This paper reviews the factors that can influence environmental quality in the course of economic development and examines critically empirical studies that have been carried out, including those that have produced evidence of environmental 'Kuznets curves.' It also considers the policy implications of the relationships that have been estimated and examines the question whether the estimates of environmental Kuznets curves imply that development will necessarily and automatically cure the environmental ills that it creates.

Cette étude passe en revue les facteurs qui peuvent influencer la qualité de l'environnement au cours du développement de l'économie et examine de manière critique les études empiriques qui ont été menées, y compris celles qui ont conduit à des preuves de création de "courbes de Kuznets" environnementales. Elle examine aussi les implications en matière de réglementation des relations qui ont été estimées et se demande si les estimations établies à partir des courbes de Kuznets impliquent que le développement guérira nécessairement et automatiquement les maux environnementaux qu'il a créés.

Energy, Externalities and Environmental Quality: Will Development Cure the Ills It Creates?

PETER J.G. PEARSON

1. Introduction

The aim of this paper is to review the factors that can influence environmental quality in the course of economic development, to examine critically the main empirical studies that have been carried out, including those that have produced evidence of environmental 'Kuznets curves,' to consider the policy implications of the relationships that have been estimated, and to consider the question whether development will necessarily cure the environmental ills that it creates.

In contrast with the fairly wide literature that addresses regulatory and other issues concerned with energy and development, until very recently relatively little analysis and modelling of the relationships between environmental quality and development appears to have been carried out. On the more narrowly delineated relationship between environmental quality and economic growth, Shafik (1994) notes that there have for long been two passionately-held views. At one extreme lies the view that rising economic activity inevitably produces environmental degradation, mounting ultimately towards possible economic and ecological collapse. At the other lies the view that environmental problems that are worth tackling will be ad-

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dressed more or less automatically as growth proceeds. Moreover, both Shafik and Grossman and Krueger (1991) note that this debate has been prolonged partly through the lack of substantial empirical evidence, itself a reflection of the absence of appropriate, comparable data for many countries.[1] Thus there is still limited evidence available on how environmental quality relates to different income levels, let alone other determining variables. However, in recent years data on environmental degradation and on environmental quality indicators (including energy-related air pollution and deforestation) have begun to improve, and over the past four or five years a certain amount of empirical research has appeared, carried out across a range of countries, at low to high income levels, using cross-section or sometimes pooled cross-section and time-series data (Grossman and Krueger, 1992, 1994; Lucas *et al*, 1991; Selden and Song, 1992; Shafik and Bandyopadhyay, 1992; Shafik, 1994; World Bank, 1992).

The empirical work suggests that while for some indicators of environmental quality, environmental quality rises as real per capita income (GDP) rises, for others environmental quality appears to fall as income rises; moreover, for an important class of impact there appears to be an inverted U-shaped relationship – the 'environmental Kuznets curve' (EKC) – between environmental quality and per capita income. For example, the *World Development Report 1992*, discussing data analysed by Shafik and Bandyopadhyay (1992), presents a figure (World Bank, 1992, Figure 4, 11) illustrating cases where: (a) some problems (e.g., poor sanitation and limited access to safe water) tend to decline as income rises; (b) some problems initially worsen but then improve as incomes rise and if countries allocate resources to deal with them (they suggest that most forms of air and water pollution fall in this category); (c) some problems worsen with income (including emissions of carbon dioxide and nitrogen oxides).

2. Relationships Between Environmental Quality and Development

The hypothesised relationship between environmental quality and development that has attracted most attention is, perhaps not surprisingly, the inverted U-shape of the EKC. The original Kuznets Curve described a hypothesised relationship between inequality of income distribution and economic development. Kuznets (1955, 1963) and Myrdal (1957) put forward the hypothesis that inequality of personal income distribution (according to a measure such as the Gini coefficient) tends to increase in the early stages of economic development, eventually reaching a peak and then falling continuously, describing an inverse U-shape. The cross-country version of the hypothesis suggests that inequality increases between the poorest and middle-income countries and then decreases in the industrialised countries. Kuznets and Myrdal argued that industrialisation and urbanisation exacerbate inequality in developing countries because of relatively fast growth in the modern sectors (where income levels are not only higher but also more unequal than in agriculture) and that it is only at fairly high levels of income that technological progress spreads throughout the economy and income transfers cause significant redistribution. Empirical research has provided some corroboration of the inverse U-shape, as well as more explanation of the determining factors apart from the level of income.[2]

1/ "The data on environmental quality are patchy at best, but are likely to improve over time with better monitoring. Comparability across countries is affected by definitional differences and by inaccuracies and unrepresentative measurement sites." (Shafik, 1994)

2/ See Chenery and Syrquin (1975, pp. 60-63) for more discussion. They note that Weisskoff (1970) confirms Kuznets's hypotheses in research on Puerto Rico, Argentina and Mexico, and that their own regressions, as well as the earlier work of Adelman and Morris (1973), confirmed the cross-country ver-

As Panayotou (1993) suggests, the idea that conditions may have to deteriorate before they improve seems to have a wider relevance – casual observation suggests that environmental degradation at first rises then falls as economic development proceeds. He contrasts rising pollution in Seoul, Bangkok and Mexico City over the past 20-30 years with improvements in cities in industrialised countries. He suggests that while the experience of the US, Western Europe and Japan and, more recently, the newly-industrialising countries (NICs) of South Korea, Taiwan, Hong Kong and Singapore, appears to conform to an inverted U-shape, the upcoming wave of NICs – Thailand, Malaysia, Brazil and Mexico – may have reached their lowest points of environmental quality, and are "gearing for an upturn." He cites the Thai logging ban and their introduction of lead-free petrol, as well as recent "serious efforts, at last to deal with urban pollution in Mexico City." The argument behind the hypothesis of environmental Kuznets curves is presented in the following way:

> At low levels of development both the quantity and intensity of environmental degradation is limited to the impacts of subsistence economic activity on the resource base and to limited quantities of biodegradable wastes. As economic development accelerates with the intensification of agriculture and other resource extraction and the take-off of industrialisation, the rates of resource depletion begin to exceed the rates of resource regeneration, and waste generation increases in quantity and toxicity. At higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, result in levelling off and gradual decline of environmental degradation. (Panayotou, 1993)

Most authors of studies on environmental quality and development present an argument fairly similar to this.

The EKC hypothesis leads to two questions: a) Does the empirical evidence support or reject the inverted U-shape, and if so for which environmental quality indicators, countries and time-periods? b) What are the policy implications of the empirical estimates? In particular, as Panayotou notes, do the empirical estimates suggest that environmental quality deterioration in the early stages of development is part of a temporary and 'natural' – even optimal – progression, which it might be inappropriate and wasteful to urge or assist countries to modify? If so, resources might be better devoted to other policies that promote rapid growth, in order simultaneously to raise incomes *and* to progress to the environmentally more benign downward-sloping portion of the EKC. Or do these estimates instead provide a starting point for understanding how most effectively to devise policies and development assistance to flatten out EKCs, avoid retarding economic growth and avoid the potentially irreversible crossing of ecological thresholds, thereby raising living standards above what they would otherwise have been?

3. Determinants of Environmental Quality

Before examining these two issues further, it is necessary to consider in more detail the factors that lie behind levels of environmental quality. One reason for doing this is that the majority of studies, with the exception of Panayotou (1993), have tended to be very empirically-oriented with remarkably thin discussion of the underlying factors and relationships. Indeed, Shafik (1994) goes so far as to argue that:

> At a theoretical level it is not possible to predict how environmental quality will evolve with changes in per capita incomes, particularly where public goods are involved. The question is more tractable empirically ....

A simple, but nonetheless effective, analytical approach is to consider both the supply of environmental quality (or its opposite, deterioration) and the demand for environmental quality. Actual environmental quality levels may then be viewed as being partly determined by the interaction of supply and demand with the stock of waste receptors and with endowments of resources, especially energy resources. However, given the extent of market failure in the area of environmental resources, this is obviously not a price-in-

sion of the hypothesis.

duced market-clearing process, since environmental quality is not usually traded and environmental quality problems arise partly *because* of the absence of markets.

3.1 *The Supply of Environmental Quality*

The supply of environmental quality is influenced by factors that affect the supply of potential pollutants (or, conversely, of pollution abatement) and/or affect the availability or capacities of the stock of waste receptors.[3] These factors are, among other influences, closely associated with energy producing or consuming activities, such as electricity generation, oil refining or transportation. Hence the supply of environmental quality is a function partly of the demand for energy, which is itself derived from the demand for those activities which require energy services as an input. The factors that influence the supply of environmental quality include the following categories (with a particular focus on those relating to energy, including electricity).

Levels of population and economic activity: Geometric growth rates in these factors lead to the creation of more residuals from production and consumption activities, including those associated with energy, placing increasing stress on waste receptors.[4]

Structures of production and consumption: For example, the level and pattern of emission changes when countries move from agriculture towards industrialisation, from heavy to light industries, or from industry to services; these transformations are associated with changing patterns of physical transformation, processing, packaging and transport. Among other influences (discussed further in the empirical section below) on these changing structures is the nature of a country's development strategy, including its trade strategy and the degree of openness of the economy. For example, as Panayotou and others have noted, economic and trade liberalisation may lead to the decline of inefficient, polluting private industries and the more efficient restructuring of polluting public enterprises (including those in the energy sector). On the other hand such policies could encourage the import of polluting industries from economies with tougher emissions controls.

Spatial locations and concentrations of activity: Major influences include industrialisation and urbanisation, in turn affected by population growth and migration. The locations and spatial agglomerations of mines, thermal or hydro power stations and industrial activities are significant here (e.g., pithead or urban thermal power stations, industrial complexes in mining areas, and so on).

Efficiencies: The efficiencies with which inputs are transformed into outputs and environmentally damaging residuals are emitted per unit of economic output depend on:

the *production technologies and the abatement technologies* employed (e.g. cleaner coal technologies, combined cycle gas turbines, electrostatic precipitators, flue gas desulphurisation equipment); and

on *organisation, management and politics* (indeed of entire political systems, as the environmental history of Eastern Europe demonstrates).

In electricity, for example, the efficiency of end-use technologies (particularly in lighting, heating, refrigeration and air conditioning), and the efficiency with which electricity is generated, transmitted and distributed both affect the level and pattern of environmental quality impacts. In both these areas developing countries have well-known problems relating both to the stock of equipment and the management of electricity supplies (Munasinghe, 1992; Bates 1993). For example,

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3/ Where pollution may be said to occur when waste residuals exceed the assimilative capacity of the environment in a given time, because of their amount or their form.

4/ At the global level, of course, much of this growth in the past came from the now-industrialised countries in the course of their development, which explains why their current levels of residuals tend to be high. Nowadays, developing country residuals tend to be growing relatively rapidly (albeit from a small base) because their population and consumption levels tend to be growing much faster than those of industrialised countries.

it has been estimated that older power plants in many developing countries consume from 18% to 44% more fuel per kilowatt hour of electricity produced than plants in industrialised countries (ICs), while transmission and distribution losses are two to four times higher than 'good practice' levels for an efficient utility, leading to losses that are often above 20% (World Bank, 1993b, 22).[5] Where, because of efficiency problems, more electricity has to be generated (especially with old and/or poorly-maintained plant), emissions levels and environmental impacts tend to be exacerbated (Anderson and Cavendish, 1992; Wilbanks, 1991).[6]

Use of new or different fuels/materials/chemicals: which affects emission patterns and can bring new absorption problems or relieve them (e.g., the discovery or importation of natural gas, use of radioactive nuclear fuels, use of lead in petrol, CFCs, new forms of packaging, and so on).

Climate: which affects activities, energy use (including space heating and cooling) and the transport of pollutants.

Costs of production and of pollution abatement: Relative prices and availability of (appropriate) imported technology are important here. As Panayotou (1993) notes, countries that impose heavy import duties on "clean" technologies are likely to have higher pollution levels than those that do not. Moreover, countries with subsidies on energy and other key resources, like water, tend to experience higher pollution levels than otherwise, because of inefficient use of the subsidised input. Furthermore, subsidies convey inappropriate signals, so damaging incentives to select and develop input and pollution-minimising technology. For example, in relation to electricity tariffs in many developing countries, the World Bank argues that:

> Prices, on average, are barely more than one-third of supply costs and are half those in industrialised countries. ... developing countries use about 20% more electricity than they would if consumers paid the true marginal costs. ... Underpricing electricity also discourages investment in new, cleaner technologies (World Bank, 1992).
>
> Over the period 1979-88, average real power tariffs in developing countries declined from 5.2¢ (US) to 3.8¢/kWh, quality of service deteriorated, technical and nontechnical losses and fuel consumption continued to be high, and poor maintenance of plants persisted (World Bank, 1993b).
>
> Allowing for the managerial inefficiencies induced by price inefficiencies, marginal costs are closer to 15 than 10¢ per kWh. (Anderson, 1993).

External influences: (a) The polluting activities of other nations can have significant effects on environmental quality, although the recipient nation may have little power to control such emissions. Consider, for example, regional air pollution, such as acid deposition, or water pollution in situations where rivers run through several countries. (b) The influence of external financing agencies can affect the level and pattern of environmental quality. For example, MacKerron (1991) discusses the potential effects of recent changes in the World Bank's lending policies (and those of other agencies) on the environmental impacts of electric power projects. He concludes that the adoption of a higher (implicit or explicit) cost of capital cannot be said in any *a priori* way to have either a net favourable or unfavourable environmental impact: total investment volumes are likely to fall, and it is not necessarily the case that because new projects may be relatively short-term in conception they will be more environmentally damaging than those they displace (consider the increasing role of gas, for example). MacKerron also warns of the danger of inconsistent messages to developing countries from different elements in the international system; if, for example, global warming came to be viewed as the major environmental threat, then a higher cost of capital might encourage the use of fossil fuels while at the

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5/ The World Development Report (World Bank, 1992) suggests that losses during transmission and distribution, partly through theft, amount to the equivalent of about 75,000 MW of capacity and 300 TeraWatt hours (300 billion kWh) per year, representing a loss of $30 billion per year through increased supply costs.

6/ Pearson (1994a) reviews efficiency problems in the power sectors of developing countries (DCs).

same time countries could be exhorted to use less fossil fuels so as to limit the growth of CO_2.

Government environmental regulation: This includes the effective 'price' at which waste receptors and other environmental resources are available. The gulf between legislated standards and enforcement varies from country to country – and merits further investigation. There has been much discussion recently of the relative merits of 'market-based' or 'economic' instruments, such as pollution charges or tradable permits, compared with the 'command-and-control' regulatory approaches that until recently have been chosen by most countries (Eskeland and Jimenez, 1992). Many economists have advocated the wider adoption of market-based instruments (Bates, 1993; Baumol and Oates, 1988).

Environmentally beneficial expenditures: These include expenditures on abating pollution emissions, mitigating damage or reducing resource demands. Relevant indicators include the share of environmental expenditures in government, industry, local authority and personal budgets. There are reasons for expecting them to vary in different development situations (Panayotou, 1993; Pearson, 1994a, 1994b).

3.2 Waste Receptors and Energy Resources

The supply of environmental quality is also influenced by a country's endowment of waste receptors and energy resources.

Waste receptors: The size and nature of a country's or region's available land, water, air and other waste-receiving resources in relation to the past and present demands placed on them is a key factor. (For example, South Korea has experienced significant problems in relation to power station siting and waste disposal and urban air quality partly because its land area is small in relation to the recent growth in its population, speed of urbanisation, economic activity and energy uses.) In the case of global pollutants, of course, such as the greenhouse gases, the waste receptor is the global atmosphere, access to which individual countries cannot ration.

Natural resources: Activities are, of course, influenced by natural resources – particularly for energy use. Primary energy consumption patterns, and consequent environmental impacts, are heavily dependent on the patterns of availability of fossil fuels and hydro resources. Moreover, there are big differences both between and within regions, in the proportions of electricity generated by hydro, thermal and nuclear sources, and within thermal between the roles played by coal, oil and gas. The major contrast between the developing countries as a whole and the OECD countries lies in the role of nuclear generation (23% in the OECD, against 4% in the developing countries). Within the developing countries, the mix of generating technologies used varies strikingly across the regions, with thermal dominant in the Middle East, China and, to a lesser extent in the other Asian countries and Africa, and hydro dominant in Latin America. Moreover, even within a region fuel shares can vary significantly. In Asia, for example, there are substantial differences in the fuel mix (influenced, of course, by resource endowments, such as coal in India and China, oil in Indonesia and natural gas in Pakistan and Thailand).[7]

Perhaps ironically, nations that do not possess the advantage of significant reserves of energy resources like fossil fuels avoid the disadvantages of the environmental impacts associated with their extraction. This will continue as long as the externalities of energy production are not internalised in exporting countries.

3.3 The Demand for Environmental Quality

The major factors that influence the demand for environmental quality are set out below.

Incomes: There appears to be a growing demand for *some* types of environmental quality as incomes rise – especially for 'luxury' envi-

7/ See (Pearson, 1994a, Table 3) for regional data, and Imran and Barnes (1990)for data relating to these four countries. See IEA (1991) for historical data at the country level.

ronmental services with high income elasticities.[8] Thus differences are not unexpected between countries at different income levels, but because of the non-marketed nature of most forms of environmental quality there are few income elasticity estimates available, especially for developing countries. At very low levels of income, private environmental 'defense' expenditures tend to be low, both absolutely and as budget shares (except for those at the top end of the income distribution, who may buy themselves out of water, noise and visual pollution (Eskeland and Jimenez, 1992)). Public expenditures also tend to be absolutely and relatively low, partly because the demand for public goods seems to be small at low levels of income.

Price: The perceived relative 'price' (or opportunity cost) of environmental quality is a key influence, although such prices are usually implicit rather than explicit. An interesting question here is whether the relative price of environmental quality in relation to other goods and services differs between industrialised countries and developing countries (one reason for such differences is that newer – and better maintained – technology stocks deliver energy services more cheaply, often with smaller pollutant emissions and fuel inputs). Government-induced price distortions and incentives, as well as trade and tariff policies can be significant influences. So also can be the structure, organisation and regulation of the energy industries.

Preferences: The demand for environmental quality is a function of preferences, which are in turn affected by attitudes to natural resources, future generations, and so on. A question that demands further research is whether and in what ways preferences change in individual countries as development proceeds – such factors as urbanisation, education, access to information and the experience of rising expenditure are likely to be significant influences. Moreover, more needs to be discovered about how and why preferences vary between countries in different development situations – a single, universal set of preferences for all countries seems highly implausible.[9] It should not be assumed, however, that poorer communities do not value the preservation of natural resources and environmental quality; budget constraints can often force undesirable tradeoffs. Shafik (1994), for example, argues that:

> There is a general perception that higher incomes enable the relative luxury of caring about amenities such as landscapes and biodiversity. But many societies with very low incomes, such as tribal peoples, place a very high value on conservation (Davis, 1992). Thus, it is not necessarily a question of different preferences between the rich and the poor, but rather one of different budget constraints.

A central issue, of course, concerns whose preferences are being represented and how, if at all, governments try to elicit them. The following three factors are related to this issue.

Information: Scientific, medical and social advances lead to more knowledge of pollution impacts (e.g., effects of hazardous air pollutants, acid deposition, radioactivity, greenhouse gases, CFCs, and so on). This changed awareness influences the demand for environmental quality.

Information acquisition: Increased information acquired by the public can affect their private and social demands for various types or attributes of environmental quality. Public provision or manipulation of information can act as a significant influence. Public provision is beginning very slowly to change in some developing countries (e.g., published measures of urban air or water quality, although these are open to manipulation by the authorities). General education makes it easier for people to understand environmental issues and information. Environmental education can play a significant role, particularly in

8/ However, for DCs it is particularly significant that environmental resources provide not only consumer services but also essential producer services – degradation of natural resources of soil, water and air damage health and people's capacities to support themselves. Those with meagre stocks of human, physical and financial capital are often the worst-affected by such natural resource degradation.

9/ That such preferences should be homothetic also seems improbable.

the case of politicians, bureaucrats and managers. It may also influence individual or group preference functions. It is regarded as an important function for museum services in some developing countries (e.g., India) and is often focused on children – although in many cases it is the decision-makers who are most in need of this kind of education.

Political opportunities: The ability to express preferences related to environmental quality is obviously very important. This encompasses not only democratic representation but also issues relating to the freedom and control of the media. Political changes in the former Soviet Union and other parts of Eastern Europe have significantly affected people's ability to influence decisions about environmental quality. The World Development Report 1994 (which focuses on infrastructure and development) argues that:

> Political developments – including the trend in many countries towards democratisation, pluralism and decentralisation – have fuelled a concern with finding more affordable and environmentally friendly solutions in infrastructure (World Bank, 1994, 35).

The Report goes on to suggest that this new commitment has led to a (long overdue) greater appreciation of the need to consult local communities, the poor, and other groups affected by environmental factors. Nevertheless, the freedom to express environmental preferences and to campaign for change varies widely across nations and by no means all governments encourage or even permit the open expression of environmental concerns, especially where they cut across official policy.

In developing countries in particular, the actions of NGOs can be very influential (and in some countries environmental NGOs can act as a focus for otherwise repressed political dissent). Moreover, international organisations like the World Bank are also influenced by the campaigns of NGOs from both industrialised countries and developing countries – indeed members of such organisations can be heard privately to complain of attempts by industrialised country NGOs to impose 'inappropriate' environmental priorities (e.g., a preoccupation with relatively expensive acid emissions abatement, rather than focusing on relatively cheaper abatement of particulates and the serious health damage they cause). It can also be argued that the well-publicised history of poor handling of population displacement and other social issues connected with hydro schemes has made aid agencies overly reluctant to embrace even appropriately-planned hydro schemes, with the result that they tend to favour fossil-fuelled projects instead.

3.4 Environmental Quality Outcomes

As has been noted, the eventual levels of environmental quality that emerge from the interaction of the supply of and demand for environmental quality are obviously not the outcomes of a well-functioning market for largely untraded environmental quality. In the presence of market failure, government action is an important element in the factors that influence and regulate environmental quality; government intervention is in turn influenced by the supply and demand for environmental quality. Many aspects of environmental quality have the properties of a public good. Consequently there are the classic problems of private supply, free-riding and demand revelation. Moreover, the suppliers of environmental quality often do not have the right incentives to supply – there is an adverse selection problem since people often cannot distinguish between goods produced with smaller or larger damaging impacts on environmental quality, and so are not willing to pay an appropriate premium for 'cleaner' goods and services. For example, electricity suppliers may not have sufficient incentives to supply 'cleaner' energy. In many cases public perception is such that people are unwilling to pay at all; e.g., it has been said that in Korea many people think that pollution is the sole responsibility of companies, who should be made to clean up *without* passing abatement costs on to consumers. The idea that the 'polluter pays principle' extends to consumers as well as producers of goods with externalities is not always easily grasped.

As already suggested, the supply function

of environmental quality (or abatement) is not a standard supply curve. Furthermore, to estimate it governments have to estimate abatement costs by getting data from organisations, such as firms, that have an incentive to distort abatement cost estimates. Obtaining and evaluating such data can be an especially difficult problem in developing countries.

3.5 Modelling the Relationships between Environmental Quality and Development

The preceding sections have discussed some of the key factors affecting the supply of and demand for environmental quality in countries in different development situations. If they could be modelled successfully – and if there were certain clear relationships, such as EKCs – we might have a much better idea of how to devise appropriate, workable energy-environment policies. This section addresses the issue of modelling the relationships between environmental quality and development.

Possibly the earliest of the recent studies, that of Grossman and Krueger (1992), used measures of three air pollutants (concentrations of SO_2, smoke and suspended particles) in a cross-country panel of urban areas located in up to 42 industrialised countries and developing countries. The study sought to 'explain' concentrations of these pollutants using data about the location of the monitoring station (city centre or suburban area, and whether land is used for industrial, residential or commercial uses), the characteristics of each city (location on a coastline or near a desert, and population density), and the country's level of income. "After holding constant the identifiable geographical characteristics of different cities, a common global time trend in the levels of pollution, and the location and type of the pollution measurement device" (Grossman and Krueger, 1992, p.5), for ambient levels of SO_2 and 'smoke' (dark matter), they found an inverted U-shaped Kuznets Curve relationship between pollution and per capita income (measured in purchasing power parity terms), for a wide range of incomes. Thus the concentrations increased with per capita GDP at low levels of national income and decreased with GDP growth at higher levels of income, with the turning-point between $4000 and $5000 per capita GDP (measured in 1985 US dollars), and then levelled off or perhaps rose again.[10] The concentrations of suspended particles, on the other hand, decreased monotonically with per capita income growth in a model specification without fixed site effects but increased in the model that allowed for them.

Grossman and Krueger argue that the negative relationships that they find between local air pollution and per capita GDP above $5000 reflect changing production techniques: "Once a country reaches this critical level of income its citizens begin to feel able to afford higher standards of environmental protection and so demand stricter regulations from their governments." Their study was intended to examine the environmental impacts of NAFTA, and it focused particularly on Mexico. However, because their air pollution data did not cover Mexico, they infer their predictions for Mexico, "... from relationships that hold in other countries at similar stages of development." They argue that because Mexico's per capita GDP in 1988 was close to $5000, further growth in Mexico, as might result from a free trade agreement, might yield an "environmental dividend" in that it would be expected to lead the country to intensify efforts to address its environmental problems. Furthermore they suggest that recent measures taken by the Mexican government imply that the country may indeed have reached the turning point in terms of air pollution.

In contrast with Grossman and Krueger,

10/ Significantly, Grossman and Krueger found that in general a cubic relationship fitted better than a quadratic, "... although in many cases the shape of the estimated relationship between income and pollution is found to be roughly the same." For SO2, for example, they note that there were only two countries in the sample (USA and Canada) with per capita incomes above $16,000, where the estimated curves turn upwards and the cubic part of the functional form is relevant.

Selden and Song (1992) used a cross-national panel data set on the *flow* of emissions of four air pollutants (particulates, SO_2, NO_X and CO) at the aggregate country level, rather than for urban areas. For each pollutant they also found an inverted U-shaped relationship with per capita GDP, but with substantially higher turning-points than Grossman and Krueger.

Shafik and Bandyopadhyay (1992) did a background study for the World Development Report 1992 (World Bank, 1992). One set of results used indicators of environmental quality as dependent variables in regression estimates derived from panel data from up to 149 countries for the period 1960-90 (most recently presented in Shafik, 1984). The other results, which were depicted in the World Development Report (World Bank, 1992, Figure 4, Figure 1.5), were derived from cross-section data.[11] Six of Shafik's indicators (water, sanitation, suspended particulate matter, SO_2, dissolved oxygen and faecal coliform in rivers) are measures of the quality of a stock of natural resources, while for the remaining three (deforestation, municipal waste and carbon emissions) data problems led to their being measured by changes in flows.

Shafik (1994), in a less comprehensive exposition than that set out in the previous sections of this paper, puts forward the hypothesis that there are four determinants of environmental quality in any given country: (1) endowment, such as climate and location; (2) per capita income, reflecting the structure of production, urbanization, and consumption patterns of private goods and services; (3) exogenous factors, such as technology, "which are available to all countries and change over time;" and (4) policies that reflect social decisions about the provision of environmental public goods. Shafik (and Bandyopadhyay) tested three basic models – log-linear, quadratic and cubic – to explore the shape of the relationship between the indicator and income. The panel regression results set out in Shafik (1994) show that: (a) some indicators of environmental quality (like water and sanitation) improve as per capita incomes rise to levels where resources for improved public services become available; (b) some problems initially worsen but then improve as incomes rise and if countries decide to allocate resources to deal with them (SO_2, suspended particulate matter and possibly deforestation fall in this inverse U-shaped category); (c) some problems worsen with income (including emissions of carbon, municipal solid wastes and dissolved oxygen in rivers). The turning-points at which the relationship with income changes differ significantly between environmental indicators.

For local air pollution, in particular, which tends to be closely associated with the use of fossil fuels, Shafik finds that the quadratic model fits best, so that environmental quality conforms to the inverted-U shaped relation with income. Air quality related to SPM (which is associated with damage to health), tends to decline initially as countries become more energy intensive, and then improves at a per capita income level of around \$3280. SO_2 pollution, through the impacts of acid deposition in particular, is of course largely caused by the combustion of fuels with high sulphur content. The turning point of the quadratic relationship occurs at about \$3670 income per capita. Shafik argues that for local air pollution, the pattern is of initial decline in air quality as industrialization and energy intensity increase, and then of improvement as cleaner technologies are employed and fuel switching takes place. Technology, proxied by a time trend, appears to have made it possible for improved air quality to be achieved at a lower level of income.

Shafik argued that her results were broadly consistent with the only other estimates of this type of which she was aware (those of Grossman and Krueger (1992) and Selden and Song (1992), mentioned above). As

11/ Shafik (1994) observes that the results were less robust. Variations in observations and country coverage across years led to variations in specifications, coefficient estimates and significance levels among cross-section regressions. The panel results have more degrees of freedom and, in her view, offer more credible results.

we have seen, Grossman and Krueger emphasise the inverted-U shape portion of their cubic functions in the case of SO_2 and dark matter. Moreover, although their turning-point for SO_2 is significantly higher than Shafik's, possibly because of sample size differences, it is consistent with the result that local air pollution tends to rise at middle incomes. Shafik suggests that Selden and Song's higher turning points probably reflect their use of aggregate emissions *flows* rather than ambient air pollution *stocks* in urban areas; since urban incomes tend to lie above national per capita income levels, turning point estimates derived from urban pollution and national income data will tend to be larger than those for aggregate emissions and national income data. Shafik also argues that measures of ambient stocks are more appropriate measures of environmental quality and health impact. Her results for particulates are different from the either monotonically increasing or decreasing relationships found by Grossman and Krueger. The paper does not attempt to reconcile or explain this difference.

Panayotou (1993) estimated relationships between four environmental indicators – deforestation (as a representative variable for resource depletion) and three air pollutants, SO_2, NO_X and solid particulate matter (SPM), representing industrial and energy-related pollutants. His air pollutant variables are emission flows rather than concentrations. Panayotou's explicit aim was to test the EKC hypothesis for his four variables.

For his three air pollutants, Panayotou tested log-quadratic relationships between each emissions variable and income. Using late 1980s data for 55 countries, for SO_2 per capita and NO_X per capita he did not reject the hypothesis of an inverse U-shaped EKC. For SO_2 the turning-point occurred between $2900 and $3800, while for NO_x the turning point occurred at a much higher income level of about $5500. In both cases, however, only about one-third of the variation in emissions was accounted for by income variations. The equation for SPM, although indicating an inverse U-shape (with a turning-point at about $4500), was such that variations in income only accounted for 12% of the variations in emissions and was "clearly unsatisfactory." Panayotou argues that these "preliminary" results lend credence to the EKC hypothesis for air pollution. He argues that his results are consistent with, and surprisingly close to, those of Grossman and Krueger (1992) and Shafik and Bandyopadhyay (1992).

For deforestation, Panayotou postulated that it was a function of income per capita and population density. He fitted a translog function with the logs of income and population density and the squares of these logged terms, plus a composite interaction variable (the product of the logs of income and population). Using cross-section data for the mid-to-late 1980s, firstly for 41 tropical, mostly developing countries and then for these 41 countries plus another 27 developed countries, he estimates two regression equation estimates that do not enable him to reject his hypothesis of an inverted U-shape EKC between deforestation and income per capita. The level of income at which deforestation starts to fall lies between $823 and $1200 (1987 US$), i.e., significantly lower than for air pollution.[12]

Panayotou (1993, p.14) interprets his results in the following manner:

> Environmental degradation overall (combined resource depletion and pollution) is worse at levels of income per capita under $1000. Between $1000 and $3000, both the economy and environmental degradation undergo dramatic structural change from rural to urban, from agricultural to industrial. A second structural transformation begins to take place as countries surpass a per capita income of $10,000 and begin to shift from energy-intensive heavy industry into services and information/technology-intenive industry.

On the basis of the findings of the studies just described, it is tempting to argue that the processes at work are as simple as saying that on the one hand, eventually as incomes rise the demand for environmental quality rises proportionately faster, while the supply of

12/ "This is as one would expect. Deforestation for either agricultural expansion or for surplus extraction (via timber exports) takes place at an earlier stage of development than heavy industrialization." (Panayotou, 1993, p.14).

environmental quality-reducing activities falls (the pattern of output switches to lighter industry and services, consumption of electricity begins to saturate, authorities feel they can afford to supply public goods like clean water, sanitation, and so on). In one sense and at one level, it probably is as simple as this. There are, however, obviously more complex processes and other variables involved.

Several of the studies mentioned above attempt to incorporate some of the other determining variables as well as income. Shafik and Bandyopadhyay (1992) added investment rates and income growth rates. They found that for SPM, high investment rates were insignificant, whereas rapid growth was clearly associated with reductions in particulate concentrations. However, both SO_2 concentrations and carbon emissions appeared to increase in high investment economies, but were not influenced by economic growth. Thus, for these two energy-related pollutants, the authors suggest that investment in physical capital is complementary to energy consumption and pollution. Shafik and Bandyopadhyay also experimented with an electricity tariff variable. They found higher electricity prices to be associated with reductions in ambient levels of particulates and, to a lesser extent, SO_2 concentrations in a specification without a time trend. Higher prices were also associated with significant reductions in per capita carbon emissions; the principal outliers were the former centrally-planned economies and some of the major oil exporters, countries that tended to subsidise energy. There was also the possibly counter-intuitive result that countries with higher electricity prices appeared to have lower annual deforestation rates.

Shafik and Bandyopadhyay experimented with other policy variables, such as trade policy (trade share in GDP, parallel market foreign exchange premia, Dollar's outward orientation index), debt as a share of GDP, and political regime (political rights index, civil liberties index). However, "perhaps the most striking feature of the econometric results is how little some of the policy variables – such as trade, distortions and debt – seem to matter for the evolution of environmental quality. ... The results are far from conclusive, but the empirical evidence points to the absence of any generalized effects of trade policy, debt or political regime." The authors note that the relationship between trade policy and environmental quality has been the subject of much debate: on the one hand, many environmentalists argue that in order to compete more open economies are forced to keep production costs down by observing low standards of environmental quality; on the other hand, many economists have argued that the costs of maintaining environmental quality are a minor determinant of comparative advantage and that the gains from trade outweigh the environmental damage costs. Grossman and Krueger (1992) studied the possible effects of a NAFTA on the composition of economic activity and concluded that: "... the cross-industry differences in the costs of regulatory compliance are small in relation to the cross-industry differences in the costs of hiring the basic factors of production."

From Shafik and Bandyopadhyay's study, the results for local air pollution, in particular, were mixed. At best there was weak evidence that more open economies were associated with lower ambient particulate levels. More open and less distorted economies that traded more seemed likely to have lower levels of ambient SO_2. The per capita carbon emissions results indicate that more open and less distorted countries pollute less, and are, not surprisingly, consistent with those for electricity prices. Grossman and Krueger also found that, while SO_2 levels were significantly lower in cities located in countries that conduct a substantial amount of trade relative to their GDP, there was no significant relationship in the case of dark matter and suspended particles. Perhaps not surprisingly, SO_2 and suspended particulates tended to be higher in urban areas located in Communist countries. Lucas *et al* (1991) found, in their time-series regressions of manufacturing pollution intensity, that it tended to in-

crease most rapidly in developing countries that are relatively closed to world market forces and growing quickly. Their results were also consistent with the hypothesis that stricter OECD-country regulation of pollution-intensive production has led to locational displacement, thus accelerating manufacturing pollution intensity in developing countries.

In their latest study,[13] however, Grossman and Krueger (1994) are reported as dismissing the suggestion that the shifting of pollution-intensive production to poorer countries with lower environmental standards accounts for a significant part of the improvements in some environmental quality indicators that occur in developed countries:

> While some 'environmental dumping' undoubtedly takes place, the volume of such trade is almost surely too small to account for the reduced pollution that has been observed to accompany episodes of economic growth.

In their earlier study, they found that on the whole their locational variables performed much as might be expected. For example, concentrations of SO_2 were higher in city centres than suburbs, lower in residential areas than in commercial areas and higher in more densely populated cities. For dark matter and suspended particles, cities located near to a desert were associated with higher concentrations, whereas for suspended particles only, a coastal location was associated with lower concentrations.

4. Policy Implications

In the 1992 World Development Report (World Bank, 1992) it is argued that the evidence (principally drawn from Shafik and Bandyopadhyay, 1992):

> ... does not imply an inevitable relationship between income levels and particular environmental problems; countries can choose policies that result in much better (or worse) environmental conditions than those in other countries at similar income levels. Nor does it imply a static picture; as a result of technological progress, some of these curves have shifted downward over recent years.

13/ Which the author has not yet had the opportunity to consult.

Rather like Grossman and Krueger, Shafik (1994) asserts that the functional forms appeared to reflect private and social valuations of the relative costs and benefits of addressing particular environmental quality issues at different "stages of economic development:"

> Water and sanitation, with relatively low costs and high private and social benefits are among the earliest environmental problems to be addressed. Local air pollution, which imposes external costs locally, but is relatively costly to abate, tends to be addressed when countries reach a middle income level. This is because air pollution problems tend to become more severe in middle income economies ... and because the benefits are greater and more affordable. Where environmental problems can be externalized, as with solid wastes and carbon emissions, there are few incentives to incur the substantial abatement costs associated with reduced emissions and wastes. ... The econometric results ... do seem to indicate that most societies choose to adopt policies and to make investments that reduce environmental damage associated with growth. Action tends to be taken where there are generalised local costs and substantial private and social benefits. Where the costs of environmental degradation are borne by others (by the poor or by other countries), there are few incentives to alter damaging behaviour.

Panayotou (1993) puts forward several reasons to question the proposition that resources are best devoted not to environmental quality but rather to achieving rapid growth so as to move quickly from the environmentally unfavourable phase of a country's development to the environmentally benign downward-sloping range of the Kuznets curve. He argues:

a) it may take decades to get past the upward-sloping portion of the EKC, so that the rapid early declines in environmental quality may more than offset future higher growth and rising levels of environmental quality;

b) it may be more worthwhile to abate some forms of pollution now, rather than in the future (e.g., hazardous waste, which is particularly costly to collect and treat once it has been dispersed);

c) some types of environmental degradation that are permitted at early stages of development may be physically irreversible or, if reversible, prohibitively costly to undo (he cites as an example the impact of emissions

from leaded gasoline on children's mental development);
d) some forms of environmental degradation constrain economic growth (e.g., soil erosion, watershed destruction, sedimentation of hydro reservoirs, and damage to human health and productivity).

Panayotou, for all his warnings about unreliable data and preliminary findings, seems fairly heavily committed to the EKC hypothesis, viewing the existence of EKCs as representing both the inevitable outcome of structural change associated with economic growth and opportunities for active policy interventions.

> In the presence of ecological thresholds that might be crossed irreversibly, ..., and of complementarities between environmental protection and economic growth, ... a deep EKC (implying high rates of resource depletion and pollution per unit of incremental GDP per capita) is neither economically nor environmentally optimal because more of both could be obtainable with the same resources, if better managed. (p.15)

He concludes that:

> Like inequality, environmental degradation tends to become worse before it becomes better along a country's development path. While some deterioration is inevitable as part of the immutable structural changes that accompany economic growth, the EK-Curve need not be as steep as appears to be the case in many developing countries. Part of the steepness of the inverted U-shaped relationship between environmental degradation and growth is due to policy distortions such as subsidies of energy and agrochemicals, protection of industry and underpricing of natural resources which are both economically and environmentally destructive. (pp.21-22)

He asserts that developing country governments can help flatten out their EKC by cutting out policy distortions, internalising environmental externalities, and defining and enforcing property rights over natural resources. Furthermore, development assistance agencies can assist in flattening a developing country's EKC by ensuring that environmental protection is an integral part of their project and policy financing.

Panayotou also warns of the danger for poorer countries of the premature, overly-rapid adoption of very high environmental standards, such as those of the richest nations, since he regards this as a prescription for slowing down economic growth without necessarily improving the environment: "It simply stretches, as it were, the EK-Curve without making it shallower." He recommends the adoption of environmental standards appropriate for the country's level of development, pursued through flexible, revenue-neutral market-based instruments that in his view would not constrain economic growth, but rather shepherd it towards a more sustainable trajectory. The result, he thinks, would be a shallower EKC. In essence, therefore, the problem is one of how to choose and obtain appropriate levels of environmental quality and resource use to accompany economic growth.

5. Limitations and Criticisms of Current Approaches

As has been indicated, the research relating to EKCs is mostly of very recent origin, and much remains to be explored, both theoretically and analytically. Most of the existing studies have placed more emphasis on the empirical side, to some extent at the expense of the theoretical aspects. The current studies include the following limitations:

- The data are still fairly poor, both in coverage and in quality. This suggests the need for particular caution in the interpretation of results. For example, in their critique of the EKC, Stern *et al* (1994, p.5) refer to cases in which they argue that the available data are not appropriate data on which to base policy conclusions of the type presented.
- On the whole, simple cubic or quadratic functions have been used to estimate the equations, usually based on ordinary least squares regressions. However, more sophisticated econometric techniques of estimation and of curve fitting, such as the use of piecewise-linear models, might allow the estimated curves more accurately to represent the underlying relationships and data.
- The widespread use of quadratic functions carries the implicit (although, surely, usually unintended) assumption that at sufficiently high income levels pollutant emis-

sions or concentrations could tend to zero. As Stern *et al* (1994) observe, this is in direct violation of the laws of thermodynamics.

• The existing studies tend to employ fairly simple, single-equation approaches. However, since the relationship between environmental quality and economic development runs in both directions, there must be grave doubts whether single-equation approaches are adequate. Indeed, Stern *et al* (1994, p.14) believe that current approaches are fundamentally suspect:

> We believe that the nature of the problems associated with both the concept and empirical implementation of the EKC make it inappropriate to conduct further studies of this type. Though we could estimate a model that improved on certain aspects of the existing literature, any cross-sectional study would still be fatally flawed by the overall problem of simultaneity between economy, environment, economic structure and trade. ... At this stage of our knowledge, more could be learnt from examining the experiences of individual countries at varying levels of development as they developed over time.

• In my view, this last point is well-taken – more does need to be known about how individual countries' approaches have changed over time. However, although I agree that the problems of simultaneity are very serious, and must be tackled, I would argue that there is some virtue in trying to conduct more sophisticated EKC studies, bearing the above criticisms in mind. In particular, more research is required into the structural and policy determinants of each environmental quality indicator to establish more clearly the relationships between environmental quality, development-related variables and different environmental policy regimes. Thus, for example, there needs to be a better theoretical and empirical decomposition of influences on the supply side and the demand side, and a more explicit incorporation of the role of stocks of waste receptors and energy resources in the evolution of environmental quality. Furthermore, it would be interesting and helpful to try to model the factors that influence the choice of environmental standards, both as individual countries develop and across countries in different development situations.

It is also clear that there is a danger that the existence and shape of the curves attracts more attention than the complex underlying relationships involved. The risk is then that this sort of approach can lead to simplistic and probably self-defeating policy recommendations, with the EKC being used to validate preconceived policy stances. The EKC should be a tool of insight rather than foresight, and certainly should not be used as crude trade-off indicator for combinations of environmental quality and income level.

It is, moreover, essential to recall that by no means all relationships between environmental quality and economic development are likely to exhibit inverse U-shapes. Some curves, including those for CO_2 concentrations, appear to be positively-sloped throughout their existing range. Other indicators, including access to safe water and effective sanitation, tend to improve with per capita income, yielding downward-sloping curves. There is no aggregate inverse-U shaped relationship that has been estimated between some kind of overall environmental quality indicator and economic development.

Overall, therefore, there remains much more to be discovered, both theoretically and empirically about the complex bi-directional relationships between environmental quality and economic and social development. The existence of EKC estimates should not be taken to imply that the problems have been solved.

6. Conclusion

The recent studies of the relationships between environmental quality and development, although providing some evidence for the existence of U-shaped EKCs for some (but certainly not all) environmental quality indicators for some countries and time periods, do not provide convincing evidence that development can be relied upon automatically to cure all the environmental ills it creates. There is a role for policy.

The studies that have been carried out are pioneering, interesting and valuable, although not without serious limitations. Their findings can be largely interpreted within

(and are mostly consistent with) the simple framework set out in section 3 of this paper. However, the authors of the studies all make clear the extent to which their work has been restricted by patchy, unavailable or poor-quality data, so their results must be approached with considerable caution. Although the data situation is improving, there is a considerable distance to travel. In the interests of more effective policy-making, it matters that developing countries continue to develop their databases on environmental quality. It is important to try to develop better conceptual and empirical understanding of the factors that influence the supply of, the demand for and government policies towards energy-related environmental quality. Whereas some modelling of the relationships between the quality of the environment and the variables that influence it has been carried out, this paper has sought to show that much more remains to be done to develop a proper understanding of the factors that impinge on environmental quality and environmental policy in countries in different development situations.

References

Adelman, I. and C. Morris (1973) *Economic Growth and Social Equity in Developing Countries*, (Stanford: Stanford University Press).

Anderson, D. (1993) 'Energy Efficiency and the Economics of Pollution Abatement,' *Annual Review of Energy and Environment*, Annual Reviews Inc., 18, 291-318.

Anderson, D. and W. Cavendish (1992) 'Efficiency and Substitution in Pollution Abatement: Three Case Studies,' *World Bank Discussion Paper No. 186*, (Washington: World Bank).

Bates, R. (1993) 'The Impact of Economic Policy on Energy and the Environment in Developing Countries', *Annual Review of Energy and the Environment*, Annual Reviews Inc., 18, 479-506.

Baumol, W.J. and W.E. Oates (1988) *The Theory of Environmental Policy*, 2nd ed, (Cambridge: Cambridge University Press).

Chenery, H.B. and M. Syrquin (1975) *Patterns of Development 1950-1970* (London: Oxford University Press).

Davis, S. (1992) 'Indigenous Views of Land and the Environment,' *World Bank Working Paper* (Washington: World Bank).

Eskeland, G S and E. Jimenez (1992) 'Policy Instruments for Pollution Control in Developing Countries,' *The World Bank Research Observer*, 7(2), 145-69.

Goldsmith, E and N. Hildyard (1984, 86) *The Social and Environmental Effects of Large Dams*, Two Vols. (Camelford: Wadebridge Ecological Centre).

Grossman, G M and A.B. Krueger (1992) 'Environmental Impacts of a North American Free Trade Agreement,' *CEPR Discussion Paper* No. 644 (London: Centre for Economic Policy Research).

—(1994) 'Economic Growth and the Environment,' *National Bureau of Economic Research Working Paper*, No. 4635, NBER, February.

Imran, M. and P. Barnes (1990) *Energy Demand in the Developing Countries*, World Bank Staff Commodity Working Paper No. 23 (Washington: World Bank).

International Energy Agency (1991) *Energy Statistics and Balances of Non-OECD Countries 1988-89* (Paris: OECD).

International Energy Agency/OECD (1989) *Energy and the Environment: Policy Overview* (Paris: OECD).

Kopp, R.J. (1992) 'The Role of Natural Assets in Economic Development,' *Resources* No. 106, Winter, 7-10.

Kuznets, S. (1955) 'Economic Growth and Income Inequality,' *American Economic Review*, 49 (March), 1-28.

—(1963) 'Quantitative Aspects of the Economic Growth of Nations, VIII: the Distribution of Income by Size,' *Economic Development and Cultural Change*, 11(2, pt. 2), 1-92.

Lucas, R.E.B., D. Wheeler and H. Hettige (1991) 'Economic Development, Environmental Regulation and the International Migration of Toxic Industrial Pollution: 1960-88,' *Symposium on International Trade and the Environment*, World Bank,

Washington, D.C., November.
MacKerron, G. (1991) 'Environmental Impacts of Investment Policies in Developing Country Power Systems,' in Pearson, PJG (ed), *Environment, Energy Efficiency and the Third World*, Energy Economics Centre Discussion Paper (SEEDS 60) (Guildford: Surrey University).
Munasinghe, M. (1992) 'Efficient Management of the Power Sector in Developing Countries,' *Energy Policy*, 20(2), 94-103.
Myrdal, G. (1957) *Economic Theory and Underdeveloped Regions*, (London: Duckworth).
Panayotou, T. (1993) 'Empirical tests and policy Analysis of Environmental Degradation at Different Stages of Economic Development,' *World Employment Programme Research Working Paper WP 238*, January (Geneva: International Labour Office).
Pearce, D., E. Barbier and A. Markandya (1990) *Sustainable Development* (London: Earthscan).
Pearce, D.W. *et al.* (1991) *Blueprint 2: Greening the World Economy* (London: Earthscan).
Pearce, D. (1993) *Economic Values and the Natural World*, (London: Earthscan).
Pearson, P.J.G. (1992) 'Greenhouse Gas Scenarios and Global Warming: the Role of Third World Countries,' in Bird, G (ed), *International Aspects of Economic Development*, 125-67 (London: Academic Press).
—(1993) 'The Environmental Impacts of Electricity Generation in the Third World,' *IEE Proceedings-A, Science, Measurement & Technology*, 140 (1), 100-08.
—(1994a) 'Environmental Quality, Electricity and Development: A Review of the Issues,' *Department of Economics Discussion Paper No. 94-09* (University of Birmingham, 1-53).
—(1994b) 'Economic Development, the Supply of and the Demand for Environmental Quality in Relation to the Electricity Sector in Developing Countries,' *Energy Markets in Transition: Conference Proceedings*, International Association for Energy Economics (IAEE) 17th Annual International Energy Conference, Stavanger, Norway, Vol. I.
—(1994c, forthcoming) 'Environmental Priorities at Different Levels of Development: Electricity, Development and Environment,' in Guerrier, Y., N. Alexander, J. Chase and M. O'Brien (eds), *Values and the Environment: A Social Science Perspective*, (Wiley: Belhaven Press).
Schramm, G. (1993) 'Issues and Problems in the Power Sectors of Developing Countries,' *Energy Policy*, July, 735-47.
Selden, T.M. and D. Song (1992) 'Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution? (Syracuse, NY: Department of Economics, Syracuse University) (mimeo).
Shafik, N. (1994, forthcoming) 'Economic Development and Environmental Quality: Patterns of Change,' *Oxford Economic Papers*..
Shafik, N. and S. Bandyopadhyay (1992) 'Economic Development and Environmental Quality: Time-Series and Cross-Country Evidence,' *Policy Research Working Paper Series*, WPS 904 (Washington: World Bank).
Stern, D.I., M.S. Common and E.B. Barbier (1994) 'Economic Growth and Environmental Degradation: A Critique of the Environmental Kuznets Curve, *Discussion Papers in Environmental Economics and Environmental Management*, No. 9409 (York: Department of Environmental Economics and Environmental Management, University of York) August.
Weisskoff, R. (1970) 'Income Distribution and Economic Growth in Puerto Rico, Argentina and Mexico,' *Review of Income and Wealth*, 16(4), 303-32.
Wilbanks, T. (1991) 'The Outlook for Electricity Efficiency Improvements in Developing Countries,' in *Electricity and the Environment*, Background Papers for a Senior Expert Symposium in Helsinki, May, IAEA-TECDOC-624, Vienna, 121-45.
World Bank (1992) *World Development Report 1992*, Oxford University Press, Oxford.

—(1993a) 'Energy Efficiency and Conservation in the Developing World,' *World Bank Policy Paper,* (Washington: World Bank).
— *(1993b)* 'The World Bank's Role in the Electric Power Sector,' *World Bank Policy Paper, (Washington: World Bank).*
— (1994) *World Development Report 1994,* (New York: Oxford University Press).