Zeitschrift: Agrarwirtschaft und Agrarsoziologie = Économie et sociologie rurales [1980-2007]

Herausgeber: Schweizerische Gesellschaft für Agrarwirtschaft und Agrarsoziologie

Band: - (2000)

Heft: 2

Artikel: Global sustainability and economic growth, some conclusions from the Environmental Kuznets Curve

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DOI: https://doi.org/10.5169/seals-966310

Global Sustainability and Economic Growth, Some Conclusions from the Environmental Kuznets Curve

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1. Introduction

The Environmental Kuznets Curve (EKC) is a much-debated hypothesis in environment economics. Simply speaking it suggests that pollution or environmental degradation first increases and then decreases with growing per capita income. (For simplicity, the terms pollution and environmental degradation are used as synonyms). The picture is that of a bell-shaped curve, the same type of curve that Kuznets (1955) postulated in his seminal paper on the development of income inequality. Hence the name.

The EKC represents an antithesis to the still widespread neo-Malthusian perception that economic growth is unambiguously harmful to environment quality (Meadows 1972; Meadows, Meadows and Randers 1992). Contrary to this position the EKC suggests that economic growth also generates forces that contribute to progressively declining growth rates of pollution and finally declining levels of pollution. However, it is argued in this paper that this development is the result of a politico-economic process, i. e. the interaction of economic and political forces. Economic growth is then a necessary but not a sufficient condition to approach sustainability.

Econometric estimates of EKCs indicate for some time to come increasing environmental degradation in developing countries (LDCs) and therefore in the world as a whole. LDCs have low to medium per capita incomes, which locate them in the left part of the EKC. Therefore economic and demographic growth will lead to growing pollution before a turning point can be reached. A simulation model is presented that - based on stylised facts - allows analysing the environmental impact of economic and demographic growth on a global scale.

The paper is structured as follows. Chapter 2 presents the empirical evidence for EKCs. Chapter 3 explains the theoretical basis of the EKC-hypothesis. In Chapter 4 critical aspects and major political issues are discussed. Chapter 5 presents the results from a simulation of a global EKC based on stylised facts.

2. The Environmental Kuznets Curve: Empirical Evidence

The EKC hypothesis has been tested by various authors and for various types of pollution (e. g. Grossman and Krueger 1992; Shafik and Bandyopadhyay 1992; Panayotou 1993; Grossman and Krueger 1995; Holtz-Eakin and Seldon 1995; Selden and Song 1995; Cole, Rayner and Bates 1997; De Bruyn, van den Bergh and Opschoor 1998; Suri and Chapman 1998; Kaufmann, Davidsdottir, Garnham, and Pauly 1998; Torras and Boyce 1998; Agras and Chapman 1999). Air pollution includes particulate matter, airborne lead, sulphur dioxide, carbon monoxide, carbon dioxide and nitrogen oxide. Water pollution includes heavy metals, such as lead, cadmium, mercury, arsenic and nickel, as well as nitrates and faecal contamination. In some studies the overall oxygen regime of rivers has been analysed, as well as people's access to safe water. In addition, municipal waste, the share of population with adequate sanitation, and deforestation have been investigated. Some of the studies use per capita emissions (flow variables) as dependant variables while others refer to levels of concentration (stock variables). Most of the studies are based on cross-national (panel) data and use reduced form equations with quadratic or cubic income terms. Only a few authors have embarked on estimating structural models.

The empirical analyses find three different types of relationships between per capita income and pollution (Figure 1). The first relationship (1a) is the archetypal picture of the Kuznets curve. Pollution increases with increasing per capita income, reaches a maximum, and declines afterwards. The per capita incomes that mark the apex of the curves vary for different types of pollution. The income thresholds fall roughly between some $ 3 000 and $ 10 000 (constant 1985 prices, corrected for purchase power parity). The fact that turning points for the same type of pollution vary between different studies indicates considerable methodological and theoretical uncertainties. Nonetheless, the archetypal pattern of the Kuznets curve holds in most studies for the majority of the types of environmental degradation mentioned above.

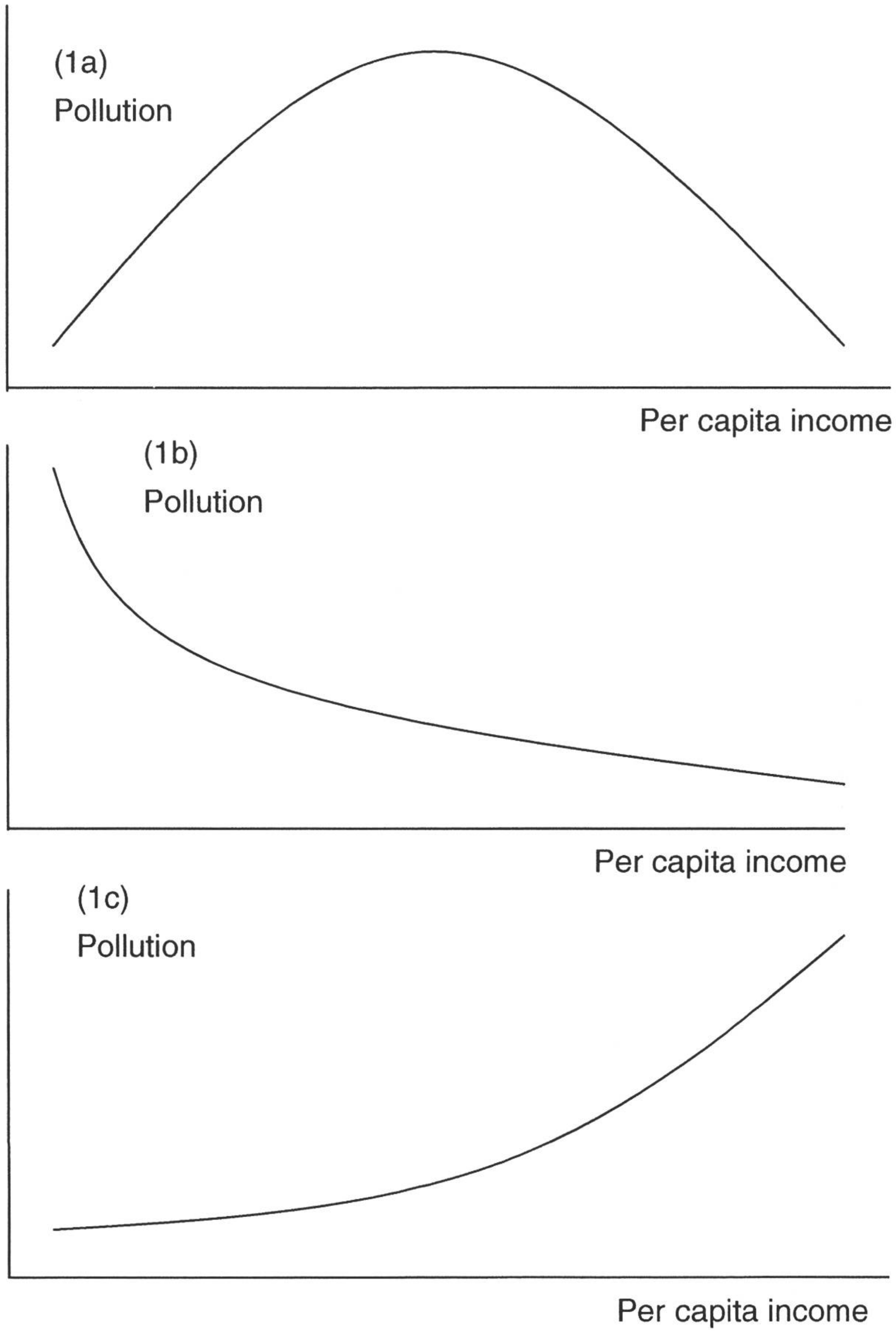

Figure 1: Relationships between per capita income and pollution.

The second relationship (1b) depicts a continuous decrease of environmental degradation as per capita incomes grow. This relationship was found for population without safe water and urban population without adequate sanitation. It is possible that these curves are nothing but part of an EKC for which the left part and the turning point are not observable; the cross-country samples may not include per capita incomes sufficiently low to display the increasing part and the apex of the curve.

The third relationship (1c) displays constantly growing pollution with higher per capita incomes. This result seems to hold for municipal waste and perhaps for carbon dioxide emissions. However, the outcomes call for closer examination. In the case of municipal waste it must be considered that the growing volumes in countries with high per capita incomes are rendered less harmful through the progressive use of sophisticated low-emission technologies of waste disposal. The most severe environmental threats from municipal waste are probably unsafe and "wild" deposits. It may well be that these problems are progressively overcome in high-income countries. The growing volumes of waste disposal do not necessarily imply growing pollution.

Carbon dioxide emissions are in general expected to grow for some time to come, perhaps even in high income-countries. Nonetheless, some authors found bell-shaped curves (e. g. Holtz-Eakin and Seldon 1995; Agras and Chapman 1999). While the estimates of Holtz-Eakin and Seldon put the inverted U-turns at per capita incomes between $ 35 000 and $ 8 million (!) Agras and Chapman find a surprisingly low income-threshold of $ 13 630. In both cases the authors seem not to have much confidence in their results. In contrast with these estimates that are only based on income as explanatory variables Moomaw and Unruh (1997) include prices of energy. They conclude from their estimates that the oil-price shock of 1973/74 and subsequent policies have induced a transition process that produced turning points of carbon dioxide in OECD-countries.

Methodological and conceptual problems plague each and every study that attempts to test the validity of the EKC-hypothesis. The studies quoted before have frequently been criticised on various accounts. But despite conceptual and methodological weaknesses, the empirical evidence that growing per capita incomes are accompanied by a constant decline or inverted U-turns for a respectable number of pollutants can hardly be rejected. Although the results indicate that in the early stages of development countries grow out of certain types of pollution and grow into some others, in the end high-income countries appear to succeed in combing high levels of economic welfare and environment quality.

3. Underlying theories

The EKC is not a purely phenomenological hypothesis. Its theoretical basis can be presented in slightly different ways. Considering the overall level of pollution, and not only per capita emissions or concentrations, the EKC is best explained by combining the economic theory of demographic transition and ecological transition (Baldwin 1995). This combination is of particular interest for the analysis of environment quality in LDCs and on a global scale.

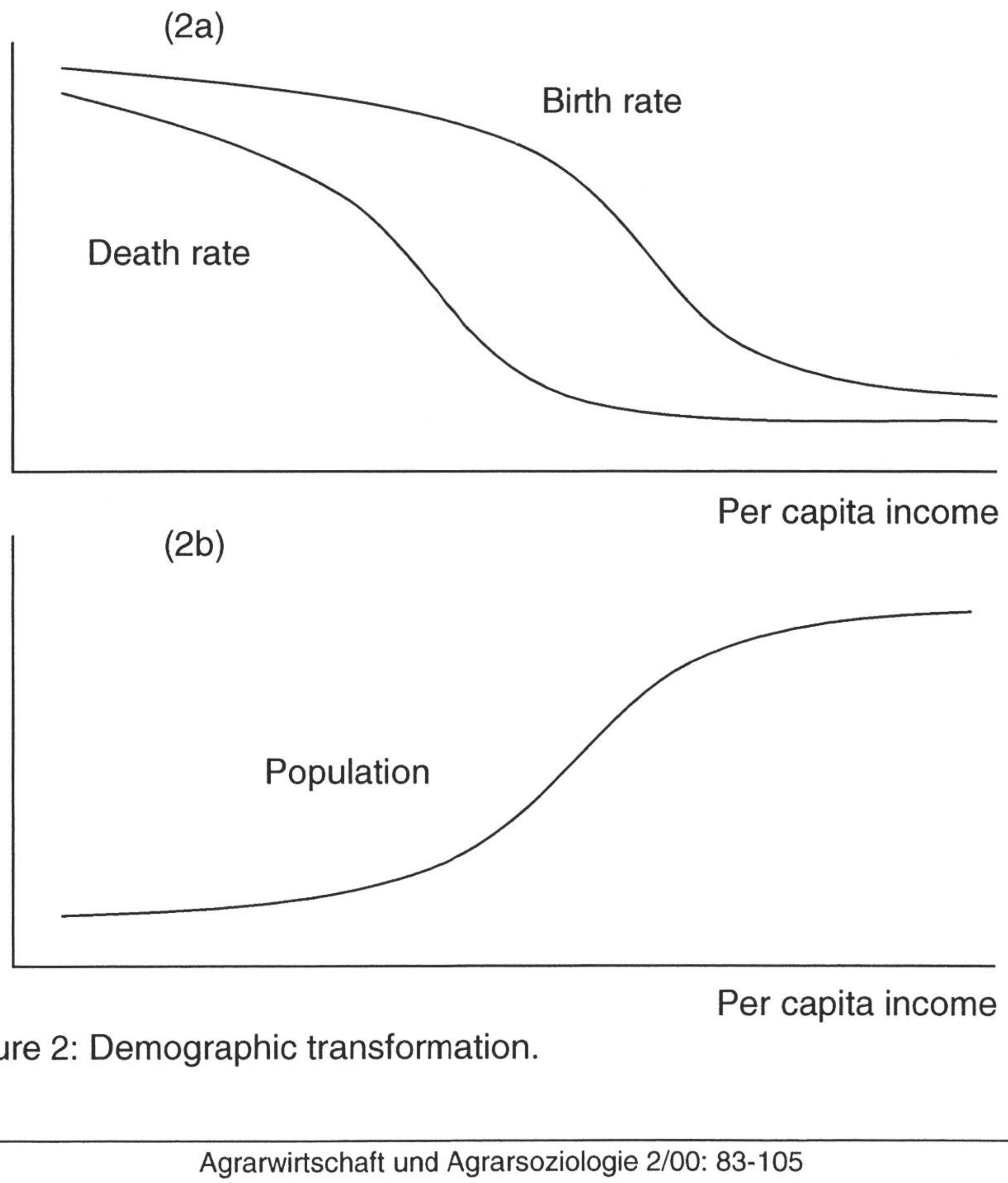

Figure 2: Demographic transformation.

The economic theory of demographic transition postulates that growing per capita incomes lead to declining death rates and declining birth rates (Figure 2). Many empirical studies have shown that the decline in birth rates is delayed compared to the decline of death rates (2a). The resulting difference between birth rates and death rates explains the temporary exponential growth of population, which finally declines and levels off towards a nearly stable population (2b).

The impact of growing per capita incomes on death rates reflects the effects of the general improvement of living conditions associated with income growth, i. e. improved nutrition, hygiene, housing facilities, access to safe water, education, health services, etc. The causal linkages between these living conditions and death rates do not require complex theoretical reasoning. Causal empiricism has confirmed the linkages time and again.

The observed relationship between growing incomes and declining fertility rates is more complicated. A widely accepted model by Becker, Murphy and Tamura (1990) suggests that low per capita incomes are associated with high fertility because at low incomes the (opportunity) costs of child rearing are relatively low and expected "returns on children" are relatively high. At high incomes the opposite holds, i. e. costs of child rearing, in terms of income and leisure forgone, are relatively high while expected "marginal returns" from additional children decline rapidly. In this context, investment in human capital plays a critical role. Simply speaking, at low incomes parents choose large families, at high incomes they invest in the education of their children. This decision is mainly determined by the assumption that returns on education are low at low stocks of human capital, but increase with increasing stocks - at least to a considerable size of the stock. Taken together, the linkages of income, human capital and fertility of the Becker-Murphy-Tamura model provide a consistent and plausible theoretical foundation for the observed correlation between income growth and fertility decline.

The economic theory of ecological transition starts out with the idea of production where pollution is completely externalised. The resulting pollution per unit of output can be described as "lowest-cost unit pollution coefficient" (LCUPC). The LCUPC multiplied by the volume of production gives "incipient pollution". This is the hypothetical volume of pollution that would be produced if private costs of pollution were zero. "Actual pollution" is the pollution that can be observed in reality, and the difference between actual and incipient pollution is nothing but "pollution abatement".

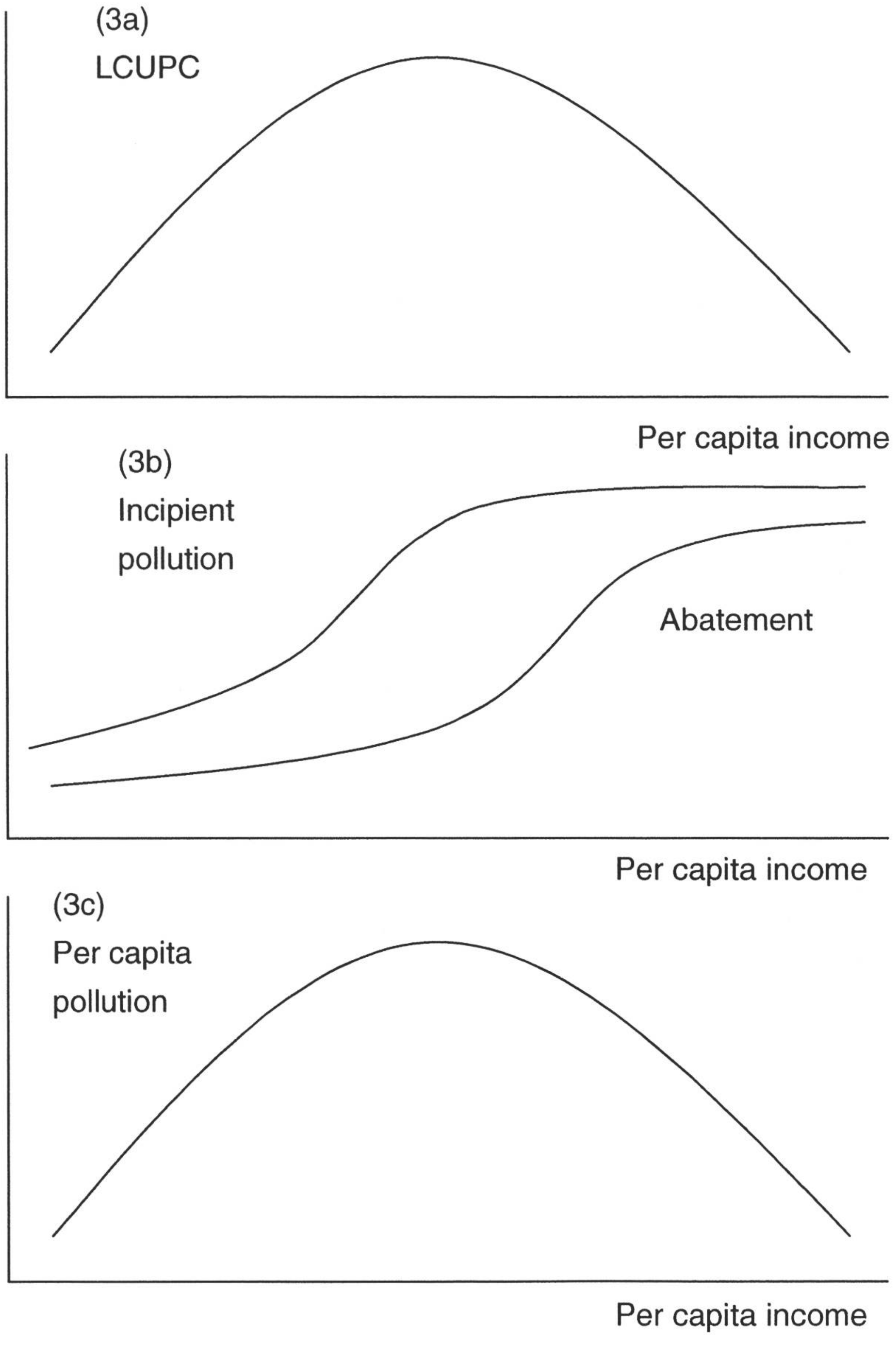

Figure 3: Ecological transformation.

The development of the LCUPC is essentially a story of technical progress and sectoral change. The impact of this change on the LCUPC is schematically shown in the first diagram (3a) of Figure 3. In economies with very low per capita income production is low and characterised by a low LCUPC. This is the situation of predominantly agricultural subsistence societies with land and labour as the main factors of production. With rising income the LCUPC grows for two reasons. First, mechanisation of agriculture and the use of chemical inputs for agricultural production increase. Second, the sectoral production pattern shifts to progressively higher shares of heavy industry and manufacturing. Both have supposedly higher LCUPCs than agriculture. At still higher levels of income the share of industry production levels off and finally declines, while the share of service production, which has typically a lower LCUPC than industry, increases. At the same time the economy makes progressively use of capital-intensive resource-saving technologies that allow for economic and environmental benefits ("win-win solutions"). Both factors contribute to a decrease of the LCUPC.

The development of incipient pollution is depicted in the second diagram (3b). The S-shape of the curve results from the multiplication of the bell-shaped LCUPC with the continuously growing level of production. Although the LCUPC declines in the range of high per capita income incipient pollution remains at a high level because of the high level of production.

The abatement curve is derived from the hypothesis that the demand for environmental quality emerges only at higher per capita incomes. At low income pollution is low and people must spend most of their income for the basic necessities of life. As both pollution and income grow the income elasticity of the demand for environmental quality becomes - for a certain income range - greater than unity. At the same time societies progressively acquire the technical, financial and institutional capacities to promote and enforce measures for environment protection.

It should be noted that two forces drive the demand for pollution abatement. On the one hand higher incomes produce higher levels of pollution and a decline of environmental quality. Environmental goods become scarcer, and growing scarcity is one cause for the growing demand for environment quality. On the other hand higher incomes fuel the demand for environment quality and the capacity to implement appropriate measures of environment policy. Increased scarcity of environmental goods plus higher demand for those goods lead to increased pollution abatement. As in the case of birth rates and death rates, empirical evidence on actual pollution indicates that pollution abatement follows incipient pollution with a certain delay.

The theoretical explanation of the abatement curve often lacks one important point. How is the growing demand for environment quality transformed into improved pollution abatement? Implicitly, the model assumes that politics responds to the demand and that adequate policies are implemented. In other words, the EKC hypothesis is a politico-economic model that includes political markets. The abatement curve is not only the result of a growing scarcity and demand for environment quality but also the result of a supply of effective environment policies. Some of these political issues will be taken up in Chapter 4.

The third diagram (3c) shows the bell-shaped curve that results from the difference between incipient pollution and abatement - the familiar EKC. The growth and decline of pollution is obviously a transition process very similar to the demographic transition. It should be noted that both axes of diagram 3c display per capita values. To derive total pollution the size of the population must be considered. As the development of the size of population is also income-driven, the calculation of total pollution requires a model that combines the demographic and ecological transition. Such a model will be presented in Chapter 5.

4. Criticism of the EKC and policy issues

As mentioned before, the EKC-.hypothesis and econometric estimates of EKCs have been criticised for various conceptual and methodological reasons. A broad range of critical arguments and warnings was prominently brought forward by Arrow, Bolin, Costanza et al. (1995) and subsequently extended and elaborated by other scholars (e. g. Ayres 1995; Common 1995; Myers 1995; Barbier 1997; McConnell 1997; Panayotou 1997; Rothman and Sander 1998). Various academic journals ran special issues on the EKC (Ecological Economics 1995 and 1998, Ecological Applications 1996, Environment and Development Economics 1997). Without attempting to be exhaustive, and leaving technical aspects of econometric procedures aside, three outstanding issues of the debate will be discussed in the following sections.

First, an important objection against the EKC refers to the environmental impact of sectoral change. Critics question the idea that all countries with high per capita incomes will actually experience the reduction of specific pollution caused by sectoral change. It is evident, and not disputed, that certain parts of industrial production move from higher income countries to lower income countries. This development of the international division of production and trade is reflected in the rise and subsequent decline of the LCUPC of the Baldwin-model outlined above. However, on a global scale it is obvious that in the end there will be some countries left that cannot "farm out" industrial production any more. In other words, some countries will not be able to follow the same path of the EKC that others have gone.

Based on this argument some authors have included international trade variables in estimates of EKCs (Suri and Chapman 1998; Agras and Chapman 1999) or have concentrated on analysing the development of consumption patterns rather than production patterns (Rothman 1998). However, the interpretation of the results is rather difficult. Suri and Chapman chose energy consumption as the dependent variable, assuming that energy consumption is a sort of catchall variable for pollution associated with energy use. However, given the large variation of specific pollution resulting from different types of energy and different energy production and consumption systems this is a highly dubious assumption. The authors' turning points for energy consumption are around $ 55 000 without trade variables and more than $ 220 000 with trade. Both income thresholds are far outside the sample range, and the turning points are therefore very uncertain. Agras and Chapman use carbon dioxide emissions as the dependent variable. Their estimates put the turning point at the surprisingly low level of some $ 13 000 quoted before, but the trade variables are statistically not significant.

In both studies the trade variables are import and export ratios that augment the set of explanatory variables. It is questionable whether this simple extension actually captures the objection referred to above. It is only the last latecomers in economic development that cannot transfer industrial production to other countries, but in the estimates the trade variables are included for all countries of the sample. Hence, from a theoretical perspective it is not quite clear what these variables explain.

Rothman's estimates, which use consumption patterns for 11 categories of goods and services as proxy variables for pollution, provide only very weak if not useless indicators for environmental degradation. Production and consumption of goods and services can obviously occur within an enormously wide spectrum of technologies and specific pollution. The author's implicit assumption of a fixed pollution coefficient over the whole income range is contradicted by abundant empirical evidence.

Therefore, even if some categories of consumption have turning points at income levels outside the range of the sample - or no turning points at all - this does not allow for the conclusion that the same holds for pollution.

It can be concluded that the influence of trade on pollution is not yet resolved. None of the available studies addresses the issue in a convincing manner. Empirical evidence exists that inverted U-turns occur if the production pattern is taken into consideration (e. g. Grossman 1995). As expected, the resulting EKC's become flatter. This indicates that the other factors causing the inverted U-turn, i. e. resource-saving technical progress, increasing scarcity of environment quality, and growing demand for pollution abatement, play a decisive role. That allows for the tentative conclusion that the last latecomers in the international division of production and trade will also experience a decline of pollution. However, the extent may differ from experiences in other countries.

Second, critics have warned that the EKC should not be mistaken as a sufficient indicator of sustainability. This argument is certainly correct. Turning points of environmental degradation do not guarantee ecological sustainability. The levels and concentrations of pollution around the peaks of EKCs may very well lie beyond the carrying capacity or resilience of ecological systems. Moreover, the EKC contains no information about how long the highest levels of degradation prevail. Therefore it cannot be excluded that irreversible damages occur around the peaks of EKCs, even if pollution subsequently declines. However, this objection, correct as it is, is less an argument against the theory and empirical evidence of the EKC than a warning against superficial interpretations. Nonetheless, although the EKC is not a sufficient condition for sustainability it is certainly a necessary condition to approach sustainability.

Third, critics have emphasised that the EKC does not imply that economic growth in itself is a sufficient condition to achieve certain goals of environment quality. This argument is also correct, but it is again more a warning against fallacious interpretations and not an argument against the concept of the EKC. As explained before, the theory of the EKC embodies both economic and political driving forces. The economic forces associated with income growth are sectoral change, technical progress, and growing demand for environment quality. The political forces enter the picture when the demand for environment quality must be transformed into political action. Lacking markets for environmental goods, the demand for environment quality must be satisfied by either public regulation or market-based interventions. As mentioned before, the EKC's inherent abatement curve will only materialise if politics responds to the demand for environment quality. Hence, functioning political markets for environment policy are a necessary precondition for the existence of the EKC.

The concept of political response to the demand for environment quality is a politico-economic hypothesis, where environment policy is an endogenous variable. This view contrasts with the traditional view of the theory of environment policy, where policy goals and prescriptions are independent or exogenous variables. It seems that the two different views create sometimes confusion in the debate on the EKC.

Econometric estimates of EKCs attempt to describe the world as it is (or has been), including political action, and it is assumed that future economic and political behaviour will not deviate significantly from the past and will be similar in all countries. Critics of the EKC tend to neglect this positive approach and often request goals and measures of environment policy from a normative point of view. It is unclear to which extent these requests adequately reflect observed demand and supply of environment policies and other factors that influence political markets. At that point of the discussion the EKC is transformed from a positive model into a normative model. The question "Is there a turning point"? is changed to "What should be done to shift the turning point to the left and to the bottom"? This is a perfectly legitimate, but a very different question.

Critics of the EKC are right in emphasising that economic growth does not necessarily create a sort of automatic mechanism to secure environment quality. Political action is a necessary condition to achieve that goal. However, empirical evidence strongly indicates that effective and efficient environment policies can only be implemented if there is broad-based social demand. Growing incomes fuel this demand, and therefore growth of per capita income is another necessary condition to approach sustainable development. Of course, social demand is not homogeneous, i. e. preferences for environment quality vary between different interest groups. Moreover, lobby power is not equally distributed among interest groups, and it is unclear which groups succeed best in achieving their goals. But it is unlikely that environment policies can be implemented against the interests of the majority of people in a society. Estimates of EKCs capture this demand and the political response, and both should be taken into consideration if prescriptions for environment policy are discussed.

5. A Global EKC: Simulation with Stylised Facts

As mentioned in Chapter 1 estimates of EKCs indicate that environmental degradation on a global scale will increase before a turning point can be reached. This indication raises two questions. First, by how much will overall environmental degradation increase? Second, how long will it take until the turning point will be reached? Following the Baldwin-model discussed before an answer to these questions would require a conditional forecast of population development and per capita pollution, both dependent on assumptions of per capita income growth. The difficulties of such a task are obvious. First, there are the empirical uncertainties of available estimates of the demographic transition and of EKCs. Second, EKCs have not been estimated for all types of environmental degradation. Third, it is not clear how different types of environmental degradation can be aggregated into a comprehensive single indicator. And fourth, the time horizon for projections is very long, which may render observed behaviour, on which the projections are based, obsolete.

These difficulties notwithstanding, available data and estimates can be translated into stylised facts, and these can serve as inputs for a simulation model. Such a model will not allow for conditional forecasts in a strict sense. But it is an instrument to generate projections that allow calculating orders of magnitude of the process. Parameter variations can help to assess the sensitivity of outcomes. Results from such a "back-on-the-envelope" model are discussed in the following sections.

The structure of the model represents the derivation of the EKC as described in Chapter 3. Growth of per capita income is exogenous, and income drives the demographic and ecological transformation. An "Environmental Kuznets Curve Index" (EI) is constructed, which captures all types of environmental degradation. The world is divided into four country groups, which correspond to the income classification of the World Bank: low income, lower middle income, upper middle income, and high income (Table 1). The initial per capita incomes are expressed in 1998 Dollars, corrected for purchase power parity (World Bank 1999). The

1998 population estimates are taken from the same source. Initial growth rates of per capita income and population, derived from growth rates over the last 20 years, are assigned to the initial income values of the four country groups (World Bank 1999; United Nations 1999).

Table 1: Starting Values and Parameters for Simulation, Scenario 1

	Low Income (L.I.)	Lower Middle Income (L.M.I.)	Upper Middle Income (U.M.I.)	High Income (H.I.)	World
Population (1998, m)	3515	908	588	885	5897
Income p.c. (1998, PPP$)	2130	4080	7830	23 440	6200
Population growth (% p.a.)	1,5	0,9	0,8	0,4	1,2
P.c. income growth (% p.a.)	4,0	2,5	2	1	1,3
P.c. income elasticity of pollution	0,25	0,5	0,2	-0,35	

The growth rates of per capita income and population of the three groups of LDCs are adjusted by linear interpolation. In the low-income countries, for example, the growth rate of per capita income declines from 4 % p. a. to 2,5 % p. a. when the income of today's lower middle-income countries is reached. The same applies to growth rates of population and to the per capita income elasticities of pollution. For the high-income countries it is assumed that the growth rate of per capita income declines to 0,5 % p. a. over the whole simulation period of 150 years.

The interaction of economic growth and population growth is corrected by an additional time-dependent factor that reduces population growth independent of income. This time-variable was introduced to fit the population development of Scenario 1 to the most recent long-run "medium" population projection of the UN Population Division (United Nations 1999). The medium projection shows a sharp drop of fertility after 2050. World population is then projected to have reached 8,9 Billion, and subsequently approaches virtual stability at around 9,8 Billion in the year 2150. Unfortunately the available UN-documents do not provide quantitative information about the assumed economic development underlying its projections. The parameters for the interaction of economic and demographic development given in Table 1, which reproduce the medium UN-projection, have been calibrated for the model presented here and are not a product of the UN Population Division.

A first crucial issue in constructing a singe pollution index is to decide about the weights with which different types of pollution enter the index. For the model the simplest conceivable approach was chosen by assuming that every type of pollution has the same weight. The types of pollution considered are those listed in Chapter 1, except municipal waste. For all these types of environmental degradation available estimates suggest an inverted U-curve or a continuous decrease.

The second crucial issue is to add up the individual EKCs and decreasing pollution curves, which includes an averaging of different estimates for the same types of pollutants. Admittedly, this aggregation is a very crude first approximation. The link between per capita income and pollution per capita is represented by a per capita income elasticity of pollution. The stylised picture that emerges is as follows (Table 1). In the low-income countries the initial per capita income elasticity of (per capita) pollution is 0,25. It grows to 0,5 as income reaches the initial value of the lower middle-income countries, then declines to 0,2 for the initial income of the upper middle-income countries, and finally declines to -0,35 for the initial income for the high-income countries. The per capita pollution in high-income countries declines to about 50 % during the simulation period. The peak of the per capita EKC is reached at an income level of $ 13 500, equivalent to an apex at $ 10 000 at 1985 prices. This reflects a relatively conservative or "pessimistic" interpretation of available estimates of EKCs.

The main results for Scenario 1 are depicted in Figure 4, which contains 5 EKCs in index form: L.I. EI is the EKC-index for the low income countries, L.M.I. EI represents lower middle-income countries, U.M.I. EI upper middle-income countries, H.I. EI high-income countries, and W. EI the entire world. The diagram illustrates that pollution roughly triples in the low-income countries and more than doubles in the lower medium-income countries before the apex is reached. It takes about 100 years and 70 years respectively to reach the turning points. The upper middle-income countries face an increase of pollution by slightly less than 50 % over the next 50 years. In the high-income countries pollution grows for about 10 years at very small amounts before it declines continuously to about 50 % of the initial level. For the entire world these developments imply an increase of pollution of some 120 % before the apex is reached in the year 2081.

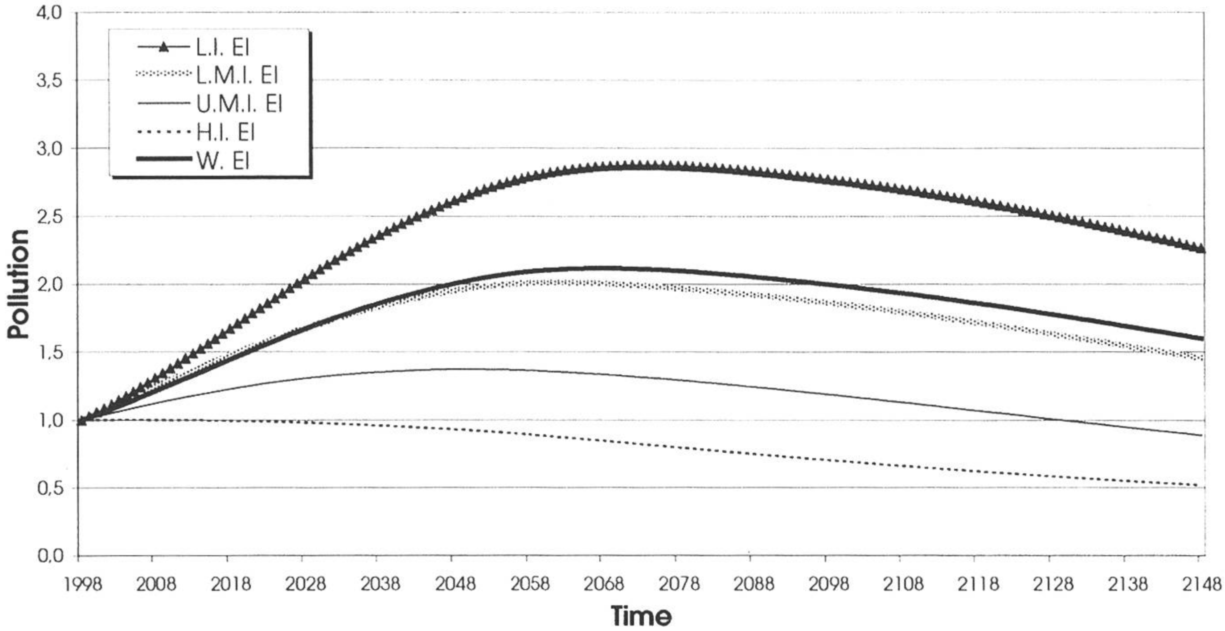

Figure 4: Environmental Kuznets Curves, Country Groups and World, Scenario 1.

It is important to differentiate between the development of per capita pollution and total pollution as captured by the EKCs. In the low-income countries, for instance, per capita pollution grows to a maximum that is 70 % higher than the initial value. This level is reached at the per capita income of $ 13 500 in the year 2077. The average per capita income elasticity of pollution between the initial income of $ 2130 and this threshold income is 0,27. The maximum of total pollution is 200 % higher than the initial value and is reached in 2090. The impact of population growth on pollution is therefore some 130 % of the initial level, 65 % of the total increase of pollution. To put it differently: the impact of population growth in the low-income countries is about 1,8 times the impact of the growth of per capita pollution. On a global scale population growth accounts for 70 % of the increase to the maximum of total pollution, i. e. its impact is 2,3 times the impact of per capita pollution growth. In other words, population growth contributes considerably more to global pollution than per capita pollution growth.

Scenario 2 (Figure 5) is a "high growth scenario". Initial growth rates of per capita income were increased as follows: for low-income countries from 4 % to 5 %, for lower middle-income countries from 2,5 % to 3 %

and for upper middle-income countries from 2 % to 2,5 %. Scenario 3 (Figure 6) is a "low growth" scenario. Initial per capita income growth rates for the three country groups were reduced to 3 %, 2 % and 1,5 % respectively. Scenario 4 (Figure 7) shows the impact of different per capita income elasticity of pollution. The initial elasticity for low-income countries was reduced to 0,2, for lower-middle income countries to 0,4 and for upper middle income countries to 0,15. Scenario 5 (Figure 8) combines these lower elasticities with the high growth assumptions of Scenario 2. In Scenario 6 (Figure 9) the low growth assumptions of Scenario 3 are combined with higher initial elasticities: 0,55 for the lower middle-income countries, 0,25 for the upper middle-income countries, and -0,3 for the high-income countries.

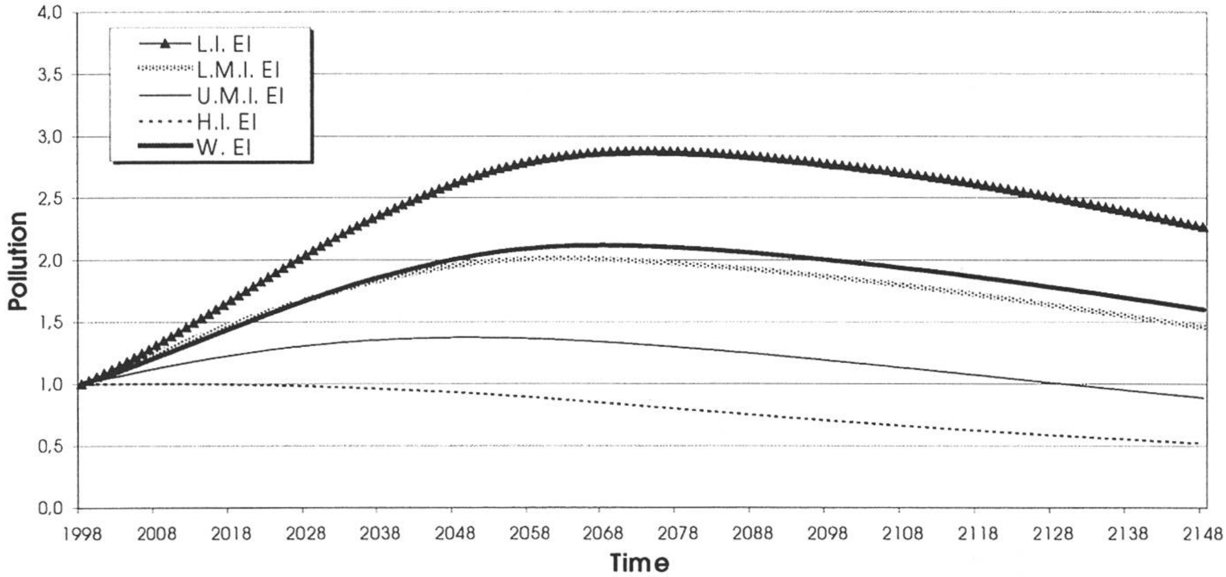

Figure 5: Environmental Kuznets Curves, Country Groups and World, Scenario 2.

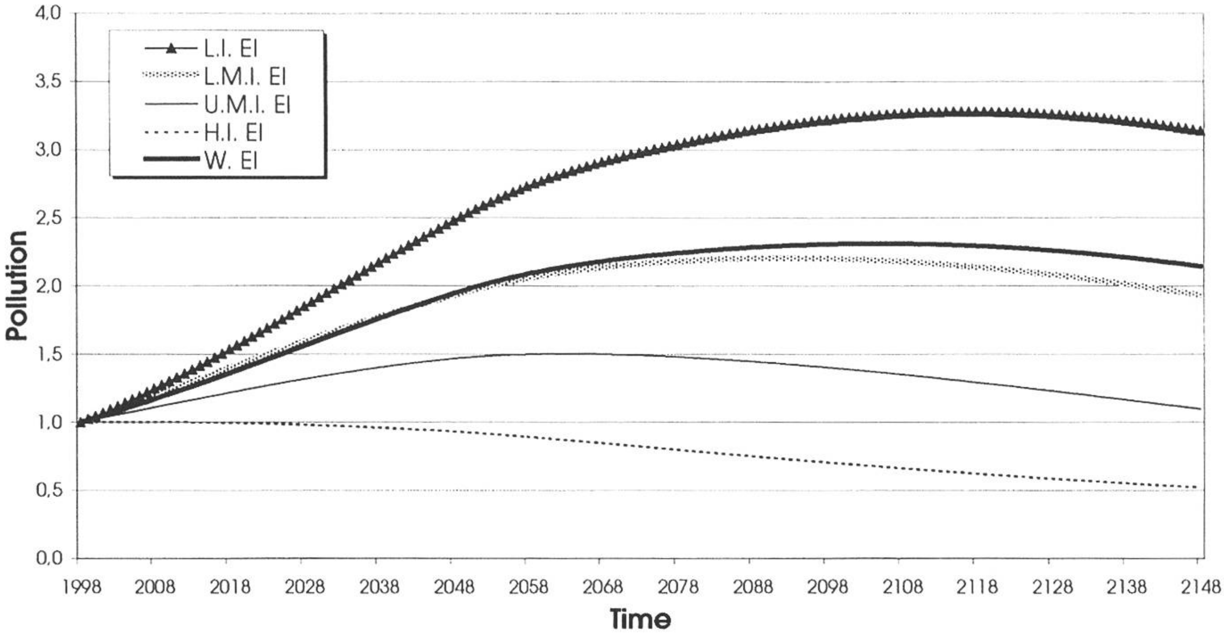

Figure 6: Environmental Kuznets Curves, Country Groups and World, Scenario 3.

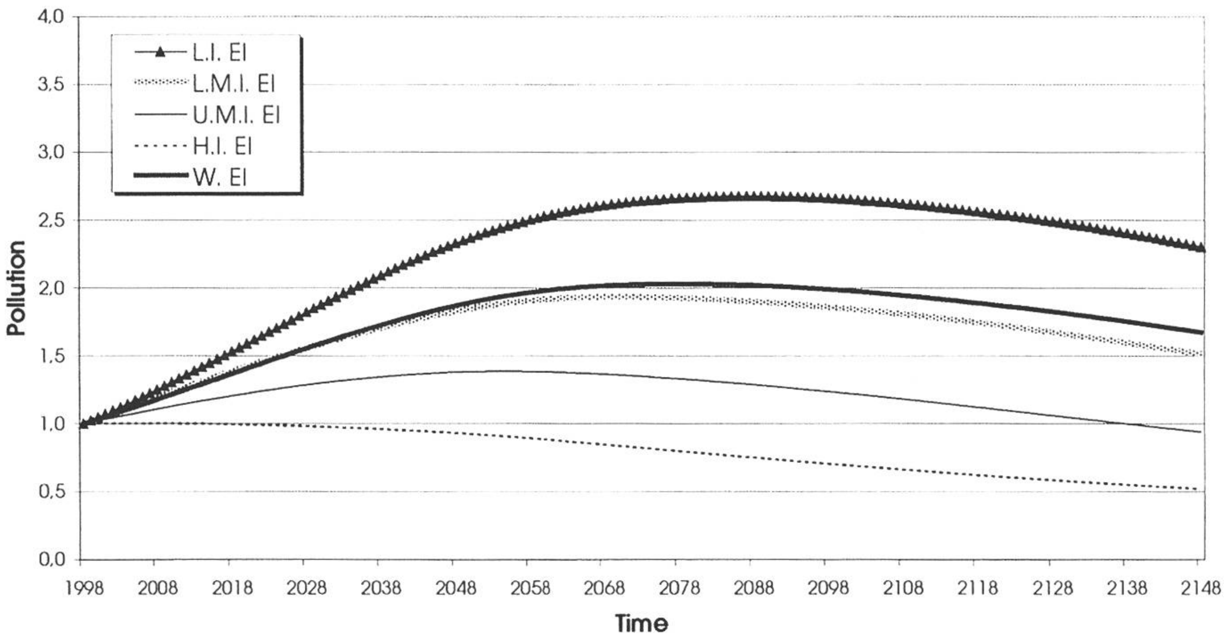

Figure 7: Environmental Kuznets Curves, Country Groups and World, Scenario 4.

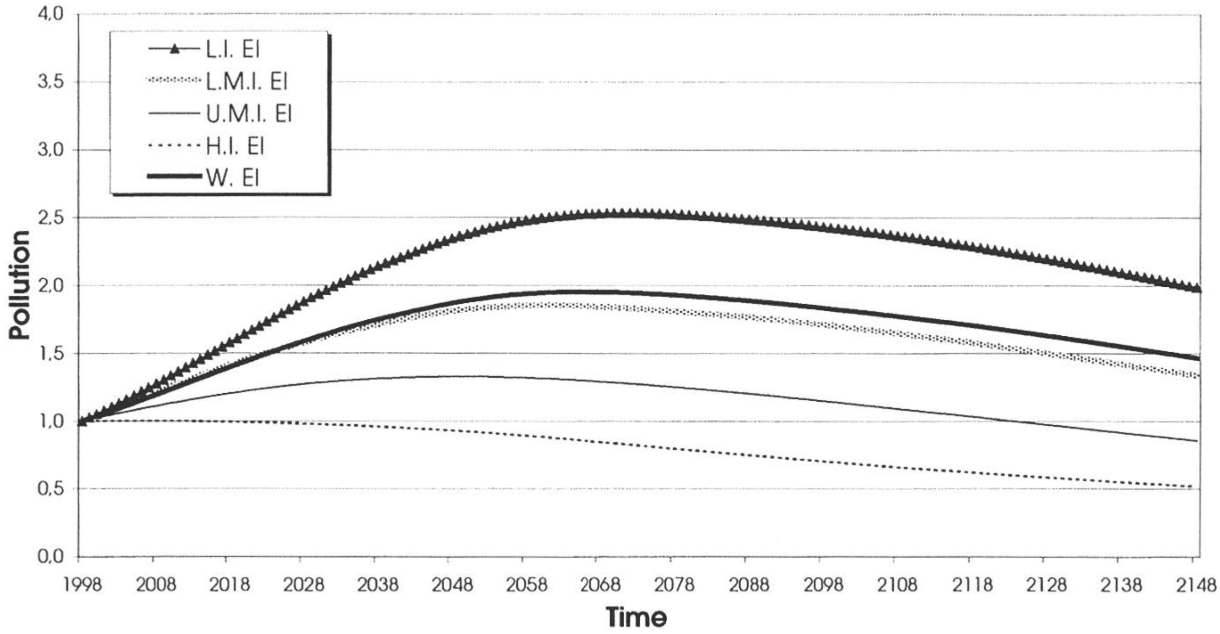

Figure 8: Environmental Kuznets Curves, Country Groups and World, Scenario 5.

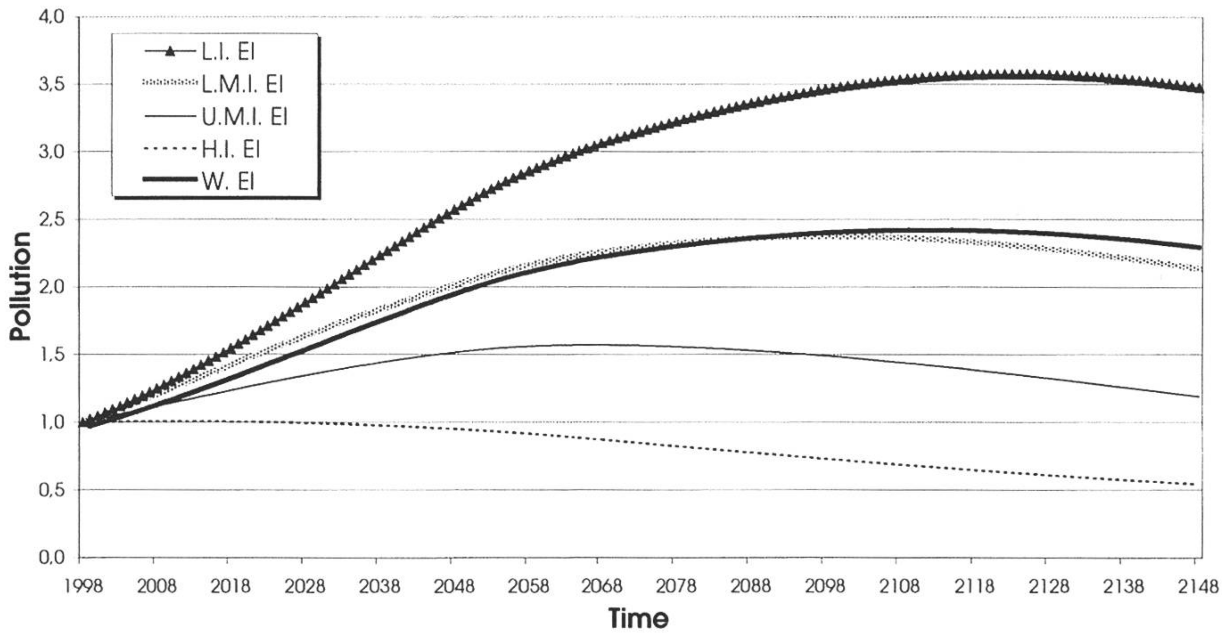

Figure 9: Environmental Kuznets Curves, Country Groups and World, Scenario 6.

The results of these scenarios reflect the expected changes in the pattern of development. The high growth assumption of Scenario 2 reduces the amplitude of the EKCs, it shifts the inverted U-turns to the left, and the whole EKC is compressed. For the low growth Scenario 3 the changes go in the opposite direction. As illustrated in Figure 7 (Scenario 4) the reduced per capita income elasticities of pollution shift the EKCs downwards.

Within the range of the selected parameter combinations Scenario 5 (Figure 8) and Scenario 6 (Figure 9) set the lower and upper limit of the development of pollution. The maximum of the pollution index of the global EKC varies roughly between 1,9 and 2,4. Related to the apex-value of 2,2 of Scenario 1 this implies a variation of about plus/minus 10 %. The time span until the inverted U-turn on a global scale is reached varies more. In the high growth / low elasticity Scenario 5 the apex for global pollution occurs in about 65 years from now, in the low growth / high elasticity Scenario 6 in about 110 years from now. Relative to the time span of 80 years in Scenario 1 this is a variation of minus 20 % and almost plus 40 %.

Taken together the results give a crude overall picture of future development, assuming that the stylised facts that serve as inputs hold. Global pollution will roughly double, and it will take some 65 to 110 years until the turning point is reached. These are the orders of magnitude of the development. It goes without saying that the stylised inputs and the results of the model bear many uncertainties. More work is needed to arrive at better estimates of the interaction of economic growth and population growth, at a better understanding of the determinants of per capita income elasticities of pollution, and at an improved aggregation procedure. But even if that can be achieved, the inevitably long time span of the projections is breathtaking.

Whether LDCs will be able to "tunnel" EKCs that emerge from observations of our contemporary world will remain an open question. One possible cause might be technical breakthroughs in various fields of production. Given the long time horizon of the process, that can never be excluded. Another cause might be unprecedented progress in environment policy. Particularly environmentalists, who are often the most avid critics of the EKC, call for such progress. But as mentioned before, such requests and hopes should be taken with care. From a politico-economic point of view it is difficult to imagine that preferences of people and reactions of politicians in LDCs will differ radically from those observed in industrialised countries.

Regarding this question it is probably helpful to remember one of the conclusions that Kuznets put at the end of his paper on income inequality almost half a century ago. On the one hand he emphasised that "the future cannot be an exact repetition of the past", on the other hand he warned against devising "solutions that are the product of imagination unrestrained by knowledge of the past, and therefore full of romantic violence." And he continued: "What we need, and I am afraid it is but a truism, is a clear perception of past trends and of conditions under which they occurred, as well as knowledge of the conditions that characterise the underdeveloped countries today" (Kuznets 1955, p24 ff). Despite the differences in the topic, and despite the progress of science between then and now, that conclusion still holds and should lead the way.

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