(Local) environmental quality versus (global) ecological carrying capacity: what might alternative aggregated indicators bring to the debates about environmental Kuznets curves and sustainable development?

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Abstract: The Environmental Kuznets Curves (EKC) hypothesis suggests that the environmental impacts of a population increase in the early stages of its development, and decline once a certain level of income is attained. After examining different criticisms that can be addressed to studies that validate this hypothesis (environmental data which concern mostly restricted and/or local phenomenon, development indicators which offer a too limited vision of human development), this paper proposes a representation that confronts two aggregated indicators: ecological footprint and human development index. This confrontation contradicts the EKC hypothesis. Different visions concerning the meaning of the term environment (local environmental quality versus global ecological carrying capacity) might partially explain our conclusions and reveals a pernicious phenomenon. While developed nations tend to improve the quality of their 'local' environment, they also tend to consume more and more 'global' resources, which might often come from developing nations.

Keywords: ecological footprint; environmental Kuznets curves; human development index; sustainable development.

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1 Environmental Kuznets Curves (EKC): hypothesis, conclusions and critics

1.1 EKC Hypothesis: richer and cleaner?

In a well-known article published in the middle of the 1950s, Kuznets (1955) suggested that growing inequity was only a preliminary phase of a nation's development path: after a first period of growing inequity, beyond a certain level of income per capita (usually called 'turning point') inequity would naturally diminish, drawing a so called 'inverted-U curve' that most economists nowadays refer to as a 'Kuznets curve'.

Over the last 15 years, this hypothesis has inspired numerous authors who intended to show whether a similar phenomenon could be observed in the field of environmental concerns. Could the pressure of a nation upon the natural environment diminish after a certain level of economic development? If such an hypothesis (often referred to as the environmental Kuznets curves hypothesis; EKC) could be proved and validated, it would demonstrate that the best way for a nation to become socially fair and ecologically sustainable is simply to become . . .richer! An argument that Beckerman made his own when he stated that 'in the end the best – and probably the only – way to attain a decent environment in most countries is to become rich' (Beckerman, 1992).

1.2 A 'weak sustainability' approach

EKC hypothesis suggests that the level of development of a given country (in most cases, expressed in terms of average income per capita) is supposed to have, 'in the end', a positive effect on the natural environment.[1] It can be noticed that such a representation considers the level of development (GDP/capita) as an input data, while the output data is the level of environmental pressure. This representation of the EKC hypothesis is not neutral: the economic income, used as abscissa, is considered as an explicative data while environmental quality indicators, placed on the *y*-axis, are seen as consequences of the economic development. We suggest that this economy based approach is typical of a vision that is often referred to as a '*weak* sustainability' approach (Turner, 1993) – a conception that does not consider the natural environment as a fundamental basis that supports economic and social development, but on the contrary, as an external and secondary factor whom capital can easily be substituted by other forms of capital.

1.3 A brief review about EKC studies: a hypothesis that is hardly validated

Numerous articles and debates have emerged during the last 15 years about EKC. Many authors (e.g. De Bruyn et al., 1998; Kriström and Lundgren, 2003; Stern et al., 1996) consider the 1992 World Development Report (World Bank, 1992) as the first step of the international debate upon EKC. Published by the World Bank in the same year as the Rio Earth Summit, the World Development Report showed several charts confronting environmental quality and economic development data. According to this Report, the emissions of several specific pollutants (particles, SO_2, NO_x) tend to decrease beyond a certain level of average income per capita. Bimonte (2002) also showed evidence of a similar relationship that links the percentage of protected natural areas to the average income per capita, in different countries. These findings are coherent with the World Development Report, which is mainly based on the work of Shafik and Bandyopadhyay: it tends to show that EKC correlations can only be observed for a small number of very specific environmental indicators or data. Thus, the conclusions of the Report are very inconclusive and mitigated and never refer to economic growth as a holistic answer to ecological problems. Following these mixed conclusions, several authors have persisted in the search of a validation of this hypothesis. The works of Grossman and Kruegger (1995), Selden and Song (1994) and several others led to results and conclusions that are quite similarly open to doubt.

1.4 Criticisms about EKC: definitions of both environment and development that are too restricted

Despite these inconclusive results, the misinterpretation that Beckerman (among others) made provoked vigorous protestations among the scientific community. In a collective article that was published in *Science*, Kenneth Arrow and his colleagues (1995) showed not only that the environmental data that were chosen for EKC were very restricted, but also that most of them did not take into account many critical environmental aspects such as non-reversibility of the damages that are done to ecosystems and natural resources, accumulation of pollutants, ecosystems fragility, depletion of non renewable resources, limited carrying capacity, etc. Stern et al. (1996) also insisted upon the fact that long- and middle-term effects were not taken into account in such analyses. Rothman (1998) concluded that the EKC hypothesis can mainly be validated while referring to very specific, reversible, and/or local environmental impacts; he also noticed that most of these impacts can be reduced thanks to a modification of production processes (end-of-pipe technologies, for example). Besides, the term ‘environment’ mainly refers in this context to the surroundings, the habitat where a current community lives and its capacity to offer a comfortable quality of life. This representation is typical from a ‘utility-based’ sustainability vision (Daly, 2002). The hypothesis seems to be more difficult to validate, on the contrary, with a throughput-based approach of sustainability, i.e. when global impacts are considered: pollutions with long-term effects or which can only be reduced thanks to a change in consumption comportments (car use, for example) does not decrease when average incomes increase. According to this vision, ‘the entropic physical flow from nature’s sources through the economy and back to nature’s sinks is to be non-declining’. Within such a vision, environment is considered as a ‘natural capital’ that is ‘the capacity of the ecosystem to yield both a flow of natural resources and a flux of natural services’.

Another major criticism, which can be addressed to EKC, concerns the so called *pollution haven hypothesis*: some authors (e.g. Cole, 2004; Muradian et al., 2002) suggest that the developed countries’ inverted-U curve could occur thanks to the displacement of ‘dirty’ industries from the developed nations to the developing ones, where environmental (and social) regulations are less restrictive. Of course, this displacement would not resolve the global ecological problem, and it will be impossible for the developing nations to do the same when they become richer.

Furthermore, we could also note that it is not only the definition of *environment* that is limited in the EKC literature, but also the one of *development*. Indeed, the index that is generally used to measure this latter is limited to a purely economic acceptation of the term: the average level of GDP per capita. However, growing criticisms about the GDP have emerged among the last years (it is notably the case in France with authors like Gadrey and Jany-Catrice, 2003; Meda, 1999; and Viveret, 2002). Despite these criticisms and the necessity of the choice of a more qualitative indicator in the broader context of ‘sustainable development’, the debate on EKC has not yet seriously tackled that question.

Finally, a last criticism about EKC literature is that authors very rarely mention numeric limits or thresholds that could nevertheless give interesting benchmarks for decision-making processes, e.g. When can we consider that a country is rich, or developed? What does it mean for a nation to be ecologically sustainable? At which point can we consider that a nation exceeds local or global ecological limits or carrying capacities? What happens if a so-called turning point appears while carrying capacities have been too widely exceeded?

2 Drawing a more global picture of environment and a more qualitative vision of development: an alternative representation

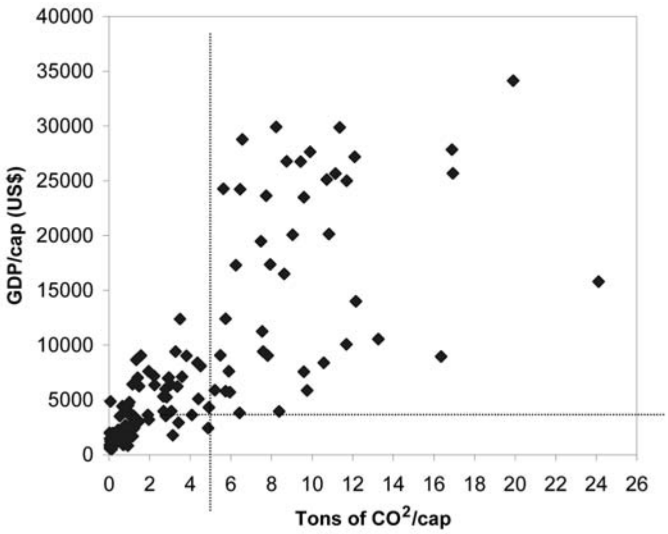
Some of the main criticisms that can be addressed to the studies that seem to confirm the EKC hypothesis are as follows: it is based upon a ‘weak sustainability’ approach; environmental indicators that are both restricted and local; an important possibility for the displacement of the pollution from rich to poor countries; a too limited definition of the notion of development; and finally a lack of information on ecological and/or economic thresholds which could be useful for a better understanding of the sustainable development dilemma by decision makers. We propose to resolve some of these limits thanks to a new representation of the sustainable development dilemma.

2.1 An alternative approach based on a 'strong sustainability' approach

The 'strong sustainability' approach considers environment as the ecological carrying support that is necessary for any human activity to be developed: the stocks of natural capital (ecological assets) should be kept constant over time. Such an eco-systemic approach suggests that the input data would be the capacity of the ecosystem to provide resources and absorb pollution, while the output data is the level of development that can be attained thanks to that level of consumption of natural resources. This approach would lead to a transposition of the graphic representation: environmental data would be on the *x*-axis while developmental ones would be placed on the *y*-axis. With such an acceptation, environment cannot be considered only as a local (human) habitat (a kind of luxury that only rich countries could take care of), but as a limited natural capital needed to sustain the current level of resources consumption and waste discharge of a given population.

A well-known example of global environmental impacts is the use of energy and/or climate change due to anthropogenic emissions of greenhouse gases such as CO_2. For example, Figure 1 shows correlation between income[2] (*y*-axis) and fossil fuel CO_2 emissions per capita[3] (*x*-axis) for 130 nations of the world in 2001.[4] We propose for these data to represent on the graph two thresholds: one for GDP per capita: US$15.000, considered by the World Bank as the threshold that separated high and middle income countries in 2001;[2] and one for CO_2 emissions per capita: 1.8 tons, which represents the estimated capacity of the global ecosystem to absorb anthropogenic CO_2 emissions, for the present population.[5]

Figure 1 CO_2 emissions from fuel combustion per capita (World Resources Institute, 2005[3]), and US$ GDP (PPP) per capita (UNDP, 2004) in 130 nations of the World (for the year 2001)



The coefficient of determination in Figure 1 is 0.5458 for a linear regression and 0.7037 for a quadratic regression. There is no evidence for a decline in CO_2 emissions when nations get richer. Some authors nevertheless suggest that a dynamic approach of these data (time series) might confirm EKC hypothesis in the history of some developed nations, such as Sweden (Lindmark, 2002). But two points have to be considered: firstly, such a decrease in CO_2 emissions does not seem to appear unless a very high level of emission has been attained – which might be a level several times higher than the level of ecological carrying capacity; secondly, a decrease in CO_2 emissions in rich countries might be the result of a displacement of the pollution from rich to poor countries, such as suggested by the so-called pollution haven hypothesis. This latter aspect leads us to propose the use of a specific index that both takes into account more complete aspects of ecological sustainability, but also this pollution haven effect: Ecological Footprint (EF).

2.2 A more global and aggregated index of environmental impact: the ecological footprint (EF)

Ehrlich and Holdren (1971) consider environmental impact (I) as the multiplication of three different components: Population (P), Affluence (A) and Technology (T): I = P.A.T. Ecological footprint clearly refers to this equation.[6] Created in the 1990s by Wackernagel and Rees (1996), EF aims to measure the extent of humanity's current demand on the planet's bioproductive capacity; it is defined as ' the area of biologically productive land and water required to produce the resources consumed and to assimilate the wastes generated by humanity, under the predominant management and production practices in any given year'.(Wackernagel et al., 2002)

Wackernagel and Rees legitimate their choice through the use of many 'biological' metaphors; they notably compare economy to a metabolism, which needs to consume resources that, in the end, will be evacuated out of the metabolism and become wastes. From that point of view it becomes easy to understand that such a metabolism needs a certain surface of land to produce its resources and absorbs the wastes it produces in the long term. Then, the question is to know how much of that bioproductive surface (per capita) is necessary to maintain the living standard of a society.

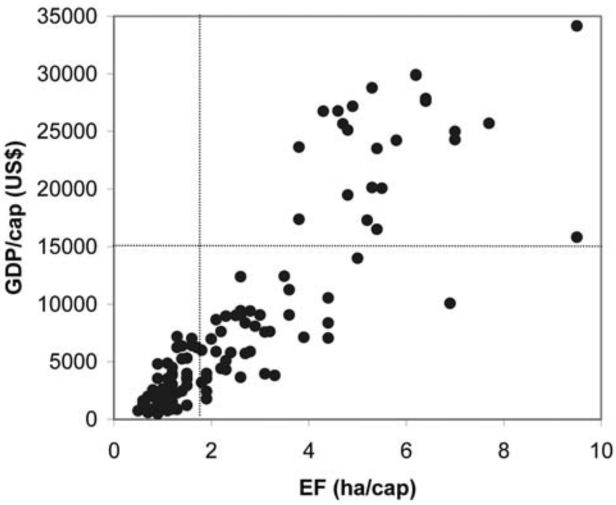
EF has been the object of many interests, questions and criticisms over the last years.

Several methodological issues are regularly discussed in scientific journals (see, for example, the forum in the Vol. 32, No. 3 of *Ecological Economics* dedicated to this subject). Its main strength is to aggregate in a single unit (hectares) a huge amount of heterogeneous impacts, which makes it a very synthetic and communicative tool. Of course, it is this same synthetic aspect that makes it a contested indicator, as it can be reproached to offer only a partial assessment of global sustainability. Another critic against EF is, e.g. that it is a static index that implicitly assumes that the global equilibrium of ecosystems is stable, which is in contrast with the view of ecosystems as adaptative systems (Deutsch et al., 2000). Furthermore, if EF portrays the relationship between human society and nature, it does not endeavour to assess the ecosystem's health (Rapport, 2000). In order to tackle some of these questions and make the calculation method more transparent, a network of experts (the Global Footprint Network) has recently initiated a committee-based process to develop standards governing Ecological Footprint applications, and for an ongoing scientific review of the methodology.[7] In the end, the growing success of EF within scientific, local governmental and international non-governmental arenas makes it an important tool in the field of sustainability. Indeed, it is widely recognised as an 'excellent tool for communicating human dependence on life-support systems' (Herendeen, 2000).

Lastly, another significant advantage in the context of EKC debates is that EF assigns these environmental impacts to the final consumer (and not to the producer). This addresses the *demand* side of the sustainability Ehrlich equation. Indeed, as Rothman (1998) noticed, 'goods and services will not be produced, bought, sold and traded across borders, unless there is a demand for them'. Therefore, the question of the above mentioned *pollution haven hypothesis* (the possibility for rich countries to displace polluting industries and activities in poor countries) is partially resolved.

Following Rothman, Figure 2 shows correlation between EF and US$ GDP (ppp) for 130 nations of the world in 2001. We propose in this graph to represent two thresholds: the US$15.000 cited above for GDP, and the average bio-productive surface of soil available for each person on Earth (which is estimated at a level of 1.8 gha/cap). Once more, the strong positive correlation between EF and GDP seems to contradict the EKC hypothesis when using indicators that are representative of a throughput-based approach of sustainability. Such a result is not surprising, regarding the fact that, in the higher income countries countries, 52.7% of ecological footprint is due to energy consumption and its related CO_2 emissions (see Figure 1). But once more, the multidimensional aspect of EF and its capacity to take into account the pollution haven dilemma seems to make it a more reliable tool in order to reveal the complexity of ecological sustainability. Indeed, this share of the different footprint sources varies according to the countries. For example, for low-income countries, fossil fuels only represent 17.7% of the EF whereas cropland represents 39.7% of the EF.

Figure 2 Ecological Footprint in global hectares per capita (Loh and Wackernagel, 2004) and US$ GDP (PPP) per capita (UNDP, 2004) in 130 nations of the World for the year 2001



2.3 *A more qualitative measure of development: the Human Development Index (HDI)*

As well as sustainability, development is not an easy concept to measure. As mentioned above, GDP per capita does not seem to provide the most appropriate data to reveal the complexity of this notion of development. The United Nations Programme for Development (UNDP) proposed at the end of the 1980s to define the concept of human development as the process that permits individuals to enlarge their capacity of choice. From that definition and to re-emphasise that people and their capabilities should be the ultimate criteria for assessing the development of a country – not economic growth – the UNDP experts elaborated an alternative index: the Human Development Index (HDI) (Ul Haq, 1990). This latter considers three basic aspects of human development: longevity, knowledge–education, and a decent standard of living. Longevity is measured by the country's average life expectancy at birth; knowledge is measured by a combination of the adult literacy rate and the combined primary, secondary, and tertiary gross enrolment ratio; and standard of living by the GDP per capita (US$ PPP). For each of these three dimensions, an index is calculated relatively to minimum and maximum values (goalposts). Then, these three indices are equally aggregated in a single index that goes from 0 to 1.

There has been a growing interest in HDI, over the last 15 years, among both political and economic arenas – notably since Amartya Sen, one of the leading experts of the UNDP, won the Nobel Prize in 1998. It can be pointed that these numerous debates and criticisms about HDI led to noticeable proposals of improvement of the index calculation method (e.g. Hicks, 1997; Neumayer, 2001; Noorbakhsh, 1998). Eventually, although it does not aim to integrate ecological sustainability, it is widely recognised that 'the human development index (HDI), (. . .) has been rather successful in serving as an alternative measure of development, supplementing GNP'(Sen, 1999).

3 A sustainable . . . human development? HDI and EF in the debate on EKC

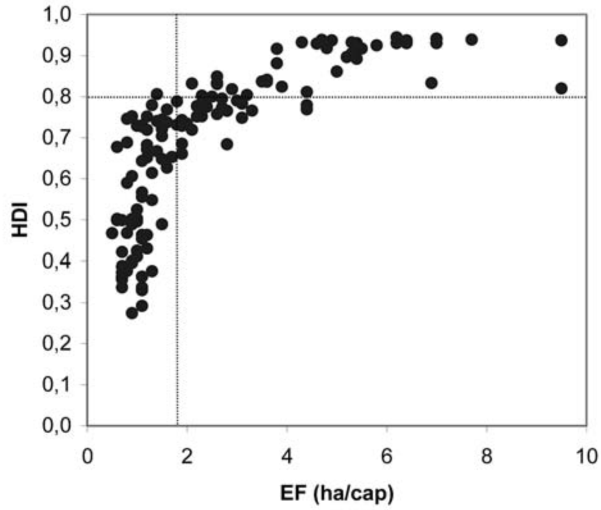
EF and HDI have both become quite popular during the last 10 years. This interest has made it possible to propose several methodological improvements that have progressively been included in both indices. Their simultaneous use addresses most of the criticisms that are mentioned above concerning EKC studies. Mostly, they give a very helpful and educational vision of sustainable development.

3.1 The HDI – EF representation

Figure 3 represents EF versus HDI, for 130 nations of the world for the year 2001. Following our suggestion (Section 2 of this article), EF represents the input data (x) and HDI the output one (y).

It is important to note that, once more, this figure compares the data from different nations, each one having very different levels of development, in the same year, instead of representing the evolution of a single nation over a longer period of time, as it is generally the case within the EKC literature. This choice is mainly due to a lack of solid data for EF time series for a large number of countries (Wackernagel et al., 2004).

Figure 3 EF (Loh et al., 2004) and HDI in 130 nations of the world (for the year 2001) (UNDP, 2003)



3.2 A rejection of EKC hypothesis?

Figure 2 clearly shows that the inverted-U curve of the EKC hypothesis is not confirmed while using EF and GDP. No 'turning point' can be noticed and the best-fitted curve has a linear equation (as mentioned on Table 1). This means that the higher the GDP, the higher the EF and reciprocally. This relationship cannot be explained by the construction of these indexes. Indeed, GDP is a measure of economic fluxes (in US$) while EF is mainly based on physical fluxes (in tons). The same conclusion can be drawn from Figure 3, which means that a higher level of income per capita and/or a higher level of human development do not lead to a lower impact on the global environment in terms of EF. In fact, if we focus now on Figure 3, it is precisely the opposite phenomenon that seems to occur: the best-fitted curve has a logarithmic trend (as mentioned on Table 1). EF does not increase rapidly in the first development phase (contrary to what the EKC hypothesis suggested). In a second phase, from a level of about 0.600 HDI to 0.750 HDI, we can notice quite an important increase of the EF of nations. In the end, beyond a limit of 0.750 HDI, the level of human development seems to only slightly increase at the price of a tremendous increase in EF. This phenomenon becomes still more obvious in Figure 3 where we can see from left to right what could be called the 'classic development curve'.[8] This curve goes from countries that have a low level of human development (HDI < 0.500; EF > 1.5 ha/cap) to the ones that have the highest level (HDI > 0.900; EF > 5 gha/cap). Such a logarithmic trend curve clearly reveals a law of diminishing returns: up to a level of development close to 0.750 HDI, a low increase of EF results in substantial progresses in terms of development. After this threshold, a slight increase of HDI tends to require a much higher increase of EF – meaning that a much more important consumption of natural capital is needed to support that growth.

Table 1 Coefficients of determination of the best-fitted curve of logarithmic regression between EF and HDI and EF and GDP with data for 131 nations (2001)

	Equation of the best logarithmic fitted curve	*Coefficient of determination*
HDI = f (ecological footprint)	y = 0.2134Ln(x) + 0.5505	$R^2 = 0.704$
GDP = f (ecological footprint	y = 3800.9x – 1514.5	$R^2 = 0.7768$

In order to make the graph easier to understand in the context of sustainable development debates, we propose once more to add two thresholds on Figure 3:

- one for 'ecological sustainability', which is the average surface of bio-productive land available for each person on earth – this threshold is of 1.8 gha/cap in 200 (Loh and Wackernagel, 2004)
- one for 'reasonably high level' of human development, which represents for the UNDP (2003) the limit beyond which a nation can be considered as having a high level of human development: 0.800 HDI.

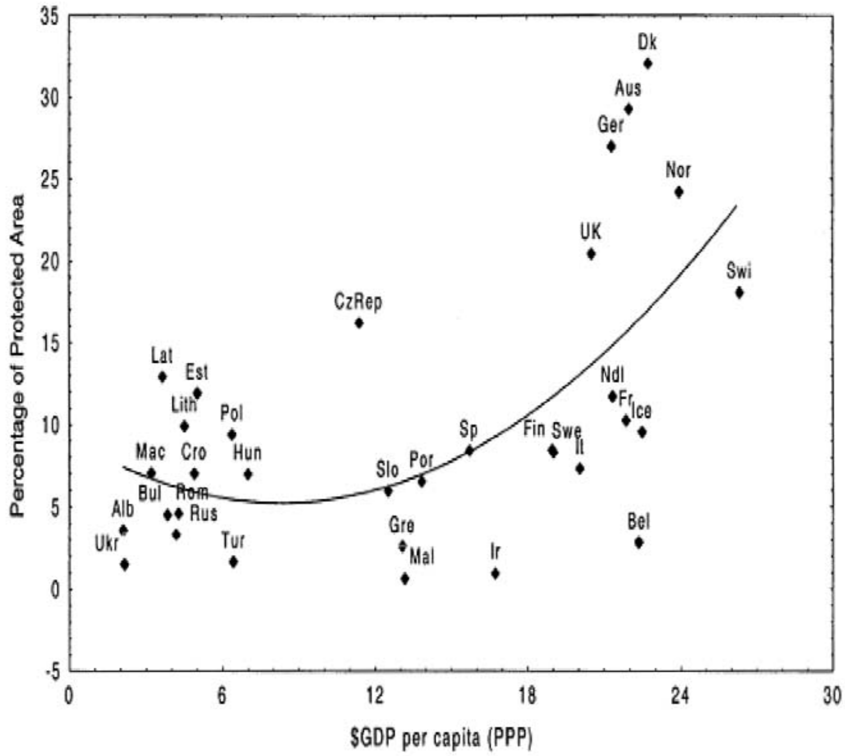
The objective of sustainable development for a nation should thus consist in attaining a level of human development of at least 0.800 HDI without outreaching a 1.8 gha/cap EF. Beyond the fact that only one nation attains such an objective in the year 2001, it can also be noticed that in terms of (ecologically) sustainable (human) development, the most developed nations seem to have at least as much efforts to make to become 'ecologically' sustainable than the less developed ones to become 'socio-economically' developed.

4 A few conclusions – the notion of environment: global carrying capacity or local environmental quality?

What conclusions can we draw from such an exercise? How can we explain that our HDI–EF representation is in such a contradiction with the EKC hypothesis?

As already mentioned, such diverging conclusions might notably be explained by the fact that different interpretations of the notion of environment face each other. EKC hypothesis is partially validated while using indexes or data which reflect the quality of local or national environment (environment as an habitat). This notion of local 'environmental quality' notably refers to the first principle of the Rio de Janeiro declaration (UNCED, 1992), in which it is noticed that:'Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature'. Figure 4 (from Bimonte, 2002) gives quite a good illustration of that interpretation of 'environmental quality': the graph clearly shows the tendency of nations with a high level of income per capita to protect their own national or local natural habitats, just as suggested by the EKC hypothesis: it means that, indeed, the most developed countries seem to be more sensitive to the protection of their own environmental quality.

Figure 4 Percentage of protected natural areas and $GDP per capita (PPP) (Bimonte, 2002)



On the other hand, considering environment as the global ecological carrying capacity that supports each human activity obliges us to consider an inverted correlation between environment and development factors: the larger the consumption of resources per capita, the stronger is the pressure on the carrying capacity (although this impact might be diminished or increased by technology, as mentioned in the Ehrlich equation). Such an acceptance of the definition of environment reminds us another principle of the Rio declaration (principle 7) which stipulates that 'the developed countries acknowledge the responsibility that they bear in the international pursuit of sustainable development in view of the pressures their societies place on the global environment and of the technologies and financial resources they command' (UNCED, 1992).

This reference to the Rio declaration illustrates at least one fact: both conceptions of environment might necessarily be taken into account while referring to the goal of sustainable development. In terms of environment, the notion of 'rights' (e.g. right to a safe environment) has no sense if it is not accompanied by 'duties' (e.g. the duty to respect the level of renewability of natural resources, or the duty to share equitably in these resources).

HDI and EF precisely reveal these latter aspects. Besides, these two indexes are very pedagogical and, as is underlined by Moffatt: 'the clarity of the message is an important function of any indicator for both policy makers and the general public' (Moffat, 2000). Even if it can be admitted that these two indexes reflect quite a limited vision of sustainable development,[9] at least they oblige us to realise at which point it might be vain and counterproductive for developed countries to protect their own national environment (Figure 4) while continuing consuming a growing amount of natural resources . . . that might mostly come from developing countries.

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Notes

[1] Authors proposed the following conceptual reasons to explain such a positive correlation: the most developed population would be more sensitive to environmental concerns, legislative contexts would be more severe, the domination of service sector in their economies would produce less damage to the environment, and ecologically friendly technologies would be more likely to be developed.

[2] Data from World Bank Development Data Group (2006), 2006 World Development Indicators Online, The World Bank, Washington, DC. Available at: http://publications.worldbank.org /ecommerce/catalog/product?item_id=631625.

[3] Data from World Resources Institute (2005). Climate Analysis Indicators Tool (CAIT) version 3.0, Washington, DC. Available at: http://cait.wri.org.

[4] It has to be noticed that Figure 1 and following ones compare data from different nations, each one having very different levels of development, in the same year, instead of representing the evolution of a single nation over a longer period of time.

[5] According to the IPCC, the global capacity of sequestration due to Ocean-atmosphere and land-atmosphere fluxes is about 3 GTC/year. Thus, the only way to stabilise the concentration of CO_2 of the atmosphere is to emit less than 3 GTC/year. With a hypothesis of 6 billion people in 2001, this would correspond to a maximum emission of 0.5 tC/year/capita. This threshold corresponds to 1.8 tCO2/year/capita. See: International Panel for Climate Change (2001).

[6] The global ecological footprint changes with population size, average consumption per person and resource efficiency' Loh and Wackernagel (2004).

[7] http://www.footprintnetwork.org.

[8] By 'classic' development, we mean non-sustainable development.

[9] In 2001, the only country which had an ecological footprint smaller that 1.8 global ha/person and a HDI slightly higher than 0.800 was Cuba (1.4 global ha/person – 0.804 HDI). This illustrates some limits that are unavoidable when choosing a limited number of indexes to evaluate sustainable development. For example, such indexes (HDI and EF) do not refer to the level of inequity that might exist within the given nation, neither to the level of freedom or democracy of this nation.