INCOME, CONSUMPTION AND HUMAN DEVELOPMENT: ENVIRONMENTAL LINKAGES

A background paper for the Human Development Report 1998

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Abstract

The perception since the Brundtland Report (WCED 1987) is that the driving forces behind the degradation of the environment are population-induced poverty in the developing world, and affluence-induced overconsumption in the developed world. By implication, growth in consumption has progressively adverse environmental consequences. Recent work in environmental economics has drawn attention to an empirical relation between per capita income and certain indicators of environmental quality that appears to contradict this view. It has been found that various indicators of local air and water quality first worsen and then improve as per capita incomes rise. This paper reconsiders this work, and extends it to include not just per capita incomes but alternative measures of economic and social performance: consumption, the HDI, the income-adjusted HDI and an index of poverty. It confirms that deeping 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. It also shows that these are part of a continuum of effects. The environmental consequences of economic activity are generally quite specific to the nature of the activity, and the type of economic activity tends to be correlated with income. The distribution of environmental effects associated with given activities may be mapped into the income range associated with those activities. The paper concludes 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. It supports the conclusions of Arrow et al (1995) that 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.

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1. Introduction

The general perception since publication of the Brundtland Report (WCED 1987) is that the driving forces behind the degradation of the environment are population-induced poverty in the developing world, and affluence-induced overconsumption in the developed world. In other words, the general perception has been that harmful environmental change is to be laid at the door of consumption by the very poor and the very rich. While the poor have been argued to lay waste to forests, wetlands, rangelands and coastal zones in order to meet their basic needs, the rich have been argued to consume disproportionate quantities of energy and natural resources, and discharge disproportionate quantities of waste as emissions to air and water. By implication, growth in consumption has progressively adverse environmental consequences.

In recent years, however, environmental economists have paid increasing attention to an empirical relation between per capita income and certain indicators of environmental quality that would seem to tell the opposite story. The relation is similar to the Kuznets curve (Kuznets, 1955). Just as the Kuznets relation showed that income inequality first rises and then falls as per capita income rises, so it has been found that various indicators of local air and water quality first worsen and then improve as per capita incomes rise. The relation was first observed in work undertaken by Grossman and Krueger (1993) on the environmental implications of Mexico's inclusion in the North American Free Trade Area (NAFTA), and was dubbed 'the Environmental Kuznets Curve' (EKC) (Panayotou, 1993).

Subsequently, a Kuznets relation 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) found the same general relation between deforestation rates and per capita income, while Coles 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; Coles et al 1997) and there are conflicting results on solid particulates (Grissman 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 consumption are wrong about the effects of poverty and affluence, it also appears to suggest that growth in the level of consumption 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 growth in consumption does, in some sense, 'take care' of the environment, the diversion of resources from environmental protection to investment may be welfare-enhancing. We need to understand what can and cannot be inferred from the EKC for the development process, and for the well-being of people at different levels of consumption.

This paper has three aims. The first is to reconsider the evidence on the EKC in the light of recent assessments. This is to clarify what is being said about the linkages between economic performance and environmental change. The second aim is to consider the relation between environmental quality and alternative measures of performance. These include consumption, the Human Development Index, and an index of poverty devised for the International Fund for Agricultural Development. The question here is what this empirical research can tell us about 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). The third aim is to use these findings to address a number of specific questions concerning the role of environmental quality in consumption and development. It has been hypothesised that the EKC indicates that environmental quality is in the nature of a luxury good: that demand for environmental quality is income elastic (McConnell, 1997). The third aim is to consider how the importance of environmental resources to human well-being is affected by the development process.

2. The Environmental Kuznets Curve Revisited

The basic model underpinning empirical research into the relation between income and environmental quality is 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 basic model assumes no feedbacks between the environment and the economy. A number of existing studies involve cross-sectional data only. Some use panel data, generally with a more restricted set of countries. To test the EKC hypothesis the functional forms employed for estimating the basic model from cross country data tends to be quadratic in either levels or logarithms.

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 are (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 a 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 relation between sulphur dioxide and per capita income, for example, estimates of the turning points for that pollutant range from $3000 (Panayotou 1995) to $10,700 (Seldon and Song 1994). The range of estimates for other pollutants is even wider (Table 1). 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.

Table 1 'Turning points' for pollutants with a 'Kuznets' relation to GDP per capita

Air pollution						**Source of estimates**
SO2	SPM	NOx	CO	CO2	CFCs	
6900	7300	14700	9900		12600	Cole et al (1997)
4107						Grossman and Krueger (1993)
4053						Grossman and Krueger (1995)
3000	4500	5500				Panayotou (1995)
5000						Panayotou (1997)
10700	9600	21800	19100			Seldon and Song (1994)
3670	3280					Shafik (1994)
				35428		Holtz-Eakin and Seldon (1995)
				12800		Moomaw and Unruh (1997)
Other effects						
Faecal coliform	BOD	COD	Arsenic	Nitrates	Deforest-ation	
7955	7623	7853	4900			Grossman and Krueger (1995)
				15600		Cole et al (1997)
					2049	Antle and Heidebrink (1995)
					823	Panayotou (1995)
					4760/ 5420	Cropper and Griffiths (1994)

Source: Adapted from Barbier (1997).

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 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.

2.1 Causal explanations of the EKC

There are various explanations offered in the literature for the EKC. The main candidates are income-related changes in the sectoral composition of economies (Panayotou 1997; de Bruyn 1997); income related changes in technology (de Bruyn 1997); the link between income and the demand for environmental quality (McConnell 1997); and the impact of evironmental constraints to growth (Arrow et al 1995).

The first two are quite intuitive, if a little descriptive. It is not surprising that local air and water quality should 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. For illustration, Table 2 shows that 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. This, in turn, 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.

Table 2 Average annual growth of polluting industries

Branch of industry	Developed countries		Developing countries	
	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).

Moreover, although large firms dominate the capital intensive industries like pulp and paper, industrial chemicals, petroleum refineries, and 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 will tend 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, will typically assign a greater weight to technological than to structural change (de Bruyn 1997). In both cases, though, the interesting question is what may be driving changes in either structure or technology.

The third explanation— the link between income and the demand for environmental quality —implies that the answer is to be found in preferences for environmental amenity. 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 at least consistent with the EKC, even if the hypothesis is not 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 lesser environmental impacts.

A related explanation considers a more generic relation between preferences and consumption levels. It has been argued that the link between environmental degradation and poverty observed in the Brundtland report is not that the poor care little for the long term quality of their environment, but that the poor must worry about the present irrespective of the long term environmental costs of their behaviour (Perrings, 1989). In many cases, environmental degradation is a consequence of actions designed to meet people's current consumption needs. They implicitly discount future costs and benefits at a high rate. This hypothesis—that people in poverty discount the future at high rates—has since been confirmed in empirical studies of consumption patterns in communities in Africa, South Asia and South East Asia (xxx, 1997). It is consistent with the fact that the EKC has been found to apply mainly to effects that are localised and short term.

The last explanation—the impact of environmental constraints to growth—stems from a critical review of the link between economic growth and environment implicit in the EKC literature (Arrow et al 1995). The review argues that the EKC hypothesis ignores the environmental context within which economic growth occurs. By focussing on per capita emissions it has little to say about about the significance of those emissions. Instead, Arrow et al argue that the focus should be on the assimilative or carrying capacity of the environment. 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. 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.

There is a link here with the notion of 'environmentally sound technology' as promoted in Agenda 21 (UNCED, 1993). The criterion for environmentally sound technologies is whether they are safe with respect to the external environment. It is largely irrelevant as to whether the technology concerned is 'clean', 'best practicable', 'best available', 'low waste' or 'resource conserving'. Technologies may be said to be environmentally sound if they do not threaten their evironment. Hence technologies at the dirty end of the product cycle may still be environmentally sound, providing that they are not used at levels which test the resilience of the ecosystems where they are applied. Exactly the same remarks apply to consumption. It is largely irrelevant as to whether the pattern of consumption has environmental consequences, so long as consumption is below the level at which those consequences test the resilience of the system.

2.2 The EKC and the role of policy

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.

Two things follow from this. 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). 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 relation 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 (a) that growth will automatically resolve the problem of environmental degradation and (b) that growth is automatically environmentally sustainable.

3. Environmental quality, consumption and human development

Most of the empirical research on the relation between economic performance and environmental change has focussed on measures of per capita income. This section considers other performance measures in an effort to identify the linkage between environmental change and (a) consumption of marketed goods and services, and (b) the process of human development. Specifically, it considers the relationship between four measures of environmental change and the same number of performance meaures. The four measures of environmental change reflect qualitatively different impacts of the development process. They comprise:

- a measure of water pollution—lack of access to safe water supplies;
- a measure of industrial pollution—emissions of sulphur dioxide (SO_2);
- a measure of the depletion of environmental resources—deforestation; and
- a measure of greenhouse gas emissions—carbon dioxide (CO_2).

The question raised in this section is how these various environmental effects are related to alternative measures of human development. The four measures considered are:

- a measure of income—income per capita (PPP adjusted);
- 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 inclusion of the first of these 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. 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 (cf Stern et al, 1996). For similar reasons, it uses performance measures for the same period as the studies with which it is being compared. The implications of changes in the measures since this period are discussed in the concluding section.

3.1 The environmental indicators

Of the four environmental indicators selected for analysis here, 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.

Water depletion and pollution

Water depletion frequently represents the mining of a natural resource to support growth in agricultural output and employment. In many cases, for example, water resources are being depleted to increase the area under agricultural production, as well as the productivity of existing agricultural lands. In both instances it is closely related to the problems of water pollution. The relative intensity of renewable water use, and the sectoral distribution of renewable water withdrawals over the period 1972-1992 are indicated in Table 3. The table shows that only the Middle East and North Africa come close to using all of the available renewable water resources. In most cases, developing countries use less than ten per cent of available renewable resources. The problem in these countries is the depletion and pollution of groundwater reserves due to:

- a reduction in recharge rates as a result of the diversion of surface flows;
- increased runoff caused by deforestation;
- increase in the direct depletion of groundwater reserves through private tubewells.

Worldwatch estimates that two thirds of all water extracted from rivers and acquifers is used for irrigation, and that in many areas water demand for irrigation is significantly in excess of recharge rates. In India, for example, water tables are estimated to be falling by more than one metre a year in Punjab, Haryana, Uttar Pradesh, Gujurat and Tamil Nadu (Worldwatch Institute, 1995).

Aside from the depletion of groudwater, irrigation is also the main cause of salinisation of groundwater reserves. Other sources of groundwater pollution include applications of nitrogenous fertilisers. Between the late 1970s and the late 1980s fertilizer applications in Asia nearly doubled. By the early 1990s fertilizer use in Asia was still lower than in Europe, but was much higher than in any other region of the world, and was rising fast. A related set of problems derive from the application of pesticides. Applications of pesticides in most developing countries have been increasing faster than applications of fertlizers, and faster than the increase in agricultural production. In South and East Asia pesticide applications increased during the 1970s and 1980s by around ten per cent a year. Since pesticide consumption in the high income countries has, like fertilizer consumption, flattened over the last decade, such markets are increasingly important to the pesticide industry. By the early part of this decade, developing countries accounted for around a third of world exports of pesticides (World Resources Institute, 1994).

Table 3 Water availability in developing countries, 1970-1992

	Total annual internal renew'bl water resources (km^3)	Total annual water w'drawal (km^3)	Annual w'drawal as a share of total water resources (percent)	Per capita annual internal renew'bl water resources (m^3)	Per capita annual water w'drawal (m^3)	Sectoral withdrawal as a share of total water resources (percent)		
						Agri-culture	Dom-estic	Ind-ustry
Sub-Saharan Africa	3,713	55	1	7,488	140	88	8	3
East Asia & Pacific	7,915	631	8	5,009	453	86	6	8
South Asia	4,895	569	12	4,236	652	94	2	3
Europe	574	110	19	2,865	589	45	14	42
Middle East & N. Africa	276	202	73	1,071	1,003	89	6	5
L. America & Caribbean	10,579	173	2	24,390	460	72	16	11
Other Economies	4,486	375	8	13,976	1,324	66	6	28

Source: The World Bank. World Development Report 1992

The proxy for water pollution used here is the percentage of the total population with 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.

Deforestation and desertification

At a regional scale, deforestation, desertification and water depletion tend to be linked with the expansion of agricultural output and employment, and so are particularly associated with economies in which a high proportion of output and/or employment derive from the agricultural sector. In addition, environmental problems associated with agricultural growth at the extensive margin tend to be found in regions with low population density but high population growth (Sub-Saharan Africa and Latin America) whilst those linked with agricultural growth at the intensive margin would be found in the regions with high rural population density and growth (South Asia and South East Asia). To some extent this is supported by the data. However, as the productivity gains of agricultural intensification have faltered in Asia, so pressure in that region has gone back on to remaining forested areas, and recent rates of deforestation are higher in South and East Asia than elsewhere.

Table 4 illustrates the extent of the problem of deforestation in selected sub-regions for the period 1981-1990. It shows that not only did the rate of forest loss accelerate in regions where the process was already under way at the beginning of the decade, but that afforestation turned to deforestation in other regions. In Sub-Saharan Africa the highest rates of forest loss occurred in West Africa—Ghana, Togo in particular. But note that the annual rate of loss in these countries, 1.3 to 1.4 per cent, was still very low compared to other regions where the forest stock is more depleted. Four countries in Latin America — Costa Rica, El Salvador, Honduras and Paraguay — were converting remaining forests at more than 2 per cent a year during the 1980s, while Bangladesh, Pakistan, Thailand and the Philippines were all converting what is left of their forest resources at 2.9 to 3.0 per cent a year.

The analogue to deforestation in arid, semi-arid and dry sub-humid areas is desertification. Like deforestation, desertification implies a reduction in the vegetative cover of land, and tends to be associated with the expansion of agricultural output. It may be associated with irrigated crops, rainfed crops or livestock production. The nature of land degradation is different in each case. At present it is thought to affect approximately a quarter of the total land area of the globe (some 3.6 billion hectares) and approximately a sixth of the world's population (some 900 million people).

Estimates of the extent of the problem in in the early 1990s showed that it was, if anything, more extensive a problem than deforestation (see Table 5).

Table 4 Forests Resources and Deforestation, 1980-1990

	Extent of Natural Forest (1000 Ha)		Annual Deforestation (1981-1990)	
	1980	1990	(1000 ha)	(percent)
West Sahelian Africa	43,720	40,768	295	0.7
East Sahelian Africa	71,395	65,450	595	0.8
West Africa	61,520	55,607	591	1.0
Central Africa	215,503	204,112	1,140	0.5
Tropical Southern Africa	159,322	145,868	1,345	0.8
Insular Africa	17,128	15,782	135	0.8
South Asia	69,442	63,931	551	0.8
Continental South Asia	88,377	75,240	1,314	1.5
Insular South East Asia	154,687	135,426	1,926	1.2
Central America and Mexico	79,216	68,096	1,112	1.4
Caribbean Subregion	48,333	47,115	122	0.3
Tropical South America	864,639	802,904	6,174	0.7

Sources: The World Resource Institute 1994. World Resources 1994-1995. Oxford, Oxford University Press.

The nature of land degradation is different in each case. In irrigated lands, for example, the problems centre on salinisation and alkalinisation. Annual losses due to these causes in the early years of this decade were running at about 1.5 million ha. In rain-fed crop lands the dominant manifestation of land degradation is soil erosion and the loss of soil organisms, which account for at least 3.5 million ha annually. In rangelands the problem is both much more severe and much more extensive. Degradation takes the form of loss or alteration of vegetation, loss of soil moisture and soil organisms and soil erosion. Annual losses at the beginning of the decade were estimated to be between 4.5 and 5.8 million ha (Tolba et al, 1992).

While the dominant cause of both deforestation and desertification is land use conversion and intensification, in many countires fueldwood scarcity is a significant part of the problem. The scarcity of fuelwood has been identified as a problem not because there are no substitutes, but because it bears most heavily on those sections of the population who are least able to invest in stoves that will accept alternative fuels. Moreover, projections by the same source of the size of the population expected to experience fuelwood deficit in the year 2000 indicated that it is a peculiarly rural problem.

Table 5 Extent of Desertification of Drylands

Moderately, severely and very severely desertified land

	Irrigated areas		Rain-fed croplands		Rangelands	
	(000 ha)	per cent	(000 ha)	per cent	(000 ha)	per cent
Africa	1902	18	48863	61	995080	74
Asia	31813	35	122284	56	1187610	75
Australia	250	13	14320	34	361350	55
Europe	1905	16	11854	54	80517	72
N. America	5860	28	11611	16	411154	75
S. America.	1517	17	6635	31	297754	76

Sources: Tolba M.K. and El-Kholy O.A. (eds). 1992. The World Environment 1972-1992: Two Decades of Challenge. UNEP. Chapman and Hall, London.: 137-139.

The indicator of deforestation used here is the percentage change in forest cover during the 1980s. The sources are World Resources Institute (1992). This indicator is, if anything, even more sensitive to the environmental reference point (the proportion of forest cover remaining. Nevertheless, this paper reports the deforestation models to ensure comparability with the literature. The data set is that used by Panayotou (1993; 1995).

Sukphur dioxide and carbon dioxide

The proxy for industrial emissions, SO_2, was selected partly because it is the indicator most widely used in empirical studies of the relation between economic growth and environmental change, and partly because it is so closely associated with a wide range of other industrial emissions including CO_2. In the developing countries, industrial growth depends to a large extent on the activities of small and medium scale enterprises (SMEs which 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. Of these, textiles and non-ferrous metals are the main sources of SO_2 pollution. But both industries are major sources of range of typical industrial pollutants.

In textiles, for example, SO_2 emissions are associated with particulates and hydrocarbon emissions to air, and BOD, suspended solids, salts, toxic metals and sulphate emissions to water. In the non-ferrous metals industry, SO_2 emissions are associated with fluoride and carbon monoxide emissions to air, and fluorine, solids and hydrocarbon emissions to water and land. In other major sources of SO_2, the iron and steel and petrochemical industries, the story is similar. SO_2 is associated with nitrous oxide, carbon monoxide, hydrogen sulphide and 'acid mists', along with BOD, suspended solids, oils, metals, acids, phenols, sulphides, sulphates, ammonia, cyanides, and effluents from wet gas scrubbers.

The point has already been made (Table 2) that production of these commodities has been shifting into the developing countries, and hence that their share of global emissions of these industrial pollutants has been rising. Many of the consequences of industrial emissions are localised and reflect the fact 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).

In Viet Nam, for instance, there is no wastewater treatment plant in any urban area in the country. Most wastewater tends to be discharged directly into rivers, canals and lakes. Since the National Environmental Authority has yet to draw up standards for industrial emissions to air or water, most industries continue to discharge untreated waste directly into the same rivers, canals or ponds. In Hanoi, for example, less than 20 per cent of industrial solid waste is disposed of in solid waste facilities. Moreover, such facilities as do exist are simply dump sites with no lining, no cover, and no leachate or methane collection and treatment. As with pesticides of high residual toxicity, the effects of industrial waste disposal tend to be more persistent. They include the build up of toxins in river sediment, in groundwater, in ecological systems supported or impacted by the water source, and in human users.

It has been remarked that CO_2 emissions are linked to deforestation. However, it is only Africa and Latin America that land use change is responsible for a significant proportion of total carbon emissions. In general, industrial sources account for the major proportion of total emissions (Table 6). The dominant sources of carbon emissions are industrial users in East Asia, the former Soviet countries, the USA and Europe. Table 6 indicates the 1991 pattern of energy consumption, and the growth in per capita terms over the preceding twenty years. Aside from South America, where growth in energy consumption has been most rapid, it is interesting that the fastest increases in commercial energy consumption have occurred in the high income economies.

Table 6 Energy consumption and greenhouse gas emissions, 1991

	Commercial Energy Consumption				Greenhouse Gas Emissions			
	Total		Per Capita		Carbon Dioxide Emissions		Methane	CFCs
	petajoules	change since 1971 (percent)	gigajoules	change since 1971 (percent)	from industry (million tons)	from land-use change (million tons)	from anthro-pogenic sources (million tons)	(million tons)
Africa	7,871	121	12	24	671.6	640	16	12
Asia	80,374	238	25	129	6,671.5	920	120	100
S.America	9,493	1,304	32	818	594.9	1,600	18	10
Ex USSR	54,730	68	193	42	3,581.1	...	28	44
N/C America	96,086	430	243	300	5,764.3	190	36	100
Europe	68,507	163	134	142	4,133.7	...	29	120
Oceania	4,367	183	161	106	288.7	29	6	6

Source: The World Resource Institute. World Resources 1994-1995.

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).

3.2 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 8. 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. In Sub-Saharan Africa a large proportion of the population is dependent on agricultural activity. But with few non-farm rural employment opportunities the incidence of rural poverty is high. In Asia, although the proportion in agriculture is similar, rural industrialisation has created more alternatives to agriculture in a number of countries, and there are more wage earning opportunities in agriculture for the landless. This is reflected in a lower proportion of the rural population in poverty. The pattern in Latin America is different. Not only is the proportion of the economically active population engaged in agriculture much lower, but the proportion of the agricultural labour force in wage employment is much higher.

Table 8 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	2019	74	83	31	26	5
Asia (exluding China and India)	567	70	74	46	20	5
Sub-Saharan Africa	337	73	98	60	11	6
Near Easy & N. Africa	106	51	73	26	23	13
L. America & Caribbean	123	29	96	61	31	1
Least Developed Countries	368	80	89	69	18	7

Source: Jazairy I, Almagir M., and Panuccio T. (1992) The State of World Rural Poverty, IT Publications for IFAD, London.

Conversion of forest land to agriculture is generally due to the actions of large numbers of usually-landless individuals encouraged by policies which have the effect of reducing the private cost of land conversion. While these actions are often independent, they may also reflect government policy. Two examples illustrate the connection.

In the Philippines, the rapid increase in the population in the upland areas is associated with high rates of deforestation in those areas. The increase in upland population is almost all due to migration from the lowlands. Sixty per cent of all upland migrants in the mid 1980s were landless. As elsewhere, it is argued that migration into the upland areas has been facilitated by a road network constructed to support the expansion of timber production, and a government resettlement programme (World Resources Institute, 1994).

In outer islands of Indonesia—Sumatra, Kalimantan, Maluku and Irian Jaya—include some of the largest remaining tropical forests. The resettlement programme known as the transmigration, moved some 3.7 million people from the most populated islands of Java and Bali to the outer islands in the 1960s, 1970s and 1980s. In most cases, migrants were settled in what were termed conversion forests. The environmental consequences of this policy have been significant. New roads have again been the spur to private expansion into the conversion forests. The increasing density of population in these forests has, in turn, changed both the area and pattern of shifting cultivation followed by indigenous people. Indeed, by the late 1980s some 34% of the conversion forest was affected by shifting cultivation.

It is difficult to identify country-specific variables that adequately capture these stylized facts. In this paper the country-specific variables selected are population growth; the proportion of the population in the rural areas; and agriculture's share of GDP.

The second set of stylised facts relate to the way in which countries are integrated into the global economy. In very many cases the driving forces behind the impoverishment of rural migrants include international market trends. Under the 'Brundtland hypothesis' countries locked in to products for which the terms of trade decline will tend to increase exports of those products just to maintain foreign exchange earnings (Pearce and Warford, 1993). The response to falling real primary commodity prices in Sub-Saharan Africa, for example, appears to have been consistent with this hypothesis. The characteristic features of many Sub-Saharan African countries are low income, primary product dependence and indebtedness. Per capita income and the external indebtedness of these countries have both deteriorated over the last decade as primary commodity prices have followed a downward trend. The barter terms of trade of countries in the region show a secular decline over the last three decades (World Bank, 1996). Yet both primary commodity production and the volume of exports have increased.

The longer-term impacts of the Uruguay Round are also thought to involve substantial downside risks for Sub-Saharan Africa. During the period 1983-93 the World Bank estimates that per capita consumption and GDP declined at, respectively, 1.8 and 0.8

per cent per year in Sub-Saharan Africa (World Bank, 1994). The Uruguay Round is expected to have two effects which could cause this trend to continue. First, it is expected to raise international food prices. This will adversely effect the balance of payments of net food importers and put further downward pressure on the real incomes of the poor. Second, countries which have historically benefitted from the terms of the Lomé Convention will lose their preferential access to European markets. Indeed, Sub-Saharan Africa is the one region where the poor are expected to increase both numerically and as a proportion of the population (World Bank, 1994).

This contradicts the World Bank's view that economic liberalisation will, in general, be beneficial to the environment. Munasinghe and Cruz (1995) argue that:

- The removal of market price distortions such as agricultural or energy subsidies improves both the efficiency of economic activity, and reduces the impact of that activity on the environment.
- Improving the security of land tenure by assigning private property or use rights promotes investment in land conservation and environmental stewardship.
- Enhancing macroeconomic stability also encourages investment, and persuades resource users to to take a longer term view of their decisions.
- Economic liberalisation creates new economic opportunities. To the extent that this reduces poverty, it also reduces pressure on scarce but open-access .environmental resources

Trade liberalisation may certainly stimulate environmental protection by lowering the cost of environmental protection (Anderson and Blackhurst, 1992). But if it stimulates demand for the products of environmentally damaging activities, it will increase environmental damage. The change in developing country share in world production and trade in the smoke-stack industries is, for example, largely a result of the liberalisation of national and international markets.

Many developing countries have undergone adjustments necessitated by acute fiscal and current account deficits in the 1980s. The nature of the adjustment has changed somewhat over the years, but the central elements remain the alignment of domestic prices with world prices through the elimination of distortionary taxes, subsidies and administered pricing practices; the reduction of public expenditure; deregulation of industry; the imposition of wage restraints; institutional reforms; trade liberalisation; and the privatisation of state-owned assets. Only recently have structural adjustment programmes begun to take any account of the environment, and the environmental impacts of structural adjustment programmes begun to be analysed (Panayotou and Hupé, 1995). There are now numerous examples of environmental degradation which can be linked to structural adjustment policies including deforestation, soil erosion, destruction of coastal habitats and depletion of fisheries (Cruz and Repetto 1992; Hansen-Kuhn 1993; Panayotou and Hupé, 1995).

The connection is thought to be the following. Stimulation of export-oriented primary commodity production increases pressure on the resource base. The real incomes of consumers fall and there is disemployment in both the public sector and a reduction in demand for domestically produced goods and services. This worsens the condition of the poor and leads to the overexploitation of resources to which they have access. The reduction in public expenditure programmes reduces the budgets of agencies protecting the environment. The reduction of credit to small rural investors leads to lower on-farm investments and declining agricultural yields, countering efforts to stabilize the agricultural frontier (particularly in the absence of effective land tenure systems). Deregulation makes it harder to correct price distortions in the forestry, irrigation and energy sectors.

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.

3.3 The economic and social perfomance measures

The performance indicators selected all involve some modificaton to the per capita income measures used in the existing EKC literature. To test the relation between environmental and economic performance in a way which sheds light on the propositions of the Brundtland Report and Agenda 21, we need to capture the effects of differences in levels not just of income, but also of consumption, poverty and a broader measure of development. Aside from per capita GDP in Purchasing Power Parity terms, there are three different models for each environmental effect comprising: private and government consumption per capita; an IFAD index of rural poverty in the developing countries; and the Human Development Index.

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 and non-marketed environmental goods and service.

Two measures of poverty have been selected for reporting. The first 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 born 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 second is the IFAD's Relative Welfare Index (RWI). This is the arithmetic mean ofthree other idices: the IPI, and index of food security, and an index of basic needs. A third measure was estimated—proportion of the rural population below the poverty line (PBPL). But this performed least well, and is not reported.

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 less indicates severe poverty; and 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.

The RWI includes the elements of the IPI, plus a set of food production and consumption variables, an index of educational attainment and an index of health status. The educational index includes adult literacy and primary school enrolment. The health index includes population per physician, infant mortality, and access to health services, safe water and sanitation. The RWI is normalised to take values between zero and one.

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.

3.4 The results

This background helps to explain the differences that emerge in the relation between our environmental indicators and the selected measures of development and economic performance. The data used in this analysis are described and reported in Appendix A. In all cases they have been selected so as to correspond as closely as possible with the data used in the main published studies of the relation between economic and environmental change. The same holds for the method of analysis.

The analysis of the relationship between economic growth and pollution carried out by Grossman and Krueger (1991, 1995), Shafik and Bandyopadhyay (1992), Selden and Song (1994) and Holtz-Eaking and Selden (1995) used pooled cross-country and time series data for regressing some measure of environmental emissions/degradation against income and a set of exogenous factors. That is, the growth-environmental quality relationship has been typically estimated in the following form:

$$P_{it} = a_i + d_t + b_1 y_{it} + b_2 y_{it}^2 + b_3 y_{it}^3 + B_k X_k + e_{it}$$

where:

P_{it}	=	pollution in the ith country or city for year t
a_i	=	site specific effect
d_t	=	time specific effect
y_{it}	=	per capita GDP for the ith country at time t
X_k	=	k-dimensional vector of other variables that impact environmental quality
e_{it}	=	error term.

The environmental and performance indicators have already been identified. They are described in Appendix A. The environmental performance indicators are denoted ACH2O (safe water), SO2 (emissions of sulphur), CO2 (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 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 estimated results for all models are given in Appendix B. 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 relation between access to safe water and the Integrated 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 Kuznet's 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. Use of the Relative Welfare Index, RWI, instead of the IPI improves the model fit slightly.

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 relation 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 7359 PPP$—9563 PPP$ while those for consumption are 6391PPP$—7239PPP$. Given the distribution of income and consumption (see Appendix A) this puts a country like Portugal at the turnng 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 relation 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. For similar reasons, the results of the RWI model have not been reported.

Deforestation

Of all the environmental indicators investigated to date, most difficulty in fitting deforestation and income data to quadratic models. Although Panayotou (1993, 1995) reports a Kuznets relation between deforestation and per capita income, although the relation 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 relation when the whole sample is considered. There is some limited support for a Kuznets relation between deforestation and three measures of performance—income, consumption and the HDI—when only tropical countries are considered. But none of models has much explanatory power. There is no statisically significant relation between the poverty index, IPI, or the relative welfare index, RWI, and deforestation. The only country-specific variable that is a 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 CO2 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 CO2 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 (a) not significant in all cases and (b) 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 they exclude many of the major sources of carbon emissions, the poverty models are weaker than the other models. The IPI model indicates a negative relation between the IPI and carbon emissions that is statistically significant, but not very strong. The RWI model, on the other hand, shows a postive (but also very weak relation) between the RWI and carbon emissions. Both confirm that the relation between the share of agriculture in GDP and carbon emissions is negative. Although forest conversion is usually driven by the expansion of agriculture, this relfects the fact that the role of land conversion in generating carbon emissions in low income countries is dominated by the effect of industrial emissions in middle and high income countries.

4. Environmental quality, patterns of consumption and human development

This brings us back to our starting point: the proposition that environmental degradation is driven both by poverty in the developing world and by overconsumption in the developed world. How does this proposition fare in the face of the evidence? Since the general inverted-U shaped relation between per capita income and various indicators of environmental quality holds for at least some environmental indicators for measures of income, consumption and human development, the answer appears to be ambiguous.

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. But it is worth recalling (a) 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 (b) that the measure of environmental quality tends to be a per capita measure of outputs (emissions). It tends not to aggregate emissions, or the volume of such 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.

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 is 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 Britain, 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 evolutionary potential 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 socities and ecosystems alike across the globe (IPCC 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 increase demand for the resource. In the extreme case (Giffin goods) an increase in the price of the good induces people to buy more of that good. The existence of Giffin 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 relation between poverty, affluence and the environment has been illuminated by the hunt for a Kuznets relation between per capita income and environmental quality. The EKC studies have shown that deeping poverty at one end of the scale, and increasing affluence at the other, both have implications for the environment. But the results are not nearly ass strong as Brundtland suggested. 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.

It also shows that these are part of a continuum of effects. The environmental consequences of economic activity are generally 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.

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 born by the poor, by future generations, or by people in other countries, the incentive to address environmental questions has been much weaker.

In the light of this, we might ask what is learned by looking at the relation 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 and the RWI. These measures of performance turn 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, the RWI and (even less the proportion of the population below the poverty line) are weaker predictors of consumption or production activities in low and middle income countries than the other performance measures.

Finally, what is being said about either the environmental sustainability of consumption and production activities? Since none of the environmental indicators measures the volume of emissions, land use change, or access relative to the assimilative or carrying capacity of the ecosystem concerned, the answer is 'not very much'. 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. As Arrow et al (1995) point out, 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.

APPENDIX A

TABLE A.1: ENVIRONMENTAL QUALITY INDICATORS

COUNTRY	CO2	ACH2O	DEF	SO2
AFGHANISTAN	0.1	21		3.9
ALBANIA	0.82	97	0	
ALGERIA	0.74	71	0.8	
ANGOLA	0.14	40	0.7	
ANTIGUA & BARB.	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	0.3	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	
CAMEROON	0.13	44	0.6	
CAMBODIA	0.01		1	0.3
CANADA	4.35	100	-1.1	143.3
CAPE VERDE	0.06			
CENT. 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	0.3	92	3	
COTE D'IVORE	0.19	69	1	
CUBA	0.9			
CYPRUS	1.7	100		
CZECHOSLOVAKIA	3.62		0.1	177.1
DENMARK	2.71	100	0	52
DJIBOUTI	0.25			
DOMINICAN REP.	0.24	68	2.9	
ECUADOR	0.44	54	1.8	
EGYPT	0.42	90	0	
EL SALVADOR	0.13	47	2.3	
EQUATORIAL GUINEA	0.09			
ETHIOPIA	0.02	18	0.3	
FIJI	0.27	80		
FINLAND	2.82	96	0	51.5

COUNTRY	CO2	ACH2O	DEF	SO2
FRANCE	1.74	100	-0.1	21.5
GABON	1.45	66	0.6	
GAMBIA	0.06	77	0.8	
GERMAN DEM. REP.	5.05			314.9
GERMAN FED. REP.	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	0.1	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	0.9	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
JAMAICA	0.52	72	7.8	
JAPAN	2.34	96	0	9.2
JORDAN	0.69	99	-1	
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	0.9	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	
NEPAL	0.01	37	1	0.6
NETHERLANDS	2.54	100	-0.3	16.1
NEW ZEALAND	2.07	97	0	

COUNTRY	CO2	ACH2O	DEF	SO2
NICARAGUA	0.15	54	1.9	
NIGER	0.04	53	0.4	
NIGERIA	0.21	42	0.7	
NORWAY	2.48	100	-1.4	1.5
OMAN	2.24	46	0	
PAKISTAN	0.14	55	3.5	
PANAMA	0.3	84	1.9	
PAPUA NEW GUINEA	0.16	33	0.3	
PARAGUAY	0.09	35	2.8	
PERU	0.27	53	0.4	
PHILIPPINES	0.19	81	3.4	6
POLAND	2.6	89	-0.1	83.5
PORTUGAL	1.09	92	-0.5	20.6
QATAR	10.47			430.8
ROMANIA	2.12	95	0	45.6
RWANDA	0.02	69	0.2	
ST KITTS & NEVIS	0.4			
ST LUCIA	0.3			
ST VINCENT/ GRANADINE	0.19			
SAO TOME AND PRINCIPE	0.15			
SAUDI ARABIA	3.64	93	0	99.2
SENEGAL	0.1	44	0.7	
SEYCHELLES	0.66			
SIERRA LEONE	0.04	39	0.6	
SINGAPORE	3.77	100	2.3	51.7
SOMALIA	0.03	36		
SOUTH AFRICA	2.15		-0.8	
SPAIN	1.41	100	0	56.7
SRI LANKA	0.06	60	1.4	1.7
SUDAN	0.04	34		
SURINAME	1.24	68		
SWAZILAND	1.8	31		
SWEDEN	1.6	100	0	24.5
SWITZERLAND	1.72	100	-0.6	9.5
SYRIA	0.66	79	-4.3	
TANZANIA	0.02	52	1.2	
THAILAND	0.46	77	3.5	11.2
TOGO	0.05	70	1.5	
TRINIDAD AND TOBAGO	3.19	96	-2.1	
TUNISIA	0.34	70	-1.9	
TURKEY	0.69	84	0	7.2
UGANDA	0.08	33	1	
UAE	9.05	100	0	
UK	2.65	100	-1.1	66.3
USSR	3.66			57.3
ARMENIA			3.9	20.9
AZERBAIJAN			1.3	12.4
BELARUS			-0.4	54.6
ESTONIA			-1.2	121.3
GEORGIA			0.7	13.9
KAZAKHSTAN			0	87
KYRGYZSTAN			1.2	12.4

COUNTRY	CO2	ACH2O	DEF	SO2
LATVIA			-0.2	20
LITHUANIA			0	38
MOLDOVA			-6.7	52.9
RUSSIA			0.2	68.2
TAJIKISTAN				3
TURKMENISTAN				5.8
UKRAINE			-0.3	53.3
UZBEKISTAN			5.5	25.2
USA	5.26		0.1	84.7
URUGUAY	0.35	95	-0.6	
VANUATU	0.12			
VENEZUELA	1.4	92	1.2	
VIET NAM	0.1		1.5	0.6
YEMEN	0.11		0	
YEMEN PDR	0.64			
YUGOSLAVIA	1.5			62.1
ZAIRE	0.03	39		
ZAMBIA	0.08	59	1.1	
ZIMBABWE	0.71	84	1.7	

NOTES:
Values for carbon dioxide (CO2) 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 appropiate 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 (ACH2O) 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 A.2: ECONOMIC/SOCIAL PERFORMANCE INDICATORS

COUNTRY	INC	HDI	DHDI	RWI	IPI	CONS
AFGHANISTAN	714	0.066		0.328	0.57	
ALBANIA	3000	0.699				
ALGERIA	3011	0.528		0.719	0.166	1866.82
ANGOLA	840	0.143		0.419	0.596	
ANTIGUA & BARBUDA	4000	0.785		0.774	0.216	
ARGENTINA	4295	0.832	0.812	0.829	0.125	3607.8
AUSTRALIA	16051	0.972	0.935			12680.29
AUSTRIA	16504	0.952				12047.92
BAHAMAS	11235	0.875				
BAHRAIN	10706	0.79				7173.02
BANGLADESH	872	0.189	0.17	0.285	0.841	854.56
BARBADOS	8304	0.928		0.851	0.017	7307.52
BELGIUM	16381	0.952	0.951			12449.56
BELIZE	3000	0.689		0.631	0.503	2400
BENIN	1043	0.113		0.399	0.622	1022.14
BHUTAN	800	0.15		0.228	0.848	624
BOLIVIA	1572	0.398		0.398	0.801	1446.24
BOTSWANA	3419	0.552		0.581	0.434	2153.97
BRAZIL	4718	0.73	0.652	0.597	0.449	3632.86
BRUNEI	14000	0.847				
BULGARIA	4700	0.854				3384
BURKINA FASO	618	0.074		0.246	0.871	593.28
BURUNDI	625	0.167		0.353	0.805	618.75
CAMEROON	1646	0.31		0.59	0.34	1349.72
CAMBODIA	1100	0.186				
CANADA	19232	0.982	0.948			15193.28
CAPE VERDE	1769	0.479		0.57	0.36	1645.17
CENT. AFRICAN REP.	768	0.159		0.28	0.878	783.36
CHAD	559	0.088		0.38	0.563	642.85
CHILE	5099	0.864	0.831	0.682	0.432	3926.23
CHINA	1990	0.566		0.829	0.126	1134.3
COLOMBIA	4237	0.77	0.72	0.68	0.365	3135.38
COMOROS	721	0.269		0.539	0.472	764.26
CONGO	2362	0.372		0.464	0.695	1653.4
COSTA RICA	4542	0.852	0.852	0.8	0.217	3542.76
COTE D'IVORE	1324	0.286	0.268	0.57	0.236	1138.64
CUBA	2200	0.711		0.786	0.256	
CYPRUS	9953	0.89		0.944	0.002	7663.81
CZECHOSLOVAKIA	7300	0.925				5256
DENMARK	16781	0.955	0.936			12921.37
DJIBOUTI	1000	0.104		0.333	0.613	1040
DOMINICAN REP.	2404	0.586		0.63	0.377	2139.56
ECUADOR	3074	0.646		0.563	0.533	2397.72
EGYPT	1988	0.389	0.383	0.71	0.22	1789.2
EL SALVADOR	1950	0.503	0.508	0.646	0.279	1930.5
EQUATORIAL GUINEA	700	0.164		0.419	0.666	742
ETHIOPIA	369	0.172		0.358	0.643	346.86
FIJI	4427	0.73		0.769	0.156	3674.41
FINLAND	16446	0.954	0.941			12170.04
FRANCE	17405	0.503	0.938			13575.9
GABON	4147	0.503		0.72	0.166	2612.61

COUNTRY	INC	HDI	DHDI	RWI	IPI	CONS
GAMBIA	913	0.086		0.291	0.826	830.83
GERMAN DEM. REP.						
GERMAN FED. REP.	18213	0.957				13113.36
GHANA	1016	0.311		0.483	0.524	914.4
GREECE	7366	0.902				6776.72
GRENADA	4081	0.787		0.776		3917.76
GUATEMALA	2576	0.489		0.446	0.647	2369.92
GUINEA	501	0.045		0.299	0.672	395.79
GUINEA-BISSAU	841	0.09		0.328	0.753	933.51
HAITI	933	0.275		0.381	0.762	923.67
HONDURAS	1470	0.472	0.436	0.578	0.483	1396.5
HONG KONG	15595	0.913	0.891			10448.65
HUNGARY	6116	0.887	0.896			4464.68
ICELAND	16496	0.96				13196.8
INDIA	1072	0.309	0.288	0.542	0.48	857.6
INDONESIA	2181	0.515	0.503	0.647	0.398	1374.03
IRAN	3253	0.557	0.538	0.599	0.475	2602.4
IRAQ	3508	0.589		0.597	0.501	
IRELAND	10589	0.925	0.928			7518.19
ISRAEL	10840	0.938				9539.2
ITALY	15890	0.924	0.923			12553.1
JAMAICA	2979	0.736	0.665	0.589	0.679	2115.09
JAPAN	17616	0.983	0.99			11626.56
JORDAN	2345	0.582		0.797	0.131	2556.05
KENYA	1058	0.369	0.372	0.531	0.515	856.98
KOREA	6733	0.872	0.897	0.869	0.048	4241.79
KOREA DEM.	2000	0.64			0.158	
KUWAIT	15178	0.815				10472.82
LAOS	1100	0.246		0.449	0.811	1111
LEBANON	2300	0.565		0.8	0.119	
LESOTHO	1743	0.431		0.549	0.497	2457.63
LIBERIA	857	0.222		0.548	0.212	702.74
LIBYA	7000	0.568				
MADAGASCAR	704	0.327		0.537	0.499	647.68
MALAWI	640	0.168		0.359	0.827	576
MALAYSIA	6140	0.79	0.743	0.734	0.261	4113.8
MALDIVES	1200	0.497		0.558	0.373	
MALI	572	0.082		0.358	0.462	514.8
MALTA	8732	0.885		0.879	0.009	7072.92
MAURITANIA	1057	0.14		0.267	0.766	1035.86
MAURITIUS	5750	0.794	0.779	0.842	0.087	4485
MEXICO	5918	0.805	0.767	0.675	0.371	4793.58
MONGOLIA	2100	0.578				2037
MOROCCO	2348	0.433		0.528	0.393	1901.88
MOZAMBIQUE	1072	0.154		0.347	0.675	1200.64
MYANMAR	659	0.39		0.628	0.384	
NAMIBIA	1400	0.289				1190
NEPAL	920	0.17	0.128	0.405	0.593	846.4
NETHERLANDS	15695	0.97	0.972			11614.3
NEW ZEALAND	13481	0.947	0.921			10784.8
NICARAGUA	1497	0.5		0.717	0.173	1526.94
NIGER	645	0.08		0.453	0.348	632.1

COUNTRY	INC	HDI	DHDI	RWI	IPI	CONS
NIGERIA	1215	0.246		0.478	0.49	850.5
NORWAY	16028	0.979	0.956			11379.88
OMAN	9972	0.598		0.645	0.188	7179.84
PAKISTAN	1862	0.311	0.304	0.558	0.271	1638.56
PANAMA	3317	0.738	0.705	0.779	0.199	2786.28
PAPUA NEW GUINEA	1786	0.318		0.395	0.678	1607.4
PARAGUAY	2790	0.641		0.655	0.404	2120.4
PERU	2622	0.592		0.501	0.597	2018.94
PHILIPPINES	2303	0.603	0.584	0.577	0.577	1934.52
POLAND	4237	0.831				2669.31
PORTUGAL	8770	0.853	0.827			6928.3
QATAR	11400	0.802				
ROMANIA	2800	0.709				2044
RWANDA	657	0.186		0.329	0.857	630.72
ST KITTS & NEVIS	3300	0.697		0.714	0.312	
ST LUCIA	3470	0.72		0.68	0.377	
ST VINCENT & GRANADINE	3647	0.709		0.69	0.405	
SAO TOME AND PRINCIPE	600	0.374		0.551	0.467	498
SAUDI ARABIA	10989	0.688				7802.19
SENEGAL	1248	0.182		0.36	0.659	1135.68
SEYCHELLES	4191	0.761		0.803	0.085	3688.08
SIERRA LEONE	1086	0.065		0.347	0.633	1031.7
SINGAPORE	15880	0.849	0.865			8892.8
SOMALIA	836	0.087		0.258	0.685	652.08
SOUTH AFRICA	4865	0.673				3648.75
SPAIN	11723	0.923	0.928			9261.17
SRI LANKA	2405	0.663	0.636	0.616	0.419	2044.25
SUDAN	949	0.152		0.271	0.807	930.02
SURINAME	3927	0.751		0.762	0.371	3612.84
SWAZILAND	2384	0.458		0.586	0.444	2026.4
SWEDEN	5047	0.977	0.963			3987.13
SWITZERLAND	20874	0.978	0.961			14611.8
SYRIA	4756	0.694	0.631	0.643	0.404	4090.16
TANZANIA	572	0.27		0.526	0.592	600.6
THAILAND	3986	0.715	0.67	0.746	0.282	2670.62
TOGO	734	0.218		0.612	0.288	653.26
TRINIDAD Y TOBAGO	6604	0.877		0.813	0.193	4490.72
TUNISIA	3579	0.6	0.572	0.724	0.12	2863.2
TURKEY	4652	0.717	0.629	0.757	0.113	3814.64
UGANDA	524	0.194		0.376	0.802	529.24
UAE	16753	0.738				10051.8
UK	15804	0.964	0.948			13117.32
USSR						
ARMENIA	4741	0.831				
AZERBAIAN	3977	0.77				
BELARUS	5727	0.861				
ESTONIA	6438	0.872				
GEORGIA	4572	0.829				
KAZAKHSTAN	4716	0.802				
KYRGYZSTAN	3114	0.689				
LATVIA	6457	0.868				
LITHUANIA	4913	0.868				

COUNTRY	INC	HDI	DHDI	RWI	IPI	CONS
MOLDOVA	3896	0.758				
RUSSIA	7968	0.862				
TAJIKISTAN	2558	0.657				
TURKMENISTAN	4230	0.746				
UKRAINE	5433	0.844				
UZBEKISTAN	3115	0.695				
USA	21449	0.976	0.944			18231.65
URUGUAY	5916	0.881		0.807	0.179	4732.8
VANUATU	2005	0.533				1824.55
VENEZUELA	6169	0.824	0.793	0.734	0.221	4379.99
VIET NAM	1100	0.472		0.588	0.586	
YEMEN	1562	0.233		0.555	0.272	1437.04
YEMEN PDR				0.558	0.279	
YUGOSLAVIA			0.868			
ZAIRE	367	0.262		0.366	0.802	322.96
ZAMBIA	744	0.314	0.325	0.454	0.791	617.52
ZIMBABWE	1484	0.398		0.534	0.543	1172.36

NOTES:
Data on population growth (POPG) are obtained from the UN population statistics. Data on agricultural share of GDP (AGSHARE) are obtained 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's share of GDP are obtained from the World Bank's World Tables 1992.

APPENDIX B: RESULTS

All models use cross-sectional data. Regression coefficients are estimated using ordinary least squares, the residuals being tested for heteroscedasticity using a Lagrange Multiplier test (Breusch and Pagan, 1979). 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 environmental indicator below:

1. <u>LACK OF SAFE WATER</u>:

The data set consists of observations on percentage of population with access to safe water (ACH2O) 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), we transform the data in the following way: LACKW=100 - ACH2O. 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 heteroscedasity and, therefore, reduced efficiency of the estimates. As the problem appears to lie with outliers we drop observations 34,43,44,75 and 106 (Congo, Ecuador, Egypt, Jordan and Oman). 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 mantain the assumption of homoscedasticity (at least for the regressions on income and consumption). We carry out a similar analysis 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.

As regards DHDI, we only report Models 4(a) and 4(b), since the Breusch-Pagan test fails to reject the null hypothesis of homoscedasticity. (Note that there are no data on DHDI for four out of the five countries considered outliers in the sample).

Table B1. RELATIONSHIP BETWEEN LACK OF SAFE WATER AND INCOME
Dependent variable: Lack of safe water (in logs)

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

Table B2 RELATIONSHIP BETWEEN LACK OF SAFE WATER AND CONSUMPTION
Dependent variable: Lack of safe water (in logs)

VARIABLE	2(a)	2(b)	2(a)*	2(b)*
constant	12.503	6.5881 1	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

Notes:
1)All variables are in logs
2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B3 RELATIONSHIP BETWEEN LACK OF SAFE WATER AND HDI
Dependent variable: Lack of safe water (in logs)

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

Table B4 RELATIONSHIP BETWEEN LACK OF SAFE WATER AND DISTRIBUTION-ADJUSTED HDI
Dependent variable: Lack of safe water (in logs)

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

Notes:
1)All variables except DHDI are in logs
2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B5 RELATIONSHIP BETWEEN LACK OF SAFE WATER AND IPI
Dependent variable: Lack of safe water (in logs)

VARIABLE	5(a)	5(b)	5(a)*	5(b)*
constant	2.2933	0.16834	2.3425	0.44610
	(13.106)	(0.264)	(13.204)	(0.734)
	(8.783)	**(0.264)**	**(8.717)**	**(0.628)**
IPI	0.023865	0.012441	0.022968	0.010210
	(7.152)	(3.736)	(6.861)	(3.114)
	(5.418)	**(3.596)**	**(5.074)**	**(3.146)**
RUPOP		0.48117		0.42287
		(2.744)		(2.526)
		(2.507)		**(2.270)**
POPG		0.82855		0.92998
		(5.078)		(5.940)
		(4.470)		**(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

Notes:
1)All variables except IPI are in logs
2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B6 RELATIONSHIP BETWEEN LACK OF SAFE WATER AND RWI
Dependent variable: Lack of safe water (in logs)

VARIABLE	(a)	(b)	(a)*	(b)*
constant			5.3495	2.5359
			(22.646)	(2.988)
			(19.127)	**(2.460)**
RWI			-0.035146	-0.018767
			(-8.590)	(-4.053)
			(-6.134)	**(-3.566)**
RUPOP				0.29651
				(1.749)
				(1.435)
POPG				0.84633
				(5.466)
				(5.108)
Adjusted R2			0.46	0.61
F			73.78	46.60
B-P chi-squared			26.9536[1]	16.8096[3]
N			86	86

Notes:
1)All variables except RWI are in logs
2)t-statistic in parentheses, White's heteroscedasticity-corrected ratio in bold

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 table 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 8000 PPP$. The sample ranges from 659 to 21450 PPP$. For CONSUMPTION the turning point is in the neighbourhood of 6500 PPP$. The sample ranges from 1111 to 18231PPP$ and, again, countries such as Portugal would be at the inflexion point. For HDI and DHDI the quadratic form is not significative.

Table B7 RELATIONSHIP BETWEEN SULPHUR EMISSIONS AND INCOME
Dependent variable: Sulphur emissions (in logs)

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	9562.83	7359.25
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

Notes:
1)All variables are in logs (turning points in levels)
2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B8 RELATIONSHIP BETWEEN SULPHUR EMISSIONS AND CONSUMPTION
Dependent variable: Sulphur emissions (in logs)

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	7238.64	6391.15
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

Table B9 RELATIONSHIP BETWEEN SULPHUR EMISSIONS AND HDI
Dependent variable: Sulphur emissions (in logs)

VARIABLE	3(a)	3(b)	3(c)	3(d)
constant	-1.8370	0.54961	-0.85428	1.6624
	(-2.026)	(0.375)	(-1.628)	(1.234)
	(-1.468)	**(0.337)**	**(-1.563)**	**(1.385)**
HDI	0.090694	0.097118	0.049286	0.037851
	(2.838)	(2.770)	(7.402)	(4.310)
	(2.110)	**(2.009)**	**(7.195)**	**(4.546)**
HDI^2	-0.00034464	-0.00050258		
	(-1.325)	(-1.743)		
	(-1.022)	**(-1.373)**		
RUPOP		-0.54731		-0.49265
		(-2.260)		(-2.008)
		(-2.493)		**(-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

Notes:
1)All variables except HDI are in logs
2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B10 RELATIONSHIP BETWEEN SULPHUR EMISSIONS AND DISTRIBUTION-ADJUSTED HDI

Dependent variable: Sulphur emissions (in logs)

VARIABLE	4(a)	4(b)	4(c)	4(d)
constant	-1.4112	-0.45537	-0.99655	-0.011141
	(-1.260)	(-0.303)	(-1.566)	(-0.009)
	(-2.626)	**(-0.645)**	**(-2.482)**	**(-0.015)**
DHDI	0.065646	0.068300	0.047066	0.042825
	(1.572)	(1.629)	(6.132)	(4.682)
	(2.499)	**(2.626)**	**(8.126)**	**(6.069)**
$DHDI^2$	-0.00015442	-0.00021663		
	(-0.453)	(-0.623)		
	(-0.620)	**(-0.875)**		
RUPOP		-0.21973		-0.19283
		(-0.954)		(-0.862)
		(1.975)		**(-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

3. DEFORESTATION:

Table B11. RELATIONSHIP BETWEEN DEFORESTATION AND INCOME

Dependent variable: Deforestation (in logs)

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	1888.52	2815.90
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

Notes:

1)All variables are in logs (turning points in levels)

2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B12 RELATIONSHIP BETWEEN DEFORESTATION AND CONSUMPTION
Dependent variable: Deforestation (in logs)

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	1604.61	2482.67
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

Table B13. RELATIONSHIP BETWEEN DEFORESTATION AND HDI
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

Notes:
1)All variables except HDI are in logs (turning points in levels)
2)t-statistic in parentheses White's heteroscedasticity-corrected t ratio in bold

Table B14. RELATIONSHIP BETWEEN DEFORESTATION AND DISTRIBUTION-ADJUSTED HDI
Dependent variable: Deforestation (in logs)

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

Table B15 RELATIONSHIP BETWEEN DEFORESTATION AND IPI
Dependent variable: Deforestation (in logs)

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)
Turning Point			
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

Notes:
1)All variables except IPI are in logs
2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B16 RELATIONSHIP BETWEEN DEFORESTATION AND RWI
Dependent variable: rate of deforestation (in logs)

VARIABLE	(a)	(b)	(c)
constant	0.60165	-0.37542	-2.0175
	(2.730)	(-0.525)	(-2.033)
	(2.469)	**(-0.460)**	**(-1.614)**
RWI	0.0029276	0.042825	0.044242
	(0.720)	(1.524)	(1.630)
	(0.579)	**(1.259)**	**(1.372)**
RWI2		-0.00037412	-0.00033216
		(-1.434)	(-1.316)
		(-1.111)	**(-1.079)**
RUPOP			0.35544
			(2.304)
			(1.946)
Adjusted R2	-0.007(ERR)	0.009	0.07
F	0.51	1.29	2.69
B-P chi-squared	8.96054[1]	11.8495[2]	7.53936[3]
N	62	62	62

Notes:
1)All variables except RWI are in logs
2)t-statistic in parentheses, White's heteroscedasticity-corrected ratio in bold

3. CARBON EMISSIONS:

The relationship is monotonically increasing. AGSHARE is the most significant country-specific factor. RUPOP is significant when AGSHARE is not included. EXPSHA is included in the third model of the tables in this section. It does not add much explanatory power to the regression except when the performance indicator is CONSUMPTION.

Table B17 RELATIONSHIP BETWEEN CO2 EMISSIONS AND INCOME
Dependent variable: Carbon emissions (in logs)

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

Table B18 RELATIONSHIP BETWEEN CO2 EMISSIONS AND CONSUMPTION
Dependent variable: Carbon emissions (in logs)

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

Notes:

1)All variables are in logs

2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B19 RELATIONSHIP BETWEEN CO2 EMISSIONS AND HDI

Dependent variable: Carbon emissions (in logs)

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

Table B20 RELATIONSHIP BETWEEN CO2 EMISSIONS AND DISTRIBUTION-ADJUSTED HDI

Dependent variable: Carbon emissions (in logs)

VARIABLE	1(a)	1(b)	1(c)
constant	-4.0858	-2.5659	-2.1406
	(-13.745)	(-3.258)	(-2.152)
	(-11.609)	**(-3.222)**	**(-1.845)**
DHDI	0.050880	0.041098	0.041166
	(13.030)	(6.696)	(6.671)
	(12.077)	**(6.616)**	**(6.687)**
AGSHARE		-0.34497	-0.37610
		(-2.092)	(-2.192)
		(-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

Notes:

1)All variables except DHDI are in logs

2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B21 RELATIONSHIP BETWEEN CO2 EMISSIONS AND IPI
Dependent variable: Carbon emissions (in logs)

VARIABLE	5(a)	5(b)	5(c)
constant	0.12095	2.8053	1.8173
	(0.533)	(7.295)	(2.296)
	(0.659)	**(8.620)**	**(2.272)**
IPI	-0.041972	-0.023041	-0.020012
	(-9.368)	(-5.371)	(-4.490)
	(-11.680)	**(-5.554)**	**(-4.573)**
AGSHARE		-1.1590	-1.1213
		(-7.903)	(-7.047)
		(-8.058)	**(-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

Notes:
1)All variables but IPI are in logs
2)t-statistic in parentheses, White's heteroscedasticity-corrected t ratio in bold

Table B22 RELATIONSHIP BETWEEN CO2 EMISSIONS AND RWI
Dependent variable: Carbon emissions (in logs)

VARIABLE	(a)	(b)	(c)
constant	-5.2871	-0.74456	-1.5753
	(-16.723)	(-1.066)	(-1.754)
	(-17.632)	**(-1.108)**	**(-1.848)**
RWI	0.062122	0.036625	0.036272
	(11.644)	(6.402)	(5.949)
	(13.406)	**(6.608)**	**(5.760)**
AGSHARE		-1.0188	-0.93302
		(-7.012)	(-5.896)
		(-7.314)	**(-6.135)**
EXPSHA			0.1402
			(1.217)
			(1.086)
Adjusted R2	0.55	0.69	0.70
F	135.57	123.47	79.58
B-P chi-squared	2.68441[1]	4.43493[2]	5.56647[3]
N	107	107	99

Notes:
1)All variables except RWI are in logs
2)t-statistic in parentheses, White's heteroscedasticity-corrected ratio in bold

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