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**DELINKING ECONOMIC GROWTH FROM ENVIRONMENTAL DEGRADATION?
A LITERATURE SURVEY ON THE ENVIRONMENTAL KUZNETS CURVE HYPOTHESIS**

by

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Abstract

The effect of economic growth on environmental quality is much under dispute. A number of empirical studies have made the claim that there exist in some income ranges a positive relation between per capita income and some measure of environmental quality. According to this inverted U-shaped pattern of different pollutants relative to per capita incomes in different countries which is also called the "Environmental Kuznets Curve" (EKC), environmental pressure increases up to a point as income goes up; after the turning point environmental quality improves as income keeps rising. Possible explanations for this pattern are seen in the progression of economic development, from clean agrarian economies to polluting industrial economies to clean service economies. This trend is enhanced through the transfer of cleaner technology from high-income countries to low-income countries and the tendency of people with higher income having a higher preference for environmental quality. Since this relationship is so fundamental to questions of economic development and sustainability it has provoked a vast load of research over the last seven years supporting but also heavily criticizing the results and conclusions. This paper gives an overview of the literature published on this topic to date and the conceptual, methodological and fundamental critique put forward.

Keywords: Economic growth, environmental protection, Environmental Kuznets Curve

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1 Introduction

A growing economy is desired for its positive social and economic effects. It is also beyond doubt that economic activities presuppose a functioning environment. However, there is less consensus about the effects that economic growth has on environmental quality. Some researchers hypothesize that higher levels of income increase environmental degradation (Georgescu-Roegen 1971; Hall et al. 1986). Others suggest that higher levels of income reduce environmental degradation (Beckerman 1993). The question is whether the relationship between income and environmental quality behaves strictly monotonic. Environmental quality could deteriorate with every unit produced within certain income ranges, but improve within others. Also it cannot be expected that the same kind of relationship exists between income and different dimensions of environmental quality.

An economic system is environmentally only sustainable as long as it is physically in a (dynamic) steady-state, i.e. the amount of resources utilized to generate welfare is permanently restricted to a size and quality that does not overexploit the sources, or overburden the sinks, provided by the ecosphere. Although it was possible in Europe to achieve improvements (particularly the reduced production of ozone depleting substances, point source pollution of rivers, and air emissions from stationary sources), the state of the environment remains a serious concern. The European Environmental Agency recently summarized the situation as follows, "no overall positive trends can be depicted within the scope of the outlooks. For most of the issues there has either been insufficient progress towards recovery of a healthy environment, or unfavourable underlying developments. Adverse developments are expected concerning impacts from climate change and waste generation" (EEA 1999:24).

Macroeconomic growth theory has mostly ignored the environment. The underlying idea is that economic growth is, in some sense, good for the environment. Implicitly the presumption is often made that these consequences could either be dealt with separately or would take care of themselves (Arrow et al. 1995). Some argued for growth being a precondition for environmental improvement (Bhagwati 1993). For example Beckerman (1992), "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". And even the more in the South, "Economic growth appears to be a powerful way for improving environmental quality in developing countries" (Panayotou 1993:14). It is then GATT's assertion that "income growth has been associated with reduced pollution over significant ranges of per capita income" (GATT 1992:30) which must be tested. Some go even further and argue that "existing environmental regulation, by reducing economic growth, may actually be reducing environmental quality" (Bartlett 1994). On the other end of the spectrum, some claimed that economic growth was a priori incompatible with environmental sustainability (Georgescu-Roegen 1971). And Daly (1977) argued that further growth would push the world economy beyond the biogeophysical limits.

Clearly, it is important to understand better the nature and causes of the relationship between economic growth and environmental quality before adopting such far reaching implications for economic

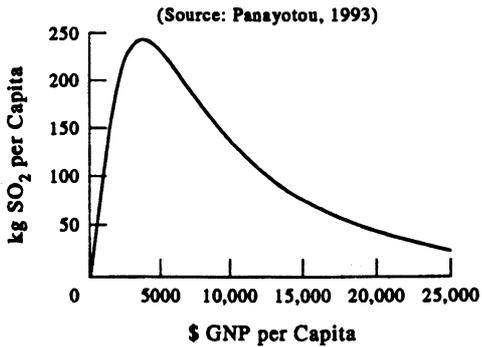
policy. The question is therefore: Can economic growth be part of the solution rather than the cause of environmental problems? This is the motivation for the mostly empirical studies searching for evidence of or proofs against the delinking of income and environmental degradation. Since this question is so fundamental to economic development and sustainability, it has provoked a vast load of research over the last seven years. Good overviews and comparisons provide Stern et al. (1996) and Ekins (1997). A slightly different position is chosen here and also the literature added since then is here taken into consideration.

2 Concept of the Environmental Kuznets Curve

2.1 General idea

The effect of economic growth on environmental quality is much under dispute. One of the positions put forward is the delinking hypothesis. The argument is based on the assumption that at the beginning of a growth path in a country increase in GDP corresponds with high environmental degradation. Environmentally friendly – and more expensive – technologies are not yet accessible and the awareness of environmental problems is low. Environmental degradation increases with income up to a certain point beyond which environmental quality is enhanced by higher GDP per capita. This relationship can be shown in an inverted U-shaped curve (see graph 1). It is sometimes described as the "Environmental Kuznets Curve" (EKC), following the observation of Kuznets (1955) that it appeared to describe the relationship between the level of income and income inequality. The EKC hypothesis is intended to represent a long-term relationship between environmental impact and economic growth.

Graph 1: The Environmental Kuznets Curve for SO₂



At low levels of development the shape of the curve is argued with environmental degradation (both in quantity and intensity) being limited to the impacts of subsistence economic activity and to limited quantities of biodegradable wastes. As economic development accelerates with the intensification of agriculture and other resource extraction and the take off of industrialization, the rates of resource depletion begin to exceed the rates of resources regeneration, and waste generation increases in quantity and toxicity. At higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations,

better technology and higher environmental expenditures, result in leveling off and gradual decline of environmental degradation (Panayotou 1993).

The EKC studies have used functional forms where results are evaluated with respect to the presence of a turning point and the significance of its parameters. The econometric techniques used are variants of regressions methods. The relationship between environmental degradation and income is usually expressed as a quadratic or log quadratic function. As measures for environmental degradation have been chosen ambient concentrations of SO₂, per capita emissions of CO₂, suspended particulate matter, lack of safe water, lack of urban sanitation, annual deforestation, municipal solid waste per capita etc. Other explanatory variables (e.g., investment shares, electricity tariffs, debt per capita, political rights, civil liberties, openness of the economy) have been included in these models, but income regularly has had the most significant effect on indicators of environmental quality. As GDP moves beyond the EKC turning points, it is assumed that the transition to improving environmental quality takes place.

2.2 The delinking of the income-environment relationship¹

In contrast to conventional economics, Daly refers by 'scale' to throughput, defined as the entropic physical flow of matter-energy from nature's sources, through the human economy and back to nature's sinks (see also Georgescu-Roegen 1971). The scale thus comprises material inputs into the economy (M) and outputs of the economy into the environment (pollution including waste, W). M and W refer to two distinct types of environmental pressure: depletion and pollution.

The scale of the economy (S_t) in year t is thus an indicator of total environmental pressure through material flows, that is, some aggregate of M and W. The scale depends on the population in year t (P_t), per capita income, y_t, and a variable reflecting the environmental pressure, E_t. This leads us to

$$S_t(M, W) = P_t \cdot y_t \cdot E_t(M, W) \quad (1)$$

Now environmental pressure is linked with driving forces such as the variation in income, population, and (indirectly) technology.

Based on Georgescu-Roegen's (1971) and Daly's conditions for (environmental) sustainability, the 'proper scale' of economic activity means: not go beyond the carrying capacity (C) of the total ecological system.

$$S_t(M, W) \leq C \quad (2)$$

One may conceive of an "environmental utilization space" as a set of steady states in terms of levels of M_t and W_t that are sustainable, i.e., compatible with the ecological processes (such as regeneration and absorption processes) and life-support systems underlying the economy (Siebert 1982; Opschoor 1995). The notion of environmental space as a sustainability frontier implies that an initial carrying capacity C₀, if exceeded by S_t(W, M) at some point in time, will lead to a subsequent capacity C_t < C₀, which could in turn be sustained, but with lower yields in terms of sustainable environmental pressure than in the initial situation. Thus

$$C_t = h(M_t, W_t, C_{t-1}) \quad (3)$$

¹ This section is for the most part based on de Bruyn and Opschoor (1997).

which makes the environmental utilization space at the end of period t a function of its initial value C_{t-1} and the level of metabolism (M_t and W_t) during the period.

Some value of C^* is chosen on the sustainability frontier, which is then imposed on the economic process as an environmental constraint. This is of course a crucial question. Daly and Georgescu-Roegen did not agree on where to draw this line. Daly argued for taking the current level as the frontier, while Georgescu-Roegen considered this as an arbitrary choice and demanded much stricter limits.

$$S_t(M_t, W_t) \leq C^*(M_t, W_t, C_0) \quad (4)$$

A crucial question is then of course, whether the economy will (or can be made to) move to a position compatible with it, or whether the economy will proceed ignoring the constraint by advancing along unsustainable paths.

The ratios M_t/Y_t and W_t/Y_t correspond to materials intensity and the pollution intensity of production; their inverses are the productivity coefficients of materials and pollution. A reduction of the materials intensities over time can be referred to as 'dematerialization' and, analogously, a reduction of pollution intensity could be labeled 'depollution'. If we want to separate these two strategies to reduce environmental pressure we find (if m_t is defined as the materials intensity M/Y in period t and w_t as the pollution intensity W/Y in period t):

$$\frac{dS}{dt} = w_t \left(Y_t \frac{dm}{dt} + m_t \frac{dY}{dt} \right) \quad \text{if } \frac{dw}{dt} = 0 \quad (5)$$

and

$$\frac{dS}{dt} = m_t \left(Y_t \frac{dw}{dt} + w_t \frac{dY}{dt} \right) \quad \text{if } \frac{dm}{dt} = 0 \quad (6)$$

For dematerialization materials consumption per unit of income must become smaller over time.

$$\frac{-dm/dt}{m} > \frac{dY/dt}{Y} \quad (7)$$

For depollution emissions and waste production per unit of income must become smaller over time.

$$\frac{-dw/dt}{w} > \frac{dY/dt}{Y} \quad (8)$$

Delinking² of economic growth from environmental degradation embraces at least these two dimensions, dematerialization and depollution. In this framework, delinking may result from different sets of developments (or combinations thereof) (de Bruyn 1997; Ekins 1997):

- changes in production processes and product design (technique effect – measured as percentage rate of technical change; achieved through more efficient use of inputs, substitution of less for more environmentally intensive inputs, less generation of wastes, transformation of wastes to less environmentally harmful forms, containment or recycling of wastes, a shift within a sector towards new, less environmentally harmful products or processes) and
- changes in the composition of production and product design (composition effect – measured as percentage rate of change of various sectors; achieved through a shift in production and/or

² The term was introduced in World Bank (1992).

consumption patterns towards existing or new sectors or industries that are less environmentally damaging).

In terms of the model delinking will continue, if dm is a negative function of income or time. Equ. (5) suggests that the manifestation as well as the magnitude of delinking depend on the relative values of the rate of economic growth (dY/Y) and the rate of change of the materials intensity coefficient (dm/m). As income grows, consumption patterns may change in less materials intensive directions and means may become mobilized towards technological innovations conducive to $(dm/m) < 0$ (de Bruyn and Opschoor 1997). Note that dematerialization and depollution as defined here and inherent in most of the EKC discussion is only relative, i.e. nothing is said about absolute levels of material use or pollution levels.

2.3 Discussion of explanations for the EKC

2.3.1 Higher income corresponds with less polluting production patterns

The composition effect

The common trajectory of economic development is that societies move from subsistence to more material and energy intensive patterns of agriculture to industrialization and then to more service-based economies. This development path is not brought about by policy but by increasing importance of capital accumulation and knowledge-based industries. With regard to the composition effect the evidence suggests (Ekins 1997:822),

- (1) that it adds to the scale effect at lower levels of income, that is, it causes environmental damage to increase faster than income, and
- (2) that it acts against but does not fully counteract the scale effect at higher levels of income.

Sound evidence for the composition effect is scarce. The findings, for instance, from Hettige et al. (1992) showed for toxic pollution the composition effect does not always work in the expected manner, particularly if international trade plays an important role. They interpreted the finding that toxic intensity decreases with openness of the economy but increases with income as the workings of comparative advantage. “[M]ore open economies have had higher growth rates of labor-intensive assembly activities which are also relatively low in toxic intensity. Highly protected economies have had more rapid growth of capital-intensive 'smokestack' sectors” (Hettige et al. 1992). In this case, international trade seems to have accelerated the process towards less polluting production. For a wider range of environmental indicators, the evidence is however mixed (Lucas 1996).

The displacement effect

Displacement instead of abatement of pollution is an alternative explanation, or at least another aspect which put the view of the increasing demand for environmental quality as a consequence of increased income. Saint-Paul (1994) suggests that poor countries are likely to be net exporters and rich

countries to be net importers of pollution-intensive goods. Also Stern et al. (1996) have suggested that the observed inverted U-curves may be the result of changes in international specialization: poor countries may attract 'dirty' and material intensive production while richer countries specialize in 'clean' and material extensive production, without altering consumption patterns. If this is the case, environmental effects are being displaced from one country to another, rather than reduced.

Stern et al. (1996) pointed out that "the assumption that changes in trade relationships associated with development have no effect on environmental quality" severely restricts the explanatory power of the conclusions drawn from EKC analyses. In fact, import substitution related reductions in environmental pressure should not be counted as an environmental gain. This is why de Bruyn and Opschoor (1997) chose consumption instead of production as an indicator of throughput.

Not only did Hettige et al (1992) find that toxic intensity decreased with openness of the economy, but also that the growth rate of the toxic intensity of manufacturing increased in the poorest countries. While toxic intensity had grown most quickly in high-income countries during the 1960s, this pattern was sharply reversed "[d]uring the 1970s and 1980s, after the advent of stricter OECD environmental regulation, ... toxic intensity in LDC manufacturing grew most quickly" (Hettige et al. 1992:479). This is consistent with the displacement hypothesis. Also Low and Yeats (1992) agree with the displacement hypothesis at a moderate degree. Also Hettige et al. (1997) found that Asian LDCs displaced OECD economies as the world's largest generator of industrial water pollution. However, it should be mentioned here that most empirical studies on displacement factors (e.g., Tobey 1990) have found rather limited evidence of displacement due to environmental regulation, at least at the moderate levels of current regulations. These findings need not be inconsistent, if polluting industries are at the same time characterized by factors more relevant for displacement (e.g., labor intensity, tax sensitivity). Thus, it could be that 'dirty' companies do not leave high-income countries because of the stricter environmental regulations, but they still do migrate to lower-income countries which happen to have lower environmental standards. Hettige et al. (1997) showed that pollution and labor intensities decline continuously with respect to output, and at almost exactly the same rate, as income increases. "Thus, sectoral pollution/labor ratios remain approximately constant during the development process" (p.3).

In conclusion, the composition effect and the displacement effect seem not to be independent. And insofar as the composition effect is due to displacement, later developing countries will not be able to benefit from it, for lack of other countries to which environmentally intensive activities can be displaced (Ekins 1997).

Danger of freezing specialization patterns

Apart of the displacement effect which may bias the composition effect, a phenomenon known in the literature as the "Dutch disease"³ can prevent economic structures from developing in the expected manner.

³ "The term Dutch Disease refers to the boom-induced rise in the real exchange rate and the associated relative decline in nonmineral traded-goods industries. It was coined to describe the effects on the Netherlands economy of the offshore gas discoveries in the late 1960s..." (Daniel 1992:93).

Comparative advantages are determined at a single point in time, but the long-term benefits of specializing in them depend on their dynamic effects on the economy. For example, two countries may at present have comparative advantages in bananas and chemicals, respectively. Specialization in bananas does little for technological innovation, the development of labor skills, or diversification into high value-added products. Specialization in chemicals usually performs well in all these areas. Where trade takes place on the basis of such unequal comparative advantages, the countries that specialize in the least dynamic comparative advantages may find themselves locked into economic stagnation and the bottom end of growing inequality (Ekins 1994). Krugman (1990) has constructed a formal model⁴ of such a situation by associating external economies with the industrial sector, claiming "this process ... captures the essence of the argument that trade with developed nations prevents industrialization in less developed countries" (p. 93). In conventional trade models, countries should simply specialize in whatever is their comparative advantage. "In practice, however, there is widespread concern that the contraction of a country's manufacturing sector that follows natural resources discoveries is a bad thing. The worry seems to be that when the natural resources run out, the lose manufacturing sector will not come back" (Krugman 1990:114). And he finds that if the extraction orientation of the economy lasts long, all of the industries that move abroad in the short run will remain abroad even when the transfer ends. "The home country's market share and relative wage will turn out to have been permanently reduced by its temporary good fortune" (Krugman 1990:116).

In addition, the specialization trap constitutes a potential environmental problem. In an attempt to increase earnings, supply of primary products is increased, resulting in a downward pressure on prices, exacerbated by a low demand elasticity and a low income elasticity for many primary products. The obvious solution of processing the primary products and adding more value to them prior to export has often been restrained by the practice of trade barriers in developed countries. Under these conditions the downward pressure on primary product prices, while a certain income still needs to be generated, will enhance natural resource depletion. Prices will not reflect their value adequately. Not free trade, but "forced trade" will result (Daly and Goodland 1994).

2.3.2 Income elastic demand for environmental quality

The common assumption is that the poor have little demand for environmental quality, and are constrained by their present consumption needs to degrade their environment. "As a society becomes richer its members may intensify their demands for a more healthy and sustainable environment in which case the government may be called upon to impose more stringent environmental controls" (Grossman and Krueger 1991) Not only are consumers with higher incomes more willing (and able) to spend more for "green products", as citizens they are also expected to exert increased pressure for environmental regulation when incomes rise.

In most cases where emissions have declined with rising income, the reductions have been due to local and national institutional reforms, such as environmental legislation and market-based incentives to

⁴ based on increasing returns to scale

reduce environmental impacts. A review of the available evidence on instances of pollution abatement suggests that the strongest link between income and pollution in fact is via induced policy response. Thus, the inverted U-relation is evidence that in some cases institutional reforms led private users of environmental resources to take account of the social costs of their actions (Arrow et al. 1995).

Is the environment really a luxury good?

Economic theory states that as incomes increase, individuals are willing to and capable to spend more (in absolute terms) for all normal goods, including environmental services such as cleaner air and water. Some authors even argued that individuals would increase their demand for environmental quality by a greater percentage than the per cent rise in income (e.g., Cochrane/Runge). However, there has been a lack of systematic evidence to support the assumption of environmental quality as a superior good (income elasticity larger than one). In a recent analysis of evidence from European countries, environmental quality was found to be a normal economic good for which demand rises less than proportionately with income, i.e. an income elasticity of about 0.4 (Kristöm 1994). Separate studies of environmental pollution cases corroborate this general finding (e.g. Caron et al). Since demand for pollution abatement policies appear to be quite income inelastic (at least beyond a certain threshold), it will increase with income, but to a lower extent than often assumed. Recently, McConnell (1997) showed that preferences consistent with a positive income elasticity of demand for environmental quality are neither sufficient for the EKC. He doubts the income elastic demand explanation for three reasons: "First, environmental quality is a set of heterogeneous goods, only some of which may be valued more highly at higher incomes. Second, the income elasticity of demand for some environmental qualities may be negative. Third, the role of the income elasticity of demand is attenuated by various simultaneous pollution-income relations" (p.384).

Poor people, especially rural poor people, are often the most direct dependent on their environment, and its resources, and the most vulnerable to its degradation. Such people do not need to become richer to become concerned about the environment. Of course, it is not our intention to argue for keeping poor people poor. Decent income is certainly a determining factor of quality of life. However, the conclusion that higher income is a precondition for higher environmental awareness does not hold (Ekins 1997). "There are some environmental problems where thresholds like survival are at stake. Here the willingness to avert damage is close to infinity and the level of per capita income only affects the capacity, not the willingness, to pay" (Shafik 1994). Not surprisingly, therefore, especially where their survival may be at stake, many low-income societies have evolved both conserving and sustainable patterns of use of the resource on which they depend. Such patterns, however, depend on these societies preserving their control over the resources in question, yet they have little capability to defend them against outside expropriation. However in some cases where external agents degraded poor people's environments, such people became environmental activists (Broad 1994, Guha and Martínez-Alier 1997; Martínez-Alier 1995).

Thus, income does not appear to be the main determinant for environmental legislation. Education and possibilities to organize are probably good alternative candidates. The mechanism of getting richer as a stimulation for people to look for environmental improvement works for some

situations, but not for others. "Action tends to be taken where there are generalised local costs and substantial private and social benefits. Where the costs of environmental degradation are borne by others (by the poor or by people in other countries), there are few incentives to alter damaging behaviour" (Shafik 1994:770).

2.3.3 International trade enhances the transfer of cleaner technology

Improved technology not only signifies increased productivity in the manufacture of old products but also the development of new products. With regards to the environment this distinction is important, as new solutions may lead to even higher improvements in material and energy efficiency. On the other hand, unknown new problems can emerge this way (e.g., use of new toxins).

With international trade, technological innovation is even more important than in a closed market economy. Developed countries must continually innovate, not just to grow but even to maintain their real incomes. For developing countries transfer of technology, in addition to its direct benefits, brings the indirect benefit of improved terms of trade (Krugman 1990).

Diffusion of technology prevents economic late-comers from requiring the same levels of materials and energy inputs per unit of GDP than older industrialized countries have needed in the past. International trade enhances diffusion of technology. Some authors suggested that this might allow developing countries to "dive through" the EKC.

With regard to the technique effect there are many examples of more efficient resource use, substitutions between resources, and containment of wastes. The most dramatic are the reduction of SO₂ in Japan, West Germany and France by the installment of flue-gas desulphurization equipment (Germany), a switch to nuclear power (France), and a combination of the two (Japan). Both alternatives however have secondary environmental effects (quarrying and transport of large quantities of limestone for flue-gas desulphurization, waste disposal, radioactive emissions, and risk of accidents for nuclear power) (Ekins 1997). Thus, when appraising benefits from advances in technology these secondary effects should always be incorporated into an environmental assessment.

Uncertainty⁵ and the Precautionary Principle

Many of the most intractable environmental problems are those in which the use of environmental resources in novel ways have effects that are highly uncertain, in both their spread and duration. The greater the uncertainty of the effects of technologically innovative use of environmental resources, the greater is the difficulty in evaluating associated environmental damage or the marginal social costs. The wider and more durable the environmental effects of economic activities are, the less is the scope for a market solution involving the allocation of property rights (Perrings 1991).

The self-organized biosphere is complex and non-linear. This is why it may be inherently impossible for science to discover the limits of the systems resilience. "[I]t may be possible to burn all the

fossil fuels, protect the coastlines from sea-level rise, convert the Amazon to a market garden, and cultivate wheat in Antarctica. But it may not. If it is impossible to know how far it is safe to perturb the system we live in without triggering a catastrophic collapse, then the only reasonable policy is not to perturb it more than it has been perturbed by natural phenomena in the past” (Ayres et al. 1995).

The class of problems for which the precautionary principle is advocated includes those in which both the level of fundamental uncertainty and the potential costs (or stakes) are high. These are mainly problems which “traditional science” is argued to be “inadequate” for and ethical judgments are argued to be “ubiquitous” (Funtowicz and Ravetz 1990).

The precautionary principle implies the commitment of resources now to safeguard against the potentially adverse future outcomes of some decisions (Perrings 1991). The precautionary principle sets the stage, but the real challenge is to develop methods of determining the potential costs of uncertainty. For policy choices this implies that the focus should be on measures that preserve options whilst encourage learning (Chichilnisky and Heal 1993).

In the Arrow-Debreu framework there is a set of exogenous "states of nature" whose values are random and represent the sources of uncertainty. Agents in the economy are allowed to trade commodities contingent on the values of these exogenous variables (called "state-contingent commodities", e.g., water in a drought compared to water in a flood). With a complete set of markets for state-contingent commodities⁶, the first theorem of welfare economics holds for economies under uncertainty. Thus, a Pareto efficient allocation of resources can be attained by a competitive economy with uncertainty about exogenous variables. In practical terms the number of markets required is often so large as to make the contingent contract approach unrealistic (Chichilnisky and Heal 1993).

The precautionary principle requires allowance to be made for the potential, though uncertain, future losses associated with the use of environmental resources. Artificially established markets for permits is one way to approach the uncertainty. However, it cannot be applied for all environmental problems. Parallel to developing such instruments the preservation of diversity (biological, social and technological) can allow different systems to co-evolve (Norgaard 1994). Depending on the resulting state/s different options may be best suitable. For agricultural systems, for example, this could mean to allow several modes of production to co-exist.

Thus, the potential problems with environmental events with a small likelihood of occurrence and a significant long-term impact need specific consideration, as international trade can increase these problems.

⁵ Risk refers to probability distributions based on a reliable classification of possible events and uncertainty refers to events whose probability distribution does not exist or is not fully definable for lack of reliable classification criteria (Vercelli 1991:72). For the cases discussed in the following all that may be known is that the probability of distant but potentially catastrophic outcomes is positive, even if there is no information on the precise nature, timing or incidence of those.

⁶ Arrow (1953) showed that not a complete set of contingent commodity markets, but only a mixture of securities markets and markets for non-contingent commodities is required.

3 Empirical Findings

The empirical analyses are based on data for various sources. Mostly data used in the empirical tests are drawn from cross-sections of countries at particular points of time and increasingly pooled data. Most prominently GEMS water and air pollution data from UNEP have been used. Other sources include the United Nations Statistical Yearbook, the World Resources Institute, FAO Production Yearbook, WHO's Health For All Global Indicator's database, IEA, EPA for U.S. data, different sources for micro-data etc. Economic data (GDP per capita and trade) come mostly from the Penn World Table (Summers and Heston 1993) or the World Bank.

Grossman/Krueger (1995) regress the level of ambient concentrations of urban air and water pollution on a cubic in GDP, lagged values of the polynomial, a time trend, population density, and indicators for the nature of the surrounding area. They find that "while increases in GDP may be associated with worsening environmental conditions in very poor countries, air and water quality appears to benefit from economic growth once some critical level of income has been reached." In the empirical analysis they used data from 42 countries between 1979 and 1990 such a relationships for SO₂, suspended particulate matter, the oxygen regime in river basins (dissolved oxygen, BOD, COD), heavy metals in water (cadmium, arsenic, mercury, nickel), and fecal contamination of rivers.

A microeconomic example can illustrate how the EKC relationship may work. Kahn (1998) investigated whether household's annual transport emissions increase with income or not. While richer households may create more vehicle emissions because they own more vehicles and drive more, poorer household may pollute because they use high polluting vintages and maintain them less well. He finds evidence for an inverted U-shaped emission/income relation.

In the World Bank Development Report (1992) strong delinking of SO_x, lead and particulates for all OECD countries since 1970, and for NO_x was reported. Also case studies for individual countries, like for the Netherlands revealed reductions in some emissions (CFC's -46 percent, NH₃ -16 percent, SO₂ - 20 percent) (RIVM 1993). Shafik (1994) finds that forest cover loss exhibits a weak inverted U-shaped relationship with income; Cropper and Griffiths (1994) identify such a pattern for Africa and Latin America, but not for Asia. Shafik and Bandyopadhyay (1992) observe an inverted U-shaped relationship between total and annual deforestation and national income for a sample of 77 countries between 1961 and 1986. With regards to material and energy intensities several studies reveal decreasing tendencies in a range of OECD countries, especially since 1970 (e.g., Chesshire 1986 for energy and Tilton 1990 for materials). Using cross-sectional US county data Wang et al. (1998) find that a EKC relationship holds using assessed risk to toxic hazardous waste exposure. And Hilton and Levinson (1998) identify an EKC for automotive lead pollution. They note, however, that lead emissions and lead content declined, even holding income constant. This suggests that some important technological changes took place. Carson et al. (1997) noted that the initial level of air toxic emissions matters which may be due to the fact that it is less expensive on a per-capita unit-of-pollution basis to clean up dirty plants than clean ones.

If there exist EKC-type relations for (a part of) the environmental pressure factors, it is crucial for the question of environmental sustainability at which levels of income the transition is expected. "The

turning points of these inverted U-shaped relationships vary for the different pollutants, but in almost every case they occur at an income of less than \$8,000 (1985 dollars)" (Grossman and Krueger 1995:370). Selden and Song (1994) found similarly for estimated per capita national emissions of SO₂, suspended particles, NO_x, and CO; but with higher turning points (below \$10,000 per capita income for particulate and sulfur emissions, above that for nitrogen and carbon emissions). For assessed risk to hazardous waste exposure Wang et al. (1998) find for the U.S. a turning point of \$23,000, which is more than double the mean per capita income, implying considerable increase in risk before the turning point is achieved for most US counties. Kahn (1998) identifies the turning point in his study of hydrocarbon emissions from vehicles in California the turning point at the high level of \$35,000. The turning points for greenhouse gas emissions such as CO₂ even range from income levels of \$20,000 to over \$8,000,000 per capita (Holtz-Eakin and Selden 1992; Suri and Chapman 1998). Combining these findings with the projected distribution of per capita GDP and population estimates, Selden and Song (1994) conclude that emissions would be increasing through the year 2100 for most pollutants.

With regards to the discussion of the turning points it should be noted that most analyses assume that if it exists, every country has an EKC with the same shape, albeit the level of this curve may vary across countries (Koop and Tole 1999).

Torras and Boyce (1998) added to the body of work by showing that the inclusion of institutional and political factors may be crucial for the EKC. They found in their analysis of seven indicators of air and water quality investigating 19-42 countries (varying depending on the pollutant) that a more equitable distribution of power contributes positively to the EKC relation. As the underlying reason they give that enhancing the influence on policy of those who bear the costs of pollution, relative to the influence of those who benefits from pollution-generating activities. They find that literacy, political rights, and civil liberties are found to have particularly strong effects on environmental quality in low-income countries. Their analysis focused on the distinctions between high-income and low-income countries.

The results confirming an EKC-type relationship led some to find the possibility confirmed "to grow out of some environmental problems" (Shafik and Bandyopadhyay 1992) or that "instead of there being a *trade-off* between greenhouse gases and economic growth, faster growth could serve as part of the *solution* to the worldwide emissions dilemma" (Holtz-Eakin and Selden 1992:3). A more cautious proposition was that economic growth could be compatible with environmental improvement if appropriate policy responses were taken.

Confirming Shafik's (1994) observation that the EKC relation can be observed only for specific environmental pressure factors and not for others. "Where environmental quality directly affects human welfare, higher incomes tend to be associated with less degradation. But where the costs of environmental damage can be externalized, economic growth tends to result in a steady deterioration of environmental quality." Similarly, Cole et al. (1997) find that "meaningful EKCs only exist for local pollutants, whilst indicators with a more global, or indirect, environmental impact either increase monotonically with income or else have turning points at high per capita income levels with large standard errors – unless they have been subjected to a multilateral policy initiative". This is the motivation for Rothman (1998) to base

his analysis on more consumption-based measures, such as CO₂ emissions and municipal waste, for which impacts are relatively easy to externalize or costly to control – they show no tendency to decrease with higher per capita income. Starting from the critique that “empirical studies have not provided any evidence that validates an EKC for pollution problems where the effects are far-displaced or long-delayed”, Ansuategui and Perrings (1999) give a behavioral explanation for the empirical observation that societies address environmental problems involving external effects sequentially: addressing those with the more immediate costs first, and those whose costs are displaced in time and space later. International co-operation is a precondition for (possibly) de-linking of transboundary pollution problems from economic growth.

But even for local or semi-local pollution problems, we cannot imply that economic growth is an adequate solution. Grossman and Krueger (1995) point to the restrictions of their analysis: “Even for those dimensions of environmental quality where growth seems to have been associated with improving conditions there is no reason to believe the process is an automatic one ... there is nothing at all inevitable about the relationships that have been observed in the past.” Wherever local institutions are unable to internalize local external effects private resource users will pollute at excessive levels.

4 Critique

4.1 Methodological Critique

With regards to the data, Stern et al. (1996) have criticized the deforestation data which informed the analysis of Panayotou (1993) and Cropper and Griffiths (1994). In general, they found that when using only OECD countries’ data, the turning points resulting were much lower than when using data of developing countries as well.

In search for a general pattern not enough attention given to country-specific differences

A critique raised recently by Dijkgraaf and Vollebergh (1998) refers to the necessary assumptions behind pooling the observations of different countries in one panel: that the outcome of the economic process would be the same for all countries with respect to emissions. That is, the curvature of the income-emission relation being the same for the pooled countries as far as they have the same GDP range. They compare EKC estimates for carbon emissions for a panel set of OECD countries and individual time series for each of the countries of the panel and find that the coefficients in the individual time series regressions varied widely. While the analysis of the whole panel had given a inverted U-shaped function, the environmental quality-economic growth relationships for the individual countries had linear, inverted U-shaped, U shaped and cubic EKCs. They conclude that there is not a meaningful EKC for carbon emissions while there are some meaningful relations between income and emissions in individual countries.

Also Koop and Tole (1999) criticize the assumption that the environment/GDP relationship varies in a very restricted way only. If an EKC exists, it is mostly assumed that “every country has the same turning point where environmental degradation starts declining, but the amount of environmental degradation at this point can differ. Given the variety of social/economic/political and biophysical factors

that may affect [for example] forest cover from country to country, this assumption of a high degree of common structure is probably unwarranted” (p.232). Koop and Tole therefore use in their analysis a random coefficients model which allows for more cross-country heterogeneity in the shape of the environment/growth relationship. This has significant impact on their results. Other than Cropper and Griffiths (1994) and Shafik (1994) they find that “a story consistent with our empirical results is that the deforestation/GDP relationship varies quite considerably across countries, and that the EKC found in the simple regressions could reflect restrictive assumptions. Overall, we conclude that, at least for forest cover, there is little evidence for the existence of an EKC“ (p.232).

Omitted variables

Recently a number of relevant variables that had been omitted in the earlier EKC studies were pointed out. So, have most theoretical models of the EKC relation not accounted for transboundary and intergenerational externalities (Ansuategui and Perrings 1999). Kaufmann et al. (1998) show that incorporating spatial intensity of economic activity turns the relation between per capita GDP and the atmospheric concentration of SO₂ upside down (U-shaped curve). They speculate that previous results may be biased by the omission of variables that represent changes in the mix and spatial intensity of economic activity. “Under these conditions, the inverted U-shaped relation between per capita GDP and sulfur emissions and/or concentrations found by previous studies may only be a proxy for the changes in the mix of economic activity that are associated with changes in per capita GDP” (Kaufmann et al. 1998:217).

The price of energy is another variable recently found relevant for the EKC relationship (Agras and Chapman 1999). And with the exception of the studies by Suri and Chapman (1998) and Agras and Chapman (1999), trade has not been considered to be an important explanatory factor in the empirical work to date. While Wang et al. (1998) had found that a EKC relationship holds using assessed risk to toxic hazardous waste exposure, the same group qualified their results after investigating the role of migration for their question (Gawande et al. 1999). “Using data on internal migration in the U.S. between 1985 and 1990, we find support for the hypothesis that migration decisions are affected by proximity to sites beyond a threshold level of income. ... We may not so much be growing out of an environmental problem as moving away from it, and only the more privileged are able to do so” (p.19).

Stern et al. (1998) found that including only high-income countries into the sample, leaves out different trade patterns. As argued above, high-income countries have higher emission reduction possibilities because they can outsource polluting industries to other countries through trade specialization. They identify problems with two classes of variables: “a. serially correlated, integrated, and/or trending variables global variables that correlate with the more consistent economic growth seen in OECD countries, and b. variables that differ between countries whose means in each country are correlated with mean GDP in those countries. Some of the latter class of variables may also be time dependent” (Stern et al. 1998). For example, for Malaysia per capita GDP was a significant explanatory variable for only two, ammoniacal nitrogen and pH, and for both higher income resulted in higher

pollution levels. Econometric analysis of Malaysian monitoring data found no evidence of an EKC for any of the usual parameters (Vincent 1997).

Robustness

The empirical robustness of the EKC relation remains an open issue (Grossman and Krueger 1996). And the reduced form equations in which environmental outcomes or correlations are related to endowments of the individual countries and to economic measure are silent about causal mechanisms. Lucas (1996) suggests that “[m]ore structural forms may warrant exploration, for some interdependence in our environmental indicators is probable. For example, pesticide use may well affect the number of bird species threatened, but this kind of interdependence remains to be explored” (p.276). Also Galeotti and Lanza (1999) suggest to consider alternative functional forms (Gamma and Weibull).

(Mis)Specification

Another strong concern was recently raised by Perman and Stern (1999). They complain that too little attention has been paid to the time series properties of the data and in particular whether variables used in EKC are stationary and whether the variables are integrated time series. Using individual unit root tests they show that both sulfur emissions and GDP per capita are integrated variables in a majority of countries. From the problems identified Perman and Stern conclude “that the EKC may be a problematic concept, as simple global EKC models are misspecified”.

4.2 Conceptual Critique

The inverted U-relation cannot be generalized for all emissions

The findings are very sensitive to a change in the type of pollutant measured (Beghin and Potier 1997). The relation was only confirmed for pollutants involving local short-term costs (for example, sulfur, particulates, and fecal coliforms), not the accumulation of stocks of waste or for pollutants involving long-term and more dispersed costs (such as CO₂), which are often increasing functions with income (Arrow et al. 1995). Or more specifically, total annual CO₂ emissions rise with GDP per capita, then subsequently tend to decline. However, the implied turning point occurs at a GDP per capita of \$24,568 (in 1987 dollars), which is well beyond the actual income of any country at the time. In other words, CO₂ emissions are estimated to continue to rise with income per capita over the range of existing incomes, though to rise less rapidly at higher incomes (Lucas 1996).

Emissions of SO₂ have fallen in OECD countries despite the growth of GDP. For CO₂ and NO_x the record is mixed. In some countries emissions have decreased (Japan for NO_x, UK and West Germany for CO₂), but in most emissions have increased but less than GDP. For energy use and municipal waste, only the UK and Germany, respectively, have maintained quantities at 1970 levels; in all other countries they have increased (Ekins 1997). Antweiler et al. (1998) base their model solely on SO₂ data and then conclude: “trade appears to be good for the environment”!

For total industrial water pollution Hettige et al. (1997) cannot identify a EKC relation. Instead total industrial water pollution rises rapidly through middle-income status and remains approximately constant thereafter.

For toxic pollution no EKC could be found. Two studies have focused on air pollution generated in the manufacturing sector using developing and developed country data for 1960-1988 (Birdsall and Wheeler 1991; Lucas et al. 1992). Both studies conclude that toxic intensity of GDP (i.e., air pollution emissions/GDP) does not decline with income. The effect of income on pollution intensity tends to be negative (i.e., pollution intensity declines) in more open countries while it is positive in closed countries. Even in the most open countries, however, the absolute level of pollution increases with income despite the fact that pollution intensity declines (López 1994)⁷.

Those environmental indicators for which the EKC hypothesis is most plausible, are various indicators of air pollution only: NO_x, SO₂, CO, suspended particles, and dark matter.

The inverted U-relation has mostly been shown for single pollutants only

Each of the studies quoted above referred to single pollutants and/or single materials, but the aggregated developments of several pollutants or materials together were not analyzed. It is possible therefore that all that is achieved is materials substitution. For this case de Bruyn and Opschoor (1997) suggest the term "transmaterialization" instead of "dematerialization". For being able to reject this possibility a more complete aggregate of materials consumption must be investigated. Only few studies have tried this.

Most prominently Jänicke et al (1989) used an aggregated indicator approximating the volume of throughput. Comparing 1970 and 1985 for a set of 31 COMECON and OECD countries, they concluded that economic growth seems to delink from the throughput indicator for most developed countries. They used four proxies for throughput: energy consumption, steel consumption, cement production, and weight of freight transport on rail and road. They found the EKC hypothesis confirmed. This result was later challenged by de Bruyn and Opschoor (1997) (see below the re-linking hypothesis).

Mac-Gillivray (1993) calculated an environmental performance measure for 22 OECD countries. The measure is made up from an aggregation of twelve different environmental indicators including emissions (CO₂, NO_x, SO₂), water, sewage treatment, protected land, threatened species, waste, energy intensity, private road transport, and nitrate fertilizer application. The regression of the total score against the countries' incomes shows no strong relationship between the environmental performance and income.

Underinvestigated institutional factors

The improvements achievable without determined environmental regulations would not suffice, since the way to the turning point of the EKC is for many countries still a long one. Most of the world's population lies on the upward-sloping portion of the EKCs. This implies that, even if the EKCs are valid, income growth across the global population will increase environmental damage before it reduces it

⁷ A problem with these studies, however, is that they are not based on actual measures of air pollution but rather on estimated virtual indicators, which were calculated using the US pollution coefficients, i.e., only the composition effect is considered.

(Ekins 1997). Selden and Song (1994:158) found in a projection that "the global flows of all four emissions remain at or above their 1986 levels throughout the entire next century, even in the most optimistic scenarios". Such damage is clearly incompatible with the political commitments that have been made to achieve sustainable development.

To conclude from the empirical evidence Arrow et al. (1995) cautioned that it should not be inferred that economic growth is a necessary condition for increased environmental quality, that environmental effects caused by economic growth may be neglected, or that the resource base is sufficient to allow unlimited economic growth. Also Grossman and Krueger (1995) were careful in their analysis and concluded that economic growth will not automatically lead to higher environmental quality but via stronger pressure for stronger environmental policy. If countries import and export more and their ability for national regulation is diminished and there is no automatic mechanism for improvement at work (even for the few factors which were proven to have developed positively), international environmental regulation must be fostered.

Panayotou (1997) showed that the quality of policies and institutions can significantly reduce environmental degradation at low income levels and speed up improvements at higher income levels, i.e. better policies can help flatten the EKC.

For another reason, a stronger institutional analysis seems necessary: Income often is not the causal factor, but rather income is correlated with causal factors such as the spatial intensity of economic activity and imports (Kaufmann et al. 1998).

Re-linking hypothesis

Pezzey (1989) and de Bruyn et al. (1998) argued that the EKC may not hold in the long run. They foresee a so-called N-shaped curve which exhibits the same pattern as the inverted U-curve initially, but beyond a certain income level the relationship between environmental pressure and income is positive again. De-linking is thus considered as a temporary phenomenon. Grossman and Krueger (1995) found, for instance, that between income levels of \$10,000 and \$15,000 there was a secondary turning-point, at which the levels of ambient air pollution increased. In this sense, de Bruyn and Opschoor (1997) challenged Jänicke et al's (1989) hump-shape results for throughput by asking whether delinking tendencies in the past can be easily extrapolated. If there are technological or economic upper bounds to the possibility to increase energy and material efficiency, equations (7) and (8) will not hold – at least until further breakthroughs in research and development occur or a more intensive application of environmental policy checks is implemented. De Bruyn and Opschoor call this possibility the "relinking hypothesis". Differently than Jänicke et al, who compared the results in the initial and final years, de Bruyn and Opschoor analyzed the changes over time by dividing the whole period into four sub-periods. Also, they extended the analysis to the period between 1966 and 1990.

The empirical analysis showed that the measure of strength of the relationship between material throughput and income (M/Y) dropped considerably after the first period (1966-1972), to drop to a low in the third period (1978-1984), and to pick up again in the final one (1984-1990). The slope has decreased until 1984, but increased slightly in the last period. The intercept increased until 1984, but decreased in the

last period. The tendency of richer countries consuming less materials and energy over time while poorer countries consuming more, was confirmed. However, this development has come to an end in the last period. Formerly Eastern bloc countries together with the northern Scandinavian countries were quite successful in reducing their throughput intensities, i.e., absolute reductions in their levels of throughput while their economy was growing. For a second group of countries (Finland, Greece, and Spain) the increase in throughput was relatively low compared to their growth in GDP, i.e., growing environmental pressure as measured by throughput-proxies, but with dropping throughput intensities. In other countries the throughput rose at a rate sometimes close to that of the increase in GDP. However, if the throughput intensities of 1989 are compared with those of 1986, it can be seen that several countries (Belgium/Luxembourg, Italy, Japan, Spain, Western Germany, and the UK) showed an upswing in their throughput intensities. That is, their (approximated) throughput rose more than their increase in GDP, which is indicative of a period of relinking. The levels of aggregate materials consumption through time may show an 'N-shape' rather than an inverted U-curve. De Bruyn and Opschoor (1997) draw the conclusion that delinking does not appear as a process which prevails or persists under conditions of sustained growth (see also Moomaw and Unruh 1997).

By using a newly developed data set Galeotti and Lanza (1999) also find a more problematic N-shaped curve than an inverted U-shaped EKC for greenhouse cases.

As explanation for the N-shaped relation de Bruyn et al. (1998) indicate that once technological efficiency improvements in resource use or abatement opportunities have been exhausted or have become too expensive, further income growth will result in net environmental degradation.

4.3 Fundamental Critique

At least two lines of fundamental critique can be identified in the literature. Stern et al. (1996) criticized that EKC cannot easily be applied to all environmental factors, as for example, biodiversity loss is conceptually different from urban air or water pollution insofar as the loss of the former is irreversible, and may have severely negative secondary effects. It may not be very helpful, if there is an EKC with a turning point beyond the point where those secondary effects arise.

The other one is more philosophical: „From a theoretical point of view, within strict instrumentalism a theory is neither true nor false, but merely adequate or inadequate for a given real-world problem. However, predictive success is really a very limited conception over a longer period of time. A good example of the latter is the optimistic conclusion regarding ‚sustainable growth‘ based on the neoclassical growth model, namely the fact that the immediate past has allowed much growth and technological progress, does not mean the same holds for an indefinite period of time into the future. Consequently, concluding the ‚growth debate‘ on the basis of empirical studies will be impossible“ (Bergh et al. 1998:7).

5 Conclusions

Evidence for the existence of the Environmental Kuznets Curve is inconclusive. Apart of the obvious conclusion resulting from the extensive critique (need for more empirical research based on

various data sets and methodological improvements), at least two conclusions can be drawn from this mixed evidence about the relationship of economic growth and environmental quality: First, on a political level – since there is no ‘automatic’ process, courageous policy measures are necessary to allow for higher sustainability. Second, “we need economic models that properly reflect the physical and ecological basis of economic activity, and for the important feedback between the economy and the environment” (Ayres et al. 1997).

Selden and Song (1995) argue that Foster’s highly simplified growth model can be used as a basis to gain theoretical insights into the empirical literature on pollution, abatement and development. However, ecological economists frequently use Solow’s (1974) statement that “the world can, in effect, get along without natural resources” as evidence for the flawed treatment of the economy-environment relation in neoclassical economics (Daly 1996).

Ayres et al. (1997) suggest to much further and to modify growth models such that they a. distinguish explicitly between different forms of natural capital (nonrenewable and renewable natural capital), b. take limits to substitution of inputs and complementarity of inputs into account, c. integrate as much as possible the specific characteristics of the environment (non-linearity, lags, discontinuities, thresholds and limits) into the analysis, and d. consider the potential problems resulting of irreversible developments.

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