CHAPTER 2

ECONOMIC GROWTH AND THE ENVIRONMENT

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2.1 Introduction

Will the world be able to sustain economic growth indefinitely without running into resource constraints or despoiling the environment beyond repair? What is the relationship between a steady increase in incomes and environmental quality? Are there trade-offs between the goals of achieving high and sustainable rates of economic growth and attaining high standards of environmental quality? For some social and physical scientists such as Georgescu-Roegen[55] and Meadows et al.,[56] growing economic activity (production and consumption) requires larger inputs of energy and material, and generates larger quantities of waste by-products. Increased extraction of natural resources, accumulation of waste and concentration of pollutants will therefore overwhelm the carrying capacity of the biosphere and result in the degradation of environmental quality and a decline in human welfare, despite rising incomes.[57] Furthermore, it is argued that degradation of the resource base will eventually put economic activity itself at risk. To save the environment and even economic activity from itself, economic growth must cease and the world must make a transition to a steady-state economy.

At the other extreme, are those who argue that the fastest road to environmental improvement is along the path of economic growth: with higher incomes comes increased demand for goods and services that are less material intensive, as well as demand for improved environmental quality that leads to the adoption of environmental protection measures. As Beckerman puts it, "The strong correlation between incomes, and the extent to which environmental protection measures are adopted, demonstrates that in the longer run, the surest way to improve your environment is to become rich".[58] Some went as far as claiming that environmental regulation, by reducing economic growth, may actually reduce environmental quality.[59]

Yet, others[60] have hypothesized that the relationship between economic growth and environmental quality, whether positive or negative, is not fixed along a country's development path; indeed it may change sign from positive to negative as a country reaches a level of income at which people demand and afford more efficient infrastructure and a cleaner environment. The implied inverted-U relationship between environmental degradation and economic growth came to be known as the "environmental Kuznets curve," by analogy with the income-inequality relationship postulated by Kuznets.[61] At low levels of development, both the quantity and the intensity of environmental degradation are limited to the impacts of subsistence economic activity on the resource base and to limited quantities of biodegradable wastes. As agriculture and resource extraction intensify and industrialization takes off, both resource depletion and waste generation accelerate. At higher levels of development, structural

[55] N. Georgescu-Roegen, *The Entropy Law and the Economic Process* (Cambridge, Harvard University Press, 1971).

[56] D.H. Meadows, D.L. Meadows, J. Randers and W. Behrens, *The Limits to Growth* (London, Earth Island Limited, 1972).

[57] H. Daly, *Steady-state Economics* (San Francisco, Freeman & Co., 1977); Second Edition (Washington, D.C., Island Press, 1991).

[58] W. Beckerman, "Economic growth and the environment: whose growth? whose environment?", *World Development,* Vol. 20, No. 1, April 1992, pp. 481-496, as quoted by S. Rothman, "Environmental Kuznets curves - real progress or passing the buck? A case for consumption-based approaches", *Global Economics*, 1998, p. 178.

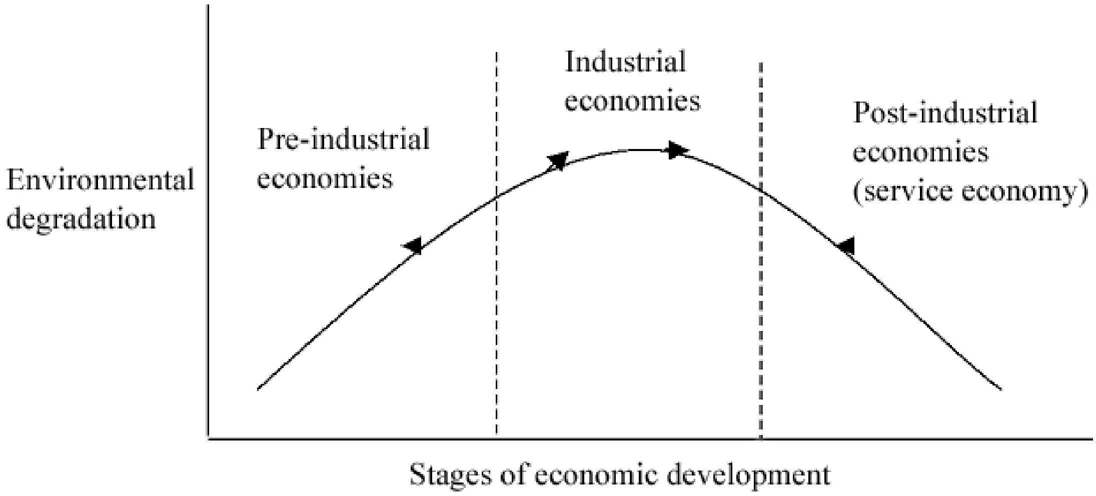
[59] B. Barlett, "The high cost of turning green", *Wall Street Journal*, 14 September 1994.

[60] N. Shafik and S. Bandyopadhyay, *Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence*, World Bank Policy Research Working Paper, No. 904 (Washington, D.C.), June 1992; T. Panayotou, *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*, ILO Technology and Employment Programme Working Paper, WP238 (Geneva), 1993; G. Grossman and A. Kreuger, "Environmental impacts of a North American free trade agreement", *The U.S.-Mexico Free Trade Agreement* (Cambridge, MA, The MIT Press, 1993); T. Selden and D. Song, "Environmental quality and development: is there a Kuznets curve for air pollution emissions?", *Journal of Environmental Economics and Management,* Vol. 27, Issue 2, September 1994, pp. 147-162.

[61] S. Kuznets, *Economic Growth and Structural Change* (New York, Norton, 1965) and *Modern Economic Growth* (New Haven, Yale University Press, 1966).

CHART 2.1.1

The environmental Kuznets curve: a development-environment relationship



change towards information-based industries and services, more efficient technologies, and increased demand for environmental quality result in levelling-off and a steady decline of environmental degradation,[62] as seen in chart 2.1.1.

The issue of whether environmental degradation i) increases monotonically, ii) decreases monotonically, or iii) first increases and then declines along a country's development path, has critical implications for policy. A monotonic increase of environmental degradation with economic growth calls for strict environmental regulations and even limits on economic growth to ensure a sustainable scale of economic activity within the ecological life-support system.[63] A monotonic decrease of environmental degradation along a country's development path suggests that policies that accelerate economic growth lead also to rapid environmental improvements and no explicit environmental policies are needed; indeed, they may be counterproductive if they slow down economic growth and thereby delay environmental improvement.

Finally, if the environmental Kuznets curve hypothesis is supported by evidence, development policies have the potential of being environmentally benign over the long run (at high incomes), but they are also capable of significant environmental damage in the short-to-medium run (at low-to-medium-level incomes). In this case, several issues arise: i) at what level of per capita income is the turning point? ii) How much damage would have taken place, and how can it be avoided? iii) Would any ecological thresholds be violated and irreversible damage take place before environmental degradation turns down, and how can they be avoided? iv) Is environmental improvement at higher income levels automatic, or does it require conscious institutional and policy reforms? And v), how to accelerate the development process so that developing and transition economies can attain the same improved economic and environmental conditions enjoyed by developed market economies?

The objective of this paper is to examine the empirical relationship between economic growth and the environment at different stages of economic development and explore how economic growth might be decoupled from environmental pressures. Particular attention is paid to the role of structural change, technological change and economic and environmental policies in the process of decoupling and the reconciliation of economic and environmental objectives. I then examine the experience of the ECE region in fostering environmentally friendly growth, whether and how it has been possible to decouple economic growth from environmental pressures in the ECE region. What has been the role of structural change, technological change and policy instruments in this decoupling for the two major groups of countries that constitute the ECE region, the developed market economies and the economies in transition?

62 T. Panayotou, *Empirical Tests and Policy Analysis…*, op. cit.

63 K. Arrow, B. Bolin, R. Costanza, P. Dasgupta, C. Folke, C. Holling, B. Jansson, S. Levin, K. Mäler, C. Perings and D. Pimental, "Economic growth, carrying capacity and the environment", *Science*, Vol. 268, 1995, pp. 520-521.

2.2 Empirical models of environment and growth

The environment-growth debate in the empirical literature has centred on the following five questions. First, does the often-hypothesized inverted-U-shaped relationship between income and environmental degradation, known as the environmental Kuznets curve, actually exist, and if so how robust and general is it? Second, what is the role of other factors, such as population growth, income distribution, international trade and time-and-space-dependent (rather than income-dependent) variables? Third, how relevant is a statistical relationship estimated from cross-country or panel data to an individual country's environmental trajectory and to the likely path of today's developing countries and transition economies. Fourth, what are the implications of ecological thresholds and irreversible damages for the inverted-U-shaped relationship between environmental degradation and economic growth? Can a static statistical relationship be interpreted in terms of carrying capacity, ecosystem resilience and sustainability? Finally, what is the role of environmental policy both in explaining the shape of the income-environment relationship, and in lowering the environmental price of economic growth and ensuring more sustainable outcomes?

Empirical models of environment and growth consist usually of reduced form single-equation specifications relating an environmental impact indicator to a measure of income per capita. Some models use emissions of a particular pollutant (e.g. SO_2, CO_2 or particulates) as dependent variables, while others use ambient concentrations of various pollutants as recorded by monitoring stations; yet other studies employ composite indexes of environmental degradation. The common independent variable of most models is income per capita, but some studies use income data converted into purchasing power parity (PPP), while others use incomes at market exchange rates. Different studies control for different variables, such as population density, openness to trade, income distribution and geographical and institutional variables. The functional specification is usually quadratic, log quadratic or cubic in income and environmental degradation. They are estimated econometrically using cross-section or panel data and many test for country and time-fixed effects. The ad hoc specifications and reduced form of these models turn them into a "black box" that shrouds the underlying determinants of environmental quality and circumscribes their usefulness in policy formulation. There have been some recent efforts to study the theoretical underpinnings of the environment-income relationship and some modest attempts to decompose the income-environment relationship into its constituent scale, composition and abatement effects. However, as Stern[64] has concluded, there has been no explicit empirical testing of the theoretical models and still we do not have a rigorous and systematic decomposition analysis.

I proceed with an overview of the theoretical microfoundations of the empirical models, followed by a survey of studies whose primary purpose is to estimate the income-environment relationship. I then survey attempts at decomposition analysis followed by studies that focus on mediating or conditioning variables, such as international trade, as well as on ecological and sustainability considerations and issues of political economy and policy.

Finally, I review the experience of the ECE region in terms of the growth and environment relationship and efforts to decouple the two.

2.3 Theoretical underpinnings of empirical models

The characteristics of production and abatement technology, and of preferences and their evolution with income growth, underlie the shape of the income-environment relationship. Some authors focus on shifts in production technology brought about by the structural changes accompanying economic growth.[65] Others have emphasized the characteristics of abatement technology.[66] And yet others have focused on the properties of preferences and especially the income elasticity for environmental quality.[67] A few authors have formulated complete growth models with plausible assumptions about the properties of both technology and preferences from which they derive environmental Kuznets curves (EKCs).[68] In this section, I shall briefly review the main theoretical strands of the Kuznets curve literature.

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64 D. Stern, "Progress on the environmental Kuznets curve?", *Environment and Development Economics,* Vol. 3, 1998, pp. 173-196.

65 G. Grossman and A. Kreuger, "Environmental impacts…", op. cit.; T. Panayotou, Empirical Tests and Policy Analysis…, op. cit.

66 T. Selden and D. Song, op. cit.; J. Andreoni and A. Levinson, *The Simple Analytics of the Environmental Kuznets Curve*, NBER Working Paper, No. 6739 (Cambridge, MA), September 1998.

67 K. McConnell, "Income and the demand for environmental quality", *Environment and Development Economics*, Vol. 2, November 1997, pp. 383-400; B. Kriström and P. Riera, "Is the income elasticity of environmental improvements less than one?", *Environmental and Resource Economics*, Vol. 7, Issue 1, pp. 45-55, January 1996; J. Antle and G. Heidebrink, "Environment and development: theory and international evidence", *Economic Development and Cultural Change*, Vol. 43, April 1995, pp. 603-625.

68 R. López, "The environment as a factor of production: the effects of economic growth and trade liberalization", *Journal of Environmental Economics and Management*, Vol. 27, Issue 2, September 1994, pp. 163-184; T. Selden and D. Song, op. cit.

The model by López[69] consists of two production sectors, with weak separability between pollution and other factors of production (labour and capital), constant returns to scale and technical change and prices that are exogenously determined. When producers free ride on the environment or pay fixed pollution prices, growth results inescapably in higher pollution levels. When producers pay the full marginal social cost of the pollution they generate, the pollution-income relationship depends on the properties of technology and of preferences. With homothetic preferences pollution levels still increase monotonically with income; with non-homothetic preferences, the faster the marginal utility declines with consumption levels and the higher the elasticity of substitution between pollution and other inputs, the less pollution will increase with output growth. Empirically plausible values for these two parameters result in an inverted-U-shaped relationship between pollution and income. This tends to explain why in the case of pollutants such as SO_2 and particulates, where the damage is more evident to consumers and, hence, pollution prices are near their marginal social costs, turning points have been identified at relatively low-income levels. In contrast, turning points are found at much higher income levels, or not at all, for pollutants such as CO_2, from which damage is less immediate and less evident to consumers, and hence underpriced, if priced at all.

Selden and Song,[70] using Forster's[71] growth and pollution model with a utility function that is additively separable between consumption and pollution, derive an inverted-U path for pollution and a J-curve for abatement that starts when a given capital stock is achieved; that is, expenditure on pollution abatement is zero until "development has created enough consumption and enough environmental damage to merit expenditures on abatement".[72] Two sets of factors contribute to an early and rapid increase in abatement: i) on the technology side, large direct effects of growth on pollution and a high marginal effectiveness of abatement, and ii) on the demand side (preferences), rapidly declining marginal utility of consumption and rapidly rising marginal concern over mounting pollution levels. To the extent that development reduces the carrying capacity of the environment, the abatement effort must increase at an increasing rate to offset the effects of growth on pollution.

A number of empirical EKC models have emphasized the role of the income elasticity of demand for environmental quality as the theoretical underpinning of the inverted-U-shaped relationship between pollution and income.[73] Arrow et al.[74] state that because the inverted-U-shaped curve "is consistent with the notion that people spend proportionately more on environmental quality as their income rises, economists have conjectured that the curve applies to environmental quality generally". A number of earlier studies[75] found income elasticities for environmental improvements greater than one. Kriström[76] reviewed the evidence from contingent valuation method (CVM) studies[77] that found income elasticities for environmental quality much less than one. Does the finding of a low-income elasticity of demand for environmental quality present a problem for EKC models?

McConnell[78] examines the role of the income elasticity of demand for environmental quality in EKC models by adapting a static model of an infinitely lived household in which pollution is generated by consumption and reduced by abatement. He finds that the higher the income elasticity of demand for environmental quality, the slower the growth of pollution when positive, and the faster the decline when negative, but there is no special role assigned to income elasticity equal to or greater than one. In fact, pollution can decline even with a zero or negative income elasticity of demand, as when preferences are non-additive or pollution reduces output (e.g. reduced labour productivity because of damage to health, material damage due to acid rain or loss of crop output due to agricultural externalities). He concludes that preferences consistent with a positive income elasticity of demand for environmental quality, while helpful, are neither necessary nor sufficient for an inverted-U-shaped relationship between pollution and income. McConnell found little microeconomic evidence in non-valuation studies that supports a major role for the

[69] R. López, op. cit.

[70] T. Seldon and D. Song, op. cit.

[71] B. Forster, "Optimal capital accumulation in a polluted environment", *The Review of Economic Studies*, Vol. 39, 1973, pp. 544-547.

[72] T. Selden and D. Song, op. cit., p. 164.

[73] W. Beckerman, op. cit.; J. Antle and G. Heidebrink, op. cit.; S. Chaudhuri and A. Pfaff, "Household income, fuel choice and indoor air quality: microfoundations of an environmental Kuznets curve", Columbia University Department of Economics, 1998, mimeo.

[74] K. Arrow et al., op. cit., p. 520.

[75] T. Boercherding and R. Deacon, "The demand for the services of non-federal governments", *American Economic Review*, Vol. 62, 1972, pp. 891-901; T. Bergstrom and R. Goodman, "Private demands for public goods", *American Economic Review*, Vol. 63, No. 3, 1973, pp. 280-296; A. Walters, *Noise and Prices* (Oxford, Oxford University Press, 1975).

[76] B. Kriström and P. Riera, op. cit.

[77] R. Carson, N. Flores, K. Martin and J. Wright, *Contingent Valuation and Revealed Preference Methodologies: Comparing the Estimates for Quasi-public Goods*, University of California, Department of Economics, Discussion Paper No. 94-07 (San Diego), 1994.

[78] K. McConnell, op. cit.

responsiveness of preferences to income changes in macroeconomic EKC models.

Kriström,[79] interpreting the EKC as an equilibrium relationship in which technology and preference parameters determine its exact shape, proposed a simple model consisting of: a) a utility function of a representative consumer increasing in consumption and decreasing in pollution; and b) a production function with pollution and technology parameters as inputs. Technological progress is assumed to be exogenous. He interprets the EKC as an expansion path resulting from maximizing welfare subject to a technology constraint at each point in time; along the optimal path the marginal willingness to pay for environmental quality equals its marginal supply costs (in terms of forgone output). Along the expansion path the marginal utility of consumption, which is initially high, declines and the marginal disutility of pollution (marginal willingness to pay for environmental quality) is initially low and rises. Technological progress makes possible more production at each level of environmental quality, which creates both substitution and income effects. The substitution effect is positive for both consumption and pollution. The substitution effect dominates at low-income levels and the income effect dominates at high-income levels producing an inverted-U-shaped relationship between pollution and income. Of course, the exact shape of the relationship and the turning point, if any, depend on the interplay of the technology and preference parameters, which differ among pollutants and circumstances.

In overlapping generation models[80] pollution is generated by consumption activities and is only partially internalized as the current generation considers the impact of pollution on its own welfare but not on the welfare of future generations. In these models, the economy is characterized by declining environmental quality when consumption levels are low, but given sufficient returns to environmental maintenance, environmental quality recovers and may even improve absolutely with economic growth.

Andreoni and Levinson[81] derived inverted-U-shaped pollution-income curves from a simple model with two commodities, one good and one bad, which are bundled together. Rising income results in increased consumption of the good, which generates more of the bad. This presents consumers with a trade-off: by sacrificing some consumption of the good they can spend some of their income on abatement to reduce the ill effects of the bad. When increasing returns characterize the abatement technology high-income individuals (or countries) can more easily achieve more consumption and less pollution than low-income individuals (or countries), giving rise to an optimal pollution-income path that is inverted-U shaped. The abatement technology is characterized by increasing returns when it requires lumpy investment or when the lower marginal cost technology requires large fixed costs (e.g. scrubbers or treatment plants); poor economies are not large enough or polluted enough to obtain a worthwhile return on such investments and end up using low fixed-cost, high marginal-cost technologies, while rich economies are large enough and polluted enough to make effective use of high fixed-cost, low marginal-cost technologies. Different pollutants have different abatement technologies and correspondingly the income-environment relationship may or may not be an inverted-U shape. The authors argue that similar results are obtained from other “good-bad” combinations, e.g. driving a vehicle associated with a mortality risk that can be abated by investments in safety equipment: “both the poor who drive very little and the rich, who invest in safe cars face lower risk from driving than middle-income people”. Indeed, empirically, Khan[82] found such an inverted-U-shaped relationship between hydrocarbon emissions and household income in California, and Chaudhuri and Pfaff[83] between indoor pollution and household income in Pakistan.

In conclusion, while many of the models used in econometric estimations of the environmental Kuznets curve have been ad hoc formulations, there has been no scarcity of theoretical microfoundations of an inverted-U-shape relationship between income and pollution, ranging from production structure, to abatement technology and consumer preferences.

2.4 The basic environmental Kuznets curve

The 1990s saw the advent of the environmental Kuznets curve hypothesis and an explosion of studies that tested it for a variety of pollutants. In this section, I review the basic EKC studies that focus on the

79 B. Kriström, “On a clear day, you might see the environmental Kuznets curve”, Camp Resources (Wilmington, NC), 12-13 August 1999 and “Growth, employment and the environment”, *Swedish Economic Policy Review*, 2000, forthcoming.

80 A. John and R. Pecchenino, “An overlapping generations model of growth and the environment”, *The Economic Journal*, Vol. 104, 1994, pp. 1393-1410; A. John, R. Pecchenino, D. Schimmelpfennig and S. Schreft, “Short-lived agents and the long-lived environment”, *Journal of Public Economics*, Vol. 58, Issue 1, September 1995, pp. 127-141.

81 J. Andreoni and A. Levinson, op. cit.

82 M. Kahn, “A household level environmental Kuznets curve”, *Economics Letters*, Vol. 59, Issue 2, May 1998, pp. 269-273.

83 S. Chaudhuri and A. Pfaff, op. cit.

income-environment relationship; in subsequent sections I review studies that focus on mediating or conditioning variables. The annex table summarizes 32 empirical studies of the EKC hypothesis and the annex chart depicts these findings in diagrammatic form. The first set of empirical studies appeared independently in three working papers: by Grossman and Krueger[84] in an NBER working paper as part of a study of the likely environmental impacts of NAFTA; by Shafik and Bandyopadhyay[85] for the World Bank's 1992 *World Development Report*; and by Panayotou[86] in a working paper as part of a study for the International Labour Office. It is reassuring that these early studies found turning points for several pollutants (SO_2, NO_X and SPM) in a similar income range of \$3,000-\$5,000 per capita.

Grossman and Krueger[87] estimated EKCs for SO_2, dark matter (smoke) and suspended particles using the Global Environmental Monitoring System (GEMS) data for 52 cities in 32 countries during the period 1977-1988; per capita GDP data were in purchasing power parity (PPP) terms. For SO_2 and dark matter, they found turning points at \$4,000-\$5,000 per capita; suspended particles continually declined even at low-income levels. However, at income levels over \$10,000-\$15,000 all three pollutants began to increase again, a finding which may be an artifact of the cubic equation used in the estimation and the limited number of observations at high-income levels.

Shafik and Bandyopadhyay[88] estimated EKCs for 10 different indicators of environmental degradation, including lack of clean water and sanitation, deforestation, municipal waste, and sulphur oxides and carbon emissions. Their sample includes observations for up to 149 countries during 1960-1990 and their functional specification includes log linear, log quadratic and logarithmic cubic polynomial forms. They found that the lack of clean water and sanitation declined uniformly with increasing incomes and over time; water pollution, municipal waste and carbon emissions increase; and deforestation is independent of income levels. In contrast, air pollutants conform to the EKC hypothesis with turning points at income levels between \$300 and \$4,000. Panayotou, using cross-section data and a translog specification, found similar results for these pollutants, with turning points at income levels ranging from \$3,000 to \$5,000.[89] (The lower figures are due to the use of official exchange rates rather than PPP rates.)

Panayotou also found that deforestation also conforms to the EKC hypothesis, with a turning point around \$800 per capita; controlling for income, deforestation is significantly greater in tropical and in densely populated countries. Cropper and Griffiths,[90] on the other hand, using panel data for 64 countries over a 30-year period, obtained a turning point for deforestation in Africa and Latin America between \$4,700 and \$5,400 (in PPP terms). These turning points are a multiple of those found in the Panayotou and Shafik and Bandyopadhyay studies, a possible consequence of Cropper and Griffith's use of panel data. A study by Antle and Heidebrink,[91] which used cross-section data, found turning points of \$1,200 (1985 prices) for national parks and \$2,000 for afforestation. On the other hand, Bhattari and Hammig,[92] who used panel data on deforestation for 21 countries in Latin America, found an EKC with a turning point of \$6,800. Furthermore, earlier studies have controlled for macroeconomic factors, such as the level of indebtedness and for the quality of institutions, which were found to have the expected signs, negative and positive, respectively.[93]

Returning to urban environmental quality, the mid-1990s saw a large number of studies focusing on airborne pollutants. Selden and Song[94] estimated EKCs for SO_2, NO_X, and SPM and CO using longitudinal data on emissions in mostly developed countries. They found turning points of \$8,700 for SO_2, \$11,200 for NO_X, \$10,300 for SPM, and \$5,600 for CO. These are much higher levels than those found by Grossman and Krueger, a difference that the

84 G. Grossman and A. Kreuger, *Environmental Impacts of a North American Free Trade Agreement*, NBER Working Paper, No. 3914 (Cambridge, MA), November 1991.

85 N. Shafik and S. Bandyopadhyay, op. cit.

86 T. Panayotou, *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*, ILO Technology and Employment Programme Working Paper, WP238 (Geneva), 1993.

87 G. Grossman and A. Kreuger, "Environmental impacts…", op. cit. and "Economic growth and the environment", *Quarterly Journal of Economics*, Vol. 110, Issue 2, May 1995, pp. 353-377.

88 N. Shafik and S. Bandyopadhyay, op. cit.

89 T. Panayotou, *Environmental Kuznets Curves…*, op. cit.; *Empirical Tests and Policy Analysis…*, op. cit.; "Environmental degradation at different stages of economic development", in I. Ahmed and K. Doeleman (eds.), *Beyond Rio (The Environmental Crisis and Sustainable Livelihoods in the Third World)* (Basingstoke, MacMillan, 1995).

90 M. Cropper and C. Griffiths, "The interaction of population growth and environmental quality", *American Economic Review*, Vol. 84, 1994.

91 J. Antle and G. Heidebrink, op. cit.

92 M. Bhattarai and M. Hammig, "An empirical investigation of the environmental Kuznets curve for deforestation in Latin America", paper presented at the SAEA meeting (Lexington, Kentucky), January 2000.

93 Ibid.

94 T. Seldon and D. Song, op. cit.

authors explain in terms of the reduction of emissions lagging behind the reduction in ambient concentrations. However, this reasoning does not explain the large difference between their results and those of Panayotou, who also uses emissions data; the use of longitudinal versus cross-section data may help explain part of the difference. Cole, Rayner and Bates[95] estimated income-environment relationships for many environmental indicators, including total energy use, transport emissions of SO_2, SPM and NO_2, nitrates in water, traffic volumes, chlorofluorocarbons (CFC) emissions and methane. They found inverted-U-shaped curves only for local air pollutants and CFCs and concluded that "meaningful EKCs exist only for local air pollutants, while indicators with a more global, more indirect, environmental impact either increase with income or else have high turning points with large standard errors". This conclusion would lead one to expect that CO_2, the global pollutant *par excellence*, would increase monotonically with income, at least within any observable income range since the impacts of global warming are (totally) externalized to other countries and future generations. Indeed, earlier studies[96] obtained such a result. Holtz-Eakin and Selden[97] estimated EKCs for CO_2 using panel data, and found that CO_2 emissions per capita do not begin to decline until income per capita reaches $35,000, a result that confirms earlier findings by Shafik.[98]

However, more recent studies, using better data and more sophisticated estimation techniques, have obtained turning points for CO_2 emissions that, while higher than those of local pollutants, are still within the range of observable income levels. Schmalensee, Stoker and Judson[99] using a spline regression with 10 piece-wise segments and the Holtz-Eakin and Selden data, obtained an inverted-U-shaped relationship between CO_2 emissions and income per capita in 1985 PPP dollars. They found negative CO_2 emission elasticities with respect to income per capita at the lowest and highest income splines, and a turning point in the range of $10,000 to $17,000 per capita. Galeotti and Lanza[100] tested alternative functional specifications for the CO_2-income relationship, including Gamma and Weibrill functions as well as quadratic and cubic functions. They found turning points between $15,000 and $22,000 depending on the specification and sample.

Another recent study by Sachs, Panayotou and Peterson,[101] using a 10 segment piece-wise spline function and panel data for 150 countries during 1960-1992, found results similar to those of Schmalensee et al. The income elasticity of emissions was low at the lowest income spline, and rose to a maximum at around $11,500 per capita (turning point) and turned negative at incomes of about $17,500. Finding an inverted-U-shaped relationship for an invisible pollutant with much delayed effects and ample scope for fee-riding behaviour is a bit puzzling, but fully explainable by the structural changes that accompany economic growth: from agriculture, to industry, to services, three sectors with different carbon emission intensities.

2.5 Decomposition of the income-environment relationship

The income-environment relationship, as specified and tested in much of the literature, is a reduced form function that aims to capture the "net effect" of income on the environment. Income is used as an omnibus variable representing a variety of underlying influences, whose separate effects are obscured. For this reason, some authors have termed the reduced form specification as a "black box" that hides more than it reveals; "without explicit consideration of the underlying determinants of environmental quality, the scope of policy intervention is unduly circumscribed".[102] In order to understand why the observed relationship exists, and how it might be influenced, more analytical and structural models of the income-environment relationship are needed. As a first step, it must be recognized that the observed environmental quality is the outcome of the interplay of emissions and abatement within a specific location, and an attempt has to be made to identify the different effects of economic development on environmental quality transmitted through the income variables.

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[95] M. Cole, A. Rayner and J. Bates, "The environmental Kuznets curve: an empirical analysis", *Environment and Development Economics*, Vol. 2, Issue 4, 1997, pp. 401-416.

[96] N. Shafik and S. Bandyopadhyay, op. cit.

[97] D. Holtz-Eakin and T. Selden, "Stoking the fires? CO_2 emissions and economic growth", *Journal of Public Economics*, Vol. 57, Issue 1, May 1995, pp. 85-101.

[98] N. Shafik, "Economic development and the environmental quality: an econometric analysis", *Oxford Economic Papers*, Vol. 46, 1994, pp. 757-773.

[99] R. Schmalensee, T. Stoker and R. Judson, "World carbon dioxide emissions: 1950-2050", *The Review of Economics and Statistics*, Vol. 80, Issue 1, February 1998.

[100] M. Galeotti and A. Lanze, "Richer and cleaner? A study on carbon dioxide emissions in developing countries", proceedings from the 22nd IAEE Annual International Conference (Rome), 9-12 June 1999.

[101] J. Sachs, T. Panayotou and A. Peterson, *Developing Countries and the Control of Climate Change: A Theoretical Perspective and Policy Implications*, CAER II Discussion Paper, No. 44 (Cambridge, MA), November 1999.

[102] T. Panayotou, "Demystifying the environmental Kuznets curve: turning a black box into a policy tool", *Environment and Development Economics*, Vol. 2, Issue 4, November 1997, p. 469.

Panayotou,[103] and Islam, Vincent and Panayotou[104] identify three distinct structural forces that affect the environment: i) the scale of economic activity; ii) the composition or structure of economic activity; and iii) the effect of income on the demand and supply of pollution abatement efforts. They name the respective effects on the environment: the scale or level effect, the structure or composition effect and the pure income or abatement effect. (Kaufman et al.[105] have identified analogous effects.)

Algebraically:

$$\begin{bmatrix}\text{Ambient}\\\text{pollution}\\\text{level}\end{bmatrix} = \begin{bmatrix}\text{GDP per}\\\text{unit of}\\\text{area}\end{bmatrix} \text{X} \begin{bmatrix}\text{Composition}\\\text{of}\\\text{GDP}\end{bmatrix} \text{X} \begin{bmatrix}\text{Abatement}\\\text{efforts}\end{bmatrix}$$

The scale effect on pollution, controlling for the other two effects, is expected to be a monotonically increasing function of income since the larger the scale of economic activity per unit of area the higher the level of pollution, all else equal. The structural change that accompanies economic growth affects environmental quality by changing the composition of economic activity toward sectors of higher or lower pollution intensity. At lower levels of income, the dominant shift is from agriculture to industry with a consequent increase of pollution intensity. At higher incomes, the dominant shift is for industry to services with a consequent decrease in pollution intensity. Hence, the changing share of industry in GDP may be taken to represent structural change. The composition effect is then likely to be a non-monotonic (inverted-U) function of GDP, i.e. as the share of industry first rises and then falls, environmental pollution will first rise and then fall with income growth, controlling for all other influences transmitted through income.

Stripped of its scale and composition effects, the income variable represents the "pure" income effect on the demand and supply of environmental quality. On the demand side, at low incomes, increases in income are directed towards food and shelter, and have little effect on the demand for environmental quality; at higher income levels, rising income leads to increased demand for environmental quality since the latter is a normal (if not a superior) good. The Engel's curve for environmental quality translates into an inverted-J curve relating income and environmental degradation,[106] that is, once the scale and composition effects of income growth are controlled for, pollution is a non-increasing function of income reflecting the non-negative elasticity for environmental quality. On the supply side, higher incomes make available the resources needed for increased private and public expenditures on pollution abatement, and induce stricter environmental regulations that internalize pollution externalities. The income variable (stripped of its scale and composition effects) captures the locus of the equilibrium abatement levels, where demand and supply, both income-dependent, are equal. Hence, the abatement effect is expected to be a monotonically decreasing function of income. Chart 2.5.1 depicts these three effects based on Islam, Vincent and Panayotou.[107]

Panayotou[108] specified a cubic functional form for all decomposition effects, and included variables representing population density, the rate of economic growth and a policy variable (quality of institutions). The model was tested with a panel data set for 30 countries, SO_2 data being taken from GEMS and PPP-adjusted GDP figures from Summers and Heston.[109] The decomposition of the income variable into its constituent channels improved the overall fit dramatically, compared with the reduced form equation. The scale of the economy increases SO_2 concentrations monotonically, but at a diminishing rate, and it is particularly strong up to income levels of $3 million per square kilometre.

The composition effect leads to monotonically increasing SO_2 emissions with the increasing share of industry (from 20 per cent to 43 per cent) up to per capita income of $8,000; beyond this level and up to $17,000, the industry share levels off and declines slightly (to 37 per cent) with analogous effects on emissions. (A "tail" effect of rising industry share and SO_2 emissions at even higher income levels may be due to the very few observations of countries at this level of income.) Income per capita, stripped of its scale and composition effects, captures only the abatement effect on ambient emissions, which is expected to be negative, at least up to income levels of about $13,000 per capita (again a "tail" upturn is difficult to explain because there are too few observations at the high end of income levels).

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103 Ibid., pp. 465-484.

104 N. Islam, J. Vincent and T. Panayotou, *Unveiling the Income-environment Relationship: An Exploration into the Determinants of Environmental Quality*, Harvard Institute for International Development, Development Discussion Paper No. 701, May 1999.

105 R. Kaufmann, B. Davidsdottir, P. Pauly and D. Garnham, "The determinants of atmospheric SO_2 concentrations: reconsidering the environmental Kuznets curve", *Ecological Economics*, Vol. 25, Issue 2, May 1998, pp. 209-220.

106 T. Selden and D. Song, op. cit.

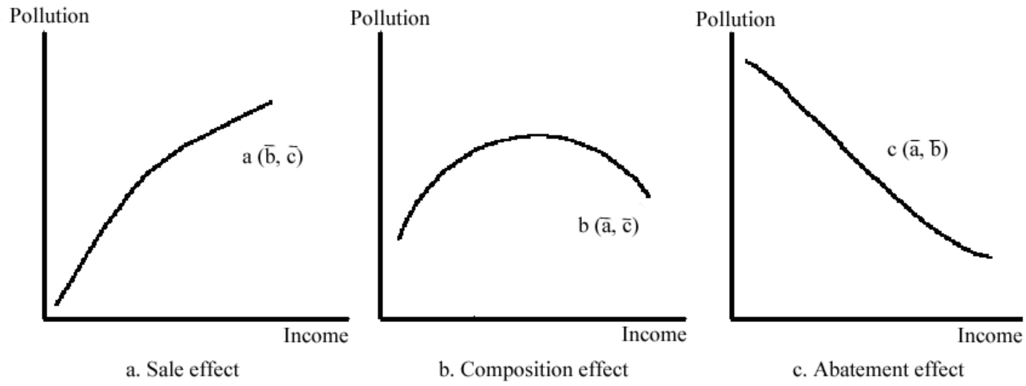
107 N. Islam, J. Vincent and T. Panayotou, op. cit.

108 T. Panayotou, "Demystifying the environmental Kuznets curve…", op. cit.

109 R. Summers and A. Heston, "The Penn World Table (Mark 5): an extended set of international comparisons, 1950-1988", *Quarterly Journal of Economics*, Vol. 106, Issue 2, May 1991, pp. 327-368.

CHART 2.5.1

Decomposition of income effects on the environment



Aside from being able to explain a larger percentage of the variation in ambient emissions, what is the policy significance of such a decomposition? Panayotou[110] demonstrates how a policy variable interacts with the abatement effect of income growth to reduce ambient emissions: a 50 per cent improvement in the efficacy of environmental policies/institutions at income levels between $10,000 and $20,000 reduces ambient SO_2 by half; at much lower income levels, the same policy change does not yield the same improvement because the demand (and supply) for environmental quality are relatively dormant. Panayotou concludes that "higher incomes tend to be associated with improved monitoring possibilities and hence, accelerate the speed of social adjustments, which, in turn, lowers the gap between the speed of environmental change and social change".

2.6 International trade

An alternative explanation for the downward sloping segment of the inverted-U-shaped relationship between certain pollutants and income per capita may be found in the hypothesized propensity of countries as they get richer to spin-off pollution-intensive products to lower income countries with lower environmental standards, either through trade or direct investment in these countries. If this is true, the past is not a good predictor of the future: developing countries, as Grossman and Krueger[111] noted, "will not always be able to find still poorer countries to serve as havens for the production of pollution-intensive goods". There is little evidence, however, that either the patterns of trade or the location of investment are significantly influenced by different environmental standards among countries.[112] This is not to say that environmental dumping does not take place, but that it has not been significant enough to explain the observed reductions of pollution in developed countries, where economic growth has continued. Hettige, Lucas and Wheeler[113] observed that there is some evidence of an "industrial displacement effect" for the dirtier industries as a result of the tightening of environmental regulations in the industrialized countries since 1970. Another contributing factor has been "import protection" in developing countries.[114] Thus, countries with high tariffs and quota on chemicals, for example, have had faster rates of growth of toxic intensity in their industrial production mix than those that followed outward oriented policies.[115]

International trade obscures the link between income and environment in a given country by delinking consumption from production within the country. This has led some authors to take a

[110] T. Panayotou, "Demystifying the environmental Kuznets curve…", op. cit., p. 482.

[111] G. Grossman and A. Kreuger, "Economic growth and the environment", *Quarterly Journal of Economics*, Vol. 110, No. 2, 1995, pp. 353-377.

[112] J. Tobey, "The effects of domestic environmental policies on world trade: an empirical test", *Kyklos*, Vol. 43, 1990, pp. 191-209; G. Grossman and A. Kreuger, "Environmental impacts…", op. cit.; A. Jaffe, S. Peterson, P. Portney and R. Stavins, "Environmental regulation and the competitiveness of U.S. manufacturing: what does the evidence tell us?", *Journal of Economic Literature*, Vol. 33, No. 1, March 1995, pp. 132-163; T. Panayotou and J. Vincent, "Consumption and sustainable development", *Science*, Vol. 276, 1997, pp. 53-55 (also published in Harvard Institute for International Development, Development Discussion Paper No. 567, January 1997).

[113] H. Hettige, R. Lucas and D. Wheeler, "The toxic intensity of industrial production: global patterns, trends and trade policy", *American Economic Review*, Vol. 82, 1992, pp. 478-481.

[114] Ibid., p. 480.

[115] G. Grossman and A. Kreuger, "Environmental impacts…", op. cit.

consumption, rather than a production, approach to the income-environment relationship; income changes are seen to drive environmental degradation. Ekins[116] argues that when consumption patterns do not change to match shifts in the pattern of production, environmental effects are displaced from one country to another, an opportunity that may not be available to today's least developed countries.

Ekins[117] tested the EKC hypothesis using a consumption-based aggregate indicator of environmental impacts developed by the OECD to include: local and global pollutants, access to water and sanitation, imports of tropical timber, energy intensity, private road transport, water abstraction, nitrate fertilizer application and threatened species, among others. He found no support for the EKC hypothesis, which is not surprising since the aggregation of so many dissimilar indicators may have eliminated any systematic co-variation with income.

Clearly, more work needs to be done to fully understand the role of international trade in mediating the relationship between environment and economic growth. On the one hand, there appears to be little evidence in support of the pollution haven hypothesis; instead, there is increasing evidence that open economies tend to be cleaner than closed economies. On the other hand, a growing body of the ecological economics literature provides evidence that, while the production patterns of developed countries may have grown cleaner over time, their consumption patterns continue to be as environmentally burdensome as ever. To resolve these issues, we need more analytical and disaggregated structural models than the standard reduced-form specifications.

2.7 Thresholds, irreversibility and the quest for sustainability

The finding of an environmental Kuznets curve or inverted-U-shaped relationship between income per capita and environmental degradation for a subset of pollutants seems to suggest that countries can outgrow their environmental problems by simply emphasizing economic growth without the need for special attention to the environment itself. While the environment is certain to get worse before it gets better, it seems that channelling a country's limited resources to achieve rapid economic growth and move quickly through and out of the environmentally unfavourable stage of development makes good environmental sense, as well as good economic sense.

However, the EKC, despite its theoretic microfoundations, is ultimately an empirical relationship, which has been found to exist for some pollutants but not for others. There is nothing inevitable or optimal about the shape and height of the curve. First, the downturn of EKC with higher incomes may be delayed or advanced, weakened or strengthened by policy intervention. It is not the higher income per se which brings about the environmental improvement but the supply response and policy responsiveness to the growing demand for environmental quality, through the enactment of environmental legislation and development of new institutions to protect the environment.

Second, since it may take decades for a low-income country to cross from the upward to the downward sloping part of the curve, the accumulated damage in the meantime may far exceed the present value of higher future growth, and a cleaner environment, especially given the higher discount rates of capital constraint on low-income countries. Therefore, active environmental policy to mitigate emissions and resource depletion in the earlier stages of development may be justified on purely economic grounds. In the same vein, current prevention may be more cost effective than a future cure, even in present value terms; for example, safe disposal of hazardous waste as it is generated may be far less costly than future clean ups of scattered hazardous waste sites.

Third, the height of the EKC reflects the environmental price of economic growth: the steeper its upward section, the more environmental damage the country suffers for each increment in its income per capita. While this depends in part on income level (stage of development), the efficiency of markets and policies largely determines the height of the EKC curve. Where markets are riddled with failures (externalities, ill-defined property rights, etc.), or distorted by subsidies of environmentally destructive inputs, outputs and processes, the environmental price of economic growth is likely to be significantly higher than otherwise. Economic inefficiency and unnecessary environmental degradation are two consequences of market and policy failures that are embodied to different degrees in empirically estimated EKCs. Perhaps more importantly, the higher the EKC, the more likely it is that critical ecological thresholds will be crossed and irreversible changes take place.[118] For example, tropical deforestation, the loss of biological diversity, extinction of species and destruction of fragile ecosystems and unique natural sites are either physically irreversible or prohibitively costly to reverse. Similarly, the economic and social consequences of

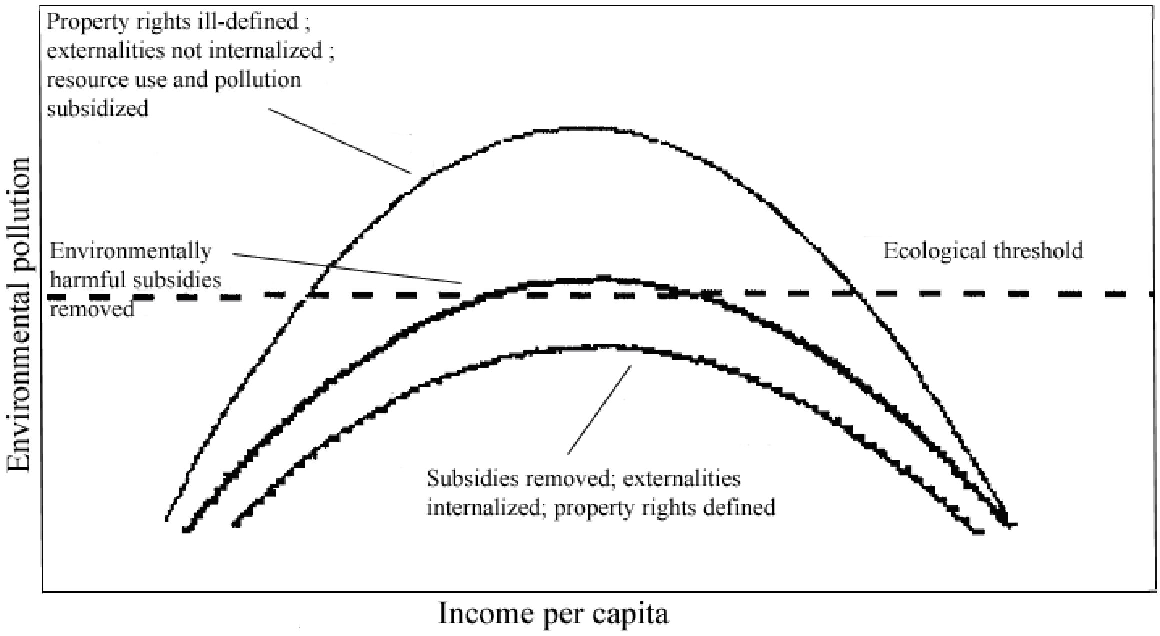
[116] P. Ekins, "The Kuznets curve for the environment and economic growth: examining the evidence", *Environment and Planning,* Vol. 29, No. 5, 1997, pp. 805-830.

[117] Ibid.

[118] T. Panayotou, *Empirical Tests and Policy Analysis…*, op. cit.

CHART 2.7.1

The income-environment relationship under different policy and institutional scenarios



Source: T. Panayotou, *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*, ILO Technology and Employment Programme Working Paper, WP238 (Geneva), 1993; "Environmental degradation at different stages of economic development", in I. Ahmed and K. Doeleman (eds.), *Beyond Rio (The Environmental Crisis and Sustainable Livelihoods in the Third World)* (Basingstoke, MacMillan, 1995); "Demystifying the environmental Kuznets curve: turning a black box into a policy tool", *Environment and Development Economics*, Vol. 2, Issue 4, November 1997.

Note: The environmental Kuznets curve is flattened out by removing environmentally harmful subsidies, internalizing externalities and ensuring a clear definition of and enforcement of property rights over natural resources.

damage to mental development and learning capacity from high lead levels in the blood of school-age children (due to lead emissions) are not easy to reverse, and they are certainly not reversed by switching to unleaded gasoline at later stages of development.

Panayotou[119] argued that, while an inverted-U-shaped relationship between environmental degradation and income per capita is an empirical reality for many pollutants and an inevitable result of structural and behavioural changes accompanying economic growth, it is not necessarily optimal: "In the presence of ecological thresholds that might be crossed irreversibly, and of complementarities between environmental protection and economic growth, a steep 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".[120] In order to reduce the environmental price of economic growth and lower the EKC below ecological thresholds, as seen in chart 2.7.1, the author recommends the removal of environmentally harmful subsidies (e.g. on energy and transport), better-defined and enforced property rights, full-cost pricing of resources to reflect growing scarcities and the internalization of environmental costs (e.g. through pollution taxes and tradeable permits).

Munasinghe is concerned that structural adjustment policies and other economy-wide reforms aimed at accelerating economic growth in poor countries might produce environmental impacts that exceed safe ecological limits. He recommends an "adjustment of the timing and sequencing of policy reforms and complementary measures to address specific distortions and 'tunnel through' the EKC, while cautioning against the temptation of making major changes in economy-wide policies merely to achieve minor environmental (and social) gains".[121]

Arrow et al.[122] drew attention to the ever-expanding scale of economic activity, as a result of economic growth, against the finite limits of the

[119] Ibid. and T. Panayotou, "Environmental degradation at different stages…", op. cit.

[120] T. Panayotou, "Environmental degradation at different stages…", op. cit., p. 30.

[121] M. Munasinghe, "Making economic growth more sustainable", *Ecological Economics*, Vol. 15, 1995, pp. 121-124.

[122] K. Arrow et al., op. cit.

carrying capacity of the planet, while recognizing that these limits are neither fixed nor static. In the absence of endogenously generated signals of increasing scarcity (e.g. rising environmental resource prices), economic activity may expand at a pace and scale that overwhelms the much slower expansion of the carrying capacity of the planet, resulting in irreversible damage to the productivity of the resource base, and the unsustainability of economic growth itself. Sustainability of economic activity may also be undermined by the loss of ecosystem resilience that results from growth-driven reductions in the diversity of organisms and the heterogeneity of ecosystems. Discontinuous changes in ecosystem functions, irreversible loss of future options, new uncertainties and increased vulnerability to natural disasters are a few avenues through which reduced ecosystem resilience may impair economic sustainability.

Arrow et al.[123] argue for a better understanding of ecosystem dynamics, and recommend reforms to improve the signals received by economic agents, including better-defined property rights and institutions that "provide the right incentives for protecting the resilience of ecological systems". However, given the inherent uncertainties and discontinuities, they also counsel the use of precautionary measures to maintain diversity and the resilience of ecosystems.

The EKC relationship, being unidirectional and without feedbacks from the environment to the economy, does not address sustainability concerns, which would involve long lags and require a dynamic model with reciprocal causality. Moreover, as de Bruyn, van den Bergh and Opschoor pointed out, "the outcomes of statistical analysis cannot be interpreted in terms of ecosystems resilience or carrying capacity".[124] They make a modest attempt to introduce dynamics by formulating a growth model based on "intensity-of-use" analysis, which they estimate for CO_2, NO_X and SO_2 in the Netherlands, the United Kingdom, the United States and west Germany. They find that the time pattern of emissions is correlated with economic growth and any reductions in emissions are attributed to structural and technological change. They then define "sustainable growth" as the rate of economic growth that leads to zero growth in emissions, i.e. any increase in emissions due to scale expansion is offset completely by structural change and technical progress.

TABLE 2.7.1

Sustainable growth rates using income levels of 1990
(Per cent)

	CO_2	NO_x	SO_2
Netherlands	1.8	2.1	11.2
United Kingdom	1.8	1.2	2.4
United States	0.3	2.6	3.8
West Germany	2.9	4.5	5.2

Source: S. de Bruyn, J. van den Bergh and J. Opschoor, "Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves", *Ecological Economics*, Vol. 25, Issue 2, May 1998, pp. 161-175.

Sustainable growth rates were calculated for each pollutant for the four countries (table 2.7.1). With few exceptions, these rates are significantly lower than the 3 per cent annual growth rate for developed countries and 5 per cent for developing countries that the Bruntland Report[125] considered sustainable.

2.8 Political economy and policy

Despite a general recognition that the empirical relationship between environmental degradation and income is neither net of policy effects nor immune to policy intervention, very few researchers have attempted to include policy variables into either reduced form or structural models. This is probably due to the lack of data on policy variables in general and environmental policy in particular. For example, Panayotou,[126] in one of the few studies that have attempted to incorporate policy variables, used the quality of institutions as proxies for environmental policies. He experimented with a set of five indicators, obtained from Knack and Keefer, of the quality of institutions in general: respect for and enforcement of contracts; efficiency of the bureaucracy; the rule of law; the extent of government corruption; and the risk of appropriation.[127] Enforcement of contracts and a composite index of all five variables worked best. It was found that improvements in the quality of institutions (policies) by 10 per cent resulted in a reduction of SO_2 emissions by 15 per cent. Having found a much smaller emissions elasticity with respect to economic growth and the density of population, the author argues that the efforts of pro-environment reforms should focus on improving the quality of institutions and policies rather than attempting to slow down economic or population growth. Indeed, Panayotou found that improvements in policy institutions

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[123] Ibid., p. 521.

[124] S. de Bruyn, J. van den Bergh and J. Opschoor, "Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves", *Ecological Economics*, Vol. 25, Issue 2, May 1998, pp. 161-175.

[125] World Commission on Environment and Development (WCED), *Our Common Future* (Bruntland Report) (Oxford, Oxford University Press, 1987).

[126] T. Panayotou, "Demystifying the environmental Kuznets curve…", op. cit.

[127] S. Knack and P. Keefer, "Institutions and economic performance: cross country tests using alternative institutional measures", *Economics and Politics,* Vol. 7, November 1995, pp. 207-227.

are likely to have higher payoffs at higher income levels, which also tend to be associated with improved monitoring possibilities.

Bhattarai and Hammig,[128] using indicators of socio-political institutions from the Freedom House and from Knack and Keefer,[129] found that the quality of government institutions has statistically significant negative effects on deforestation, especially in developing countries with publicly managed forests. Strengthening of property rights institutions, such as security of tenure and enforcement of contracts was also found to reduce deforestation pressures, all else equal.

While the study of the role of policy in mediating the environment-growth relationship is still in its infancy, the question arises as to what determines environmental policy itself. If it is not simply income dependent but at least in part exogenous, what explains the difference in environmental policies of countries at similar levels of economic development? Torras and Boyce[130] examine how various indicators of democracy affect the formation of preferences and mediate between individual preferences and public policy. They show, for example, that when democracy variables are included, income loses some of its significance in explaining variations in emissions.

Deacon[131] showed that the income-environment relationship varies across political systems and environmental quality tends to be lower in non-democratic regimes. Since only the elite-specific costs and benefits are usually considered in setting policies in such regimes, one would expect underinvestment in environmental quality and other public goods characterized by non-excludability of benefits. Deacon finds strong empirical evidence for his hypothesis in public investments in roads, public education, access to safe water and sanitation, and unleaded gasoline in a cross-section of 118 countries. Controlling for differences in income (undemocratic countries tend to be poorer) Deacon found statistically significant differences in the provision of public goods and environmental protection between the most democratic regime and each of the other regimes in 56 out of 65 cases, consistent with his hypothesis. Military and police expenditures are the major exceptions among public goods, as they tend to be higher in dictatorial regimes, apparently because they are viewed as conferring protection to the privileges of the elite. While Deacon's results are preliminary, they do suggest that political systems and political economy have an autonomous influence on environmental quality, or at any rate they mediate the income-environment relationship. The recent trends towards democratization should have beneficial effects on environmental quality (through a more complete accounting of benefits from public goods), as well as on economic growth, through the introduction of the rule of law and more secure property rights, factors that may also benefit the environment.

2.9 The ECE region

The ECE region consists of 55 member countries evenly divided between developed market economies and economies in transition. In terms of level of development as represented by income per capita (an admittedly crude indicator), they range from very poor central Asian countries such as Tajikistan with per capita incomes under $1,000 to very wealthy countries in Europe and North America with incomes in excess of $30,000. In general, transition economies have incomes below $10,000 and developed market economies above $15,000. It can thus be said that economies in transition find themselves to the left of the turning point of the environmental Kuznets curve, that is, on the rising segment of the curve where growth comes at the price of increased environmental damage. In contrast, developed market economies find themselves to the right of the turning point and hence on the falling segment of the EKC (chart 2.9.1).

However, it is also possible for low-income countries to improve their environment if they succeed in decoupling environmental pollution and resource use from economic growth. This can be done through structural, technological or policy change, or a combination of all three. The systemic change that the formerly planned economies are undergoing involves a process of decoupling as previously unpriced or mispriced resources are brought into the domain of markets, but this is only temporary. Sustained decoupling can only take place with full-cost pricing that is inclusive of environmental externalities. In an analogous manner, developed market economies often recouple environment and growth through environmentally harmful subsidies to sectors such as energy and transport (chart 2.9.2).

The above caveat notwithstanding, developing and transitional economies are bound to pay a higher environmental price for economic growth than developed economies if for no other reason because a) their rate of population growth is generally higher since their demographic transition is not yet complete; and b) their rate of economic growth tends to be higher because

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[128] M. Bhattarai and M. Hammig, op. cit.

[129] S. Knack and P. Keefer, op. cit.

[130] M. Torras and J. Boyce, "Income, inequality and pollution: a reassessment of the environmental Kuznets curve", *Ecological Economics*, Vol. 25, Issue 2, May 1998, pp. 147-160.

[131] R. Deacon, *The Political Economy of Environmental Development Relationships*, University of California, Department of Economics, Preliminary Framework Working Paper (Santa Barbara), 1999.

CHART 2.9.1

Positioning the ECE developed market economies on the environmental Kuznets curve

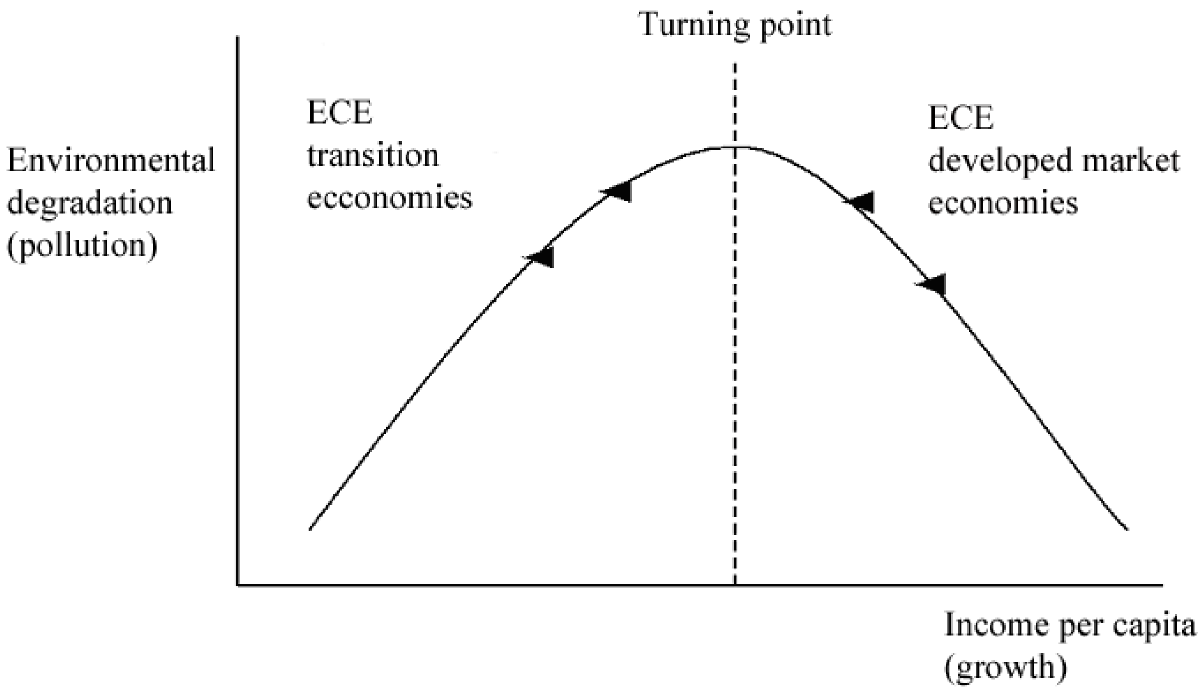
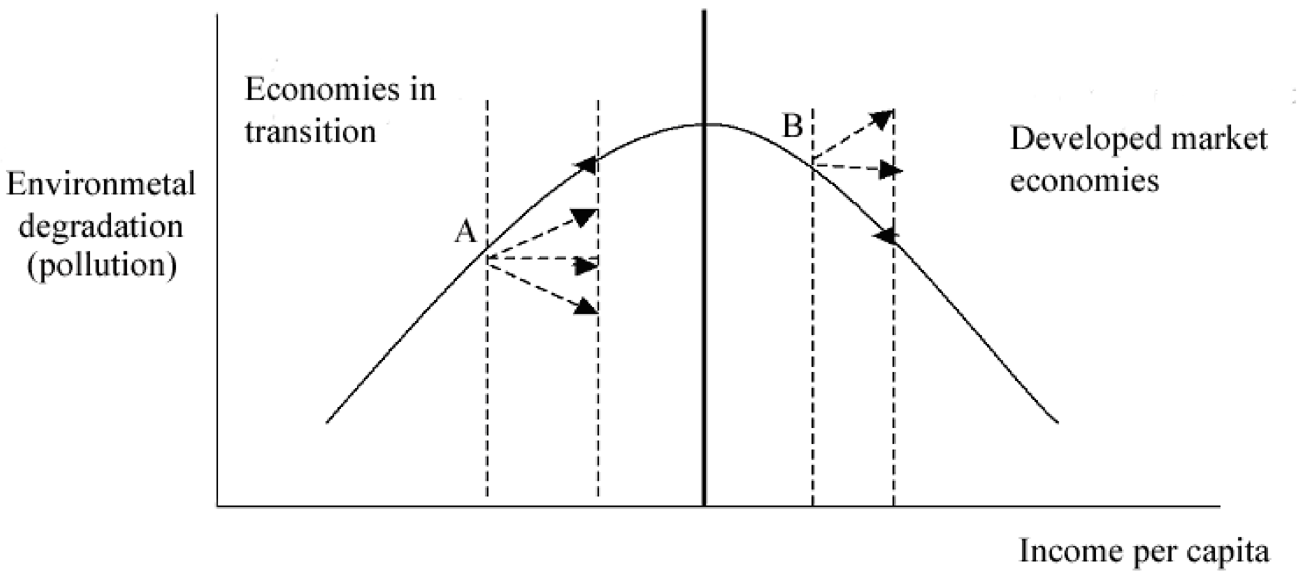


CHART 2.9.2

Decoupling (A) and recoupling (B) of environment and growth in transition and developed economies respectively



they are in a process of convergence (catching up with more advanced countries). The process of convergence does involve significant technological and structural changes. However, the decoupling effect of these changes may be offset by scale effects, unless it is reinforced by conscious and aggressive environmental policies. The demand for such policies, however, tends to be income elastic and thus in low-income ECE countries such demand is likely to be limited. Hence, some form of exogenous inducement (e.g. aid from developed ECE countries) may be necessary to induce a faster rate of decoupling of income growth and environment in low-income countries.

A similar dichotomy between ECE economies in transition and ECE developed market economies exists with regard to technological change. While developed economies are adopting emerging technologies that contribute to the decoupling of economic growth from pressures on the environment and natural resources, transition economies are still catching up with the environment-intensive technologies of the past, which dominate the transport, energy and industry sectors and cause many environmental problems. Again, in the same way that developed ECE counties can help to reinforce the slow shift of consumer's preference in transitional ECE countries away from environment-intensive products towards more environmental protection, they can also help to accelerate their transition to new environment-friendly technologies such as renewable energy and transport. Ultimately, however, the extent to which more efficient technologies will be adopted depends on the relative prices of different sources of energy, types of fuels and modes of transport, which are determined by markets and governments policies.

2.10 The state of growth and environment in the region

In the last decade, the developed market economies of the ECE region have had significant growth in GDP per capita and in industrial production accompanied by structural changes and a shift from energy and material-intensive industries to services, leading to a reduction of emissions and energy intensity per unit of GDP by more than 25 per cent in the past 20 years. The economies in transition are beginning to recover from the economic collapse of the 1990s and to grow again but at varying rates. Despite improvements in energy efficiency and levels of energy consumption per capita lower than in the developed market economies, their energy intensities of GDP are three to four times higher due to the large shares of heavy industry and obsolete technology in their economies.

Environmental pressures from increasing consumption are expected to intensify in the coming years despite the shift from heavy industry to services and a reduction in the energy and material intensity of consumer goods. The consumption patterns of economies in transition are expected to follow the same path as that in the developed market economies. Technology cooperation can help to exploit the large potential for the introduction of cleaner technology and less damaging patterns of production.

Improvements in energy efficiency in the developed market economies in the ECE region are being offset by the growth of demand for energy, which is satisfied mostly by polluting fossil fuels and only to a small extent by renewable sources. Economies in transition, in contrast, have huge potential for reducing energy intensity and increasing energy efficiency. Restructuring industrial production could improve energy efficiency, reduce pollution and gradually replace obsolete technology. Technology transfer from the advanced market economies can play a key role in this regard.

Transport in the ECE developed market economies is characterized by increasing congestion and car-related pollution and an environmentally harmful shift from rail and other public transport to car and air travel. Low road transport prices and inefficient public transport systems discourage behavioural changes towards more sustainable modes and patterns of transport. In the ECE economies in transition the earlier scarcity of private cars and the reliance on public transport is being increasingly replaced by the growing use of cars (many of which are older and more polluting than later models) at the expense of cleaner rail and other less energy-intensive public transport systems.

2.11 Policy response

There has been a strong decoupling of energy use from economic growth over the past 20 years, with the economy growing by 17 per cent between 1980 and 1998 and energy use falling by about the same proportion. At the same time, in the OECD countries there has also been a marked decoupling of emissions of local air pollutants from economic growth. Water and resource use continued to grow but more slowly than GDP growth reflecting a relatively weak decoupling of the two. Thus, the decoupling of emissions in OECD and generally in the developed ECE countries has been accomplished through a combination of technological change and strong environmental policies. The latter have included "greening" of fiscal policy, the removal of subsidies to environmentally harmful activities, and the use of economic instruments to internalize environmental cost.

A number of EU policy initiatives, such as the Broad Economic Policy Guidelines, introduced in 2001, among others, are promoting a gradual but steady and credible change in the level and structure of the tax rates with the aim of ensuring that external costs are fully reflected in prices, thereby addressing most of the fundamental structural problem in the developed countries, the unsustainable patterns of production and consumption. In the energy markets these guidelines aim to use taxes and other market-based instruments to rebalance prices in favour of renewable energy sources and technologies. Other EU initiatives in this direction are the European Climate Change Programme (ECCP), the directive establishing an EU framework for emissions trading, and the Integrated Product Policy (IPP). All the initiatives aim to realign relative prices and stimulate investments in new technologies to promote sustainable development. Member states are encouraged to improve market functioning by addressing market failures such as externalities through the "increased use of market-based systems in pursuit of environmental objectives as they provide flexibility to industry to reduce pollution in a cost-effective way, as well as encourage technological innovations". Economic instruments, such as gradual but steady and credible changes in the level and structure of tax rates until external costs are fully reflected in prices, are promoted as the most efficient means of decoupling economic growth from pollution, as thereby they drive changes in technology and consumer behaviour (preferences) that lie behind the growth-environment relationship. As exemplified by the energy and transport sectors, the EU decoupling policy consists of demand management through full-cost pricing and the development of more environmentally friendly alternatives by promoting technological innovations.

Since 1990 all the economies in transition have made efforts to restructure their energy and transport sectors according to market principles and to raise energy prices closer to economic and international levels. Because of the political sensitivity of energy pricing, however, and the slow pace of reform in many transition economies a gap of 20-85 per cent continues to persist between energy prices in the transition economies and world market prices. For example, electricity prices for households in eastern Europe are only 50 per cent of those in the European Union; for industrial consumers, electricity prices are closer to their economic and international levels, being 20 per cent lower than those of the EU. The United Nations Economic Commission for Europe has repeatedly called upon its members to raise the prices of various energy sources to reflect their true economic costs and to adopt economic instruments to internalize the costs to human health and the environment arising from energy production and consumption. The aim is to decouple emissions from energy use and energy use from economic growth.

2.12 Conclusion

The ECE region includes many of the most developed market economies in the world and most of the economies in transition. These two groups of countries are at different stages and levels of development and economic and environmental policy integration, yet both groups, for different reasons, have achieved a degree of decoupling of environment and growth. In the developed market economies this has been the result of structural change towards a service economy, of technological change towards less material- and energy-intensive production, and the adoption of new economic and environmental policies to internalize environmental externalities. In the economies in transition, decoupling has been largely the result of industrial restructuring and market reforms to bring the prices of energy, material and other resource inputs closer to their economic and international costs.

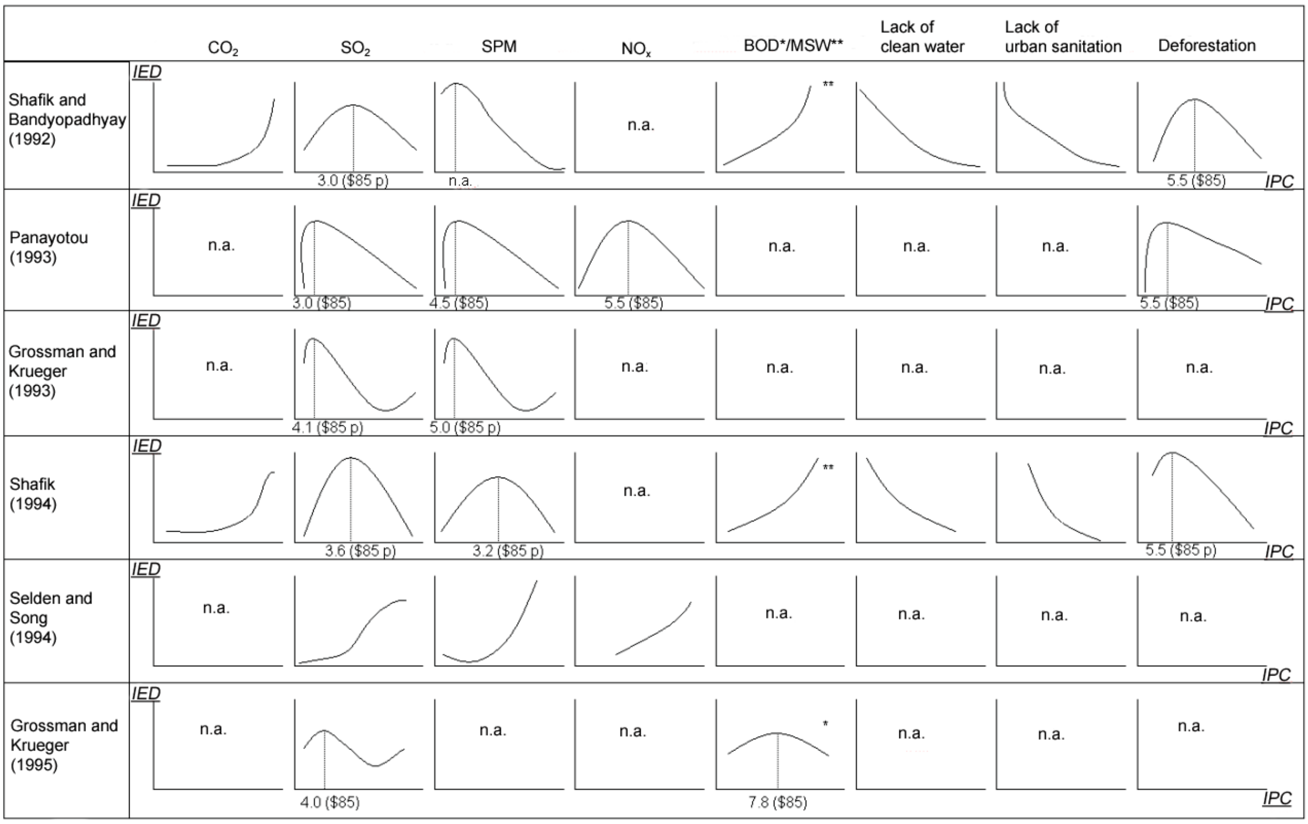
Despite significant progress towards sustainable development, developed countries still have unsustainable consumption patterns as evidenced by the continued growth of municipal waste and CO_2 emissions. As transition economies begin to recover and grow again their emissions and resource use are also increasing although less than proportionately. Their energy intensity of GDP, although declining, continues to be several times higher than that of the developed countries, while their consumption patterns are following those in the more developed economies. A further decoupling of growth and environment, and thus progress towards sustainable development, calls for action on many fronts by both groups of countries as well as cooperation between them especially in the area of technology transfer:

- Adoption of an effective mix of economic instruments such as taxes, charges and tradeable permits to correct market and policy failures, internalize environmental and social costs and induce changes in the composition of consumption and production;
- Improvements in the efficiency of resource use and the "dematerialization" of the economy;
- Changes in the content of economic growth that will involve adjustment costs, which will tend to be greater the faster the rate of change in relative prices; in particular, those who lose need to be compensated by those who benefit;
- Introduction of specific policies to preserve the living standards of those directly affected by the required adjustment and to avoid unemployment and social disruption; issues of inequality and social exclusion must be addressed;
- Education to encourage industrial and collective responsibility and thereby induce behavioural changes that will support sustainable development;
- Strengthening democracy and citizens' rights so that there is a free expression of preferences that will enable civil society to play a full and active role in the formulation of policies, which will induce changes in consumption and production patterns.

The experience of the developed market economies in the ECE region holds valuable lessons for the east European and central Asian economies in transition. First, the transition from a trade-off to a complementary relationship between economic growth and environmental quality is both a long process and one that requires active policy interventions in terms of i) the integration of economic and environmental policies (e.g. the greening of fiscal policy), and ii) the phasing out of environmentally harmful subsidies and the introduction of policy instruments to internalize environmental costs. Second, the battle that can be won on the production side through structural change and technological progress can be lost on the consumption side through wasteful and unsustainable consumption patterns, which are slow to change when environmental damage is remote in space or time, as in the case of climate change. Third, industrial restructuring and market pricing do not guarantee the decoupling of economic growth from environmental pressures; in the presence of environmental externalities, pricing in sectors such as energy and transport (but also agriculture and industry) should reflect not only economic and international costs but also the social costs that have been traditionally ignored by markets and international trade. Last, while command and control regulations have been quite effective in decoupling environment and growth and bringing about significant improvements in environmental quality in the developed market economies of the ECE region, this has been accomplished at an unnecessarily high cost in terms of both the inflexibility of response and the slowness of adjustment to change as well as the lack of incentives for innovation and for going further than just compliance. As the more recent experience of OECD countries demonstrates, combining command and control regulations with a healthy dose of economic instruments is a more cost effective and flexible means of decoupling economic growth from environmental pressures and ensuring sustainable development.

ANNEX CHART

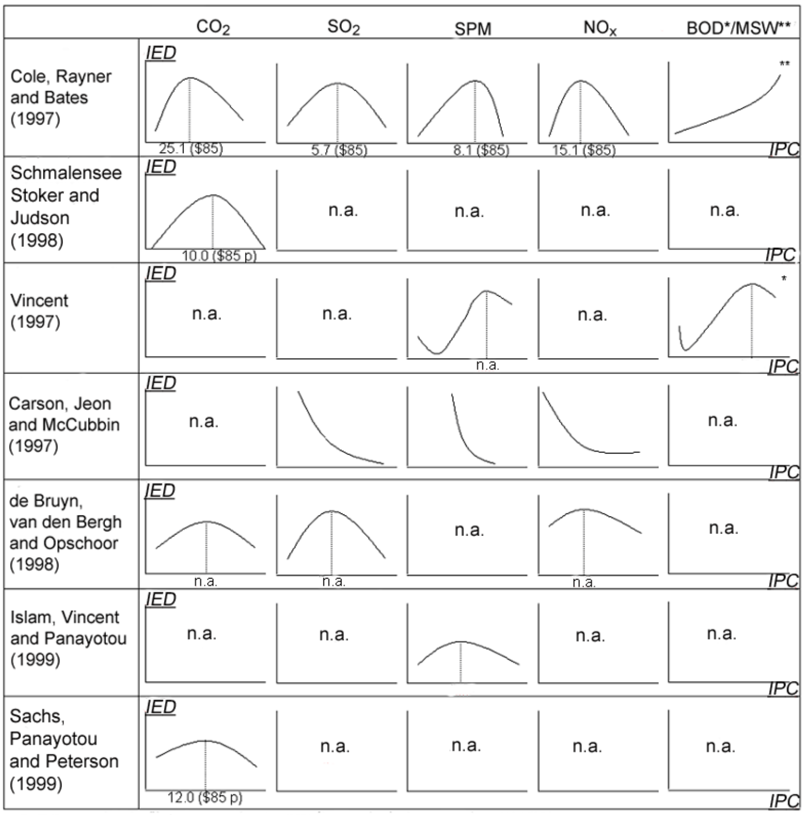
Selected estimates of the empirical relationship between income per capita (IPC) and selected indicators of environmental degradation (IED)



(For source and notes see end of chart.)

ANNEX CHART (concluded) [a]

Selected estimates of the empirical relationship between income per capita (IPC) and selected indicators of environmental degradation (IED)



CO_2 = carbon dioxide
SO_2 = sulphur dioxide
SPM = suspended particulate matter
NO_x = nitrogen oxide
BOD = biochemical oxygen demand
MSW = municipal solid waste
n.a. = not available (study did not cover this indicator)

Turning points:
First two digits mean thousands, i.e. 25.1
($85): GDP/per capita in $1995
($85 p): GDP/per capita in $1985 PPP

Source: N. Shafik and S. Bandyopadhyay, *Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence*, World Bank Policy Research Working Papers, No. 904 (Washington, D.C.), June 1992; T. Panayotou, *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*, ILO Technology and Employment Programme Working Paper, WP238 (Geneva), 1993; G. Grossman and A. Kreuger, "Environmental impacts of a North American free trade agreement", *The U.S.-Mexico Free Trade Agreement* (Cambridge, MA, The MIT Press, 1993); N. Shafik, "Economic development and the environmental quality: an econometric analysis", *Oxford Economic Papers,* Vol. 46, 1994; T. Selden and D. Song, "Environmental quality and development: is there a Kuznets curve for air pollution emissions?", *Journal of Environmental Economics and Management,* Vol. 27, Issue 2, September 1994; G. Grossman and A. Kreuger, "Economic growth and the environment", *Quarterly Journal of Economics*, Vol. 110, Issue 2, May 1995; M. Cole, A. Rayner and J. Bates, "The environmental Kuznets curve: an empirical analysis", *Environment and Development Economics*, Vol. 2, Issue 4, 1997; R. Schmalensee, T. Stoker and R. Judson, "World carbon dioxide emissions: 1950-2050", *The Review of Economics and Statistics,* Vol. 80, Issue 1, February 1998; J. Vincent, R. Ali, et al, *Environment and Development in a Resource-rich Economy: Malaysia under the New Economic Policy* (Cambridge, MA, Harvard University Press, 1997); R. Carson, Y. Jeon and D. McCubbin, "The relationship between air pollution emissions and incomes: US data", *Environment and Development Economics*, Vol. 2, Issue 4, 1997; S. de Bruyn, J. van den Bergh and J. Opschoor, "Economic growth and emissions: reconsidering the empirical basis of environmental Kuznets curves", *Ecological Economics*, Vol. 25, Issue 2, May 1998; N. Islam, J. Vincent and T. Panayotou, *Unveiling the Income-environment Relationship: An Exploration into the Determinants of Environmental Quality*, Harvard Institute for International Development, Development Discussion Paper No. 701, May 1999; J. Sachs, T. Panayotou and A. Peterson, *Developing Countries and the Control of Climate Change: A Theoretical Perspective and Policy Implications*, CAER II Discussion Paper, No. 44 (Cambridge, MA), November 1999.

[a] The studies on this page did not cover lack of clean water, lack of urban sanitation or deforestation.

ANNEX TABLE

A summary of empirical studies of the environmental Kuznets curve (EKC) hypothesis

Author and explanatory indicator	*Dependent variable*	*Relation shape*	*Turning point (GDP/per capita)*	*Remarks*
I	*II*	*III*	*IV*	*V*
Shafik and Bandyopadhyay	Lack of clean water	Linear downward	Declines monotonically	Sample includes 149 countries
(1992)	Lack of urban sanitation	Linear downward	Declines monotonically	for the period 1960-1990
GDP/per capita $1985 PPP	Level of particulate matters	Quadratic	n.a.	
	SO_2	Quadratic U-inverted	3 000	
	Changes in forest area	Quadratic	n.a.	
	Annual rate of deforestation	Quadratic U-inverted	2 000	
	Dissolved oxygen in rivers	Quadratic	n.a.	
	Municipal waste per capita	Quadratic	n.a.	
	Carbon emissions per capita	Quadratic U-inverted	4 000	
Hettige, Lucas and Wheeler	Toxic intensity of GDP	Quadratic U-inverted	12 790	Global; toxic intensity of 80
(1992)	Toxic intensity of industrial output	Quadratic	n.a.	countries; logarithm
GDP/per capita $1985				
Panayotou	SO_2	Quadratic U-inverted	3 000	Global; emissions per capita;
(1993)	NO_x	Quadratic U-inverted	5 500	deforestation
GDP/per capita $1985	SPM	Quadratic U-inverted	4 500	
	Deforestation rate	Quadratic U-inverted	1 200	
Grossman and Krueger	SO_2	Cubic N-normal	a) 4 107; b) 14 000	Global; GEMS data; urban
(1993)	SPM	Cubic N-normal	Decreasing	concentration of pollutants
GDP/per capita $1985 PPP	Smoke	Cubic N-normal	a) 5 000; b) 10 000	
Shafik	Lack of safe water	Linear downward	n.a.	Global; World Bank data (*World*
(1994)	Lack of urban sanitation	Linear downward	n.a.	*Development Report (WDR)*
GDP/per capita $1985 PPP	Annual deforestation	Quadratic U-inverted		*1992,* environmental data
Time series	Total deforestation	Quadratic U-inverted		appendix); linear, quadratic and
	Dissolved oxygen in rivers	Linear downward	n.a.	cubic logarithm are tested
	Fecal coliform in rivers	Cubic N-normal	a) 1 375; b) 11 500	
	Ambient SPM	Quadratic U-inverted	3 280	
	Ambient SO_2	Quadratic U-inverted	3 670	
	Municipal waste per capita	Linear upward	n.a.	
	Carbon emission per capita	Linear upward	n.a.	
Selden and Song	Estimation by random effect:			Global; data from World
(1994)	SO_2	Cubic N-normal	10 700	Resources Institute (WRI) *World*
GDP/per capita $1985	SPM	Cubic N-normal	9 600	*Resources 1990-1991;* 30
Population density	NO_x	Cubic N-normal	21 800	countries in the sample
	CO	Cubic N-normal	19 100	
	Estimation by fixed effect:			
	SO_2	Cubic N-normal	8 900	
	SPM	Cubic N-normal	9 800	
	NO_x	Cubic N-normal	12 000	
	CO	Cubic N-normal	6 200	
Cropper and Griffiths	Deforestation rate	Quadratic,		Regional; 64 countries in the
(1994)		Africa, U-inverted	4 760	sample; deforestation observed
GDP/per capita $1985		Latin America, U-inverted	5 420	during 1961-1991; FAO data
Wood price		Asia, n.a.	n.a.	
Density of rural population				
Holtz-Eakin and Selden	CO_2	Quadratic U-inverted	35 400	Global; emissions per capita
(1995)		Cubic N-normal	28 010	
GDP/per capita $1985				
Antle and Heidebrink	Total area of parks and protected			Data from *WDR 1987,*
(1995)	areas	Quadratic U-inverted	U-shape pattern	environmental data appendix and
GDP/per capita $1985	Deforestation	Quadratic U-inverted	U-shape pattern	from WRI *World Resources*
	Afforestation	Quadratic U-inverted	U-shape pattern	*1990-1991*
	Total forest area			

(For source see end of table.)

ANNEX TABLE (continued)

A summary of empirical studies of the environmental Kuznets curve (EKC) hypothesis

Author and explanatory indicator	*Dependent variable*	*Relation shape*	*Turning point (GDP/per capita)*	*Remarks*
I	*II*	*III*	*IV*	*V*
Grossman and Krueger (1995) GDP/per capita $1985	SO_2	Cubic N-normal	a) 4 053; b) 14 000	Global; GEMS data; pollutant concentration in cities and rivers
	Smoke	Cubic N-normal	6 151	
	Heavy particles	Cubic N-normal	Decreasing	
	Dissolved oxygen	Cubic N-normal	2 703	
	Biological oxygen demand	Cubic N-normal	7 623	
	Chemical oxygen demand	Cubic N-normal	7 853	
	Concentration of nitrates	Cubic N-normal	10 524	
	Fecal coliform	Cubic N-normal	7 955	
	Total coliform	Cubic N-normal	3 043	
	Concentration of lead	Cubic N-normal	1 887	
	Cadmium	Cubic N-normal	11 632	
	Arsenic	Cubic N-normal	4 900	
	Mercury	Cubic N-normal	5 047	
	Nickel	Cubic N-normal	4 113	
Panayotou (1997) GDP/per capita $1985 PPP Population density; industrial share; GDP growth; policy	SO_2	Cubic N-normal	a) 5 000; b) 15 000	The sample includes 30 developed and developing countries for the period 1982-1994
Roberts and Grimes (1997) GDP/per capita $1987	CO_2	Quadratic U-inverted	n.a.	World Bank data and Carbon Dioxide Information and Analysis Center data
Cole, Rayner and Bates (1997)	NO_x	Quadratic U-inverted	15 100 (14 700)	Cross-country/regional data from OECD countries
	SO_2	Quadratic U-inverted	5 700 (6 900)	
	SPM	Quadratic U-inverted	8 100 (7 300)	
	CO	Quadratic U-inverted	10 100 (9 900)	
	NO_x of transport sector	Quadratic U-inverted	15 100 (17 600)	
	SO_2 of transport sector	Quadratic U-inverted	9 400 (9 800)	
	SPM of transport sector	Quadratic U-inverted	15 000 (18 000)	
	Nitrates	Quadratic U-inverted	15 600 (25 000)	
	CO_2	Quadratic U-inverted	25 100 (62 700)	
	Energy consumption	Quadratic U-inverted	22 500 (34 700)	
	CFCs and halons	Quadratic U-inverted	15 400 (12 600)	
	Methane (NH4)	Quadratic U-inverted	n.a.	
	Municipal waste	Quadratic U-inverted	n.a.	
	Transport energy use	Quadratic U-inverted	400 000 (4 million)	
	Traffic volume	Quadratic U-inverted	108 200 (65 300)	
Vincent (1997) GDP/per capita Malaysian ringgit 1978 Population density	SPM	Cubic N-inverted	n.a. (increasing)	Malaysia; used data set with observations from late 1970s to early 1990s
	Biochemical oxygen demand	Cubic N-inverted	n.a. (decreasing)	
	Chemical oxygen demand	Cubic N-inverted	n.a. (increasing)	
	Ammoniac nitrogen	Cubic, n.a.	n.a. (no form)	
	pH	Cubic, n.a.	n.a. (no form)	
	Solid particles in rivers	Cubic, n.a.	n.a. (no form)	
Hettige, Mani and Wheeler (1997)	Industrial water pollution	Linear upward	n.a.	Factor level data on industrial water pollution from 12 countries
Carson, Jeon and McCubbin (1997) GDP/per capita $1982	Greenhouse gases	Linear downward	Decreasing	Data from 50 states of the United States
	Air toxics, 1990	Linear downward	Decreasing	
	CO	Linear downward	Decreasing	
	NO_x	Linear downward	Decreasing	
	SO_2	Linear downward	Decreasing	
	Volatile organic carbon	Linear downward	Decreasing	
	Particulate matter	Linear downward	Decreasing	
	Air toxics, 1988-1994	Linear downward	Decreasing	
Moomaw and Unruh (1997) GDP/per capita $1985	CO_2 (panel)	Cubic N-normal	12 813; 18 333	Oak Ridge National Laboratory data and Penn World Tables
	CO_2 (for each country)	Linear downward	n.a.	

(For source see end of table.)

ANNEX TABLE (continued)

A summary of empirical studies of the environmental Kuznets curve (EKC) hypothesis

Author and explanatory indicator	*Dependent variable*	*Relation shape*	*Turning point (GDP/per capita)*	*Remarks*
I	*II*	*III*	*IV*	*V*
Komen, Gerking and Folmer (1997) GDP/per capita $1991	Environment R&D	Linear upward	n.a.	19 countries of the OECD
Ravallion, Heil and Jalan (1997) GDP/per capita $1985 PPP	Carbon emissions	Cubic N-normal	U-shape pattern	Data are from the Oak Ridge National Laboratory and United Nations Statistical Division
Schmalensee, Stoker and Judson (1998) GDP/per capita $1985 PPP	CO_2	Log linear	10 000	National level panel dataset for 47 countries from 1950 to 1990
Torras and Boyce (1998) GDP/per capita $1985 PPP	SO_2 Smoke Heavy particles Dissolved oxygen Fecal coliform Access to safe water Access to sanitation	Cubic N-normal Cubic N-normal Cubic N-normal Cubic N-normal Cubic N-normal Cubic N-normal Cubic N-normal	3 890 4 350 Decreasing Increasing Increasing 11 255 10 957	GEMS data cover the period 1977-1991
Unruh and Moomaw (1998) GDP/percapita $1985 PPP	CO_2 emissions	Cubic N-normal	n.a.	Data obtained from Summers and Heston (1991), for 16 countries
Suri and Chapman (1998) GDP/per capita $1985 PPP	Consumption of primary commercial energy per capita, expressed in terms of oil equivalents	Quadratic U-inverted	55 000	Data consist of observations of 33 countries over the period 1971-1990; IEA data
de Bruyn, van den Bergh and Opschoor (1998) Economic growth rate	CO_2 NO_x SO_2	Linear logarithm Linear logarithm Linear logarithm	n.a. n.a. n.a.	Data from the Netherlands, United Kingdom, United States and west Germany for various time intervals between 1960 and 1993
Rothman (1998) GDP/per capita $1985 PPP	Food, beverages and tobacco Garment and footwear Gross rent, fuel and power Medical care and services Other commodities	Quadratic U-inverted Quadratic U-inverted Quadratic U-inverted Quadratic U-inverted Quadratic U-inverted	12 889 35 263 23 278 47 171	United Nations International Comparison Programme data
Kaufman, Davidsdottir, Pauly and Garnham (1998) GDP/per capita $1985	SO_2 (cross-section) SO_2 (fixed effects) SO_2 (random effects)	Quadratic U-inverted Quadratic U-inverted Quadratic U-inverted	11 577 12 500 12 175	United Nations *Statistical Yearbook 1993* data; panel of international data for 23 countries
Chaudhuri and Pfaff (1998)	Indoor air pollution	Quadratic U-inverted	n.a.	Micro data from the Pakistan Integrated Household Survey 1991
Kahn (1998)	Vehicle hydrocarbon emissions	Quadratic U-inverted	35 000	Data from the Random Roadside Test, created by the California Department of Consumer Affairs, Bureau of Automotive Repairs
Islam, Vincent and Panayotou (1999)	SPM	Quadratic U-inverted	n.a.	GEMS data on suspended particulate matter; data contain 901 observations from 23 countries for the period 1977-1988
Sachs, Panayotou and Peterson (1999) GDP/per capita $1985 PPP	CO_2	Quadratic U-inverted	12 000	The study combined time series and cross-section national level data to construct a panel with 3,869 observations for the period 1960-1992

(For source see end of table.)

ANNEX TABLE (concluded)

A summary of empirical studies of the environmental Kuznets curve (EKC) hypothesis

Author and explanatory indicator	*Dependent variable*	*Relation shape*	*Turning point (GDP/per capita)*	*Remarks*
I	*II*	*III*	*IV*	*V*
Galeotti and Lanza (1999)	CO_2	Quadratic U-inverted	13 260	New data set developed by IEA that covers the period between 1960-1995
Bhattarai and Hammig (2000) GDP/per capita $1998 PPP	Deforestation	Quadratic U-inverted	6 800	Data from FAO, WRI and UNEP for 1980, 1990 and 1995. National income, exchange rates and trade data taken from Penn World Tables, Summers and Heston (1991).

Source: N. Shafik and S. Bandyopadhyay, *Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence*, World Bank Policy Research Working Papers, No. 904 (Washington, D.C.), June 1992; H. Hettige, R. Lucas and D. Wheeler, "The toxic intensity of industrial production: global patterns, trends and trade policy", *American Economic Review*, Vol. 82, 1992; T. Panayotou, *Empirical Tests and Policy Analysis of Environmental Degradation at Different Stages of Economic Development*, ILO Technology and Employment Programme Working Paper, WP238 (Geneva), 1993; G. Grossman and A. Kreuger, "Environmental impacts of a North American free trade agreement", *The U.S.-Mexico Free Trade Agreement* (Cambridge, MA, The MIT Press, 1993); N. Shafik, "Economic development and the environmental quality: an econometric analysis", *Oxford Economic Papers,* Vol. 46, 1994; T. Selden and D. 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Heston, "The Penn World Table (Mark 5): an extended set of international comparisons, 1950-1988", *Quarterly Journal of Economics*, Vol. 106, Issue 2, May 1991.

DISCUSSANTS' COMMENTS

2.A Richard Herd

My remarks on the paper by Professor Panayotou are divided into three sections: first, I would like to mention a few recent papers that throw some doubt on the hypothesis of the environmental Kuznets curve (EKC), at least in its application to carbon dioxide emissions; second, I would like to report briefly on a recent OECD study that looks at the movement of various environmental indicators over the past decade; and, finally, I would like to discuss why such a relationship has not emerged for greenhouse gas (GHG) emissions.

Turning to the first area, my remarks are those of a non-specialist in the area of the environmental Kuznets curve. One striking feature of this literature is its focus on very straightforward reduced form equations, what could really be described as "data illustration" regressions. It is only recently that a theoretical account of the process behind the observations has appeared in the literature. Another feature is that much of the literature focuses on what Professor Panayotou calls the "human metric" of environmental damage. The result is a focus on air pollution variables that has also been extended recently to carbon dioxide. Given that the regressions are essentially undertaken for data-illustration purposes, what use can an economist make of these curves? Do they describe a fundamental technological relationship, or are they the result of decisions taken by policy makers? To be useful to an economist advising on policy these curves need to have more content.

Another key aspect of the literature is the optimistic conclusion that any link between economic growth and environmental damage will eventually end, and the environment will start to improve, as income rises. The three-way split into scale, structure and income, introduced by Professor Panayotou is welcome in that it starts to give more content to the curves. However, I wonder whether the interpretation of the downward sloping income component is correct. Suppose that the cost of retro-fitting sulphur abatement technology is constant across all countries, being determined by capital equipment prices in world trade. Then, if policy makers are rational, the degree of desired abatement will be greater at higher incomes. This would not be because of the supposed income superiority of a clean environment but simply because the benefits of avoiding morbidity and mortality rise with incomes but the cost of abatement remains constant. This analysis would suggest that above a certain level of income, stringent abatement regulations would be rational.

This view is supported by the fact that the EKC literature does not offer incontrovertible evidence of a negative relationship between income and environmental damage, beyond a certain income level. From a brief review of the literature, it would appear that most attention has focussed on air pollutants (sulphur dioxide, nitric oxides, suspended particles and ozone) with an extension to emissions of carbon dioxide. It is not surprising that the best relationships are with sulphur dioxide emissions and also with suspended particles. These are areas where the public benefits are well known and where technology is available to obtain clean production processes.

Even so, the evidence for the existence of EKCs for NO_X and ozone are less than convincing. In the developed world, emissions and concentrations of these gases are closely linked to the use of motor cars. So the evidence of Kahn[132] that there is an inverted U-curve for hydrocarbon emissions in California could be seen as grounds for optimism. However, a more recent study by Khanna[133] casts doubt on this result. In this study concentrations of air pollutants at individual monitoring sites in the United States were linked to census data for the areas around them. For NO_X, the data suggest not an inverted U-curve but rather a U-shaped curved. For carbon monoxide and ozone, however, there was no evidence of any correlation between such concentrations and income.

Varying results have been obtained for carbon dioxide. These emissions are clearly related to energy demand and so one might have expected the EKC literature to focus on the standard literature on energy demand, which itself has pin-pointed the role of price in determining energy demand. This literature has always paid careful attention to specifying the dynamics of such relationships. An article by Agras and Chapman[134] illustrates the importance of allowing

132 M. Kahn, "A household level environmental Kuznets curve", *Economics Letters*, Vol. 59, Issue 2, May 1998, pp. 269-273.

133 N. Khanna, "The income elasticity of non-point source air pollutants: revisiting the environmental Kuznets curve", *Economics Letters*, Vol. 77, Issue 3, November 2002, pp. 387-392.

134 J. Agras and D. Chapman, "A dynamic approach to the environmental Kuznets curve hypothesis", *Ecological Economics*, Vol. 28, 1999, pp. 267-277.

for dynamic properties: they found that allowing for an autoregressive structure in the residuals could double the estimate of the turning point for carbon dioxide emissions. They also focussed on the need to include the price of energy in the standard specification of EKC functions. The inclusion of both price and dynamics leads to substantial changes in the estimates of the turning point. Incidentally, the predictions of some of the earlier EKC studies on carbon dioxide[135] have to be seen against the continuing growth of carbon emissions in the United States.

More worrying for the EKC literature is a recent paper by Dijkgraaf and Vollebergh.[136] Their work casts some doubt on the estimation methodology used in most of the EKC literature. Typically the literature mixes cross-country time series with panel data. This assumes that the income relationship is homogenous across all countries. The authors claim that across OECD countries, the homogeneity assumption is not supported by the data. A turning point is still found when cross-country heterogeneity is allowed for, but it appears at higher income levels. Moreover, when panel-based estimates are replaced by estimates based on individual country time series, half of the country equations do not show any turning point.

In the second part of my comments, I would like to summarize briefly a recent OECD study of changes of a number of variables that are generally thought to have negative impacts on the environment. Here the objective was markedly less ambitious than estimating pooled cross-section time series panel equations. Rather, the objective was to look at a number of environmental measures and try to determine whether they were continuing to grow and, if so, whether they were growing faster or slower than GDP. The conclusions of the study were as follows:

- NO_X emissions fell 3 per cent against GDP growth of 63 per cent, in the period 1980 to 1999;
- SO_2 emissions fell by 50 per cent in the period 1980 to 1999;
- Particulate emissions fell in the United Kingdom and United States, but for OECD as a whole data are not available;
- Volatile organic compound emissions fell by 15 per cent in the 1900s;
- Water abstractions exhibited no growth;
- Forest cover expanded;
- Pollution of water by nitrogen from farms stabilized;
- Pollution of water by phosphate from households fell;
- Pesticide use in agriculture fell and became less toxic.

There were two areas where stability was not achieved:

- Municipal waste generation continues to rise but less rapidly than private consumption;
- Greenhouse gas emissions grew 4 per cent in the 1990s against GDP growth of 23 per cent.

The two areas where there is still concern, waste generation and greenhouse gases, are those that Professor Panayotou mentions in his paper. These two areas, though, have markedly different consequences for the environment. The OECD is currently looking at member country policies in a number of environmental areas, in the context of its *Economic Surveys*. For waste, the emerging conclusions are that disposing of waste in correctly managed landfill sites is neither particularly expensive nor does it cause appreciable environmental externalities. The same can be said of incineration, although its cost is greater than that of land filling. Some argue that because we are running out of natural resources, recycling should be encouraged. Our studies show that, on the contrary, it is quite easy for recycling to use more resources than burning or tipping the waste. For example, land-filling waste in compliant sites costs just €40 per tonne in Denmark, while across the border in Germany recycling plastic waste costs €900 per tonne (after deducting the value of the recycled material). Unfortunately, such differentials are not isolated examples.

Finally, I would like to turn to the question of why countries have been able to break the link between GDP growth and pollution in so many areas, but not to the same extent in greenhouse gas emissions, where the gains in the past decade have been mainly due to the restructuring of industries and changes in fuel use. The answer seems fairly clear. Where there is an available technology that allows emissions to be controlled with a reasonable cost-benefit ratio and without fundamental changes in consumption and production patterns, then the techniques will be adopted, although not always in the most cost efficient way. However, for greenhouse gases, there is as yet no "end-of-pipe" technology available. Achieving the goals for reduction through prices or regulation is very costly as they entail replacement of capital stock and changes in

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[135] D. Holtz-Eakin and T. Selden, "Stoking the fires? CO_2 emissions and economic growth", *Journal of Public Economics,* Vol. 57, Issue 1, May 1995, pp. 85-101.

[136] E. Dijkgraaf and H. Vollebergh, *A Note on Testing Environmental Kuznets Curves with Panel Data*, OCFEB Research Memorandum 0103, Working Paper Series 7 (Rotterdam), May 2001.

consumption patterns. As a result, scenarios for reducing emissions all require carbon prices that are high or even higher than some estimates of the benefits.

There are some signs of change in this area. In Europe, countries appear to be willing to adopt carbon trading policies that will give considerable incentives to finding end-of-pipe technologies. Indeed, there is growing interest in the development of technology to collect and then to sequester carbon emissions. My personal view is that it is only through such developments that an EKC will emerge for GHG emissions.

2.B Tomasz Zylicz

This paper addresses the important questions surrounding the so-called environmental Kuznets curve (EKC). Its review of dozens of relevant papers confirms the characteristic inverted "U" trend for various pollutants. However, while a lot of research confirms that many environmental characteristics first deteriorate and then eventually improve once a sufficiently high-income level has been reached, the underlying mechanisms are uncertain. Several explanations of the phenomenon have been advanced, but their validity is usually confined to limited data sets.

Professor Panayotou decomposes the EKC into i) scale or geographical intensity of the production, ii) the structure of production and iii) abatement. Every EKC is a product of these three factors. By making simple mathematical assumptions regarding the shape of each of them, he explains why and when a given environmental variable is likely to pass its "turning point" and start improving as the economy grows.

The only area that seems to be left out in this model is international trade. At least theoretically, it is possible to improve the local environment by "exporting" pollution to somewhere else. It has been claimed that this is how the richest countries have achieved lower pollution levels. By the same token, poor countries are doomed to serve as "pollution havens". Despite a number of attempts, these claims have never been satisfactorily tested empirically. Professor Panayotou's review would have been more comprehensive and policy relevant if the trade question had been fully addressed.

Nevertheless, the paper conveys an important message for environmental policy makers, namely that "policies matter". It is apparent from the paper that none of the decomposition variables – scale, structure and abatement – can be explained solely in terms of income or GDP per capita. In other words, there is no mechanistic relationship between personal incomes and economic pressure on the environment. Or, to put it differently, environmental degradation is not a "child's sickness" that everyone has to go through in the early stages of development.

Thorough research into the EKC demonstrates that the quality of socio-political institutions may have a crucial impact on the timing of the turning point for a given variable. Of course, the quality of institutions often depends on income as well, and so richer countries are likely to have more professionally run governments. Nevertheless, there is no deterministic trend and efforts are needed at all levels of affluence to make sure that socio-political institutions are adequate to meet the challenges. Democracy matters too. There is evidence that democratic societies reach turning points earlier than totalitarian ones. This is another interesting and perhaps somewhat unexpected outcome of studying EKCs.

The good news for those concerned with environmental protection and, more generally, with achieving sustainable development, is provided by a number of successful "decoupling" stories. The aim of environmentalists is to decouple certain goods from bads; for instance, to decouple welfare from material consumption, energy from fossil fuels or economic growth from pollution. Having passed the respective turning points many countries have indeed been able to decouple environmental degradation from GDP. The fact that these decouplings and turning points occurred at very different income levels once again demonstrates that there is no automaticity in this process and that policies matter.

An interesting question which is not explored in Panayotou's paper is whether transition economies are likely to replicate the EKCs of their neighbours whose market institutions were not destroyed after the First or Second World Wars. A more general question is whether low-income economies are doomed to repeating the trajectories and mistakes of the rich countries? The answer expected by many – and supported by some EKC analyses – is "no", but many governments in developing and transition economies continue to stress the need for growth even at the expense of the environment. Although decoupling can be accelerated by good policies and international assistance, the overwhelming evidence is that transition economies are not taking advantage of the experience of others. Apparently one can only learn from one's own mistakes.

Another unexplored question is the so-called Porter hypothesis. This asserts that strict environmental regulations help entrepreneurs to develop more efficiently than their competitors who are subject to weaker regulation. The hypothesis has never been rigorously tested, but numerous success stories suggest that it cannot be easily rejected. It would be fascinating to combine the Porter hypothesis with EKC research in order to see if rigorous policies designed to speed up the process of reaching turning points retard or accelerate economic growth.

One conclusion which emerges from studying the transition economies, although it is not highlighted in Professor Panayotou's review, is the need for cost effective environmental policies. All developing and transition economies are being pressed to behave in a more environmentally responsible way than developed market economies did when they were at comparable income levels some decades ago. At that time, however, environmental awareness was not so high as it is now, and consumers and firms were subject to less stringent regulations. Consequently the regulatory burden on economies is now much higher than it used to be. In the past the question of what instruments should be used to make economic agents comply with regulations was of secondary importance, but now it is crucial that agents are regulated in ways that make the compliance as inexpensive as possible. It has been known for some time that economic instruments such as taxes and marketable permits can be cost effective. Analyses of EKCs may be able to contribute to a better understanding of how policies using alternative instruments can influence the relationship between wealth and environmental degradation.

2.C Kaj Bärlund

I agree with much of what Professor Panayotou has to say in his paper. I will not go into the more theoretical background in the first parts of his paper. Instead I would like to focus on the concluding parts, where it touches upon some of the practical implications of the analysis.

Economic development in a market economy is a pretty wild horse that drags along the political decision makers in the liberalized trade and financial markets. Political decisions still set a framework for the developments, but the tools to implement the framework are becoming more scarce than before. Part of the framework consists of regulations and other internationally agreed measures to protect the environment.

Some of Professor Panayotou's reflections on the importance of institutional factors are of particular interest to those of us who are involved in environmental policy on a daily basis. He notes that improvements in the quality of institutions and policies have an important impact on the environment. Likewise, he refers to the findings that democratic structures and procedures have beneficial effects on the environment.

In the context of ECE these are, of course, crucial findings. In particular, as part of their transition from centrally planned economies to market economies, many ECE member countries have faced different challenges in reforming their institutions of governance. In many cases there has been a move from strong state structures to a situation where the public administration is very weak both in terms of legal status and resources. This is often the case also for institutions concerned with environmental protection.

Environmental problems were very prominent in the political debates during the first years of the transition process. The previous social system had produced enormous environmental problems, which was one reason for changing that system. When the system changed, however, the political focus on the environment lost some of its prominence as it became one of the many problems that had to be tackled in the transition process.

But the democratic spirit could not be put back into the bottle. New legislation was adopted and an environmental civil society started to develop. Even if the road towards fully-fledged democracies proved to be bumpier than had been expected, these societies continued to move – perhaps with some exceptions – in a more democratic direction.

I believe that the ECE has made an important contribution to the process of democratization, in particular in the environmental sphere. The Aarhus Convention on environmental information and public participation in decision-making is a landmark instrument in this regard. Its full implementation is on its way, but much work still needs to be done. One can assert without exaggeration, however, that the Aarhus Convention has changed the scene in terms of promoting democratic procedures. As a result of broad international cooperation it has introduced a legally binding tool for implementing environmental democracy.

Returning to Professor Panayotou's paper, I think that the ECE has contributed to the reduction of environmental harm by promoting democracy. This is, of course, a long and slow process, but it is one that has the potential to spill over to other areas of society beyond the environment. Thus, it would strengthen democratic thinking in a broader context, which, again, would be beneficial for the environment. Environmental education is part and parcel of environmental democracy. Environmental problems are often complex and they sometimes appear only after a long lapse of time, the obvious example being global warming. If the population is confronted with these problems without any basic knowledge of their causes, the possibilities for real participation in decision-making are limited. Of course the media also have an important role in this regard: they can make or break public debates on environmental issues. But a solid educational basis for the population is crucial. Therefore I feel that the initiative for better environmental education, to be submitted to the May 2003 Kiev Ministerial Conference "Environment for Europe", is worthy of as much political support as possible.

From environmental education we need to take only a short step to our habits of consumption. Panayotou's paper notes that production patterns in most ECE countries have improved over the last 20 or so years. Technology has improved and fewer resources are used per unit of output. But on the consumption side there have been few improvements, despite consumers nowadays tending to be more aware of the impact of their choices on the environment.

The accumulation of waste as an end result of current consumption habits is steadily growing. In this regard consumers in the richer parts of the region have a particular responsibility. We cannot make a strong case for more sustainable consumption patterns in the poorer countries if the richer ones cannot manage to show an example. This is part of the problem of decoupling economic growth from environmental impacts. On present trends, continuing economic growth is leading to increasing environmental pressures, not to a decoupling.

This seems to be the case for example with road transport. Technological improvements have been overtaken by an enormous surge in road traffic at the expense of more environmentally friendly modes of transport. In most countries, investments in transport networks have favoured roads, while railways, walking and cycling facilities have received little investment. This pattern, prevalent in the developed market economies, is now spreading rapidly to the emerging market economies.

Once again, economic growth, as such, is more at the root of the problem than a solution. In this particular case, moreover, we have to deal with a number of unwelcome impacts such as air and noise pollution, the loss of biodiversity and undisturbed natural urban space, congestion, accidents and the loss of transport alternatives for those with little choice.

Professor Panayotou's paper is thought provoking and inspirational. It shows that there are options for decoupling economic growth from environmental damage and that promising results have been obtained in several instances. On the other hand it also reveals that a laissez-faire approach is not an option. We should feed the wild horse of the market economy with environmentally friendly grass, while cautiously but firmly trying to change its direction towards a more sustainable future.