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LIMITS TO GROWTH, SUSTAINABLE DEVELOPMENT AND ENVIRONMENTAL KUZNETS CURVES: AN EXAMINATION OF THE ENVIRONMENTAL IMPACT OF ECONOMIC DEVELOPMENT

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The nature of the relationship between economic development and the environment has been discussed since the 1960s, yet opinion remains divided. This paper provides a comprehensive analysis of the relationship between economic growth and environmental degradation and begins by reviewing the largely theoretical discussions from the 'limits to growth' debate of the 1970s to the advent of sustainable development in the 1980s. The paper then examines the recent studies that have subjected the growth – environment relationship to a statistical analysis through the estimation of environmental Kuznets curves (EKCs). The extent to which these studies indicate a decoupling of environmental damage from growth is considered and reasons are suggested why some environmental indicators appear to improve with growth whilst others deteriorate. In order to illustrate the need to interpret EKCs carefully, forecasts of global emissions are made, for the period 1990–2020, for two pollutants that EKCs suggest are being decoupled from economic growth. Policy implications are then discussed.

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INTRODUCTION

Despite receiving considerable attention in the 1960s and 1970s, the nature of the relationship between economic development and the environment continues to generate debate. On the one hand global institutions and national governments typically argue that only economic growth can provide the resources with which to tackle environmental problems. In contrast, many environmentalists claim that industrial expansion is the root cause of environmental degradation and should therefore be restrained.

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This paper provides a comprehensive analysis of the relationship between economic growth and environmental degradation and begins by examining the literature that has developed on this topic from the 'limits to growth' debate of the 1960s and 1970s to the rise of the notion of sustainable development in the 1980s. With these largely theoretical arguments in mind, the paper then reviews the numerous empirical studies that, in recent years, have statistically examined the historical relationship between economic growth and a wide range of environmental indicators. These studies assess the proposition that, in the early stages of a country's economic development, economic growth increases environmental degradation, but once a certain level of development is attained, further economic growth actually serves to benefit the environment. Thus, by assessing whether there is an inverted-U shaped relationship between economic growth and environmental degradation, these studies indicate to what extent environmental damage is being decoupled from economic growth.[1] The reasons why some environmental indicators appear to have improved with economic growth, whilst others have worsened, are suggested. Finally the paper forecasts global emissions of two pollutants for the period 1990–2020 and illustrates why the existence of an inverted-U shaped relationship between economic growth and environmental degradation requires careful interpretation.

THE 'LIMITS TO GROWTH' DEBATE

With a few notable exceptions, the relationship between economic growth and the environment received little attention prior to the 1960s.[2] The publication of Rachel Carson's *Silent Spring* in 1962, however, increased public awareness considerably by examining the impact of man's indiscriminate use of chemicals in the form of pesticides and insecticides.

Perhaps as a result of *Silent Spring*, environmental issues received growing attention throughout the 1960s. In 1966, Kenneth Boulding produced his seminal article 'The economics of the coming spaceship Earth', in which he highlighted the danger of steadily increasing production levels, both in terms of reducing finite resource stocks and in terms of environmental pollution. Boulding described the current economy as the 'cowboy economy', believing it to be characterized by reckless and exploitative behaviour. The volume of production is the cowboy economy's measure of success and should be maximized accordingly. This is in contrast to the future 'spaceship economy', which will have to be self-sufficient and hence will aim to *minimize* economic throughput. It is interesting to note that Boulding did not believe it would be very long before the cowboy economy was replaced by its new incarnation. 'The shadow of the future spaceship, indeed, is already falling over our spendthrift merriment [although] it seems to be in pollution rather than exhaustion that the problem is first becoming salient' (Boulding (1966) from Daly and Townsend, 1993, p 307).

With these concerns in mind, in 1972 Donella and Dennis Meadows and a team from the Massachusetts Institute of Technology produced a report for the Club of Rome's Project for the Predicament of Mankind entitled *The Limits to Growth*. A world model was constructed to estimate the future impact of continuous exponential growth under a number of different assumptions. The 'standard' world model assumed that the physical, economic or social relationships that have historically governed the development of the world system would remain effectively unchanged. Additionally, this model assumed that population and industrial capital would continue to grow exponentially, leading to a similar growth in pollution and in demand for food and non-renewable resources. The supply of both food and non-renewable resources was assumed to be fixed. Not surprisingly given the assumptions, the model predicted collapse due to non-renewable resource depletion.

The radical nature of the report attracted much attention, not only in academic circles, but also in society at large. As a result, *The Limits to Growth*

[1]This inverted-U relationship is often known as an environmental Kuznets curve (EKC) after the original Kuznets curve which postulated an inverted-U relationship between *per capita* income and income inequality (Kuznets, 1955).

[2]One such exception is the classical economist John Stuart Mill. Writing in 1848, Mill comments 'Nor is there much satisfaction in contemplating the world with nothing left to the spontaneous activity of nature; with every rood of land brought into cultivation . . . every flowery waste or natural pasture ploughed up, all quadrupeds and birds . . . exterminated and scarcely a place left where a wild shrub or flower could grow . . .' (Mill, 1871, p 331).

fuelled a debate that continued throughout the 1970s. A major critique of the report came from Cole *et al*. (1973), who were based at Sussex University's Science Policy Research Unit. Their criticism firstly concerned the model's preoccupation with purely physical factors, a weakness recognized by Meadows *et al.* Secondly, Cole *et al.* questioned the model's assumptions, particularly the assumption of finite limits to non-renewable resource stocks. Indeed, Cole *et al.* re-ran the model with the assumption of continual exponential increases in resource stocks, through new discoveries and recycling, and produced altogether different results.

The contrasting viewpoints in the debate that followed can be seen to stem from differing opinions concerning three factors: the rate of technical progress; future changes in the composition of output and the possibilities of substitution (Lecomber, 1975). 'If these three effects add up to a shift away from the limiting resource or pollutant equal to or greater than the rate of growth, then the limits to growth are put back indefinitely.' (Ekins, 1993, p 271). However, for Lecomber (1975, p 42) the point to be stressed is that 'this establishes the *logical* conceivability, not the certainty, probability or even the possibility in practice, of growth continuing indefinitely'. He goes on to distinguish between resource optimists and pessimists:

> The optimists believe in the power of human inventiveness to solve whatever problems are thrown in its way, as apparently it has done in the past. The pessimist questions the success of these past technological solutions and fears that future problems may be more intractable' (Lecomber, 1975, p 45).

A different perspective on the growth debate is provided by considering the second law of thermodynamics, also known as the entropy law.[3] Georgescu-Roegen (1973) is primarily associated with work of this nature and utilized the second law to emphasize the physical limits to the economy. Rees (1990) clarifies the meaning of the second law: 'The second law states that in any closed isolated system, available energy and matter are continuously and irrevocably degraded to the unavailable state'. Furthermore, 'Since the global economy operates within an essentially closed system, the second law is actually the ultimate regulator of economic activity' (Rees, 1990, p 19). As Daly (1973) states, entropy may be considered to be a measure of the unavailable energy within a closed thermodynamic system. To use Georgescu-Roegen's (1973) example, a piece of coal contains available, or free, energy and therefore has low entropy. However, once that coal is burned the energy is no longer available, but has become dissipated in the form of smoke, heat and ashes. The energy is now bound and hence has high entropy i.e. the coal has now become waste.

As Georgescu-Roegen states, man has access to two sources of free energy (low entropy). Firstly there is the terrestrial stock of mineral deposits, and secondly the flow of solar energy, which allows the 'production' of renewable resources. An economy fuelled by solar energy is constrained only by the limited flow of that energy; hence it is the fixed nature of the terrestrial stock which is the ultimate regulator of economic activity. Furthermore, 'Growth in physical production and throughput that is not based on solar energy must increase entropy and make environmental problems worse, implying an eventual limit to such growth.' (Ekins, 1993, p 272). Attempts to increase the efficiency of energy use simply have the effect of achieving a net economy of low entropy. Whilst this is clearly necessary, it is not sufficient. As Georgescu-Roegen (1976) points out, an unwelcome implication of the entropy law is that *all* of man's activities *must* result in an entropic deficit for the entire system. 'If there were not this entropic deficit we would be able to convert work into heat, and, by reversing the process, to recuperate the entire initial amount of work' (Georgescu-Roegen, 1976, p 10).[4]

In view of the implications of the entropy law, Herman Daly advocates that unrestrained

[3]The first law of thermodynamics states that energy can neither be created nor destroyed, thereby implying that economic activity is not damaging to energy stocks. However, the second law clarifies the point by stating that, whilst energy cannot undergo a *quantitative* change, it can change *qualitatively*. Economic activity transforms *free*, or available, energy into *bound*, or unavailable, energy.

[4]As a result, Georgescu-Roegen claims that the entropy law is the root cause of economic scarcity: 'Were it not for this law, we could use the energy of a piece of coal over and over again . . .' (p 9).

economic growth should be replaced by a steady (or stationary) state, defined as 'a constant stock of physical wealth (capital), and a constant stock of people (population)' (Daly, 1973, p 15). For both stocks to remain constant, the rate of inflow must be equal to the rate of outflow, i.e. the birth rate must equal the death rate and the level of depreciation must equal the rate of production.

Clearly, the economic and environmental implications of a steady state economy are likely to be numerous and far reaching. However, Daly stresses that a steady state does not hold constant knowledge, technology, the distribution of income or the allocation of resources. He therefore claims that a steady state economy will develop qualitatively rather than quantitatively.

THE RISE OF SUSTAINABLE DEVELOPMENT

The advent of the 1980s saw attention turn from the limits to growth arguments of the 1970s towards the notion of sustainable development. The term 'sustainable development' appears to have been first advanced in 1980 by the International Union for the Conservation of Nature and Natural Resources (Ruttan, 1994), although it was the *Brundtland Commission Report* (WCED, 1987) that brought the concept to the top of the agenda of institutions such as the United Nations and the World Bank. Since the *Brundtland Report* the goal of sustainable development has been adopted by an ever-increasing number of organizations and bodies.

The popularity of sustainable development would seem to belie, or is perhaps indicative of, the vagueness of the term. Pretty (1995) claims there have been over 70 definitions of sustainable development since the *Brundtland Report*, and comments 'The implicit assumption is that it is possible to come up with a single correct definition' (Pretty, 1995, p 11). Pretty clearly believes such a task to be impossible and quotes Campbell (1994) as stating 'attempts to define sustainability miss the point that, like beauty, sustainability is in the eye of the beholder. . .' (p 11). The amorphous nature of the concept means that it is impossible to state the precise relationship between sustainable development and economic growth although, as shall be seen below, certain general viewpoints may be defined. Opponents of sustainable development use its ambiguity as ammunition, however, claiming such a vague concept to be meaningless. Wilfred Beckerman, continuing his pro-growth stance adopted in the 1970s, clearly holds such a view and believes sustainable development to be 'devoid of operational value' (Beckerman, 1992, p 491). Others are critical of the 'watered down' interpretation of sustainable development that has been adopted by the political mainstream, believing it to provide little scope for environmental improvement.

Despite the countless definitions, a key characteristic of virtually all versions of sustainable development is the principle of equity. Such a notion of equity includes not only providing for the needs of the least advantaged in *today's* society (intragenerational equity), but also extends to the needs of the next generation (intergenerational equity). Although it is generally agreed that the most appropriate mechanism for ensuring the well-being of future generations is to ensure that the next generation has access to a stock of capital at least as large as the current stock, two viewpoints emerge regarding the precise nature of the capital stock which is to be maintained. These differing viewpoints allow a distinction to be drawn between 'weak' and 'strong' forms of sustainable development (see, for example, Pearce, 1993).

The capital stock consists of man-made capital (such as the means of production, infrastructure and human capital) together with natural capital (such as fossil fuels, habitat and clean water). Proponents of 'weak' sustainable development simply require that the *aggregate* capital stock be maintained and thus believe that a fall in natural capital can be compensated by an increase in man-made capital. In contrast, the strong sustainability school questions the substitutability between these two forms of capital and hence believes it insufficient to simply maintain the aggregate capital stock irrespective of the relative size of its constituents.

With regard to the relationship between economic growth and the environment, the two viewpoints again differ. Typically, the 'weak' sustainable development position is that economic growth and environmental health are often complementary. By this definition, the recommendations of the *Brundtland Report* would

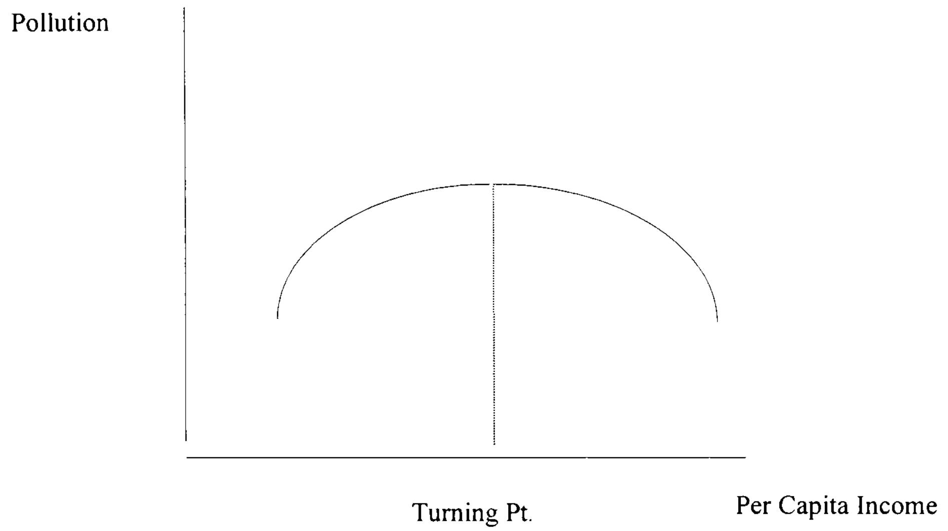

Figure 1. An inverted-U shaped relationship between pollution and *per capita* income.

fall into the weak sustainability category since it actually called for 'more rapid economic growth in both industrial and developing countries.' (WCED, 1987, p 89). Indeed, most governments and global institutions also see no conflict between economic growth and place great faith in future technological advance and in our ability to find substitutes for scarce resources. Many believe there to be an inverted-U shaped relationship between pollution and production, as illustrated in Figure 1, and use this as evidence of our ability to decouple pollution from production. Proponents of this viewpoint typically argue that the early stages of economic development see a positive relationship between economic growth and pollution. However, as a country develops and the more basic needs of the population are met, individuals begin to demand a cleaner environment. Furthermore, since economic development provides increasing resources with which to tackle environmental problems, the result is often the development of environmental regulations.

This inverted-U relationship is also known as the EKC relationship and will be examined in detail below.

The 'strong' sustainability school believes that the only way to achieve reductions in the scale of materials and energy throughput is to reduce the scale of economic output. Concentrating on sink limits rather than resource exhaustion, supporters of this viewpoint (e.g. Daly and Cobb, 1989) are therefore sceptical of the potential for decoupling and point to the risk of irreversibility associated with damage to the natural environment. Furthermore, Rees (1990) believes that as sustainable development has been increasingly adopted by the political mainstream, its meaning has moved ever further from its true goal of achieving ecological sustainability. He comments 'to those who regard present levels of industrial activity as the root cause of global environmental decline, the [Brundtland] Commission's appeal for a 'revitalisation' of economic growth . . . seems paradoxical at best' (Rees, 1990, p 18). Rees concludes that sustainable development must be 'development that minimises resource use and the increase in global net entropy' (p 9).

ENVIRONMENTAL KUZNETS CURVES

Clearly, there remains a great deal of uncertainty surrounding the impact of economic growth on the environment. However, in recent years, the availability of environmental data has improved considerably and it is now possible to assess the extent to which pollution is being decoupled from economic growth.

A number of recent studies (Cole *et al.*, 1997; Grossman and Krueger, 1995; Selden and Song, 1994; Holtz-Eakin and Selden, 1992; Shafik, 1992)

Table 1. Estimated turning points (1985 US $).

Environmental indicator	Cole *et al.*	S&S	H-E&S	Shafik	G&K
Sulphur dioxide	$6 900	$8 916		$3 670	$4 053
Sulphur dioxide – transport	$9 800				
Particulate matter	$7 300	$9 811		$3 280	$6 151
Particulate matter – transport	$18 000				
Nitrogen oxides	$14 700	$12 041			
Nitrogen oxides – transport	$17 600				
Carbon monoxide	$9 900	$6 241			
Nitrates in river water	$25 000 P				$10 524
Faecal coliform in rivers					$7 955
Lead in rivers					$1 887
Mercury in rivers					$5 047
Arsenic in rivers					$4 900
Carbon dioxide	$62 700 P		$35 428 P & $8 million P	No turning pt	
Total energy use	$34 700 P				
CFCs & halons 1986	No turning pt				
CFCs & halons 1990	$12 600				
Transport energy use	$4 million P				
Traffic volumes	$65 300 P				
Municipal waste	No turning pt			No turning pt	

Cole *et al*. refers to Cole *et al*. (1997), G&K refers to Grossman and Krueger (1995), Shafik refers to Shafik (1994) and S&S refers to Selden and Song (1994). All estimated turning points are in 1985 US dollars. All air pollutants considered by Cole *et al*. and Selden and Song are measured as *per capita* emissions. Other studies examine *concentrations* of air pollution in urban areas. All river pollutants are measured as concentrations.

have therefore econometrically estimated the relationship between *per capita* income and various environmental indicators to ascertain whether the EKC relationship actually exists.

Typically, an equation (either in logs or levels) of the following form is estimated using cross-country time series data:

$$e_{it} = (\alpha + \beta_i F_i) + \lambda y_{it} + \delta (y_{it})^2 + \varepsilon_{it} \qquad (1)$$

where e_{it} denotes the environmental indicator either in *per capita* form, or in the form of concentrations, in country i, year t, y_{it} denotes *per capita* income in country i, year t, F_i denotes effects specific to country i, ε_{it} is the error term for country i, year t, $i = 1, \ldots, n$ countries and $t = 1, \ldots, T$ years.

For most environmental indicators considered in the literature, $\lambda > 0$ and $\delta < 0$ in equation (1) resulting in a maximum turning point in the estimated curve. This implies that, for each indicator, there is a level of *per capita* income beyond which, on average across the countries and years considered, the environmental indicator begins to improve. Although this would seem to support the inverted-U hypothesis, it is the size of the turning point *per capita* income level that is important.

Table 1 provides the estimated turning points from the various studies that have estimated the relationship between *per capita* income and environmental indicators. Those estimated turning points that are higher than the maximum observed income in the data set, and are therefore projected turning points, are labelled 'P'. As a point of reference, in 1992, *per capita* income (in 1985 US$) was $17 945 in the USA, $12 724 in the UK, $1282 in India and a mere $408 in Chad (Summers and Heston, 1991).

Clearly, a large number of indicators have now been examined. Sulphur dioxide, particulate matter, nitrogen oxides and carbon monoxide may be considered to be local air pollutants since they all have a detrimental impact on the locale in which they are emitted. Sulphur dioxide and nitrogen oxides are also largely responsible for acid rain and hence have a transboundary effect as well as a local effect. Cole *et al*. also consider transport generated emissions of nitrogen oxides, sulphur dioxide and particulate matter to see whether these behave differently to total emissions of these pollutants. The quality of river water has been considered by examining concentrations of nitrates, faecal coliform, lead, mercury and arsenic. Carbon dioxide, methane and CFCs are global air pollutants that are believed to be responsible for global warming, whilst CFCs also deplete the ozone layer. Total energy use, energy use from transport, traffic volumes and municipal waste may be considered to be indirect environmental indicators since their environmental impact is not as direct as that of an air pollutant, for example.

An examination of the estimated turning points allows a number of conclusions to be made regarding the relationship of these indicators to economic growth.

The distinction between local and global pollutants

The first point to note from the table is that the estimated turning points for total (as opposed to transport) emissions of all local air and water pollutants are at *per capita* income levels ranging from $3280 to $14 700, which have been passed in most developed countries.[5] This finding would appear to support those who believe that it is possible to decouple economic growth from the environment. The fact that these pollutants have a detrimental impact on the area in which they are emitted may mean that governments find inaction to be politically difficult. Furthermore, in most cases the technology to tackle local pollutants already exists. The increased demand for environmental quality that occurs at higher income levels, together with the relative ease with which greater resources can tackle local pollutants, would appear to explain the positive relationship between economic growth and these pollutants.

However, turning attention to carbon dioxide, estimated turning points are at income levels far beyond those currently experienced, indicating that emissions are still increasing in all countries. The global nature of the impact of carbon dioxide, and the lack of a direct local impact, means that governments have little incentive to *unilaterally* tackle carbon dioxide emissions. Furthermore, nations are able to free-ride by benefiting from the abatement efforts of other nations. As a result, although the existence of a turning point implies that emissions are increasing at a decreasing rate, the evidence suggests that there is likely to be a positive relationship between economic growth and carbon dioxide emissions for many years to come. The case of CFCs provides some optimism, however. A cross-section analysis conducted for 1986 indicated that emissions were increasing steadily with economic growth, with no turning point estimated. However, since the Montreal Protocol, which committed its signatories to a reduction in a number of substances including CFCs and halons, emissions of these pollutants have fallen steadily. A cross-section analysis for 1990 estimates a turning point at a *per capita* income level that has been passed in virtually all developed regions.

Clearly, multilateral action of this nature is necessary to tackle global pollutants, given the disincentives for countries to unilaterally reduce emissions.[6]

Indirect Environmental Indicators

As the table illustrates, the indirect indicators considered by Cole *et al*. all increased throughout the observed time series and hence have only *projected* turning points. Municipal waste is the exception since it has no estimated turning point with volumes of waste predicted to increase steadily with income. There is clearly little evidence of an inverted-U shaped relationship between these indicators and *per capita* income, perhaps due to the lack of a direct local environmental impact associated with each. Apart from possibly causing a loss of amenity value when disposed of in landfill, municipal waste only indirectly harms the environment by representing an increased use of resources and by generating methane when disposed of in landfill sites. Furthermore, methane is a global air pollutant and as such there is little incentive to reduce emissions unilaterally. Similarly, both energy use and traffic

[5] Athough river pollutants, by their very nature, have a transboundary impact, they can also directly affect the ecology of the locale in which they are emitted. They are therefore considered to be local, rather than global, pollutants.

[6] CFCs have proved relatively easy to reduce due to the direct substitutes which exist. The reduction of carbon dioxide emissions is more troublesome, however.

volumes may have only an indirect impact on the environment.

The Impact of the Transport Sector

With regard to pollution emissions by the transport sector, the turning points estimated by Cole *et al*. for transport generated emissions *per capita* of local air pollutants are notably higher than those estimated for total emissions *per capita* for the same pollutants. Referring to the table, estimated turning points for transport emissions occur at *per capita* income levels ranging from $9800 to $18 000 compared to the turning points for total emissions which range from $6900 to $14 700. Although the turning points for transport emissions do fall within current income levels, they indicate that *per capita* pollution emissions in the transport sector are proving more difficult to control than emissions in other sectors. The steady increase in traffic volumes throughout the time series would appear to have hampered efforts to reduce pollution through greater fuel efficiency.

Although the turning point for total energy use is beyond current income levels, energy use is increasing at a decreasing rate due to improved energy efficiency, which has seen the energy intensity of GDP (energy use/GDP) fall steadily in recent years in the developed world. However, energy use by the transport sector displays an almost linear relationship with *per capita* income, again largely due to the steady increase in traffic volumes.

Clearly, these results highlight the environmental impact of the transport sector and suggest that many transport related environmental indicators are worsening with economic growth.

The Distinction Between Pollution Emissions And Concentrations

An interesting point raised by both Selden and Song (1994) and Cole *et al*. (1997) is the distinction between pollution emissions and urban air concentrations. Selden and Song suggest that turning points for *per capita* emissions are likely to be at higher levels of *per capita* income than those for urban air concentrations since it is easier to reduce the latter than the former. Selden and Song point to a number of reasons why this may be the case, including the fact that simply constructing taller chimneys would improve urban air concentrations but would obviously not change total emissions. The results of Selden and Song and Cole *et al*. support this hypothesis since their turning points for *per capita* emissions of sulphur dioxide and particulate matter are all higher than those estimated by Shafik (1994) and Grossman and Krueger (1995) for urban air concentrations of these pollutants.

It is clear from these studies that environmental indicators do not all experience the same relationship with economic growth, with some indicators improving beyond certain income levels whilst others deteriorate with income. Furthermore, careful interpretation of turning points estimated at relatively low *per capita* income levels is needed. As mentioned above, the existence of a low turning point for pollution *concentrations* does not necessarily mean that *emissions* of the pollutant are falling. In addition, as shown below, a low turning point for *per capita* emissions does not mean that *total* emissions are falling at a global level. This latter fact stems from the skewed nature of global income distribution, with far more people possessing income levels below the global *per capita* average (approximately $4000) than above it.

Figure 2 provides a forecast of global emissions of sulphur dioxide and nitrogen oxides for the period 1990–2020. The projections were made by forecasting *per capita* income and then estimating *per capita* pollution emissions using the same sulphur dioxide and nitrogen oxide data, and the same estimated equation, as Cole *et al*. (1997). These *per capita* estimates were then multiplied by population for each region and the regions were then aggregated to provide a global level of total (as opposed to *per capita*) emissions.[7]

It is clear that both pollutants are predicted to increase throughout the period 1990–2020, despite the fact that *per capita* emissions were estimated to peak at a *per capita* income level of $6900 and $14 700 for sulphur dioxide and nitrogen oxides, respectively.

A point to note is that the inverted-U shaped relationship between pollution and income may simply result from the fact that the structure of economies changes as countries develop, with the

[7]UNEP (1993) population forecasts and World Bank (1994) forecast *per capita* income growth rates were used.

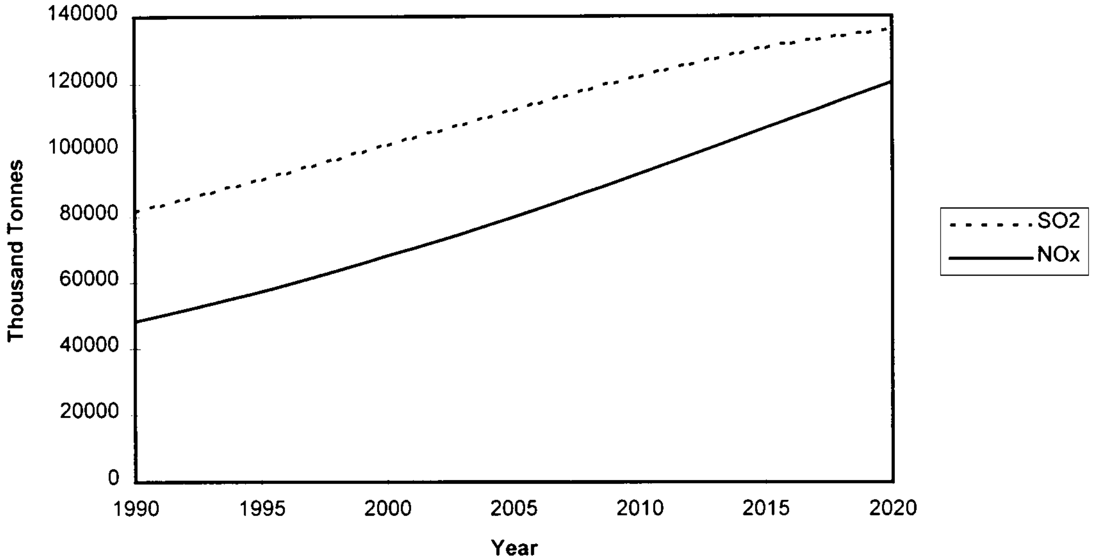

Figure 2. Projected global emissions of sulphur dioxide and nitrogen oxides, 1990–2020.

emphasis moving from the industrial sector to the service sector. The contraction of the manufacturing sector in the developed world, and its corresponding expansion in the developing world, may therefore explain why pollution levels have typically decreased in developed countries and increased in developing countries. If this reasoning is valid then it suggests that pollution may not fall with economic growth, but rather it may simply be passed elsewhere. This then implies that the developing regions will not be able to follow the same inverted-U pollution–income path as the developed regions, since they will have no-one to whom their pollution can be passed.

A final note of caution required for the interpretation of EKCs is that there are many environmental problems for which it is not possible to statistically estimate the relationship to economic growth due to lack of data. Indeed, this is the case for problems such as soil erosion, desertification, biodiversity loss, pollution and depletion of groundwater aquifers and many, many more. As a result, the relatively few indicators that have been considered may not be representative of the larger number of indicators that have not been subjected to this type of analysis.

POLICY IMPLICATIONS

Whilst the polarized views of the 1960s, 1970s and 1980s provide little in the way of guidance for future policy, the EKC analyses provide a number of implications for the direction of environmental policy.

The distinction between local and global pollutants illustrates the need for multilateral agreements to tackle those pollutants with global impacts. The lack of incentives for unilateral action, coupled with the fear of suffering a competitive disadvantage, has meant that individual countries have generally not acted to reduce global pollutants. It is therefore apparent that international co-operation is the only way forward. With regard to local and transboundary pollution, Europe adheres to the UNECE Convention on Long-Range Transboundary Air Pollution and to various protocols within the convention, although, at present, the developing world has made no commitments to tackle such pollutants. Clearly, developing regions often have more pressing needs and few resources to devote to environmental problems. The role of an internationally funded environmental organization (see e.g. Esty, 1994; Runge, 1994) may therefore prove vital.

The EKC analyses also highlight the need for domestic policy-makers to tackle the environmental impact of the transport sector since both transport related pollution and energy use are proving more difficult to control than in other sectors.

Perhaps more fundamentally, the fact that each environmental indicator has a different relationship with economic development provides a strong justification for the use of a system of physical accounts to operate alongside the national monetary accounts. The physical measurement of natural resources allows an examination of their use over time and would indicate to policy-makers whether the economy is operating in an environmentally sustainable manner. Attention can then be geared towards those indicators that appear to be deteriorating. There is also a strong case for arguing that the system of monetary accounts should be amended to provide a measure of 'sustainable production' by allowing for the depreciation of natural capital in the same way as man-made capital, and to deduct the value of environmental damage. Any increase in the resultant 'green' net national product would then indicate that the economy was developing sustainably.[8]

CONCLUSION

The largely theoretical arguments of the 1960s, 1970s and 1980s did little to clarify the typical impact of economic development on the environment. Opinion was largely polarized between those in favour of continued economic growth, who placed great faith in the ability of new technologies and resource substitution to overcome environmental limits, and those who believed that resource and sink limits meant that economic development could not continue unchecked.

The 1990s have seen the use of statistical techniques to try to estimate the relationship between economic growth and the environment. These techniques indicate that there is no single relationship between development and the environment. Certain local pollutants have fallen in the developed world, perhaps as a result of the financial resources that stem from economic growth. However, at a global level these pollutants are still increasing, raising the possibility that economic development may simply cause a movement of pollution from the developed world to the developing world. Other pollutants and indicators continue to increase with development, perhaps due to the lack of a direct local environmental impact and the fact that technological fixes are not readily available.

The impact of economic development on the environment is clearly complex in nature. It is important to note, however, that whilst economic growth may facilitate some environmental improvements, this is not an automatic process and will only result from investment and policy initiatives.

[8]Such a measure of 'green' NNP provides only an indication of 'weak' sustainability since increases in man-made capital can compensate for decreases in natural capital. See, for example, Pearce (1993) or Jacobs (1991) for a fuller explanation.

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