.790)**
IPI	–0.00013595	0.010088	0.011776
	(–0.047)	(0.726)	(0.859)
	(–0.041)	**(0.789)**	**(0.915)**
IPI^2		–0.00010221	–0.000095617
		(–0.733)	(–0.696)
		(–0.733)	**(–0.707)**
RUPOP			0.25224
			(1.708)
			(1.348)
Adjusted R^2	–0.019(ERR)	–0.02(ERR)	0.007
F		4.09	5.38
B-P chi-squared	1.58669[1]	3.89546[2]	7.57929[3]
N	62	62	62

Note: Dependent variable: deforestation (in logs)

Table AXVI. Relationship between deforestation and IPI

4. Carbon emissions

Variable	1(a)	1(b)	1(c)
Constant	–12.222	–8.1213	–9.1323
	(–22.862)	(–6.289)	(–6.542)
	(–23.651)	**(–5.833)**	**(–5.864)**
INCOME	1.3957	1.0408	1.0666
	(21.065)	(8.720)	(8.978)
	(22.138)	**(8.169)**	**(8.038)**
AGSHARE		–0.47139	–0.40302
		(–3.329)	(–2.729)
		(–2.989)	**(–2.395)**
EXPSHA			0.17086
			(1.423)
			(1.500)
Adjusted R^2	0.74	0.76	0.78
F	443.73	230.11	161.15
B-P chi-squared	0.802206[1]	6.80381[2]	6.16373[3]
N	150	143	135

Note: EXPSHA is included in the third model of the Tables in this section. It does not add much explanatory power to the regression, but when the economic performance indicator is CONSUMPTION it becomes a significant variable; dependent variable: carbon emissions (in logs)

Table AXVII. Relationship between CO_2 emissions and income

Variable	2(a)	2(b)	2(c)
Constant	–12.488	–7.2389	–8.4051
	(–20.282)	(–5.217)	(–5.547)
	(–20.984)	**(–4.944)**	**(–5.103)**
INCOME	1.4574	1.0027	1.0168
	(18.638)	(7.527)	(7.690)
	(19.687)	**(7.234)**	**(7.167)**
AGSHARE		–0.62754	–0.53245
		(–4.258)	(–3.435)
		(–3.890)	**(–3.111)**
EXPSHA			0.24170
			(1.831)
			(1.963)
Adjusted R^2	0.72	0.75	0.76
F	347.38	201.17	137.71
B-P chi-squared	1.31678[1]	4.15931[2]	3.29637[3]
N	132	130	130

Note: Dependent variable: carbon emissions (in logs)

Table AXVIII. Relationship between CO_2 emissions and consumption

Variable	3(a)	3(b)	3(c)
Constant	–3.8857	–0.77203	–1.3008
	(–22.000)	(–1.529)	(–1.770)
	(–22.559)	**(–1.449)**	**(–1.786)**
HDI	0.049800	0.030756	0.030827
	(17.998)	(8.280)	(8.078)
	(19.863)	**(8.284)**	**(7.902)**
AGSHARE		–0.76302	–0.72876
		(–6.397)	(–5.642)
		(–5.852)	**(–5.194)**
EXPSHA			0.11907
			(0.955)
			(0.938)
Adjusted R^2	0.68	0.75	0.76
F	323.93	219.72	146.29
B-P chi-squared	1.02867[1]	2.02691[2]	2.37276[3]
N	150	137	135

Note: Dependent variable: carbon emissions (in logs)

Table AXIX. Relationship between CO_2 emissions and HDI

Variable	1(a)	1(b)	1(c)
Constant	–4.0858 (–13.745) **(–11.609)**	–2.5659 (–3.258) **(–3.222)**	–2.1406 (–2.152) **(–1.845)**
DHDI	0.050880 (13.030) **(12.077)**	0.041098 (6.696) **(6.616)**	0.041166 (6.671) **(6.687)**
AGSHARE		–0.34497 (–2.092) **(–2.192)**	–0.37610 (–2.192) **(–2.045)**
EXPSHA			–0.10734 (–0.707) **(–0.626)**
Adjusted R^2	0.76	0.78	0.77
F	169.77	90.39	59.8
B-P chi-squared	5.28301[1]	7.12684[2]	8.05455[3]
N	52	51	51

Note: All variables except DHDI are in logs; dependent variable: carbon emissions (in logs)

Table AXX. Relationship between CO_2 emissions and distribution-adjusted HDI

Variable	5(a)	5(b)	5(c)
Constant	0.12095 (0.533) **(0.659)**	2.8053 (7.295) **(8.620)**	1.8173 (2.296) **(2.272)**
IPI	–0.041972 (–9.368) **(–11.680)**	–0.023041 (–5.371) **(–5.554)**	–0.020012 (–4.490) **(–4.573)**
AGSHARE		–1.1590 (–7.903) **(–8.058)**	–1.1213 (–7.047) **(–7.031)**
EXPSHA			0.20972 (1.400) **(1.313)**
Adjusted R^2	0.45	0.65	0.66
F	87.75	100.78	65.83
B-P chi-squared	0.325804[1]	3.90484[2]	3.89688[3]
N	107	107	98

Note: All variables except IPI are in logs; dependent variable: carbon emissions (in logs)

Table AXXI. Relationship between CO_2 emissions and IPI