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Economic Growth and the Environment: Whose Growth? Whose Environment?

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Summary. — The widespread clamor for immediate draconian action to reduce the danger of global warming is an unjustifiable diversion of attention from the far more serious environmental problems facing developing countries. Resource constraints do not constitute limits to growth, and the likely economic damage done by climate change would be a negligible proportion of world output. The loss of welfare of the population in developing countries today as a result of inadequate access to safe drinking water and sanitation, or of urban air pollution, is far greater, and should be given priority over the interests of future generations. The "sustainable" growth concept is either morally indefensible or totally nonoperational.

1. CONFLICTING INTERESTS IN THE ENVIRONMENT-GROWTH RELATIONSHIP

Towards the end of the 1960s considerable concern began to be expressed in the developed countries of the world about the impact that economic growth was having on their environments. Many of these concerns were brilliantly formulated by Mishan (1967), who enumerated various alleged shortcomings of economic growth. Similar concerns were later set out in well-known books by Hirsch (1977) and Schumacher (1973).

One of the consequences of this growing concern was the 1972 UN World Conference on the Environment in Stockholm. But at this conference the developing countries made it perfectly clear that, in their ranking of objectives, development was given greater priority than the environment. Slowing economic growth in the interests of protecting the environment might appear to be a worthy cause to the richer countries but was certainly not high on the agenda of the developing countries. As one commentator put it "In developing countries . . . while industrial growth without pollution control measures reduces environmental quality and degrades natural systems, it also may reduce poverty and, as such, reduce what is termed poverty-related pollution" (Tobey, 1989).

In fact, even in the advanced countries it was never clear that environmental protection was high on the agenda for the majority of the population, as distinct from the more affluent members of society. The vast majority of the ordinary working people in the developed countries appreciated only too well the improvements in their living standards that technological advance could bring. For them the washing machines, television sets, and automobiles which some environmental groups affected to despise represented a release from drudgery and boredom, and an opening up of mobility. The virtual elimination of malnutrition and many fatal diseases associated with poverty undoubtedly made a major contribution to the welfare of the majority of the working population in the more developed countries.

Insofar as the less affluent members of the population were concerned with the environment at all, it was with their inadequate housing or the dirty, noisy and dangerous conditions in which many of them worked. But the noise levels or

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safety precautions in factories have rarely appeared in the lists of environmental concerns that are prominent in the environmentalist literature, and improvements in these aspects of the environment have been obtained largely by pressure from trade unions.

Thus there was always some conflict of interest between different groups in society — and between richer and poorer nations — concerning the relative benefits of economic growth. In richer countries the majority of the population certainly gained from economic growth. Even though this growth brought with it certain changes that were perceived — rightly or wrongly — by the more affluent groups in society as being harmful, by the end of the 1960s almost all of the most important components of the physical environment — notably air quality in cities — in the more advanced countries were also improving.[1]

This improvement was, of course, partly to the credit of the environmentalist movements. But it was also made possible by the changes that were taking place in social and economic conditions and that both raised environmental problems in the hierachy of concerns of the population in advanced countries and increased the means available to deal with these problems.[2] One might be excused for predicting that the same environmental improvement would take place — at least in the longer run — in the developing countries insofar as they were able to achieve or maintain steady rates of economic growth. It is now being widely proclaimed, however, that continued economic growth is no longer possible. Or that the advanced countries must accept a cut in their living standards so the developing countries can have access to limited resources.[3] Or that the problems created by economic growth are such that we must make some fundamental changes in our attitudes. Among the many specific proposals of this nature made by one of the foremost prophets of doom, Sir Crispin Tickell, are that "We need not only to behave differently but to think differently . . . we need to recast our vocabulary . . . we need to change the culture . . . we need a value system which enshrines the principle of sustainability over generations."[4]

Two major reasons are usually given for the "unsustainability" of economic growth of the type to which we have become accustomed. One is the alleged exhaustion of resources of the conventional kind — minerals or food supplies. Another is the alleged global scale of environmental pollution with, in particular, the threat of climate change associated with the continuing increase in emissions of greenhouse gases (GHGs). In Sections 2 and 3 of this paper an attempt is made to demonstrate that neither of these obstacles to continued economic growth is valid.

In contrast, it is argued in Section 4 that the important environmental problems for the 75% of the world's population that live in developing countries are local problems of access to safe drinking water or decent sanitation, and urban degradation. Furthermore there is clear evidence that, although economic growth usually leads to environmental deterioration in the early stages of the process, in the end the best — and probably the only — way to attain a decent environment in most countries is to become rich.

Of course, this does not mean that economic growth will solve all environmental problems by itself. Even if mineral resources or food supplies do not constitute a constraint on growth, clean air and water may, in effect, be in limited supply. This applies not merely locally, but also nationally and globally, and the "tragedy of the commons" calls for collective action to protect these limited resources from excessive pollution. Thus policies will be needed to deal with a host of serious and difficult environmental problems. Local pollution will always tend to be excessive in the absence of appropriate policies, and action on a national and international scale will be needed to deal with many forms of pollution, such as the contamination of underground water supplies and the seas, deforestation, acid rain and chlorofluorocarbons (CFCs). These would include policies designed to remedy the many market failures — for which governments are often responsible — that lead to emissions of GHGs at a rate that is unjustified in any hardnosed economic calculation, and policies to support research into the economically efficient use of fuels.

Thus the main theme of this paper is not that economic growth will solve all our problems and that environmental policies are not needed. It is that concentration on resource constraints or global warming is not merely unjustified taken in isolation but is a distraction from more serious environmental problems, particularly the urgent environmental problems of the poorest sections of today's population. To the extent that the momentum toward widespread adoption of policies to curb GHG emissions were to lead to policies that slowed economic growth, or diverted environmental policy and resources away from environmental improvements of the kind that really matter in developing countries, it would further reduce the welfare of these countries. In other words, the conflict of interests in today's environmental debate is not between

richer and poorer groups within the advanced countries as it was in the 1960s. It is now primarily between richer countries and poorer countries or, worse still, between even richer countries in the future and the poorer countries today.

2. ECONOMIC GROWTH AND RESOURCE CONSTRAINTS

There are two main components of the thesis that, unless fairly drastic policies are adopted, economic growth of the conventional kind that we have experienced over the last few decades is not "sustainable." These are that (a) we are approaching limits to the world's resources and (b) there is a danger that, unless drastic action is taken to reduce energy consumption per unit of output, continued economic growth threatens the global environment — notably through the "greenhouse effect" — in a manner that threatens the survival of the human race.

The first of these two issues is a relatively simple matter to dispose of, since it is based on such a clear failure to face up to the implications of historical trends in resource availability and to understand the economics of resource availability and the economic feedback mechanisms involved. Nor does the resource constraint issue raise questions of conflicting interests in such a direct manner as does the global pollution problem.[5] Consequently I shall limit my comments on the resources constraint concern to a few statistics and their interpretation.

In 1972 a report to The Club of Rome entitled *The Limits to Growth* received enormous attention and was treated with great respect by numerous important sections of the media and in social and political circles (Meadows, *et al.*, 1972). This report presented estimates of what were then the known reserves of several key minerals and showed that, if the prevailing annual rates of consumption were to be maintained, these reserves would soon be exhausted. But, of course, the "known" reserves at any point of time are only the reserves that have been worth finding. Exploration continues if the known reserves begin to look inadequate in relation to expected levels of demand, particularly since this usually leads to a rise in the price of the materials in question. Thus, for example, in *The Limits to Growth* 1970 world supplies of lead were put at 91 million metric tons. Between 1970 and 1989 the world consumed 98.5 million metric tons. The sort of methodology used in *The Limits to Growth* would imply that we had used up more that we had started with! Yet by 1989 total known reserves of lead were actually 125 million tons. Exactly the same applies to natural gas and zinc, in that cumulative world consumption during the period 1970–89 equaled or exceeded the 1970 "known reserves," yet the known reserves at the end of the period were greater than at the outset.

Similarly, the balance between world supply and demand for food has not developed along the lines of the "doomsday" predictions. World food output over the last 20 years — as, indeed, over the preceding 20 years as well — has continued to rise faster than world population (UNCTAD, 1989). It is true that this does not apply to every area of the globe and that this has not prevented human factors — such as civil wars and blatant discrimination — from leading to massive food shortages in particular regions.[6] But the fact that human stupidity and evil are capable of leading to disasters is nothing new and has nothing to do with the "limits to growth" thesis.

The reason why the resource limitations predicted by the Club of Rome — like many other such predictions over the years — have proven false is simply their failure to allow for economic feedback mechanisms. These include the various effects of a rise in the price of any resource that is becoming scarce: increased profitability of exploration, of improved processing techniques, of increased research into substitutes; increased replacement of the resource by existing substitutes in final use; or, at the worst, a reduction in the use of the goods that finally embody the resource in question.[7]

3. HOW SERIOUS IS THE "GREENHOUSE EFFECT"?

The second point raised above, however — how urgent is the threat of global warming — raises more complicated issues. It is argued below that, although there are enormous uncertainties in both the science and the economics of global warming, the damage done by global warming is likely to be far less than the costs that would be incurred by hasty and draconian measures to reduce GHG emissions on the scale widely advocated by environmental groups and many scientists.

It is now well known that — other things being equal — economic growth will lead to greatly increased concentrations of carbon dioxide in the atmosphere, with a resulting impact on the global climate, including, notably, "global warming" caused by the "greenhouse effect." This particular danger, together with the thinning of the ozone layer, has captured the headlines and the

imagination of many people. Dire predictions of imminent ecological disaster as a result of climate change are commonplace. And they are not confined to presidents, prime ministers and leading politicians, not to mention retired British ambassadors, or even monarchs, such as Queen Beatrix of the Netherlands, who might have been supposed to be indifferent to electoral considerations.[8] Many scientists have also joined in the chorus of calls for drastic immediate action.

For example, in his introduction to one of the best documented and balanced of the flood of publications on this subject, Jeremy Leggett, the Director of Science at Greenpeace, UK, calls for the "implementation of immediate cuts in carbon dioxide emissions and the drawing-up of integrated strategies aimed at the phase-out of fossil fuels as early as possible in the next century" (Leggett, 1990, p. 469). He also complains that "The Response Strategies Working Group [of the International Panel on Climate Change] did not even come down on the side of a freeze in greenhouse-gas emissions, much less the deep cuts the scientists clearly indicate will be necessary if any attempt is to be made to slow or arrest the greenhouse effect."

But it is not for scientists to say what costs should be incurred by present generations in order to avoid the effects of global warming on the welfare of future generations, who will be far wealthier on any reasonable extrapolation of trends. It is a matter of balancing these effects against the social costs of preventing global warming. Scientists have a key role to play in arriving at this balance, since they are needed to provide the inputs on the physical consequences of global warming. But that is only the beginning of the calculation. Although all the estimates are subject to wide margins of error, any reasonable survey of the evidence suggests that the threat to future standards of living posed by climate change is not nearly as great as is widely asserted. The reasons for this are numerous. They include the uncertainties attached to the scientific predictions, the modest scale of the likely economic impacts — even if the gloomier scientific predictions prove to be correct — and a logical analysis of the relative costs and benefits of alternative courses of action.

In considering the danger of severe climate change resulting from the accumulation of greenhouse gases, it should be noted, first, that most reputable scientists agree that there are still major gaps in their understanding of the global warming phenomenon in general and, in particular, the relationship between carbon dioxide and global warming. There are corresponding very large differences in the predictions made by alternative climate models.[9] As well as the influence of natural factors there appear to be two other important reasons for these uncertainties:

First, modeling the earth's climate is a task of heroic proportions and the progress made so far represents an intellectual achievement of the first order. Nevertheless, there are still enormous gaps in the models currently used. For example, there are major gaps on account of the absence of any proper treatment of the behavior of water vapor and cloud cover, of the interaction between the atmosphere and the oceans, and of the way that the mix of water at different depths and at different temperatures affects the models. It is generally agreed that better modeling of the increased evaporation and convection that would occur as a result of warming would show that these could have negative feedback effects and hence moderate the increase in warming that would otherwise take place.[10] For example, improvements in the modeling of cloud cover recently introduced in the British Meteorological Office model reduced the mean estimates of the temperature increase associated with a doubling of the CO_2 concentrations from 5.5 degrees Celsius to 1.9 degrees.[11]

Second, contrary to widespread belief, the models that predict increases in world temperature as a result of increased CO_2 concentrations are not confirmed by temperature changes over the past century. The only reliable data on temperatures relate to the 48 contiguous states of the United States and these data show no upward temperature trend at all.[12] Insofar as one does accept the world average temperature estimates purporting to indicate a trend increase of about 0.5°C over the last century, it is difficult to match these observations with the global warming models since: most of the trend rise occurred between 1900 and 1940, when CO_2 concentrations were increasing by only about 0.1% per year compared with 0.5% per year now; there was a fall in temperature between 1940 and the early 1970s; and the models predict that more warming would take place at higher latitudes than near the equator, whereas the opposite has occurred. Hence, as Mason concludes, with reference to such upward trend in temperature as can be observed, "The timing of the fluctuations in the temperature record, and the fact that any significant greenhouse warming is likely to be delayed for several decades because of the thermal inertia of the oceans, strongly suggest that these are natural climatic fluctuations".[13]

Let us leave aside these scientific uncertainties and adopt, for the sake of argument, the current

existing scientific consensus[14] that in about a hundred years' time average world temperature will rise by about 3°C (though there are many eminent scientists who dispute this). Let us suppose, too, that this will lead to an overall increase in rainfall (though the opposite effect will occur in some large continental regions far removed from seas). What then can be said, in a rough and ready way, about the orders of magnitude of the economic effects that such climate changes would produce — *taking the world as a whole*?

(a) *Agriculture*

One of the most important effects of global warming, if any, will be on agriculture. The climate models predict that global warming will cause the interior of most continents to be drier, which will have an unfavorable effect on agriculture in many areas. But there will also be favorable effects in other areas, partly due to longer growing periods in higher latitudes, partly due to greater rainfall caused by generally increased evaporation over land and sea, and partly because of the fertilization effect of higher CO_2 concentrations on plants.[15] Estimates by the Environmental Protection Agency show that the net effect on USA agriculture is uncertain in direction, with the possible range of effect lying between a net gain of $10 billion and a net loss of $10 billion.[16] Now this may sound like big money to the layman, but, of course, by the standards of the US economy it is negligible — about the size of an average monthly trade deficit. Agricultural net output constitutes about 3% of total US national product — i.e., about $150 billion out of a national product of about $5.2 trillion.

Of course, in other countries the effects will be different. In some, notably Canada, the Soviet Union and China, the net effects will be favorable as the production regions move northward and growing periods are extended.[17] In his survey of estimates for other countries, Nordhaus reported that "Detailed studies for the Netherlands and Australia found that the overall impact of a CO_2 equivalent doubling will be small and probably difficult to detect over a half-century or more. The Coolfont Workshop [in which teams of experts gathered on a very short-term basis] estimated the impact of climate change upon six large regions — the U.S., Europe, Brazil, China, Australia, and the USSR. This report found the impact of climate change to be generally favourable."[18] Thus Nordhaus finds that, for the world as a whole, ". . . our best guess is that CO_2-induced climate change will produce a combination of gains and losses, with no strong presumption of substantial net economic damages."[19]

Furthermore, all this leaves out the probable — indeed inevitable — contribution that will be made by the continued rapid improvements in agriculture and plant technology as a result of genetic engineering. Even if, on balance, global warming did raise the real costs of achieving given agricultural output by, say, 10–20% by the middle of the next century, this is likely to be overwhelmed by continued increases in control over plants, possible production of new proteins, technological progress in water conservation and irrigation and so on.

(b) *Sea level rise*

The situation does not change much even if we bring into the picture the other main fairly certain effect of global warming, namely the rise in sea levels. The estimated rise in sea levels has been greatly reduced over recent years. As recently as 1980 it was seriously believed that sea levels might rise as much as eight meters. In early 1989 the prevailing estimate was down to about one meter; in early 1990 it was down to about 65 centimeters by the end of the next century (as in the IPCC report), and current authoritative estimates now put it as low as 30 centimeters by the end of the next century, assuming a 4°C rise in average temperature by then.[20] (If one were to extrapolate trends in these estimates, they would soon be predicting a fall in the sea level, with consequences for many seaside resorts that might be as serious as sea level rises!) Although alarmists frequently refer to the impact on sea levels resulting from the disintegration of the West Antarctic Ice Sheet and the melting of sea-ice cover, most glaciologists now discount the possibility of the former and there is, as yet, ". . . no evidence that the Arctic sea-ice cover has changed appreciably over the last two or three decades . . .," a conclusion that has received further confirmation in more recent findings.[21]

But suppose sea levels did rise appreciably, what would be the economic consequences? Estimates by the United States Environmental Protection Agency for a large rise in sea levels (one meter) are that the cost of protecting US cities by sea walls would be about $100 billion at current prices. Applying a 1.5% per annum compound growth rate to the present US GNP of about $5.2 trillion, would give a GNP by 2090 of $23.0 trillion. As a fraction of GNP in the year 2090 the once-and-for-all capital cost of the sea walls would be about 0.43% of GNP.

What about the rest of the world? Cline's

estimates, assuming a one meter rise in the sea level and costs for sea walls for other threatened coastal cities comparable to those of the United States, arrive at costs of adaptation, plus valuing the land lost in Bangladesh, of about $2 trillion.[22] By the year 2090 world GNP will be about $115 trillion (assuming the US share remains roughly constant at one-fifth of world GNP). Cumulative world GNP would thus be in the region of $7,000 trillion, so that the capital cost of the sea level rise would be about 0.03% of world cumulative GNP over the whole period. Suppose the margin of error is so great that the capital costs needed to protect areas from sea level rise, including the damage done by salination of aquifers and compensation for lost land, were ten times as great as these figures would suggest. They would still be only 0.3% of cumulative GNP. Given that the latest predictions of the rise in the sea level are about half those assumed in these estimates and any reduction in the estimated sea level rise implies a more than proportionate reduction in the costs of adaptation or the damage done through land loss, the above estimate is as likely to be on the high side as on the low side.

Now that may be all very well for the world as a whole but it is not much consolation for the people of Bangladesh, where 20% of the land could be lost with a one meter sea level rise. The problem is then to consider what it would cost to prevent the sea level rise *by taking draconian action to reduce CO_2 emissions*. If this cost turned out to be far greater than the cost to Bangladesh of the sea level rise, it would obviously be in everybody's interests to abstain from this drastic action and to compensate Bangladesh generously out of the savings that would be made. For example, suppose, purely for the sake of illustrating the logic of the choices to be made, that an early 50% cut in CO_2 emissions would cost the world community $20 trillion — i.e., ten times the cost of protection against the rising sea level (leaving aside the downward revisions that have since been made to the amount of predicted sea level rise). It would clearly be in everybody's interest — including the Bangladeshis — to make some sort of deal to avoid incurring these costs and then hand over a small part of the savings — say $4 trillion — to the people who would suffer from the sea level rise. The latter then gain — $4 trillion as compensation for damage estimated at only $2 trillion — and the rest of the world still has a net gain of $16 trillion. As shown below, our hypothetical $20 trillion figure is, in fact, lower than most estimates of the cost of cutting CO_2 emissions by 50%.

In other words, the best policy would be to compensate the Bangladeshis for inevitable damage from sea level rise and to help them in other ways, such as moving them away from threatened coastal areas, adapting the pattern of economic activity to the incidence of regular flooding, improving flood control and, perhaps, making it easier for those who prefer to emigrate to do so. During the last few decades regular river flooding that has nothing to do with climate change has added to the general terrible poverty of Bangladesh. Yet the rest of the world has shown no sign of genuine willingness to hand over, in the form of aid, resources commensurate with the task of eradicating that poverty or preventing the flooding. So the notion that it should now suddenly be seized by a fit of unprecedented altruism and incur possibly enormous costs to prevent or attenuate GHG emissions, rather than accept the far less costly alternatives of adaptation, is absurdly naive and unrealistic. In any case, since far more land is being lost every year as a result of soil erosion than is likely to be lost through climate change, if the world is seriously concerned about land loss there are policies that could be adopted to reduce it without drastic reductions in world CO_2 emissions.

(c) *Other effects*

Estimates have been made for other effects of climate change, such as greater need for air conditioning (offsetting less need for space heating), forest loss, and the sheer disutility for some people of living in a warmer climate (but not for all those people who would like to do so but cannot afford to or are tied to their present locations by other factors). These estimates, however, are even more uncertain than those referred to above, and are likely to be relatively trivial. Another alleged effect is an increase in the frequency of storms, but, in fact, very little hard evidence has been produced concerning this effect of global warming. The IPCC scientific working group reported that ". . . climate models give no consistent indication whether tropical storms will increase or decrease in frequency or intensity as climate changes; neither is there any evidence that this has occurred over the past few decades."[23]

Hence, it seems impossible to escape the conclusion that even under pessimistic assumptions the annual cost to the world as a whole of global warming associated with a doubling of CO_2 concentrations is likely to be almost negligible in comparison with the value of world output over the period in question. But before comparing it with the scale of the environmental problems facing the developing world today, it is

necessary to examine the magnitude of the costs of action to prevent global warming.

(d) *The costs of preventing global warming*

As with estimates of the damage that would be done by global warming, the available estimates of the costs of preventing it are subject to major conceptual and statistical reservations. In the space available here only one or two key examples can be set out.[24] One of the many difficulties of drawing conclusions from the available data is their incomparability; for example, they relate to different degrees of CO_2 emission reduction over different time periods and from different base "business as usual" assumptions. Notable attempts have been made by Nordhaus to convert the "snapshot" estimates of costs and benefits of measures to reduce carbon emissions into the economist's paradigm of balancing marginal costs and benefits of abatement, taking account of the time path of the emissions (Nordhaus, 1990a).

Nordhaus's detailed estimates confirm the more impressionistic estimates referred to earlier. They demonstrate that modification of the CO_2 emissions sufficient to slow significantly the rise in CO_2 concentration and postpone doubling it for several decades would be far more expensive in terms of the real resource costs to society than would be the damage done by a doubling of CO_2 emissions. However, Nordhaus shows there is a case for a much more modest reduction in GHG emissions, at least if the reduction is concentrated on low-cost measures, notably the elimination of CFCs (which there is a case for doing anyway on other grounds, namely the threat to the ozone layer), and the prevention of uneconomic deforestation. In addition, a cut in CO_2 emissions of about 10% would also be justified.

Thus if carbon taxes were raised to the levels necessary to bring about a 50% reduction in GHG emissions, which many environmentalists advocate but which is well beyond the Nordhaus estimates of the optimal reduction, the net losses to the world as a whole could be very large indeed. The costs of reducing GHG emissions will rise sharply the greater the reduction achieved. For example, estimates of the carbon taxes needed to reduce CO_2 emissions by 50% usually put the taxes in the region of a few hundred dollars per ton of carbon, which usually translates into taxes of 400–500% on the net (of tax) price of energy.

One recent comprehensive survey of the "costs" of attempts to reduce carbon emissions by 50% arrives at the conclusion that the estimates show ". . . that an abatement of 40 to 50 percent relative to base might *tentatively* be expected to reduce long-run GDP by no more than 3 percent."[25] If GNP grew at a compound rate of 1.5% per annum this would amount to only a $1.3 trillion loss if applied to GNP in 40 years. But cumulating a 3% loss over the whole intervening period would imply a total loss of up to $40 trillion depending on exactly how it was spread out over time. Other estimates, notably those by Whalley and Wigle, arrive at the conclusion that the taxes required to reduce emissions by 50% would lead to net economic welfare losses over 1990–2030 of about $18 trillion, or about 4% of their estimate of total world output over the same period (Whalley and Wigle, 1990). A survey of estimates for the United States of similar cuts in emissions point to a somewhat lower figure in the region of 1–2% of US GNP, but, as the authors of this survey point out ". . . the taxes and output losses in other areas of the world would have to be substantially higher, because these areas are already more energy-efficient than North America and so face higher costs of further reductions in fossil fuel use."[26] Thus, there is in fact a certain amount of convergence in the estimates of the orders of magnitude involved in a 50% cut in CO_2 emissions around the figure of about 3–4% of cumulative GNP over the next 40 years, which translates into about $20–40 trillion.

Of course, the margin of error in all such estimates must be substantial. Among other things it will depend on the type of measures adopted. If some tax-based policy is adopted — which would be the cheapest policy — much will depend on what is done with the revenues. If they are handed back in ways that reduce other taxes they would tend to reduce other distortions in resource allocation. On the other hand, the issue here is not just a shift in taxes on final output but the imposition (or increase) of a tax on a basic input into the productive system, namely energy, and the shift away from cheap coal to more expensive, if less carbon-intensive, forms of energy. As Bruno and Sachs have shown, in connection with the effects of the oil shocks, a cut in energy inputs can have a significant effect on total output.[27] But, again, it may well be that reductions in taxes on other basic factor inputs would offset some of the negative effects of a cut in energy inputs and a switch to more costly forms of energy.

Furthermore, there is great uncertainty as to the econometric estimates of key components of any such exercise. For example, there is a wide variety of estimates on the sensitivity of response

of CO_2 emissions to alternative taxes on carbon, or some corresponding price mechanism disincentive.[28] Depending on the elasticities of response of fossil fuel use to alternative taxes one would arrive at alternative estimates of the costs to society of this particular method of reducing GHG emissions. These costs are difficult to estimate even without uncertainty as to the elasticities.

Nevertheless, it is fairly clear that the costs that would be incurred by even the most efficient policy — the use of a carbon tax — to cut CO_2 emissions by 50% would be greater than the damage that global warming would do — i.e., about 3–4% of GNP as compared with damage on the order of 0.1–0.2% of GNP, or a ratio of about 20 or 30 to 1. If the cuts were to be achieved partly or largely by regulation as distinct from a carbon tax, the costs would be far greater. Thus it is clear that, whatever the margins of error involved, rapid draconian action is totally unjustified.

But, as indicated above, this does not mean that no action is justified. For example, along with the elimination of CFCs, ending the subsidization of heavily carbon-intensive forms of fuel production and use, and stopping uneconomic deforestation, there are other possible "no regret policies" that would encourage the greater use of economically viable technological innovations of this kind. Much is known about some of the technological possibilities, but relatively little is known about the economics of introducing them.[29]

Many environmentalists proclaim that, if only governments would take the requisite steps, there is enormous scope for economically justifiable, energy-saving techniques. The question then arises: why, if that is the case, have profit-maximizing agents failed to adopt them? There may be perfectly valid answers to this question for there is no doubt that the real world is full of market imperfections. But so far — with a few exceptions such as coal production in Eastern Europe and Germany — there is little hard evidence to confirm that such techniques are more widespread in energy production and consumption than in economic activity in general. Nevertheless, the fact that there may be considerable scope for such policies and the general uncertainty attached to technological progress in this areas strengthens the case for not rushing into very costly, early draconian action and for waiting until more knowledge has been obtained concerning alternative, cheaper ways of reducing energy use.

Furthermore, the fact that the developing world is so far behind the advanced industrial countries in energy consumption per capita suggests that more than the widespread adoption of energy-saving techniques would be needed to prevent a significant increase in world-wide energy consumption and CO_2 emissions over the course of the next century. For example, China's carbon emissions already constitute roughly 10% of world total and half that of the United States. But China's emissions per capita are just over one-tenth of those of the United States. Hence, if nobody else increased their carbon emissions at all, and China raised its per capita emissions to half of the US level total world emissions would rise by about 40%! Clearly, encouraging housewives in advanced countries to put the lids on their saucepans when cooking or to insulate the lofts of their houses is not likely to make any impact on emissions in a world in which the developing countries will be increasing their emissions on a massive scale.

(e) *Uncertainty and choice*

It is sometimes argued that since the climate change effect of GHG emissions is irreversible in a relevant time period and that it just *might* be catastrophic — all the evidence above to the contrary — it is urgent that action be taken without delay. This argument is false for, as Arrow and Fisher put it, "Just because an action is irreversible does not mean that it should not be undertaken. Rather, the effect of irreversibility is to reduce the benefits, which are then balanced against costs in the usual way . . . Essentially the point is that the expected benefit of an irreversible decision should be adjusted to reflect the loss of options it entails."[30] If human beings took no action that would have irreversible consequences the human race would have ceased to exist a long time ago!

Of course, it is difficult to apply this sort of analysis to cover the case of catastrophe, particularly when, in addition, there is no statistical basis for assessing the relevant probabilities. It is sometimes proposed that ". . . strong catastrophic risks should, in the limit, not be undertaken at any price" and that risk aversion should justify "prudence" even if the risks of catastrophe are minimal.[31] Nevertheless, people do not invest time or resources in measures to avoid every minuscule risk that they face, even where the consequences of their failing to do so just *might* be catastrophic and would also be irreversible. This is obvious in the way people drive! Or in the degree to which they invest in measures to ensure that, for example, their houses never burn down under any circumstances or they are never hit by

an out-of-control drunken driver while walking along the pavement minding their own business.

The conclusion that emerges from the above is that the costs of any major cut in CO_2 emissions would be incomparably greater than the damage that global warming is likely to bring, even allowing for vast margins of error in the estimates on both sides. Furthermore, the argument that, nevertheless, these costs ought to be incurred on account of uncertainty is by no means compelling. Nobody invests unlimited amounts in order to avoid a future threat, however small the risk.[32]

In particular, one must consider who would bear the burden of the investment costs. Any policy designed to bring about a rapid reduction in GHG emissions through carbon taxes or quantitative controls is likely to encounter severe conflicts of interest between different countries. For example, countries such as China and — to a lesser extent — India, that have vast cheap coal resources, or oil-dependent countries, would stand to lose from policies aimed at reducing dependence on carbon-intensive fossil fuels. The industrialized countries of the world, with two or three exceptions, are not relatively large producers of fossil fuels. Hence, measures to impose taxes on carbon may be relatively harmless in the Netherlands or Sweden but would have very serious consequences for China, India, countries totally dependent on oil exports, and some Eastern European countries.

Furthermore, even in the most unlikely event that some internationally acceptable transfer mechanism could be negotiated for compensating the latter countries for the impact of measures to reduce rapidly world CO_2 emissions, if this is designed to further raise the standard of living of future generations by protecting their environment, an alternative use of resources is to improve the environment in developing countries today. For it is arguable that the environmental conditions therein are incomparably more serious in terms of welfare losses than any of the losses arising from global warming.

4. ECONOMIC GROWTH AND THE ENVIRONMENT IN DEVELOPING COUNTRIES

Although environmental data are subject to enormous conceptual and practical difficulties, in comparison to the uncertainties attached to the global warming threat the present environmental position of the developing world is fairly clear.

(a) *Water supply, sanitation, and health*

In spite of the data difficulties three points concerning water supply and sanitation in developing countries can be firmly established. First, water supply and sanitation are still major problems, with at least one billion people in developing countries not having access to safe drinking water, and at least two billion having no access to satisfactory sanitation.[33] Although during the 1980s water supply was provided for an additional 730 million people in developing countries, and sanitation for another 400 million, this was barely enough to keep pace with the increase in population in these countries. Indeed, the number of people without satisfactory sanitation in developing countries rose by nearly 300 million in the 1980s. Given the expected future growth of population, it is expected that by the year 2000 there could still be well over a billion people without adequate water supplies and more than double that without sanitation, chiefly in Africa and Asia.[34]

Second, the serious welfare effects on developing countries of inadequate water and/or sanitation supplies are indisputable — in spite of much uncertainty concerning the precise relationship between water supplies and health. For example, it appears that about 1–1.5 billion people are affected by water-related diseases in one form or another — notably schistosomiasis, hook-worm, diarrhea, ascariasis, guinea worm, and trachoma.[35] Diarrhea, which has a strong relationship to clean water supplies and sanitation facilities, is estimated to cause about five million infant deaths per annum.[36] For example, in Algeria, where the relationship between water-related disease and the degradation of water supplies is well documented, about one-third of all infant deaths are attributed to diarrhea. In fact, in the areas most affected by worsening water supplies, water-related diseases account for about three-quarters of all reported sickness.[37] In Pakistan, nearly half of infant deaths are attributed to the same cause. It is not only children who are at severe risk as a result of diarrhea. For example, in Bangladesh, diarrheal diseases also account for about one in five deaths in all age groups over five years.[38]

Third, even though over a certain range of incomes economic growth can lead to a short-term worsening of some features of the environment, it is quite clear that, over the medium to longer run there is a positive relationship between income levels and water supplies and access to decent sanitation. Table 1 shows the percentage of the population with access to safe drinking water in countries with different income

Table 1. *Income levels and access to safe drinking water, 1975 and 1985**

Quintile	1975 Average income	1975 Water access	1985 Average income	1985 Water access
1	$206	25%	$224	39%
2	$342	25%	$373	48%
3	$692	35%	$746	48%
4	$1,094	48%	$1,209	60%
5	$2,381	75%	$3,372	87%

*Quintiles are based on income ranking for 1985 in $US 1987, and all income figures are in $US 1987. Water access refers to the percentage of the total population of the countries in question having access to safe drinking water. For definitions and sources see World Resources Institute (1990), Table 16.4 and pp. 265–266.

levels, in 1975 and 1985. As one would expect, higher incomes tend to be associated with a higher proportion of the population having access to safe drinking water.[39] There has also been some progress in almost all countries over 1975–85, in spite of the rapid growth of population of most developing countries during this period. It can be seen that there is a generally much higher percentage of the population with access to safe drinking water in the top two quintiles, and that in all quintiles the rise in incomes between 1975 and 1985 was accompanied by a rise in this percentage.

Although satisfactory sewerage and sanitation arrangements are more difficult to define and hence to represent in a simple number, Table 2 also confirms what one would expect, namely that an increase in incomes is the best way of attaining levels of access to the sanitation facilities that most people in advanced countries would take for granted as normal attributes of a minimum standard of living. Of course, in the large cities in many developing countries, the pace of urbanization and very rapid population growth have meant that sanitation and waste disposal arrangements have been totally unable to cope with the additional demands. In these cities, the services are not even up to the levels normally associated with medium-income countries. For example, even in Thailand, where the growth of prosperity has been remarkably sustained, it is estimated that in Bangkok only 2% of the population is connected to sewers.[40]

(b) *Air*

The air pollution picture is very similar. As far as sulphur dioxide (SO_2) and suspended particulate matter (SPM) or smoke are concerned, if cities are grouped into broad bands corresponding to the income levels of their countries an interesting pattern emerges. Data for the earlier years (between 1977 and 1981 depending on the cities in question) show that cities in countries classified by the World Bank in its *World Development Reports* as "low-income countries" had lower ambient concentrations of SO_2 than cities in "middle-income countries," which in turn had lower concentrations then cities in "high-income countries."[41] But about ten years later (usually mid or late 1980s) the position had been reversed. This corresponded to a decline in SO_2 concentrations of about 9% per annum in the high-income countries and a rise of about 3.7% in the low-income countries. Taking all 33 cities covered in the Global Environment Monitoring System (GEMS) data on SO_2 ambient air quality ". . . 27 have downward (at least 3% per

Table 2. *Income levels and access to sanitation, 1980 and 1985**

Quintile	1980 Average Income	1980 Urban Access	1980 Rural Access	1985 Average Income	1985 Urban Access	1985 Rural Access
1	$211	33%	9%	$236	51%	11%
2	$404	52%	28%	$420	55%	28%
3	$785	53%	15%	$790	68%	41%
4	$1,178	78%	35%	$1,313	85%	50%
5	$2,814	85%	49%	$3,140	87%	57%

*Incomes in same units as in Table 1. Access numbers relate to percentage of the population with access to sanitation. For definitions and sources see World Resources Institute (1990), Table 16.4 and pp. 265–266.

year) or stationary trends and 6 have upward trends (at least 3% per year) with most improvements noted in cities of developed countries."[42] While the trends over time are similar for SPM or smoke, in that they moved more sharply downward in the richer countries, and upward in the poorest countries, even in the earlier years the cities in low-income countries had far higher concentrations of SPM and smoke than did cities in the middle or high-income countries.

The picture is slightly more confused when one turns to two other pollutants, namely carbon monoxide (CO) and nitrous oxides, since emissions of these, particularly CO, are heavily influenced by automobiles — both the numbers and the speeds at which they are able to circulate.[43] Nevertheless, some overall difference can be observed between poor and rich cities. For example, although there are some exceptions — notably London, Frankfurt and Amsterdam — trends in ambient nitrous oxide concentrations in most other developed countries' cities are now stable or declining, in spite of sustained increases in automobile numbers. In contrast, although data are scarce it appears that concentrations are generally rising in cities in developing countries.[44] The picture is roughly the same for CO ambient concentrations. Data are only available for cities in 11 countries and CO concentrations are declining in all of them. With one exception — Santiago — the cities are all in high-income countries. In contrast, fragmentary data for a few individual cities in developing countries confirm the rise in concentrations of these pollutants.

Another important pollutant from mobile sources has been lead. Here, again, it appears that the surest route to a cut in the lead content of gasoline is a fast growing, or rich, economy. GEMS reports that "Few developing countries have yet made significant reductions in petrol lead content . . ."[45] There has been no or a negligible fall in lead levels in gasoline in Africa, Latin America, and the Caribbean, whereas there has been a big fall in Europe and North America, and quite a big fall in Asia, even without taking account of the consumption of unleaded gasoline in these countries.[46]

In general, therefore, as with access to safe drinking water or sanitation, although one cannot say precisely how overall "air quality" should be defined, or at exactly what income level individual aspects of air quality begin to improve with further growth, it is fairly clear that the correlation is positive. Taking the main environmental indicators together, therefore, the exact point, or income level at which environmental conditions reach a stage when effective policies are introduced will depend on a host of variables, including technical, social and political variables. But as far as these components of the environment are concerned it is fairly clear that the best way to improve the environment of the vast mass of the world's population is to enable them to maintain economic growth. Some developing countries may go through a transition period when population is still rising fast — particularly in the cities — and before environmental protection measures have been effectively implemented. But the strong correlation between incomes and the extent to which environmental protection measures are adopted demonstrates that, in the longer run, the surest way to improve your environment is to become rich.[47]

5. THE INTERGENERATIONAL CONFLICT

Finally, one hears on all sides the claim that by damaging the environment we are depriving future generations of their potential to obtain the same welfare that we enjoy today. This, in turn, is often alleged to imply that we should pursue the objective of "sustainable development."

Of course, there is a proliferation of definitions of "sustainability," but it is far from clear what concept of "sustainable development" can be both morally acceptable and operationally meaningful. The size of the morally desirable capital stock to hand on to future generations is, of course, an ethical value judgment, not a matter of statistical definition. Hence, it raises deep philosophical issues concerning the theory of distributive justice that lie far outside the competence of a mere economist, and to which Pasek addresses some remarks in another paper in this issue. But at first sight it would not appear that a "hard" and clearly defined concept of "sustainability" could be morally compelling, simply on account of its lack of permissible tradeoffs between one component of human welfare and another.

For example, one such "hard" version of the "sustainability" concept is that we should bequeath to future generations the same amount of every single component of the environment that one can identify. This definition of the capital stock is at least reasonably clear and precise, if totally impossible to measure in practice. But surely, few people would subscribe to the value judgment that passing on to posterity every single one of the over two million species of beetles that are believed to exist should be an aim of policy especially if it means prolonging the suffering imposed on millions of children in the developing

world today on account of inadequate water supplies and sanitation, health care and nutrition.

Of course, as Pearce *et al.* point out in *Blueprint for a Green Economy*, there is a whole range of definitions of "sustainability." Some of them operate under a "sustainability" constraint that might be more morally acceptable, in that they do allow for some tradeoffs.[48] For example, we might interpret the "sustainability" constraint as a requirement to leave to future generations a stock of assets that gives them some predetermined level of potential for welfare, such as that existing today. Beetles might give way to improvements in other aspects of the environment, such as clean water supplies and sanitation. But even if the difficulties of justifying this constraint in terms of some acceptable theory of intergenerational justice are easier to overcome than with the "hard" concept of sustainability, it is — as Dasgupta and Maler (1990) point out — totally devoid of informational content. In the absence of any knowledge of future preference patterns and technological possibilities it is impossible to know what substitutions would permit the same level of welfare to be obtained from different combinations of assets. More trees and fewer insects? More machines and fewer fish?

Thus the aggregative concept of global "sustainability" that is so widely encountered these days in any environmental discussion seems to be either morally indefensible or devoid of operational value. For we simply have no basis for judging what the tradeoffs would be in the future between, say, work and leisure, certain forms of economic activity and others, economic welfare versus the noneconomic welfare one may obtain from the environment, and so on. Since the goal cannot be defined, therefore, there is no answer to questions such as "how do we achieve sustainable development?" Scientists, even social scientists, should not expect to be taken seriously if they go around asking unanswerable and meaningless questions.

Once again, therefore, one is driven to the conclusion that to give priority to highly speculative global environmental issues in general and to global warming in particular, in the interests of future generations who are likely to be far richer than we are today, and to take drastic action in pursuit of this goal, however costly it may be in terms of current living standards, would represent an unjustified sacrifice of the clearly apparent interests of billions of very poor people today. This sacrifice would fall most heavily on people in developing countries, where local environmental conditions are flagrantly and incomparably worse than those that the majority of people in the advanced countries have ever experienced.

Of course, every assistance must be given to developing countries to enable them to raise their levels of energy consumption per capita, in order to achieve higher levels of prosperity. This should be done on the basis of technologies that do not waste energy and that are less intensive in carbon dioxide emissions — provided they are also economically viable. Reasonable and economically justifiable research into renewable forms of energy must also be supported, particularly as such forms of energy use appear to offer prospects of significant, economically viable contributions to energy supplies. But this is a far cry from the evangelical spirit in which the world is being asked to face up to the need for unlimited sacrifices and to mend its wicked ways if the future of the human race is to be secured.

NOTES

1. See, for example, the British submission to the 1972 UN Conference on the Human Enviroment, Stockholm, 1972; "First Report of the Royal Commission on Environmental Pollution" (1972); Warren Spring Laboratory (1972); and information given in a reply to a parliamentary question by a Minister for the environment, Mr. Eldon Griffiths, December 22, 1972 (*House of Commons Debates, Col. 1794*).

2. See for example, Ashby and Anderson (1981) and Brimblecombe (1987). For correlation between income levels and voters' attitudes toward environmental priorities see Deacon and Shapiro (1975).

3. For example, Jonathan Porritt, who was until recently the Director of Friends of the Earth, has recently argued (in the "Linacre Lectures on the Environment" in Oxford) that a cut in living standards in the more developed countries is needed in order to permit the others to have adequate access to the world's resources (*Oxford University Gazette*, November 21, 1991).

4. See his lecture to the British Association for the Advancement of Science, August 26, 1991, which was described in the following terms by various newspapers on the following day: "Earth slides into anarchy, Tickell says . . . The population explosion and the effects of global warming will bring civilization to the brink of collapse" (*The Times*). "Tickell warns of global ecology disaster" (*The Independent*). "Grim prophecy of ruinous famines for overloaded Earth" (*The Daily Telegraph*).

5. However, it may indirectly raise problems of conflict of interest. For example, if it is true that the rich countries would have to reduce their living standards in order to make limited resources available for the growth of the developing countries, this would be fiercely resisted by the poorer groups in the advanced countries and the developing countries who would realize — as they did in the 1972 World Environment Conference — that their economic growth would be unattainable without continued growth in their markets in the developed world.

6. See, in particular, the brilliant contribution to our whole understanding of the relationship between famines and the physical balance between food supplies and demand in Drèze and Sen (1991).

7. See the survey of earlier predictions of the imminent exhaustion of mineral resources in Beckerman (1974) and (1975), chapter 8.

8. In her Christmas message to the people of the Netherlands, Queen Beatrix said, ". . . The Earth is slowly dying, and the inconceivable — the end of life itself — is actually becoming conceivable. We human beings ourselves have become a threat to our planet" (quoted in Leggett, 1990, p. 113).

9. For example, while all the main models predict that there will be increased precipitation as a result of global warming, the estimated increases in precipitation range from 3% to 15%.

10. See Intergovernmental Panel on Climate Change (IPCC) (1990), p. 19.

11. See Mason (1989), Table 2, p. 428; Leggett (1990), p. 31; Lindzen (1990, 1989); and Mitchell (1989), who states ". . . the major shortcoming is our poor understanding of the processes governing the formation and radiative properties of clouds" (p. 136). One of the many reasons for this is that their impact depends partly on the precise composition of clouds and that "anthropogenerated pollutants can therefore serve to 'brighten' clouds, reflecting away increasing amounts of solar radiation, and possibly compensating for greenhouse warming. A recent calculation demonstrates that the magnitude of this effect could indeed explain the fact that the Northern Hemisphere, where most sulfate emissions occur, shows no net warming during the last half century" (Michaels, 1990).

12. There are various reasons why the data usually quoted are unreliable, such as the fact that the methods used to measure sea temperatures have changed over the decades in a manner that will have raised the recorded temperatures, or the fact that, since temperatures in cities is usually higher than in rural areas, growing urbanization will have biassed estimated land temperatures upward. See Lindzen (1990), p. 4, and White (1990).

13. Mason (1989), p. 421, and Lindzen (1990). See also the statistical criticism of the proposition that data for the past century provide evidence of an upward trend in world temperature associated with CO_2 concentrations in Solow and Broadus (1989) and (forthcoming).

14. This is also the prediction reported at the recent Sundsvall meeting, held to produce the final report of the Intergovernmental Panel on Climate Change (IPCC) set up in 1988 under the auspices of the UN Environment Program and the World Meteorological Organization.

15. Experiments at the US Water Conservation Laboratory have shown enormous increases in plant growth as a result of increased CO_2 concentrations. In other words, with higher CO_2 concentrations the same plant growth can be obtained with less water. See White (1990), p. 23. However, such experiments under somewhat artificial conditions are not a totally reliable guide to the effects of a genuine global rise in CO_2 concentrations, as has been pointed out in a survey of various experiments by Easterling, Parry, and Crosson (1989), p. 98.

16. The estimates of an approximately zero net effect on agricultural output made by the EPA in 1988 (Smith and Tirpack, 1988, pp. 21–22) have been confirmed in a more recent and very detailed study, breaking down the United States into a large number of regions and using alternative climate models (see Adams, *et al.*, 1990, pp. 219–224).

17. See Cline (1989), p. 23.

18. Nordhaus (February 1990), p. 27 and (1991).

19. Nordhaus (March 1990), p. 10. Exactly the same conclusion is reached by Cline (1989), p. 23.

20. See Solow and Broadus (forthcoming). IPCC (1990), p. 1; and Mason (1989), p. 431. More recent research suggests that much smaller rises in the sea level would be associated with a 3°C increase in temperatures (see reports in *The Times* and the *Independent*, January 4, 1991).

21. Mason (1989), p. 431, and McClaren, Barry, and Bourke (1990), p. 762. Even back in 1988 — which is a long time ago given the speed of downward revision of predictions in this field — it was thought that "Changes in the mass balance of antarctic ice will probably have little impact on SLR [sea level rise] in the next few centuries . . .. Indeed, it is possible that an increase of precipitation over Antarctica due to climate change could act to reduce the rate of SLR" (Hekstra, 1989), p. 54. This publication was a report of a conference in June 1988).

22. Cline (1989), p. 18.

23. IPCC (1990), p. 18.

24. For a much more detailed discussion of both conceptual and statistical limitations on the available estimates see Beckerman (1991).

25. Winters, Boero, and Clarke (1991), p. S16.

26. OECD (1991), p. 105, and p. 121, note 82.

27. Bruno and Sachs (1985), especially chapters 1 and 2.

28. In a survey of some of the estimates, Barker (1991) points out that estimates for the United Kingdom alone of the tax rates needed to achieve the Toronto target of cutting GHG emissions by 20% below 1988 levels by the year 2005 varied from 41% on coal (and less on other fossil fuels) in Scott Barrett's work through anything from 123% to 277% on coal (depending on timing assumptions) in Ingham and Ulph, up to about 600% in Capros *et al.*

29. A very detailed summary of some of the most important British work in this field is contained in Leach and Nowak (1990), and Barbier, Burgess, and Pearce (1990). See also Fulkerson, Judkins, and Sanghvi (1990), and Anderson, and Bird (1990).

30. Arrow, and Fisher (1974). A very sound outline of some of these issues in relationship to environmental disaster in developing countries is contained in Anderson (1990).

31. See, for example, Collard (1988); Pearce, Markandya, and Barbier (1989), especially pp. 16–17. A recent summary discussion of this issue is in Pearce and Turner (1990), especially pp. 314–320.

32. The insurance premium analogy, which is sometimes quoted in this regard is not really applicable. Insurance usually means that, in the event of the unfavorable event taking place, the insured party will be compensated, so that it makes no difference to him or her, once insured, whether it occurs or not. Here, the proposition would be that present generations invest in a manner designed to narrow the range of future outcomes regarding climate change, thereby cutting out possible very harmful extremes. It is an investment rather than an insurance premium.

33. These are the estimates contained in *Global Consultation on Safe Water and Sanitation for the 1990s* (1990). These estimates, which were published in 1990, were lower than World Bank estimates published in 1988, both for 1980 and for projections to 1990. The former are probably more consistent with another estimate according to which over 1.5 billion people in the world still do not have access to safe drinking water, in Briscoe and de Ferranti (1988).

34. *Global Consultation on Safe Water and Sanitation for the 1990s* (1990), p. 5. Estimates from this document have to be based on the charts contained therein and so are about as rough as the basic reliability of the data justify. The projections quoted above for numbers without access to safe drinking water or satisfactory sanitation in the year 2000 are lower than those made in World Bank (1988), Annex 1.

35. Briscoe and de Ferranti (1988), p. 1; a breakdown by these diseases is given in Esrey, Potash, Roberts and Shiff (1990), p. vii, but no total is shown. Presumably there is considerable overlap in that people suffering from one of the diseases are also likely to be suffering from one or more of the others.

36. This estimate refers to mortality among children below five years of age. See Esrey *et al.* (1990) and Snyder, and Merson (1982), pp. 605–613.

37. World Bank (1989), p. 65.

38. Aziz *et al.* (1990), p. 10.

39. For the reasons given above, figures for individual countries are not strictly comparable, so that a more reasonable picture of the income/water supply relationship is provided by grouping countries into broad income bands.

40. World Bank (1991), p. 5.

41. In World Bank (1990) a high-income country is defined as one with a per capita GDP of over $6000, and a low-income country is one with a per capita income of less than $700. Air quality data have been taken from the Global Environment Monitoring System (GEMS) (various issues), and United Nations Environment Program (1991).

42. UNEP (1991), and GEMS (1988), p. 15.

43. Up to a point the emission of pollutants from an automobile falls off rapidly as its speed increases, so that a major cause of urban air pollution from automobiles is traffic congestion. See Asif Faiz, Sinha, Walsh, and Varma (1990), Tables 19, 20, and 21, pp. 42, 43, and 46.

44. GEMS (1988), p. 43. Even here, however, there are notable exceptions, namely Singapore.

45. GEMS (1988), p. 60.

46. GEMS (1988), p. 60.

47. See also correlations confirming the positive intercountry relationship between per capita income levels and the stringency of environmental protection measures in Walter and Ugelow (1979), pp. 102–109.

48. Pearce, Markandya and Barbier (1989), Annex 1.

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