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Economic Development and the Environment:

A Theoretical Model to Explain the Existence of Environmental Kuznets Curves

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Abstract

A number of empirical studies has identified environmental Kuznets curves representing an inverted U-shaped relation between pollution and gross domestic product (GDP) per capita, that is replicated here by an empirical time series of surface water quality data. To analyze the driving forces behind these empirical patterns the paper provides a theoretical model postulating a universal welfare function constant over time and valid for all countries. The country-specific choice of a certain level of environmental quality depends on the shape and position of the national production possibilities frontier in a GDP per capita / environmental quality space. Shape and position of the current transformation curve are determined inter alia by the stocks of capital, technological capabilities and the environmental quality at the beginning of the preceding period as well as by the rates of technical progress, population growth and resource depletion in period t-1. Environmental quality in period 1 depends on the initial endowment, the depletion rate and the recovery rate in period t-1. The transformation curve shifts with rising income and continued resource depletion. Connecting the welfare maxima of successive periods reveals country-specific Environmental Kuznets Curves reflecting the effect of rising income per capita and diminishing environmental resources on the choice between more consumption or more environmental quality.

The model allows to discuss the effects of environmental policy, technical progress and population growth as well as the relevance of spatial aspects of pollution. The analysis helps to identify policy options to "tunnel through the Environmental Kuznets Curve" - as for example by innovation enhancing policies or transfer of more efficient technologies from the industrialized to the developing countries. Nevertheless it comes to a pessimistic prognosis with respect to a reduction of greenhouse gas emissions.

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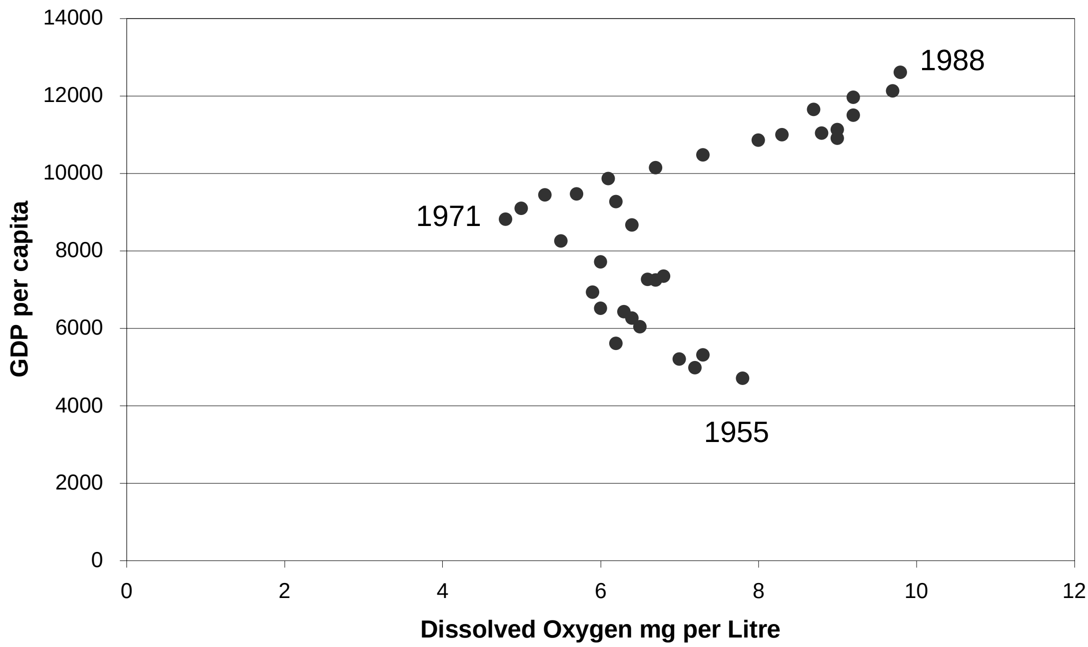
1. Environmental Kuznets Curves

In recent years the literature on the relation between economic development and the environment has expanded rapidly.[1] It proceedingly concentrates on a debate on the existence of the so called "Environmental Kusznets Curve" which postulates an inverted U-shaped relation between GDP per capita and the degradation of a country's natural environment. A number of empirical studies try to identify the respective "peaks" of these Environmental Kuznets Curves concerning several pollutants that are supposed to have the most serious or at least most obvious detrimental effects on the environment. For local pollutants the pollution peaks are estimated between e.g. 1,887 US $ (lead) and 10,524 US $ (nitrates) per capita[2], albeit varying excessively between studies. For global pollutants like CO_2 the question where a peak is to be identified or whether it is identifiable at all is discussed vividly[3].

Figure 1: Water Quality of the River Rhine and GDP per capita, Germany 1955-88



Source: Own calculations based on Umweltbundesamt (1997) and Worldbank (Shafik 1992) data.

Time series data on the water quality of the river Rhine[4] replicate these findings (see fig. 1). The content of dissolved oxygen (DOX), which is essential for the maintenance of aquatic life and serves as an indicator mainly for organic, phosphate and nitrate pollution, declined in the period of strong economic growth after the Second World War. GDP per capita rose while water quality

[1] See e.g. Grossman and Krueger (1994), Selden and Song (1994), Holtz-Eakin and Selden (1995), Panayotou (1997), Galeotti and Lanza (1998), Stern et al. (1998).

[2] Grossmann and Krueger (1994), table 1.

[3] See e.g. Holtz-Eakin and Selden (1995), Stern (1998).

[4] The river Rhine flows through several countries. The water samples referred to in fig. 1 were taken in Germany, but might also contain pollutants from sources in Switzerland. Part of the quality amelioration may therefore be due to emission reductions in Switzerland. Because of the relative importance of the German share of total emissions and the largely parallel growth of German and Swiss GDP per capita the findings are to be relativized only slightly.

deteriorated. The minimum of water quality (4.8 mg DOX per litre), i.e. the pollution maximum, was reached in 1971 at a GDP of 8,800 US $.[5] After that negative peak water quality and GDP p.c. were on the rise together.

In contrast to many other papers the empirical Environmental Kuznets Curve is presented here open not to the bottom but to the right of the diagramm and this practice will be followed throughout the paper. This should be taken as a first hint at the theoretical point to be made here - that GDP per capita is not the only variable determining the shape of the Environmental Kuznets Curve. The choice of a certain environmental quality (and also the choice of a certain GDP measured in conventional terms) strongly depends on the relative satisfaction of several important and often concurring development goals, one of it being environmental quality itself.

Apart from the attempts to tackle the problem empirically only a few articles try to analyze the underlying driving forces theoretically. Most articles formulate their hypotheses only verbally. Antle and Heidebrink (1995) and Munasinghe (1999) present models that are aimed to explain the empirically observable patterns.

Antle and Heidebrink (1995) develop a stylized model of environment-development trade-offs. From a production function with the arguments labor, conventional capital stock and environmental capital stock devoted to market goods production and an environmental services production function with the environmental capital stock as the independent variable they derive a transformation frontier between market goods and environmental services. Economic growth shifts this frontier outward and brings more market goods within reach. The movement of the transformation curves is restricted by the assumption that no part of the environmental capital stock is irreversibly exhausted and can always be rebuilt by reducing its use. This assumption keeps the same maximum of environmental services within reach for all periods - irrespective of the intertemporal consumption path chosen.

Wether the shifts of the transformation curve lead to lower or higher levels of environmental services depends on the income elasticity of demand for environmental goods. Without specifying a preference function, Antle and Heidebrink choose a series of production points to show that there might exist a growth path that entails an only transitional reduction of environmental services. This phase of "environmental transition", as the authors call it, is nothing else but the peak of the Environmental Kuznets Curve, as other authors would name it.

Munasinghe (1999) derives an Environmental Kuznets Curve from marginal benefit and cost functions with income per capita and environmental degradation as the independent variables. When the income level rises, the marginal costs as well as the marginal benefits derived from the degradation of the environment increase, the marginal costs at a decreasing pace, the marginal benefits with an increasing one. According to Munasinghe's argumentation, "the marginal costs of controlling environmental degradation rise more rapidly with initial income growth than the corresponding willingness to pay (i.e. marginal benefits) for reducing environmental damages"[6].

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[5] Purchasing Power Parities, calculated with the World Bank *Atlas*-procedure for 1987 US prices.

[6] Munasinghe (1999), p. 107.

The present paper attempts to add a new approach to this discussion, identifying the Environmental Kuznets Curve to be a peculiar case of an Engel curve concerning the demand for environmental quality. Essential to the argumentation is the identification of country-specific transformation spaces that shift during the process of economic development and the introduction of a welfare function with certain properties to be discussed below.

2. The Model

If environmental quality is a public good and external effects are present the market process does not lead to a social optimal allocation. Political measures must be taken to correct the allocation process. One way to define the optimal level of environmental quality in relation to other objectives of economic policy is to refer to a social welfare function[7]. As explanatory variables such a function could include the amount of goods for private consumption (C_t) (that could be approximated by GDP per capita), environmental quality (E_t), and other relevant development objectives such as income distribution, employment, price level stability, and balance of payments situation. The term "environmental quality" referred to in this paper is similar to the "natural capital" used by Pearce and Warford (1993). It has stock and flow aspects. Environmental goods (fresh air, clean water), other renewable resources like fish, wood, assimilative capabilities, and non-renewable ones like fossil fuels provide the individual with utility that results from the current flow of usage. But that flow is not independent from the stock out of which it is taken. The continued use of non-renewable resources must come to an end when the resource is depleted while the use of renewable resources can be continued infinitely if it remains within the limits of sustainability. Diminishing the stock of a renewable resource like forests can affect the flow of utility out of that resource (be it here the air-cleaning capacity) and it might take a long time of refraining from usage or reinvestment into that resource to regain the level once at disposal.

For convenience and concentrating on the main focus of this paper only consumption per capita and environmental quality are taken into account. Nevertheless it should be kept in mind that also other development objectives must be satisfied as well if one wants to talk of a sustainable development process. The simplified social welfare function reads as follows:

(1) $W_t = W_t(C_t, E_t)$

W_t is a universal welfare function valid for all countries at each point in time: Each society would decide the same way if it was in the same situation. Let W_t be standardized that $W = 0$ is the minimal welfare level and the partial differentials with respect to each variable are positive but decreasing[8].

Maximizing W_t subject to a multidimensional concave transformation space of the period t yields the current social optimum.[9] The transformation space is characterized by the following

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[7] See Siebert (1995): Chapter 5.

[8] The properties of the welfare function are discussed in more detail in: Hirschfeld (1995): 50-53.

[9] "Period" is considered to be a planning period of about five years.

function:

(2) $Y_t = Y_t(K_t,H_t,,E_t,T_{t,}P_{t,}G_t)$

with K_t representing the stock of man-made physical capital, H_t human capital, T_t the technological capabilities at hand in the economy in question, and E_t the present environmental quality. P_t represents population size and G_t characterizes the current environmental policy, implemented as a tax on the use of environmental quality as an input of production. The variables K_t, H_t, T_t and E_t are itself the outcome of functions taking into account variable values of previous periods:

(3) $K_t = K_t(K_{t-1},k_{t-1})$

(4) $H_t = H_t(H_{t-1},h_{t-1})$

(5) $T_t = T_t(T_{t-1},t_{t-1})$

where K_{t-1} is the capital stock at the beginning of the previous period and k_{t-1} the rate of capital growth in period *t-1*, analogously h_{t-1} the growth rate of human capital and t_{t-1} the rate of technical progress in period *t-1*. The function E_t is slightly more complicated since it takes into account the stock and flow aspects of environmental quality as well as renewable and non-renewable components:

(6) $E_t = E_t(E^i_{t-1}, e^i_{t-1}, \hat{e}^i_{t-1}) = E^i_{t-1} * e^i_{t-1} * \hat{e}^i_{t-1}$

(7) $e^i_{t-1} = e^i_{t-1}(K_{t-1}, H_{t-1}, T_{t-1}, P_{t-1})$

E^i_{t-1} is the stock of resource *i* (or environmental quality dimension) available at the beginning of period *t-1* and e^i_{t-1} the share of this initial resource stock utilizeable (or the quality dimension to be deteriorated) in period *t-1*, with $0 \le e^i_{t-1} \le 1$. Furthermore e^i_{t-1} rises with K_{t-1}, H_{t-1}, T_{t-1} and P_{t-1} because a larger economy is able to deplete its resources more quickly and more thouroughly. The stock of resource *i* recovers during period *t-1* at the rate $\hat{e}^i_{t-1}$. For renewable resources $\hat{e}^i_{t-1}$ is ≥ 1, non-renewable resources do not recover, so their $\hat{e}^i_{t-1}$ is equal to 1. Wether E^i_t is greater or smaller than E^i_{t-1} depends on the size of e^i_{t-1} in relation to $\hat{e}^i_{t-1}$.

Beside the stock and flow aspects of environmental quality the spatial dimension must be taken into account. There are local and global environmental goods which have to be treated quite differently: Empirical studies on the environmental Kuznets curve[10] define specific turning points for different pollutants. The assumption made in the present paper is that the income level required to turn the pollution curve downward is subject to the subjective urgency or obviousness of the problem. The empirical findings suggest urban air pollution and surface water quality to be the problems regarded as the most urgent ones. It would be misleading in this context to consider the amount of pollution per capita since it is the detrimental effect on the individual that drives it to take measures against the negative externality. If the concentration of

[10] Grossman and Krueger (1994), Selden and Song (1994), Panayotou (1997), Galeotti and Lanza (1998).

SO_2 rises from X parts per million to Y ppm it is irrelevant to the individual if a hundred or a thousand people breath with him, it is the absolute concentration that matters.

In the second and third section of the present paper the variable "environmental quality" is defined by the presence (or better: absence) of *local* pollutants like SO_2, CO, total suspended particulate (air), biochemical oxygen demand, suspended solids (water), respectively a weighted index representing their joint impact. The problem of global environmental goods (like CO_2 assimilative capacity and possibly resultant climate effects) will be discussed in section 4.

For each variable of the welfare function we can identify a critical minimum level of achievement below which a society loses its survival capability. If the value of the variable in question (e.g. consumption per capita or environmental quality) approaches that critical minimum level the welfare function's partial slope tends towards infinity:

(8) $$\frac{\partial W}{\partial C} \rightarrow \infty \quad \text{if} \quad C \rightarrow C_{crit}$$

(9) $$\frac{\partial W}{\partial E} \rightarrow \infty \quad \text{if} \quad E \rightarrow E_{crit}$$

As mentioned before the partial differentials with respect to each variable are positive but decreasing, so there exist regions of relative saturation with respect to one of the objectives:

(10) $$\frac{\partial W}{\partial C} \rightarrow 0 \quad \text{if} \quad C \rightarrow C_{sat}$$

Out of the multidimensional space of positively formulated development objectives the following figures 2-11 take the partial plane consumption possibilities per capita ("**C**", vertical axis) versus environmental quality ("**E**", horizontal axis). The third dimension above this plane of reference is occupied by the welfare function, represented by concave indifference curves.

2.1 Growth of Physical Capital

Growth of physical capital (k_t * K_t) increases in the first place a society's consumption possibilities but it also opens the opportunity to spend more resources on the improvement of environmental quality. Nevertheless increased production possibilities also enable the society to deplete the environment more thoroughly. The transformation curve expands, higher amounts of both variables come into reach, but also a reduction of environmental quality might be the case (see figugers 2a, 2b).

Figure 2a: Growth of Physical Capital (IC case)

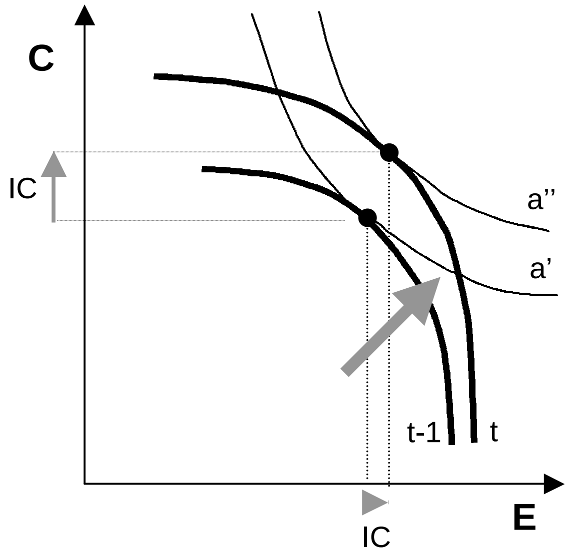
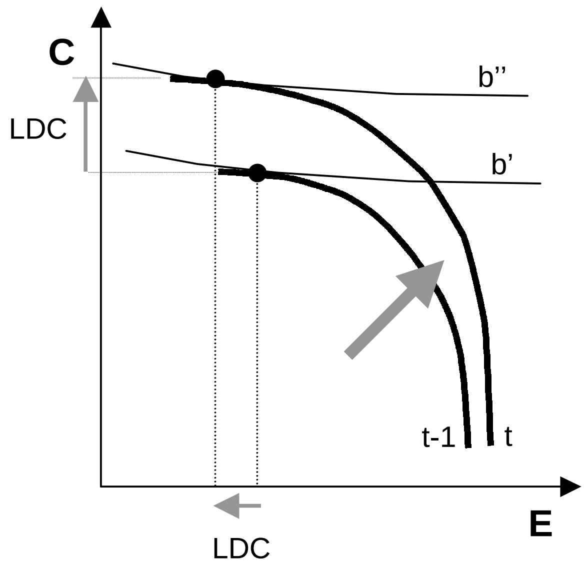


Figure 2b: Growth of Physical Capital (LDC case)



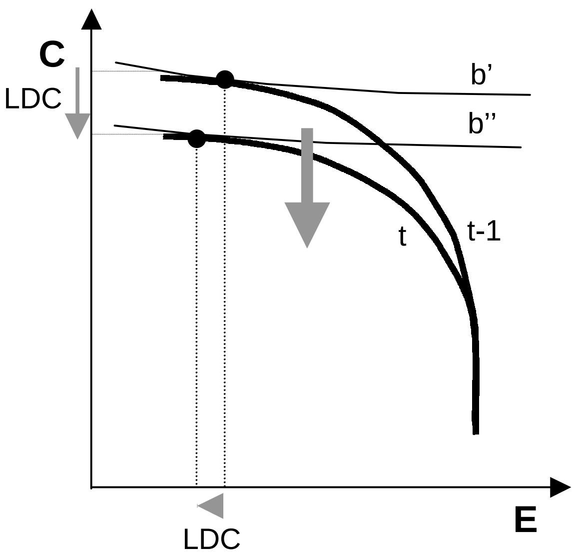
Wether environmental quality is enhanced or reduced in the process of capital growth depends on the relative slope of the welfare function in the relevant interval of decision opportunities and this in turn – as we will recognize in section 3 - on the position of the country's transformation curve in the consumption/environmental quality plane of reference. A growing already industrialized country (IC) will choose more of both variables (fig. 2a), while a growing least developed country (LDC) seeks as much additional consumption as possible and will therefore accept a loss of environmental quality (fig. 2b). The indifference curves a' and a'' versus b' and b'' reveal quite different attitudes towards the environment: while the industrialized country's society is willing to accept some sacrifice in favour of better environmental quality, people in the least developed country are nearly completely occupied by the problem to get more consumption goods (satisfying basic needs) while they are relatively ingorant towards the state of their environment. This rather polarized picture is drawn to discuss the effects of two polar cases between which most economic policy is supposed to take place in reality.

Note that because of the stock effects the transformation curve of period *t* is not independent from the curve's shape and position in *t-1*. Without the existing stock of capital in *t-1* (and also the stocks H_{t-1}, T_{t-1} and E^{i}_{t-1}) it would not have been possible to reach the enlarged curve in *t*.

2.2 Population Growth

If the population size grows at a higher rate than the capital stock per capita (which is the case in many least developed countries), the output-enhancing effect of the labor force enlargement is overcompensated by a decline of the capital/labor ratio and results in a reduction of output per capita.[11] The shift in Figure 3 therefore represents the likely outcome in a least developed country: per capita consumption possibilites and environmental quality deteriorate – as does the welfare position. In developed countries with moderate rates of population growth along with higher rates of capital growth the curve can behave just the other way around: Population growth can expand the transformation curve away from the origin rather than shrinking it – but only with respect to the dimension “consumption per capita”. Due to the effect of P_{t-1} on e^{i}_{t-1} environmental quality is challenged like in the LDC case.

Figure 3: Population Growth (LDC case)



2.3 Technological Progress

The effect of technological progress is very similar to that of capital growth. It is presented separately because of its relevance to ensure that the process of growth takes place not only in the dimension of consumption goods but also in the environmental dimension (see figures 4a, 4b). It expands the possibilities frontier much more pronounced in the direction of more environmental quality than does in comparison mere capital growth.

In fact technical progress is one of the key tools to prevent the developing countries from growing on the same dirty path the now industrialized took in the centuries behind. With an enhancement of total factor productivity, technological changes make it possible to get more output out of a constant or even reduced amount of inputs. As figures 4a and 4b show technical progress will move the curve upwards and to the right, so that even the LDC (fig. 4b) can realize gains in consumption per capita without losing evironmental quality. Even more is to gain for the developed country with respect to both dimensions (fig. 4a). Capital growth without technical progress relying on old fashioned production techniques would drive the curve left with only limited consumption enhancing effects.

[11] See Mankiw (1992), Chapter 4.

Figure 4a: Technological Progress (IC case)

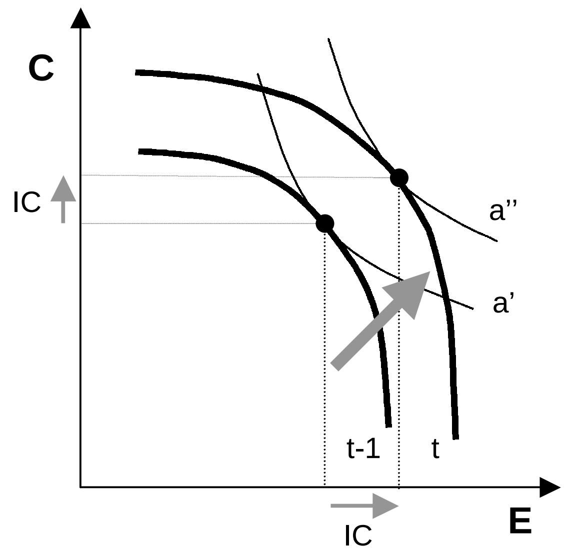
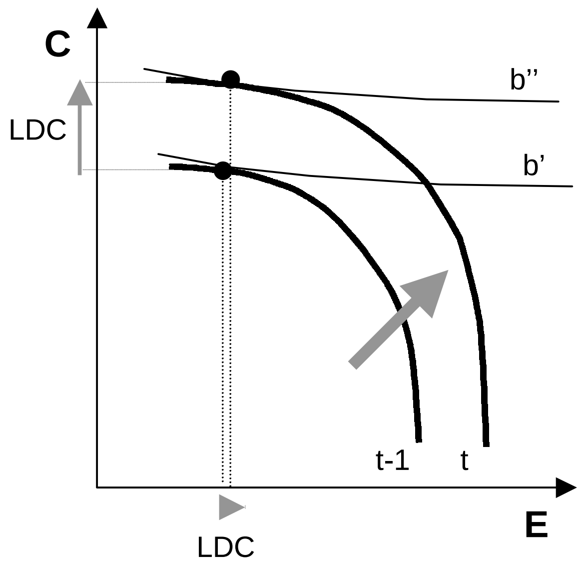


Figure 4b: Technological Progress (LDC case)



2.4 Environmental Policy

The disussion of environmental policy within the model leads to some unorthodox insights: Environmental policy can be implemented either "on the curve" or by shifting the transformation curve. The common argumentation states that if you want to preserve the environment, you have to sacrifice some "conventional" per capita consumption – that would be a movement *on* the transformation curve. Such a policy is driven by a change of preferences within the society – represented by a shift of the welfare function. Imagine to rotate the LDC's indifference curve (b') in direction of a' and a'' – representing the industrialized country's welfare function. You would move on the curve towards less consumption and more environmental quality. But is this really plausible? Did something like that really happen in any country? In fact industrialized societies try to steer the growth process into directions that make possible more consumption *and* more environmental quality simultaneously. A shift of preferences as described above can be explained by a move of the entire transformation curve within the welfare space. Here comes the point where the graphical representation in figures 2a to 5b reaches its limits: The LDC's possibilities frontier is not identical with the transformation curve representing a fully developed country's production possibilities – and the presentation in very similar diagramms is misleading. Cases a and b happen at very different places in the comsumption per capita/environmental quality plane (compare fig. 7 in the following section 3). Environmental policy taking place "on the curve" does in fact take place "on a moving curve". This will be discussed in more detail in section 3.

Figure 5a: Environmental Policy (IC case)

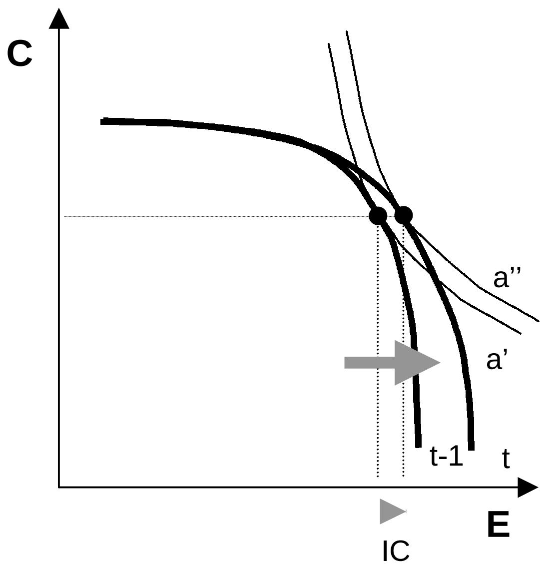
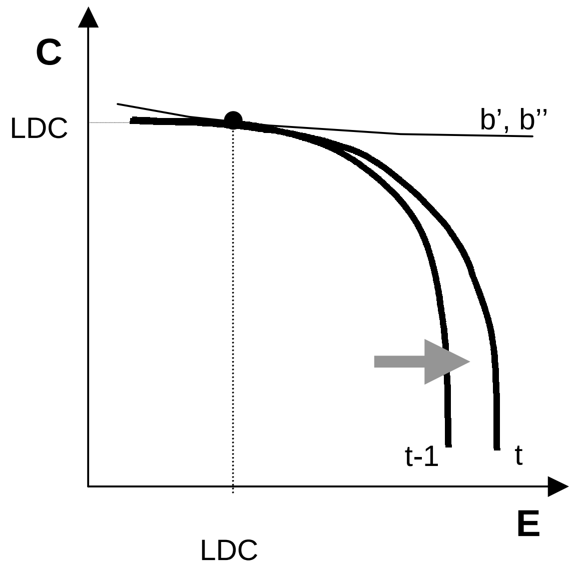


Figure 5b: Environmental Policy (LDC case)



Environmental policy extends the transformation curve to the right (i.e. by increasing the recovery rate $\hat{e}^i_t$). This is likely as the outcome of a democratic decision only if this extension of the transformation space brings into reach a higher indifference curve – which is plausible only from the perspective of an industrialized country (indifference curves a' and a''): The improvement of environmental quality is highly appreciated. The LDC's situation is different: If its government followed the IC's example with the same environmental policy – welfare would remain constant, the relative as well as the absolute amounts of "conventional" goods and "environmental quality" chosen would not change. The developing countries' population would simply not be interested in an environmental policy not enhancing consumption possibilities.

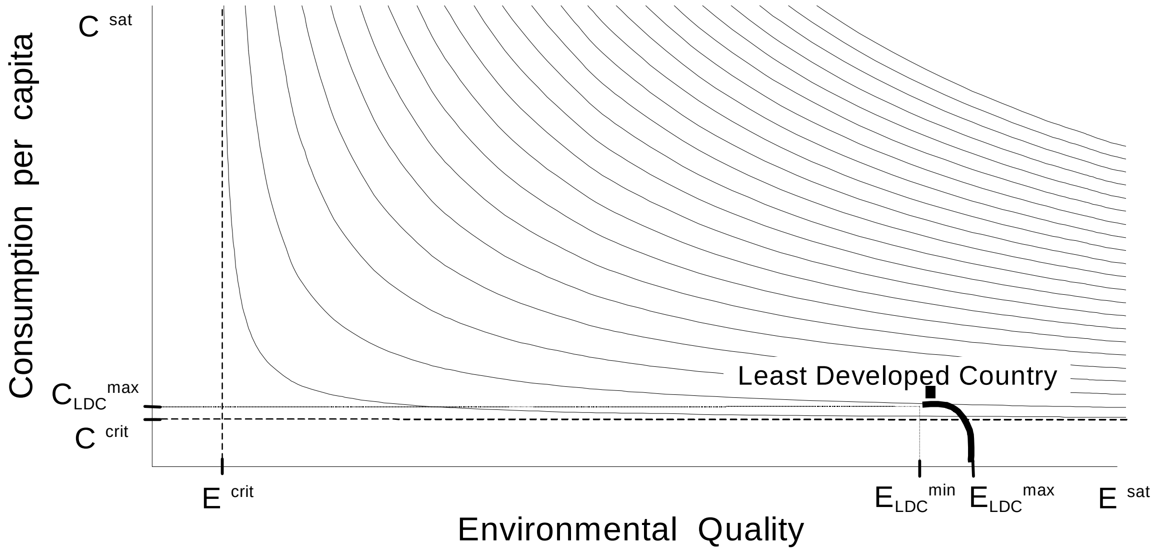
3. The Process of Development

The transformation curve revealing a country's production possibilities is not stable over time. Section 2 outlined how capital and population growth, technological progress and environmental policy shift the curve from one periode to the following. Section 3 will now discuss the stock effects determining its position in the welfare space.

If we compare the peculiar transformation curve in fig. 6 with familiar production possibility frontiers in two-product-cases it shows one aspect which is unfamiliar: It does not stretch from one axis to the other but refers only to a limited interval. The interval is limited because the set of possibilities to choose from in period *t* is subject to structure and scale of the production possibilities of the examined country in the period referred. As a case of path dependency the

LDC cannot jump to the curve of an industrialized country in only one period. In the short run (the introduced planning period of about five years) it is bound to its narrower growth possibilities (defined by not only by k_t, h_t, t_t and e^i_t but also by the stocks K_t, H_t, T_t and E^i_t).

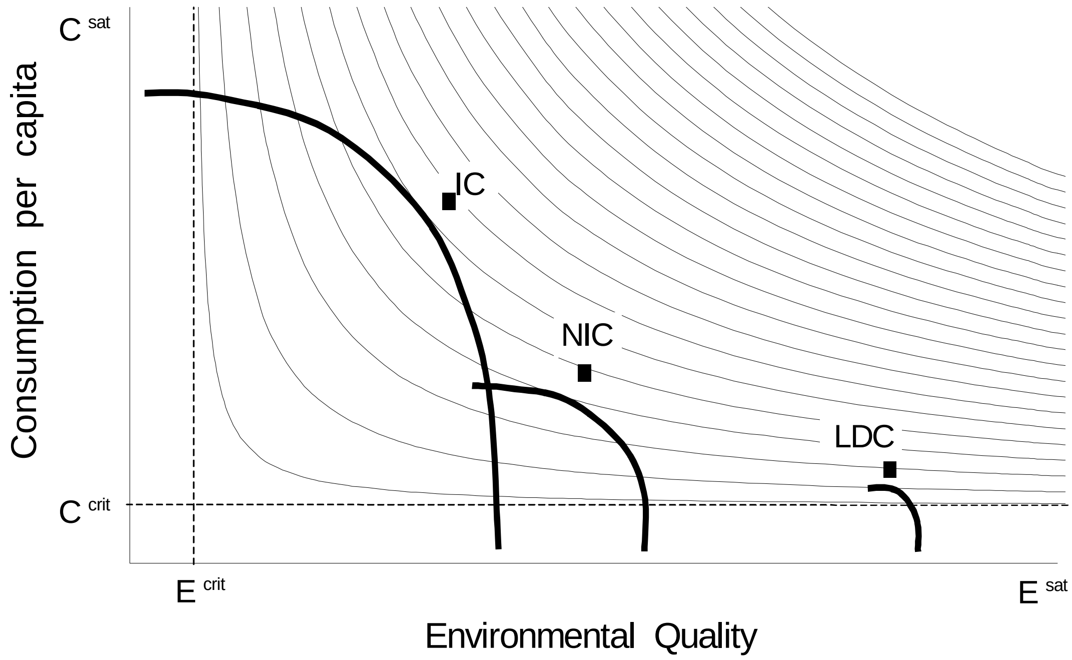
Figure 6: LDC Transformation Curve



A developing country with only a small industry sector is unable to diminish its environmental quality to zero in the course of only one period. The least developed country (LDC) in fig. 6 is well endowed with natural capital but hardly able to feed its population. Subject to its limited production possibilities the developing country can choose its environmental quality out of the interval [E_{LDC}^{min}; E_{LDC}^{max}] and its consumption per capita out of [0; C_{LDC}^{max}]. Since the critical level of consumption per capita is very close, the welfare function's indifference curves in this area run almost horizontally: With respect to consumption possibilities the welfare function's partial slope is close to its maximum. In contrast the partial slope with respect to the objective environmental quality is near to zero. Out of its production possibilities the country will choose the maximal possible consumption per capita, accepting indifferently the minimal possible environmental quality.

The transformation curve of the newly industrializing country (NIC) in Figure 7 shows a different situation: Due to proceeded industrialization environmental quality has already deteriorated considerably (the interval to choose from lies more to the left). On the other hand higher consumption levels are within reach (the transformation curve stretches higher). The NIC's choice is not that extremely one-sided as the LDC's: Within its possibilities the NIC does not choose the consumption maximum but accepts moderate cuts in favor of some more environmental quality.

Figure 7: LDC, NIC and IC Transformation Curves in the Welfare Space



If we finally look at the industrialized country's transformation curve (IC, fig. 7) we find it stretched nearly from one axis to the other: To reach the maximal possible consumption level the country's industry would be capable of depleting its environmental quality almost entirely within one period. This will not happen though because in that case the welfare function would approach the value zero, far higher levels of welfare being well within reach elsewhere. In contrast to the NIC and LDC the industrialized country is willing to accept a substantial sacrifice in the dimension of consumption to preserve a certain desired level of environmental quality: The increased scarcity of the good "environment" is felt. Nevertheless the IC's welfare level is far higher than the NIC's whose in turn lies still much above the LDC's.

4. The "Environmental Engel Curve": The Demand for Environmental Quality - from Inferiority to Superiority

We looked so far at the different situations of countries at different stages of economic development at one point in time. But how did these countries come into the current situation? Will the LDC in some years face exactly the same transformation curve as the IC does today and where will the industrialized country's curve have moved to then?

The choice of the preceding period influences the production possibilities to choose from in the following one. This is the crucial assumption to get to the curve to be deducted in this section -

known as the environmental Kuznets curve which will turn out be a peculiar case of an Engel curve[12].

The observation that in early stages of economic development environmental quality is treated as an inferior good is well documented[13]: With rising income per capita less environmental quality is chosen. To understand that process in the framework of the model presented here the growth effect introduced in 2.1 must be complemented by the unfavourable stock effects of environmental depletion.

Figure 8: Stock Effects in the LDC case

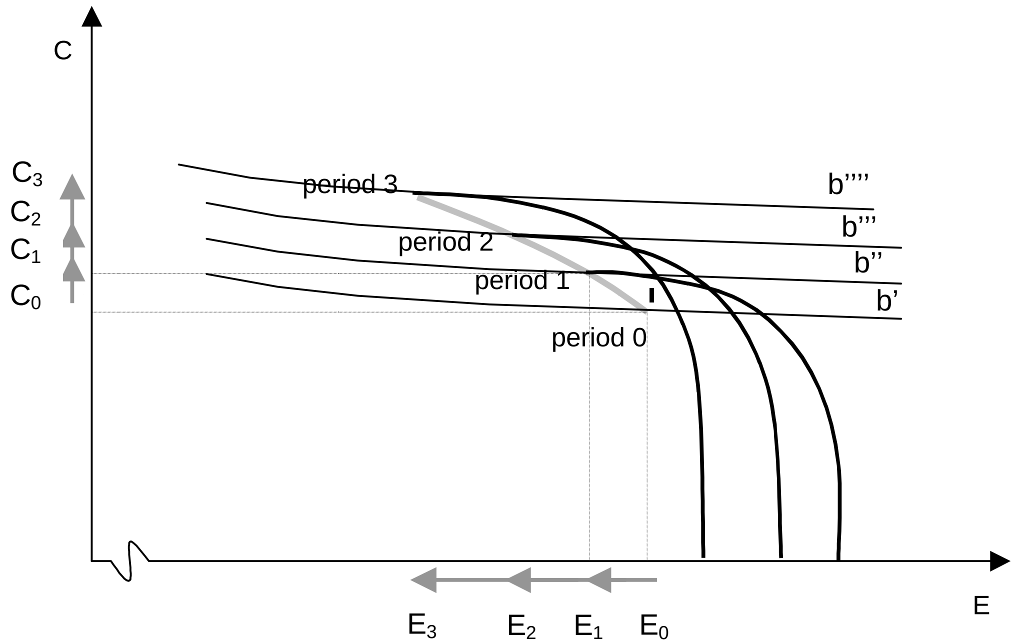


Figure 8 illustrates what might happen in a particular LDC: According to the prevailing preferences (the LDC's indifference curves b' to b'''' run almost horizontally) (E_0;C_0) was chosen in period 0. In presence of economic growth the transformation curve will move as introduced in Figures 2a, 2b. With (E_1;C_1) a deterioration of environmental quality is accepted in favour of a maximal expansion of the consumption possibilities (e^i_{t-1} is maximized subject to C_t , H_t and T_t). Due to the negative stock effect the transformation curve of period *2* lies above but left of the previous one. Some of the environmental capital sacrificed cannot be replenished within the scope of the current production possibilities ($e^i_{t-1} > \hat{e}^i_{t-1}$ and therefore $E_t < E_{t-1}$). The following transformation curves continue to move upwards and to the left: consumption possibilities expand, environment quality deteriorates.

An economic interpretation of that particular process might be that a poor developing country tries to compensate its lack of physical and human capital as well as its deficient technological capabilities (C_t , H_t and T_t) by consuming its stock of environmental quality (E_t). This path is

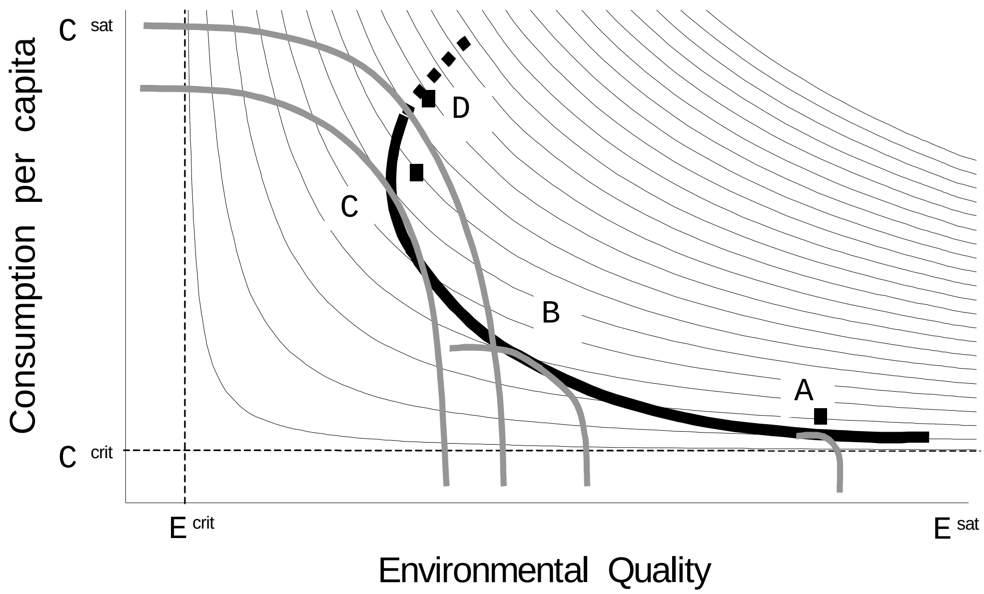
12 See e.g. Samuelson (1989): 467-469.

13 See for example Selden and Song (1994)

unsustainable when stocks of “man-made” capital (C_t, H_t and T_t) are accumulated insufficient to compensate for the losses of “natural” capital or if it was followed until reaching the critical minimum level of environmental quality.[14]

Step by step the developing country (see point A, fig. 9) becomes a newly industrializing country (B), later a fully industrialized one (C and D). This could have been the story of England, France, Germany, the USA. They all have grown into regions of the consumption/environmental quality space where the welfare function now reveals priorities very much different from the ones followed in earlier stages of economic development: From nearly complete indifference towards environmental quality in the 19th and early 20th century they developed into a region of the welfare space where they now give up a considerable part of their consumption possibilities in favour of a better environment.

Figure 9: The Engel Curve of Environmental Quality



Connecting the optimal points in the course of such a typical process of economic development reveals an Environmental Engel Curve (fig. 9): If we take consumption as income and the transformation curves as budget constraints we could speak of a curve representing the demand for environmental quality subject to income. It illustrates that in the beginning of economic development (low levels of income in terms of consumption goods) the income elasticity of the demand for environmental quality is negative, that in the process of industrialization it slowly approaches zero and finally becomes positive. Exchanging the axes and defining environmental quality negatively as pollution would reveal the Environmental Kuznets Curve in its common shape.

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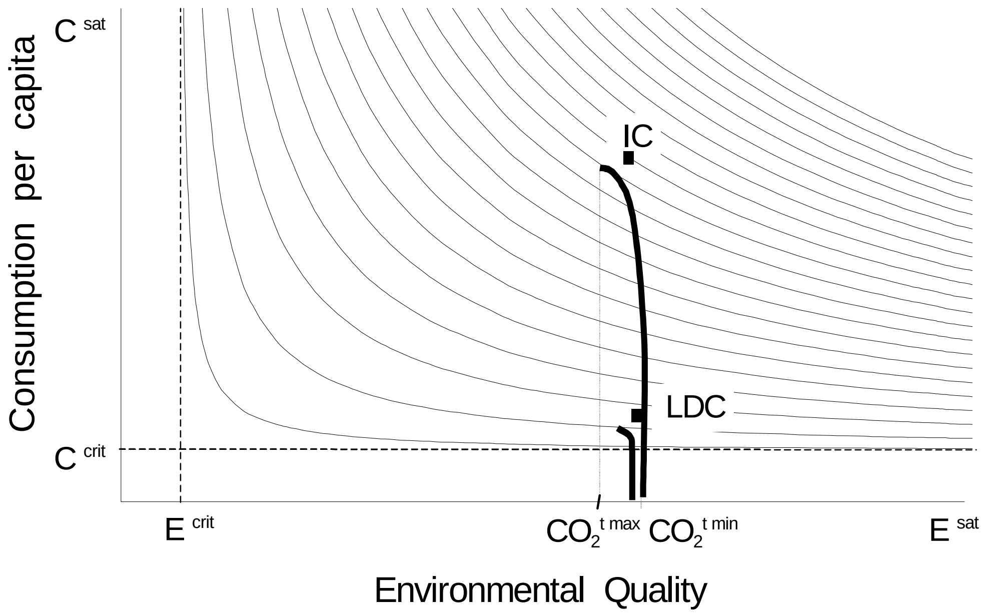
14 See Pearce and Atkinson (1993)

5. Extensions and Limitations of the Model

5.1 Global Environmental Goods

As already mentioned, things might look very different if we are dealing with global commons like the atmosphere. The detrimental effects of global pollutants like CO_2 are less immediately visible or sensible, a single country's effort to ameliorate or to worsen the situation has a much smaller impact and the time lags between action and effect are much more considerable. Fig. 10 illustrates the situation within the framework developed above.

Figure 10: Global Environmental Goods



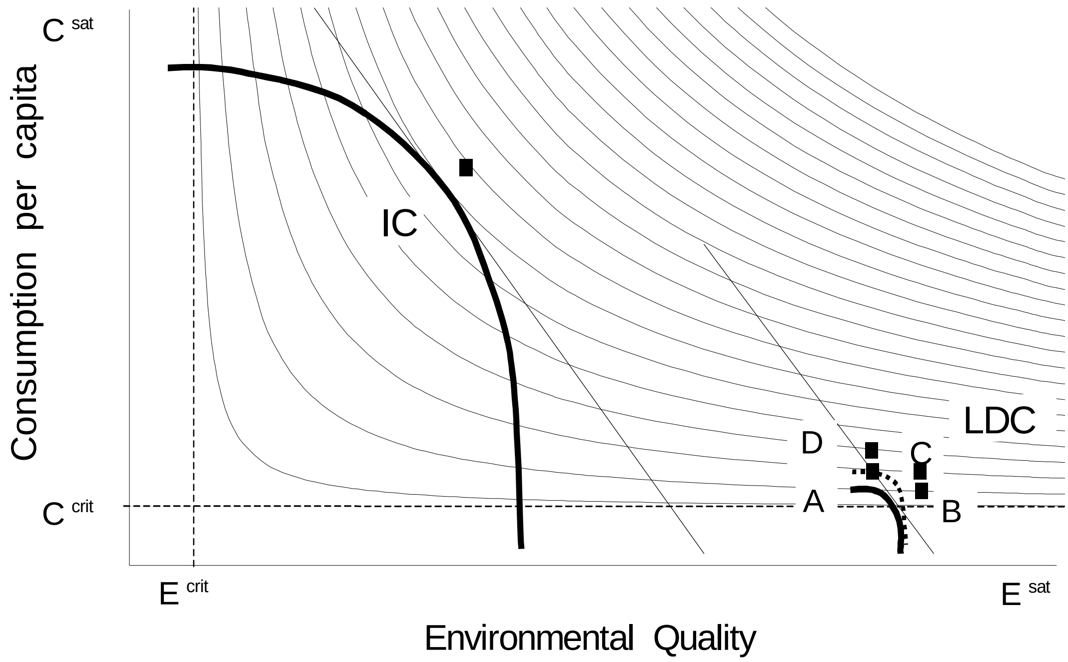
The LDC's decision has hardly any effect on the atmospheric concentration of CO_2, even the IC can influence the concentration only within an extremely narrow range. If the countries decided with respect to a planning period of a hundred instead of five years the transformation curves would cover a slightly bigger interval with respect to environmental quality and the optimal points chosen might be located at higher levels of environmental quality. What time horizon has to be considered is open to the political process. The discussion becomes even more complicated if the different opinions on the climatic impact of CO_2 are taken into account. If there is no consensus on the point where to locate the critical minimum line we no longer have a single welfare function which clearly determines the point to be chosen. These questions can be answered only by an international agreement which is extremely difficult to reach but in progress since many years[15].

[15] See e.g. World Bank (1992)

5.2 International Environmental Standards

Referring to the international discussion on environmental topics another point of mutual discontent should be illustrated: The diverging opinions on the integration of environmental standards in the world trade regime[16]. The ICs would very much like to see their high environmental standards adopted by the NICs and LDCs in order to avoid the perils of ecological dumping which harms the world's environment and the industrialized countries' competitiveness. If we look at Figure 11 we can imagine why the LDCs are not too fond of this idea.

Figure 11: International Environmental Standards



The different views on the relative relevance of environmental policy are represented by the respective slopes of the tangents to the welfare function's indifference curves in both countries' social optima (for convenience figure 11 shows only the tangent representing the IC's preferences, the LDC's tangent would run almost horizontally through point *A*). If the LDC adopted the IC's environmental preferences it would have to realize point *B* which in this case lies below the critical minimum level of consumption (generally *B* lies on a lower indifference curve than the actually achievable one touched in point *A*). This argument illustrates why the LDC's policy is as justified as the IC's. The conflicting preferences are even derived from the same preference function.

If the IC wants to persuade the LDC to implement a stricter environmental policy it must offer compensation that secures at least the welfare level reached with the former policy. But even with compensation the incongruity of preferences remains a problem: If the IC offered a

[16] See the overview in: Rauscher (1997): 295-312.

compensation in the amount of the exact difference between the former optimal consumption level in point *A* and the level associated with point *B* the dotted transformation curve comes within reach. The LDC would now prefer to choose point *D* instead of *C* (which the donor would prefer the LDC to choose) since *D* lies on a higher indifference curve. If the LDC accepts an environmental agreement with compensation it will seek possibilities to divert the budget to purposes other than intended by the donor.

5.3 Supporting Development

There is an alternative to avoid the mutual frustrations described above: To step up the LDC's development by investing in human capital and by stimulating the use of more efficient technologies. This should not be a call to revive the costly and failure-prone modernization programs of the 1950's and 60's. But much could be done on the exchange of experts, knowledge and access to patents. The goal is to expand the LDC's transformation curve in both dimensions: consumption per capita *and* environmental quality – which is possible with technological progress (as presented in figures 4a, 4b). Further liberalizing world trade to ameliorate development opportunities and thereby fostering physical and human capital accumulation would be another important step.

5.4 The Role of Income Distribution and Political Participation

From the debate on the determinants of economic development it is well known that growth is seen as a necessary but not sufficient condition for development. If it does not reach the poor it will not enhance the welfare of the society as a whole. Growth without development is the worst thing that could happen to the environment since it drives the transformation curve left without gaining height: The environment is depleted without raising welfare into regions where preferences take pollution more serious, i.e. where the income elasticity of demand for environmental quality is positive.

Such developments are explicable only by imperfections in the political process – which unfortanetely are prevalent in many least developed countries: If a ruling minority appropriates a substantial share of a country's wealth it might act in accordance to a transformation space separated far above the majority's possibility frontier. In a democracy such a separation would be sanctioned by elections: If a ruling party acted in an interest different from the people's it would be replaced. The more thoroughly the political participation the more truly does the transformation space reflect a society's common possibilities.

5.5 The Initial Endowment

Environments are different with respect to their vulnerability or - taken as a factor of production – productivity. Within the model this could be respresented by differences in the parameter $\hat{e}^i_t$ –

the smaller the recovery rate, the more vulnerable is the domestic environment. Fragile ecosystems can be destroyed by minor irritations while others may tolerate severe interference. The degree of vulnerability is relevant to the shape of the transformation curves: The more vulnerable the ecosystem the more environmental quality must be sacrificed per unit of production, the flatter is the resultant transformation curve. The transformation curve of a growing country with a very fragile environment slips far more quickly to the left (massive losses of environmental quality for only little welfare gains) than in case of a more robust endowment, where growth is achievable much cheaper in environmental terms. Worst case is a country with a fragile ecosystem depleting its environmental quality down to the critical level without any success in reaching higher levels of income per capita - which is the case in some South Saharan Africa countries[17].

6. Conclusions

The present paper should not be taken as an invitation to just lean back and watch the countries of the world grow one by one into states of true environmental concern, consistently implementing nothing but strictly sustainable policies. It did not answer the question what will happen when in course of their further economic development countries like China or India are approaching their national environmental minima. Will the global environment stand a wider spread of Western affluence? To answer these questions the national transformation spaces would have to be aggregated and an international consensus would have to be achieved on the number of generations whose interests are to be considered and on the position of the critical minimum levels in all relevant dimensions of global environmental quality. Detailed speculation about possible outcomes lies beyond the scope of this paper.

The aim was to shed some light on the driving variables behind the environmental Kuznets curve. This knowledge could help to identify lines of discussion and means of assistance that avoid conflicts and enhance coherence in a joint effort to preserve the quality of the global environment.

Local environmental goods will be the first to gain from a substantial improvement of the economic endowment of the poor. Global commons can be protected only by global agreements since they are the last to be valued in isolated local decisions. The transfer of human capital and more efficient technologies is a more promising tool to promote natural resource preservation than fungible financial compensation or the use of sheer bargaining power in international negotiations. If the industrialized countries do not respect the legitimate preferences of the developing countries all efforts to turn their development paths into a sustainable direction must fail.

If it serves to ameliorate the economic situation of the poor economic growth will make an improvement of environmental quality not only more urgent but also more likely.

[17] See Worldbank (2000): 96, 97.

7. References

Antle, J. M., Heidebrink, G. (1995): Environment and development: Theory and international evidence, in: *Economic Development and Cultural Change 1995:* 603-625.

Galeotti, M., Lanza, A. (1998): *Desperately seeking (environmental) Kuznets.* Paper presented at the World Congress of Environmental and Resource Economists, Venice, 25-27 June 1998.

Grossman, G. M., Krueger, A. B. (1994): *Economic growth and the environment.* Cambridge, Massachusetts.

Hirschfeld, J. (1995): *Umweltpolitik im Prozess wirtschaftlicher Entwicklung - Das Beispiel Malaysia. [Environmental policy in the process of economic development - The case of Malaysia].* Thesis. Faculty of Economics, Free University of Berlin, Germany. March 1995 (not published).

Holtz-Eakin, D., Selden, T. M. (1995): Stoking the fires? CO_2 emissions and economic growth, in: *Journal of Public Economics, 57*: 85-101.

Lutz, E., Munasinghe, M. (1993): Integration of economic concerns into economic analyses with special emphasis on valuation issues, in: Lutz, E. (ed.): *Towards improved accounting for the environment.* Washington D.C.: p.198-208.

Mankiw, N. G. (1992): Macroeconomics. New York.

Munasinghe, M. (1999): Is environmental degradation an inevitable consequence of economic growth: tunneling through the environmental Kuznets curve, in: *Ecological Economics 29*: 89-109.

Munasinghe, M. (1993): *Environmental economics and sustainable development*. Washington, D.C..

Panayotou, T. (1997): Demystifying the environmental Kuznets curve: turning a black box into a policy tool. In: *Environment and Development Economics 2* (1997): 465-484.

Pearce, D. W., Atkinson, G. D. (1993): Capital theory and the measurement of sustainable development: an indicator of “weak” sustainability, in: *Ecological Economics 8 (1993): 103-108.*

Pearce, D. W., Warford, J. J. (1993): *World without end.* New York.

Rauscher, M. (1997): *International trade, factor movements, and the environment.* Oxford.

Selden, T. M., Song, D. (1994): Environmental quality and development: Is there a Kuznets curve for air pollution emissions?, in: *Journal of Environmental Economics and Management 27*: 147-162.

Shafik, N., Bandyopadhyay, S. (1992): *Economic Growth and Environmental Quality: Time-Series and Cross-Country Evidence*. Backround Paper prepared for the Worldbank World Development Report 1992.

Siebert, H. (1995): *Economics of the environment, 4th, revised and enlarged edition*. Berlin.

Stern, D. I., Auld, T., Common, M. S., Sanyal, K. K. (1998): *Is there an environmental Kuznets curve for sulfur?* Paper presented at the World Congress of Environmental and Resource Economists, Venice, 25-27 June 1998.

Stern, D. I. (1998): Progress on the environmental Kuznets curve? in: *Environment and Development Economics 3*: 173-196.

Umweltbundesamt (1997): Daten zur Umwelt *(Data Concerning the Environment, in German language)*. Berlin.

World Bank (1992): *World Development Report 1992*. Washington, D.C..

World Bank (2000): *The Quality of Growth*. Oxford.