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Abstract

This paper presents an initial review of the theoretical and measurement discussions of sustainability and its relation to human development. As we show in this paper, there is an overall consensus about the importance of sustaining development and well-being over time, but in reality different development paradigms lead to different definitions and measures of sustainability. We review some of those measures, among which the Adjusted Net Savings (a green national accounting measure calculated by the World Bank and rooted in a weak concept of sustainability), the Ecological Footprint (calculated by the Global Footprint Network and rooted in a strong concept of sustainability, where environment is considered a critical resource), and the carbon dioxide emissions (a simple environmental indicator, used in international debate of climate change). Our analysis shows conflicting conclusions when studying the correlations between these indicators of sustainability and existing human development indicators, namely HDI, which emphasizes the need for further analysis to understand what “sustainable human development” means. Nevertheless, as we show here, over time there has been a close link between higher economic performance and energy consumption, which has been mostly based in the use of fossil fuels.

Keywords: sustainability, human development, measurement, energy.

JEL classification: O13, Q56, Q59.

1. Introduction

What is the meaning of sustainability in the human development framework? Until now, what have been the main proposals of measuring sustainability and what are the main patterns and trends? Do these measures reveal that is possible to have simultaneously a high human development and being unsustainable, and if so what can explain such (dis)connection? Despite the great relevance of these questions, the answers to these questions still face significant challenges today. The literature on sustainability and human development has focused mostly on specific issues like water management and climate change, but large conceptual and measurement gaps remain. By advancing the debate, this paper tries to contribute to fill these gaps.

The expression "sustainable development" has become a political and academic buzzword since the UN report "Our common future" (UNWCED, 1987), also known as the Brundtland Report (table 1 below). The Brundtland report presented the most widely known definition of sustainable development:

> *"Progress that meets the needs of the present without compromising the ability of future generations to meet their own needs."*

This definition of sustainability, adopted at the UN General Assembly of December 1987 (A/RES/42/187) is rooted in an intergenerational notion of justice, and is very much aligned with the dominant conceptual paradigm of development at the time: the *basic needs* discourse of the World Bank.

In 1992, the UN Earth summit in Rio de Janeiro (UNCED) transformed the contents of the Brundtland Report into several documents, among which the agenda of action, the Agenda 21. The main text of this non-binding document, supported by more than 178 countries, explicitly recognizes the link between environmental challenges and social and economic development – the three "pillars" of sustainable development.

Table 1 – Historical international milestones on sustainable development

Year	Milestone…	… also known as…	Brief description
1972	UN Conference on the Human Environment, in Stockholm	Stockholm conference	Introduction of environmental challenges in the political development discourse
1987	"*Our common future*" - UN World Commission on Environment and Development Report	Brundtland report	Introduction of a definition of sustainable development linking environmental challenges with economic and social development
1992	UN Conference on Environment and Development (UNCED), in Rio de Janeiro	Earth Summit	Adoption by more than 178 governments of 5 main documents: • *Rio declaration* on environment and development, which presents 27 principles related with environment and development, for both industrialized and developing countries • *Agenda 21* on sustainable development, composed by three "pillars" – economic, social, and environmental. Not a legally binding document but a "work plan," or "agenda for action," with a political commitment to pursue a set of goals on environment and development. The largest product of UNCED. • *Convention on Climate Change* (the basis for UNFCCC), signed by representatives from 153 countries. Formal international discussion for this convention began in 1988 with the establishment of the Intergovernmental Panel on Climate Change (IPCC). Entered into force in 1994.

Table 1. (cont.)

Year	**Milestone…**	**… also known as…**	**Brief description**
1992	UN Conference on Environment and Development (UNCED), in Rio de Janeiro (cont.)	Earth Summit	• *Convention on Biodiversity*. Discussions started in initiated in 1988 by the United Nations Environment Programme's (UNEP) Governing Council. • *Principles* for the Sustainable Management of Forests
2000	UN Summit on the Millennium Development Goals	MDGs Summit	Adoption of a global action plan to achieve the eight anti-poverty goals by their 2015 target
2002	International Conference on Financing for Development, Monterrey-Mexico	Monterrey Conference	Monterrey Consensus
2002	World Summit on Sustainable Development (WSSD), in Johannesburg	World Summit	Adoption of the Johannesburg Declaration and the Johannesburg Plan of Implementation, focusing on poverty reduction as part of sustainable development strategy reaffirming the principles of Agenda 21 and the Rio principles
2005	Kyoto Protocol entered into force	Kyoto	The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 (UNFCCC-COP3) and entered into force on 16 February 2005. The detailed rules for the implementation of the Protocol were adopted at COP7 in Marrakesh in 2001, and are called the "Marrakesh Accords."

In the public debate there is a generalized understanding that sustainable development is desirable, relates with intertemporal equity and future generations, and serves multiple aspects for the achievement of a *good life*. Pezzey (1992) reviews many of the definitions introduced in the two preceding decades, presenting an overall conclusion that different people emphasize different aspects of *what* a *good life* means and *what* is important to be *sustained*. The 2003 World Development Report (World Bank, 2003) asserts that "sustainable development is dynamic" and "is about sustaining human well-being through time". However, it also acknowledges that "what constitute a good life is highly dubious" and proceeds with a list of some elements "most people could probably agree":

> "*Having the ability and opportunity to shape one's life—which increase with better health, education, and material comfort—is certainly one of them. Having a sense of self-worth is another, enhanced by social contact, inclusiveness, and participation in society. So is enjoying physical security and basic civil and political liberties. And so is appreciating the natural environment—breathing fresh air, drinking clean water, living among an abundance of plants and animals varieties, and not irrevocably undermining the natural processes that produce and renew these features*."
>
> (World Bank 2003, Chapter 2, pp.13).

In Section 2 of this paper we present the main conceptual frameworks for the analysis of sustainable development, emphasizing crucial aspects/questions that need to be addressed in the context of human development.

In Section 3, we review some of the existing sustainability indicators: consumption, investment, wealth, environmental goods and services, etc., highlighting their advantages and criticisms as indicators of sustainable human development. We also use these same indicators to assess the evolution of sustainability in the past four decades. From this analysis, it is visible that the world has become more unsustainable.

Section 4 explores what has been the relationship between sustainability and existing measures of human development. The conclusions are, at least, mixed. Depending on the measure used, it is possible to find a positive, a negative and even a non-significant correlation. In the face of such puzzling disconnect between the two groups of indicators, we explore possible answers, namely the strong association between economic performance and carbon dioxide emissions.

2. Conceptual discussion

The word ***sustainability*** is commonly defined as *the property of any system to maintain its* ***performance*** *over time*. In our discourse, the *performance* of interest is ***development,*** and along this paper the words *sustainability* and *sustainable development* are used as synonyms.

The many existing definitions of sustainable development (e.g., Pezzey, 1992) commonly emphasize aspects of equity across generations. One of the most often used analytical framework in the study of sustainability expresses social welfare as the discounted sum of utility of all people in a society, over time. In this utilitarian approach, sustainability is achieved when the well-being (the *outcome*) of a representative agent is non-declining for the rest of the time onwards.

Considering that consumption (of goods and services, including environmental) is the relevant input for the individual utility, and that the representative agent is able to transfer consumption between different periods of time, the consumption stream $\{C_t\}_{t=0,\ldots,\infty}$ corresponds to a sustainable development path at time *t*, if

$$V_{t+1} \geq V_t,$$

where $V_t = \sum_t^{\infty} \beta^{(t-1)} \mathcal{U}(C_t), \beta \equiv \frac{1}{1+\delta}$, and the discount rate $\delta \geq 0$. In the present period of time, $t = 0$ and, therefore, $V_0 = \sum_0^{\infty} \beta^t \mathcal{U}(C_t)$.[1]

A second common approach to define sustainable development focuses on maintaining the resources (the *means*) to generate the consumption valued by individuals. These resources are physical stocks of different types of capital:

- Man-made/produced capital, e.g., machinery and equipment, infrastructures, telecommunications;
- Human capital, namely knowledge and skills/ability;

[1] In a typical problem of maximizing the present value of a consumption stream, the path may be rising in some periods and decreasing in others. However, according to this definition of sustainability, such consumption path is not considered sustainable.

- Social capital, e.g., social networks of family and friends among which there is mutual support and trust, institutions, norms and values;
- Natural capital, namely all the goods and services given by nature and ecosystems, which include (among others) biodiversity, clean air and water, and atmosphere.

Among the advocates of sustainability as maintaining the different types of capital, there are two main schools of thought:

i) The *weak sustainability*, which considers the different types of capital are substitutes of each other and, therefore, the main concern should be the total stock of capital (produced, human, social and natural). Under this concept, sustainability translates in a non-decreasing real value of the total stock of capital.[2]

ii) The *strong sustainability*, which considers some types of capital as *critical*, namely natural capital (or parts of it), and cannot be substituted by other types of capital. Under this concept, sustainability means that the stock of the critical capital(s) does not decrease.

Weak sustainability has been more thoroughly explored. In an influential paper, John Hartwick showed that there is a correspondence between the two approaches of non-declining utility and non-declining total capital. In exhaustible resource economies, the Hartwick Rule (Hartwick 1977) -often abbreviated as "invest resource rents" – provides a rule of thumb for sustainability: a constant level of consumption is sustainable if the value of investment (on human or physical capital) is equal to the value of rents on extracted resources at each point in time.[3] In other words, the Hartwick Rule requires that a country reinvest *completely* the rent obtained from the extraction of exhaustible resources.

This rule has been later extended by Hartwick (1990) and Hamilton and Clemens (1999), the first considering a more flexible production technology, and the second the existence of both an

[2] A different, related question, would be to know how the investments in each type of capital affect the stock, e.g., while buying one machine translates in a direct increase in the stock of produced capital, it is not clear if improving school buildings translates in a direct increase of human capital.

[3] Note that the rule refers to consumption and not utility.

exhaustible and a renewable natural resource. With the necessary adjustments, the conclusions are very similar.

While this theoretical framework assumes optimality of decisions along the path, there has been a more recent branch of the literature advocating for a more broad and flexible analysis. In fact, as Arrow et al. (2003) argue sustainability only requires that the production set of the economy is growing, and this does not require optimality.[4] They define social welfare through a value function, whose arguments are the initial stocks of capital and a resource allocation mechanism. A sustainable development path is a sequence for a vector of consumption, resource flows and (different types of) capital assets that is compatible with a non-decreasing social welfare; and this path can be locally non sustainable (at some point in time, it may decrease), while simultaneously sustainable in the long run.

Is this a reasonable framework to study sustainability in human development?

Since human development is about expanding people's choices, a better option would be to replace, in the previous framework, the consumption by the set of capabilities (or the collection of all possible functionings that a given individual can have, given his personal characteristics and access to commodities). In that line, the utility function could be replaced with an alternative valuation function that transforms the vector of functionings into a measure of well-being.

However, a main question arising would be whether capabilities are fungible across time, so that one would be able to transfer choices today at a defined rate (relative price) into the future? One would think it is not possible (and perhaps not even desirable) as choices are defined by current, time-specific, circumstances and these, by definition, are outside an individual's control. However, one could think of exchanging the *possibility* to do or to be something *today* for the *possibility* to do or to be something *tomorrow* (and again, these are not the same choices).

[4] The fact that sustainability, as defined by Arrow et al. (2003) may not require optimality, this does not decrease the importance of optimality and efficiency for better human development outcomes.

Presenting the discussion more formally, using Sen's approach to entitlements, capabilities and functionings, let:

- x_i be the vector of endowments of a person i, in the n-commodity space X;
- $E(\cdot)$ be the entitlement mapping, from X to the power set of X;
- $E(x_i)$ be the entitlement set for person i;
- y_i be the vector of commodities available for individual i, which is an element of his entitlement set.

The entitlement set of a person is given by the initial endowments (x_i) and the ones acquired at an exchange rate (p) determined by the society's legal rules for those endowments:

$$E(x_i) = \{y_i \mid y_i \in X \& py_i \leq px_i\}$$

It is worth noticing that the entitlement set can include any social transfers since the exchange rule is not restricted to market transactions.

Additionally, let:

- $c(\cdot)$ be the correspondence mapping commodities into characteristics of commodities;
- $f_i(\cdot)$ be the utilization function mapping the characteristics of commodities into the personal use of them;
- b_i the vector of "beings and doings" of person i (e.g., well-nourished, safe, knowledgeable, etc), also called *functioning*.

Therefore, the "beings or doings" of individual i is determined by his entitlement set and by the function transforming the characteristics of the commodities into personal use:

$$b_i = f_i(c(y_i)).$$

The capability set for individual i, Q_i, consists in all possible functionings he can achieve. The capabilities are also determined by the entitlements $E(x_i)$ and the function transforming the characteristics of the commodities into personal use $f_i(\cdot)$:

$$Q_i(E(x_i)) = [bi|bi = f_i(c(y_i),\ for\ some\ f_i(\cdot) \in F_i\ and\ some\ y_i \in E(x_i)].$$

$Q_i(E(x_i))$ represents the freedom that a person has in terms of the choice of functionings given his personal features F_i and his command over commodities x_i.

Is it possible and how can this static framework be expanded to capture a notion of sustainability of human development?

While most of the work using the capabilities framework focus on current generations, it could be possible to extend it to describe (and also make prescriptions) in an inter-temporal setting. In a recent book "An Idea of Justice" (Sen, 2009), there is the argument that sustainable development needs to achieve "sustainable freedom": the preservation of human's freedom and capabilities today without "comprising capabilities of future generations to have similar or even more freedom". This includes the responsibility towards other living elements on Earth and, although Sen does not make it explicit, to the unborn generations of human beings. The conceptual problem is how to evaluate the trade-offs between different capabilities, and between capabilities and commodities/entitlements over commodities in different points in time.

To evaluate these trade-offs, it is necessary to use a value function that transforms the elements in the set of capabilities $Q_i(x_i)$ into a well-being measure of happiness or fulfilled desire (Sen 1985, p9). In Sen's words "given the valuation function $v_i(.)$, it is of course possible to characterize the values of well-being that a person can possibly achieve, given by the set V_i". A contentious issue is the form of this valuation function, which determines how the trade-offs between capabilities and commodities are counted. Since sustainability is an inter-temporal concept, another contentious issue is how to choose between *temporal paths*.

Once the capability set is transformed into a well-being indicator by the valuation function v_i, there are at least three possible ways to model the conceptual framework that would guide us to the solution of the challenges raised above:

a) *Sum of discounted capabilities*. Akin to an inter-temporal utility maximization framework, this approach quickly runs into problems such as how to discount the capability set/human development level of subsequent generations. Assuming that the function v_i is continuous and concave in capabilities with a positive first derivative and a negative second derivative, a non-trivial solution requires a discount factor. A lengthy academic debate (e.g., Stern 2006, Nordhaus 2009; Weitzman, 2007 and 2009; Dasgupta 2009 and 2010; Heal 2008) about the "right" value of the discount rate erupted after the publication of the Stern Report on The Economics of Climate Change. The issue remains unsolved but it is easy to argue that Frank Ramsey's quote that discounting is "ethically indefensible and arises merely from the weakness of the imagination" (Ramsey 1928) applies better in the capabilities framework than in a utilitarian one. One possible justification for applying a discounting factor to the intertemporal sum of capabilites is to account for the very small possibility of humankind disappearing. The uncertainty generated by the possibility of such end grants us the use of an adjusting element identical to the discount factor, but with a different interpretation: the discount factor is the "probability that the world exist at that time" (Stern, 2006, p51).[5]

b) *Mini-max approach*. Akin to a Rawlsian norm, this approach would choose the path that maximizes the level of human development of the least favored generation. Llavador et al. (2009) show that under uncertainty, both the Rawlsian and the utilitarian approach discount with the same factor but for different reasons.

c) *Responsibility approach*. Akin to the concept of stewardship, it requires that each generation endows the next generation with the resources necessary to achieve at least the same level of human development. This approach is also very close related to the *environmental pragmatism* defended by Norton (2007), according to which the uncertainty about the true value of natural systems in the future is an extra argument to protect and preserve them today.

Future research can shed additional light on the specific implications that each of these conceptual frameworks (and possibly others) have for answering the challenging questions of integrating sustainability in the human development and capability approach.

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[5] As Stern explains, this would be the case where the destruction of humankind WAS the first event of a Poisson process with parameter *d*.

A key aspect to take into consideration in such additional future research is the principle of universalism in which human development is deeply rooted. Human life is valuable by itself and for everyone without discrimination, which demands both intra and intergeneration equity. This has a *simple* implication that "inequities of today are neither sustainable nor worth sustaining" (UNDP, 1998). As Anand and Sen (2000) argue, in the search of what to sustain from a human development perspective, we need to consider more than living standards; we must aim for the expansion of the entitlements and the guarantee of distributional equity across and within generations.

3. The evolution of sustainability, according to indicators currently available

There is today a broad consensus on the importance of sustaining development and well-being over time, enabling future generations to have access, at least, to the same opportunities as we enjoy today. However, this common goal translates in several different conceptual frameworks and even many more proposals to measure how current behavior is aligned with that goal.

A possible classification of the existing measures of sustainability makes a distinction between:

1. ***Green national accounting***, measures that adjust economic indicators, namely GDP, by environment change and resource depletion;
2. ***Composite indices*** addressing socio-economic and environment performances aggregated in an unique single value;
3. ***Dashboard*** of indicators for different aspects related with socio-economic aspects as well as environment.

Jha and Pereira (*forthcoming*) present a review of more than 30 different measures and frameworks of measurement related with sustainability.

Here, in this section, we particularly review three of the above measures, each of them falling in one of the three broad categories of measures initially identified. We then use those measures to identify the trends in sustainability over the most recent decades. Annex A presents the descriptive statistics of the data used in the paper, which uses the most possible information available, though not a balanced sample (as explicit in the annex).

3.1 Adjusted GDP measures, total wealth and adjusted net savings

Based on the seminal papers of Samuelson (1961) and Weitzman (1976), the conceptual paper of Hartwick (1990) presents the National Net Product (NNP) as a better economic indicator for national income accounts, compared with GDP, since it takes into account the depreciation of natural resources stocks. The basis of the argument is a theoretical model of optimal growth where the goal is to maximize the welfare of a society, measured by the present value of the infinitely discounted utility of that same society (its *wealth*).

Along the optimal path, the change of the value function (also known as the *Hicksian income*, the maximum amount of produced output that can be consumed while leaving total income instantaneously constant) is equal to the optimal consumption flow plus the value of the investment in all assets (including natural stocks) evaluated at their unitary rent.[6] This Hicksian income is the NNP:

$$NNP = \\ consumption + investment\ in\ produced\ assets + investment\ in\ human\ capital + \\ value\ of\ the\ change\ in\ the\ natural\ resources.$$

Rooted in this conceptual framework that adjusts economic indicators by the value of (des)investment in several types of resources, there are two main tentative approaches of measuring sustainability:[7]

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[6] Unitary rent can be seen as the difference between the value of the resource for the society (i.e., its market price if all resources are tradable and markets are perfectly competitive) and its marginal creation cost.

[7] There are other proposals for measuring sustainability by “Adjusted GDP” techniques, such as: green GDP, Sustainable measure of economic welfare (SMEW) and its successors. Please refer to Jha and Pereira (*forthcoming*) for a more complete review.

i) the UN System of Environmental and Economic Accounting (SEEA). [8] This is a comprehensive framework drawing guidelines to measure the economic-environmental relationship, through the use of satellite accounts. These accounts complement the conventional system of national accounts that countries have, and include asset accounts with natural resource balances, flow accounts for materials, energy and pollutions, environmental protection expenditures and green alternatives to GDP. Being tailored at national level is both the main strength of this system for policy design and its main challenge for its use in international analysis.

ii) the World Bank Genuine Savings or Adjusted Net Savings (ANS) which we review below.

Expanding the theoretical framework of Hartwick, Hamilton and Clemens (1999) define *Genuine Savings* (later called *Adjusted Net Savings*) as: ANS= NNP – Consumption.

Currently, the Environmental department of the World Bank proposes the use of ***Total Wealth*** as an indicator of social welfare, and its changes (ANS) the indicator of sustainability. A negative ANS implies that at a point in time along the optimal path, consumption and utility will decrease.[9]

Theoretically, **total wealth** W_t is the present value of infinitely discounted consumption flows C, where the discount rate is the social rate r of return from investment. This social rate includes a pure rate of time preference, and the elasticity of utility with respect to consumption multiplied by the percentage change in consumption:

$$W_t = \int_t^{\infty} C(s).\, e^{-r(s-t)}.\, ds$$

In practice, **total wealth** is calculated as the present value of consumption, where:

- the initial level of consumption is calculated as the average of constant dollars of consumption between 1998 and 2000,

[8] http://unstats.un.org/unsd/envaccounting/seea.asp

[9] Please refer to World Bank - Environmental Department (http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/), and to World Bank and Hamilton (2006).

- consumption is assumed to grow at a constant rate,
- the time horizon considered is 25 years,
- the pure rate of time preference is 1.5, and
- the elasticity of utility with respect to consumption is 1.

Based in the theoretical work of Hamilton and Hartwick (2005), the World Bank also estimates countries' total wealth as the **sum** of the stock of different types of **capital**:

- **produced capital**, which includes machinery, equipment and structures, and urban land,
- **natural capital**, which relates to energy resources (oil, natural gas, hard coal, and lignite), mineral resources (bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin, and zinc), timber and non-timber forest resources, cropland, pastureland, and protected areas, and
- **intangible capital**, which refers to human and social capital and quality of institutions. This is calculated as a residual, i.e., the difference between total wealth and the sum of produced and natural capital.

As argued in the theoretical work of Hamilton and Clemens (1999) and adopted by the Environmental department of the World Bank, an indicator of sustainable development is the Adjusted Net Savings measure. Its calculus involves:

- *the sum of* Net National Savings (NNS), which are the Gross National Savings less the consumption of fixed capital,
- *with the* expenditures on education, which corresponds to the public current operating expenditures in education, including wages and salaries and excluding capital investments in buildings and equipment,
- *less the* value of depletion of natural resources (energy resources, minerals, and net forest),[10]
- *and less the* value of damages from pollutants (CO_2 emissions valued at \$20 per ton, and particulate damage).[11]

[10] For the current calculus of ANS, the value of energy resources refers to oil, natural gas, and coal; and the value of minerals refers to tin, gold, lead, zinc, iron, copper, nickel, silver, bauxite, and phosphate.

[11] The data on ANS used in this paper does not include particulate emissions damage. First, because the values of these emissions are only available for 1990 on, which would reduce in about half the period of analysis; second,

In brief,

$$ANS = NNS + Education\ Expenditures - Energy\ depletion - Mineral\ depletion - Net\ forest\ depletion - CO2\ damage - Particulate\ emissions\ damage.$$

The values of ANS are presented as percentage of GNI. This normalization implicitly assumes that richer countries have capacity (and are expected) to save more and compensate the depletion of natural resources, without compromising its *well-being*.

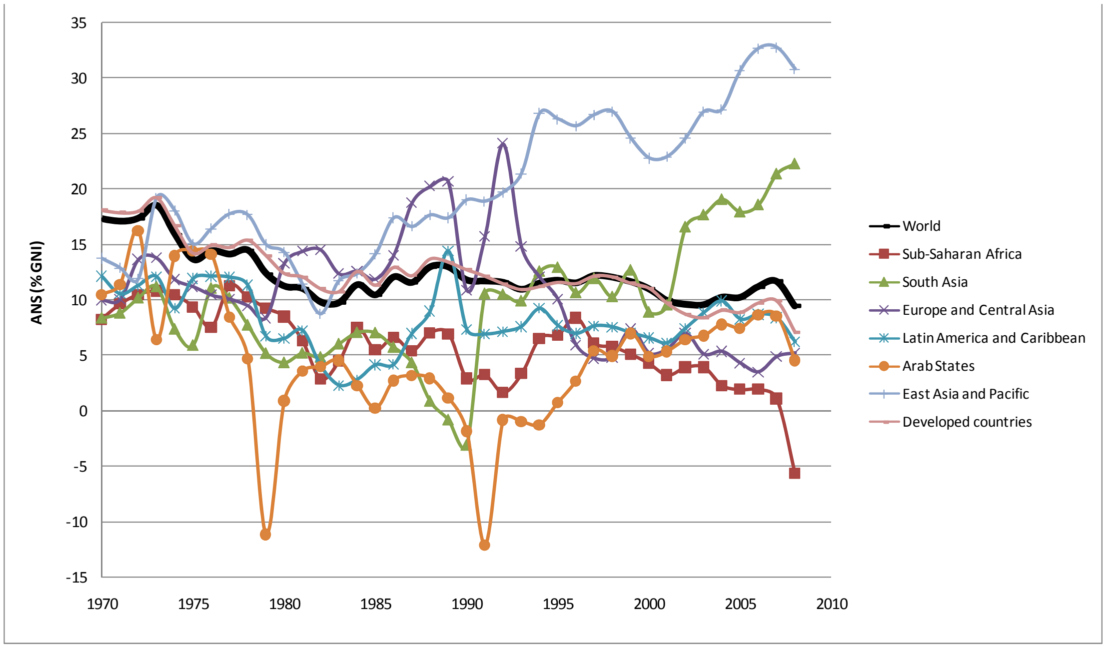
A negative value for ANS implies that total wealth is declining and, therefore, consumption is taking an unsustainable path, since it implies a (des)investment greater than the *savings*. From this reasoning, it is clear that ANS is a measure consistent with a broad definition of sustainability, where several dimensions have to be considered (productive, natural resources, human capital); and is also consistent with the weak concept of sustainability, which argues that disinvesting in one resource can be compensated by investing in another.

To answer the question "over time, what has been the evolution of sustainability", using ANS as an indicator of sustainability, we plot the distribution of ANS for the world and at regional level. The value of ANS for each aggregate is the average value based in the country level data, weighted by GNI. The regions are defined as in HDR2010, i.e., the *developed* countries are those with a HDI in 2010 in the upper quartile of the HDI distribution, and the remaining countries (*developing*) are classified by their geographical location.[12]

because this component has a relatively negligible weight in the value of ANS, so its inclusion would not change fundamentally our results.

[12] http://hdr.undp.org/en/reports/global/hdr2010/

Figure 1.Trends on ANS,[13] world and regional averages weighted by GNI



Note: Table 1B in Annex B presents the values supporting this graph.

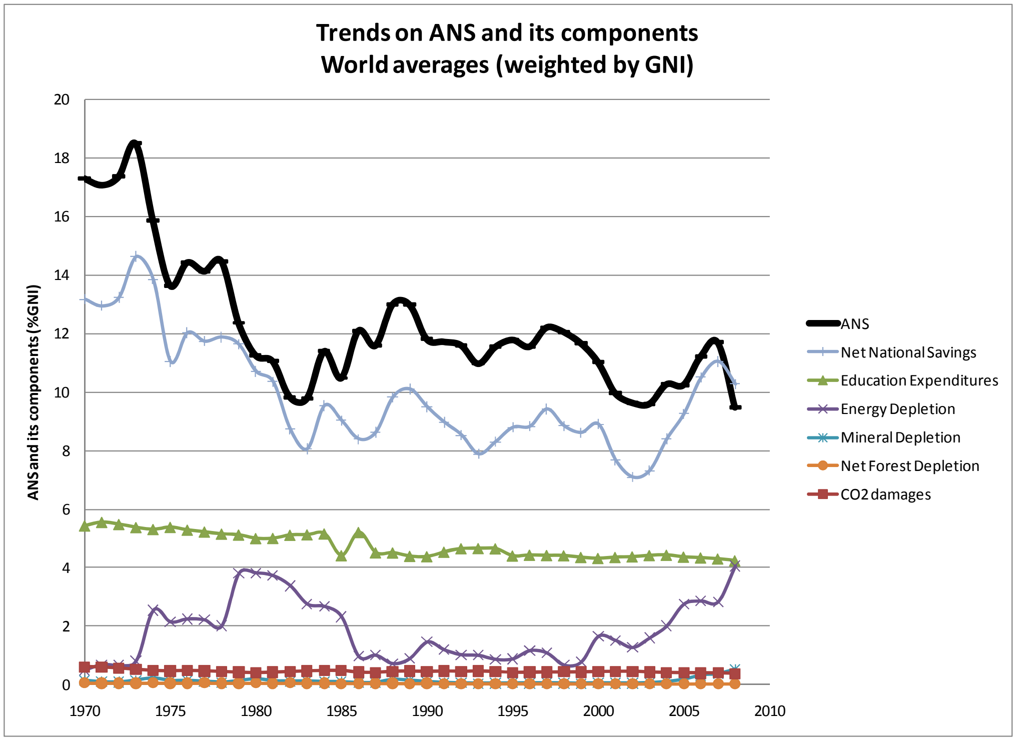
As shown in figure 1, over the previous decades there has been a clear decrease in world sustainability: in 1970, average ANS for the world was 17.3 percent of GNI, while in 2008 was almost half 9.5 percent. However, looking at the regional decomposition of this world average, the variety is striking:

- two developing regions saw an increase in their average ANS during the period: East Asia and Pacific (which includes China) started from an average value of 13.8 percent in 1970 and achieved a noticeable 30.8 percent in 2008, which means a 124 percent increase; South Asia went from 8.4 percent in 1970 up to 22.3 percent in 2008, a remarkable 167 percent increase (almost three time higher);
- in all the other regions, ANS has decreased in the period. The most extreme reduction occurred in Sub-Saharan Africa, which started with an average ANS of 8.3 percent in 1970 and reached a disappointing negative value of 5.6.

[13]The world and regional values of ANS differ from the ones published by the World Bank, due to differences in the way of aggregating the country level data. Please see Annex A for more detailed information.

This relative performance of different regions seems to reinforce a frequent critic to ANS as a measure of sustainability: its path is very much associated with NNS. In fact, this is very clear once we contrast the evolution of ANS with its components, as shown in figure 2 below.

Figure 2. Trends on ANS and its components, world averages weighted by GNI



Note: Table 2B in Annex B presents the values supporting this graph.

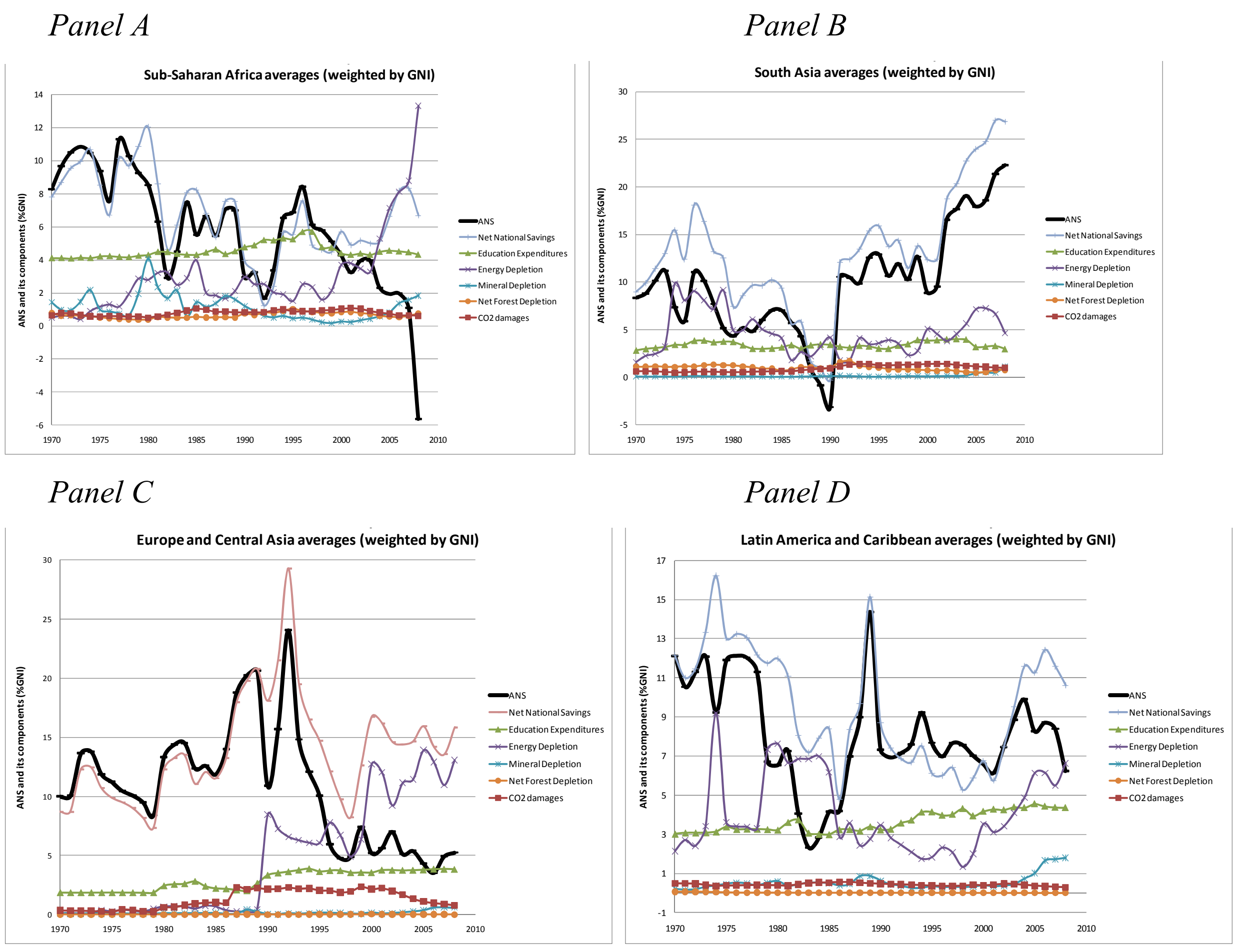
The analysis of linear correlations confirms the strong positive association between ANS and NNS, but it also shows a significant negative association between ANS and energy depletion (table 2 below):

Table 2. Correlation between ANS and its components, world level, over time

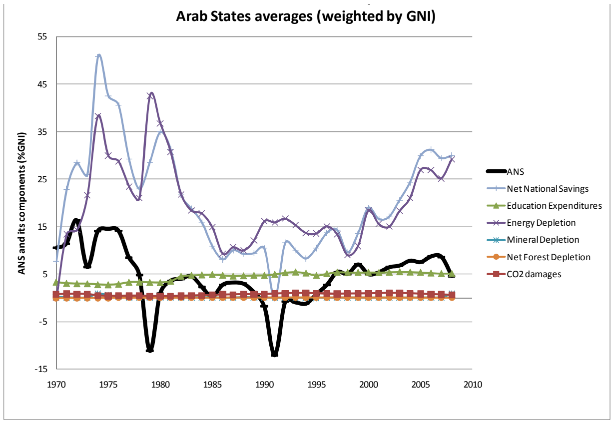
	1970	1980	1990	2000	2008
NNS	**0.92**	**0.47**	**0.82**	**0.63**	**0.58**
(p-value)	0.00	0.00	0.00	0.00	0.00
Educ Exp	**0.48**	**0.25**	**0.06**	**0.17**	**0.19**
(p-value)	0.00	0.01	0.51	0.04	0.03
Energ Dlp	**0.03**	**-0.36**	**-0.63**	**-0.46**	**-0.51**
(p-value)	0.83	0.00	0.00	0.00	0.00
Min Dpl	**-0.07**	**-0.03**	**-0.13**	**-0.07**	**-0.02**
(p-value)	0.60	0.73	0.13	0.41	0.80
Net Forest Dpl	**-0.28**	**-0.15**	**-0.13**	**-0.06**	**0.28**
(p-value)	0.03	0.13	0.15	0.48	0.00
CO2 damages	**0.28**	**0.10**	**-0.04**	**-0.28**	**-0.04**
(p-value)	0.03	0.31	0.65	0.00	0.64

Once disaggregating the analysis at regional level, it is visible: first, a diversity of paths; and second, the strong influence of NNS and energy depletion in the evolution of ANS (figure 3 below).

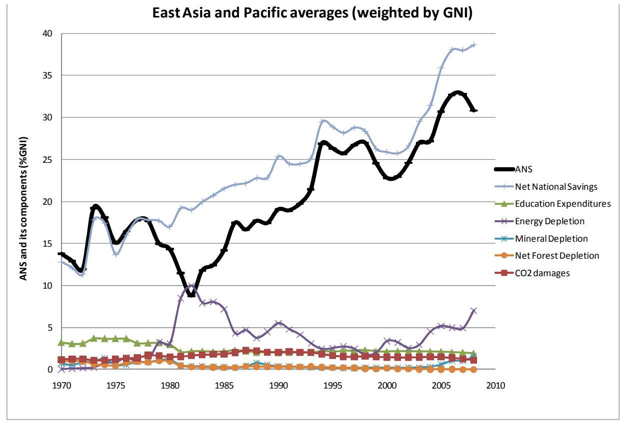
Figure 3. Regional trends of ANS and its components, weighted by GNI



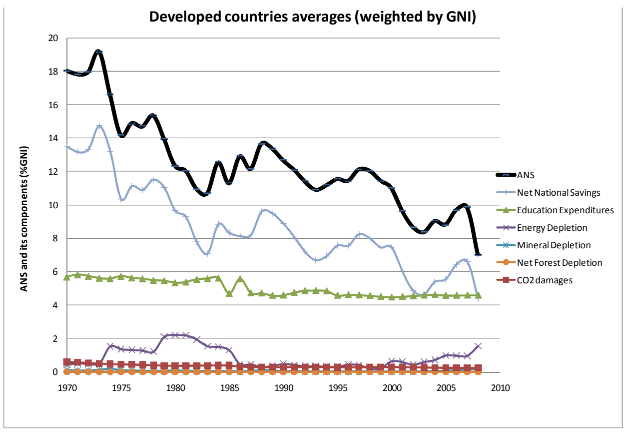
Panel E



Panel F



Panel G



Note: Tables 3B-9B in Annex B present the values supporting these graphs.

As an indicator of sustainability, ANS receives **other critics** besides the strong bias towards NNS, namely:

- ANS assumes weak sustainability, and therefore it does not account for the possibility of some assets being *critical* and not substitutable;
- In the calculus of ANS, assets are valued at their market prices, implicitly assuming that markets are perfectly competitive, and individuals and firms are perfectly forward looking and able to anticipate the future value of assets. Under imperfect or incomplete markets, the value of the resources (namely natural) can be very different, leading to biased ANS estimations;
- ANS does not include investments in health, an important component of human capital;

- ANS does not include the value of depleting important components of natural resources, such as: soil erosion, underground water depletion, unsustainable fisheries, soil degradation, and loss of biodiversity;
- the burden of depletion of natural resources is uniformly allocated to the producers/polluters, missing the global nature of sustainability. In reality, not only consumers share responsibility, but also the consequences of depletion may not be felt by producers and rather by countries that are more vulnerable to the impacts of environmental change;
- by considering an uniform value for the damages associated with pollution, ANS does not take into account that impacts may vary from country to country.

Results could be substantially different if one took these critics into account.

What can ANS add to the sustainable human development discussion?

The conceptual base of ANS provides a relevant starting point for thinking on sustainability of human development, while understanding this last as the way we can actively contribute today for non-decreasing capabilities in the future. Sustainability can and should be practiced in all spheres, not only environmental but also economic, financial, social, and political, and the areas where they overlap.

A particular valuable aspect of the ANS framework for the human development discourse is the multidimensionality of the measure, capturing various types of resources. However, two significant differences are:

i) In the theory underlying ANS, resources only have an instrumental value (direct or indirect) to the achievement of consumption, while in the human development framework they also have an (additional) intrinsic value;
ii) ANS assumes sustainability between all types of resources (weak sustainability), which is not consistent with the stewardship principle in the human development paradigm.

3.2 Composite indices

The critics to the use of composite indices are well-known in the literature (e.g., Stiglitz, Sen and Fitoussi, 2009; Kovacevic, 2010). Among them, we can emphasize the questions related to the ways of aggregating and weights of the different components, how indices deal with the possible substitutability of the different components, or what is their role in informing policy design. However, given the powerful message of a simple and unique measure, such indices are widely accepted and used. This is also the case when it comes to measuring sustainability and performance of countries' management of environmental resources.

In this section, we review two of these composite indices, which became more prominent in the international debate: the Environmental Performance Index and the Ecological Footprint.

3.2.1. Environmental Performance index

The Environmental Performance Index (EPI) is a product from a partnership between the Yale Center for Environmental Law & Policy at the Yale University and the Center for International Earth Science Information Network at Columbia University[14]. This composite index of environmental pollution and resource management issues builds in 2 objectives, 10 policy areas (which may have sub-categories), and 25 indicators.[15] The level of each indicator is compared to a target (*proximity-to-target* methodology), and the scores range from zero (worst performance) to 100 (at target). The weights in the aggregation are given.

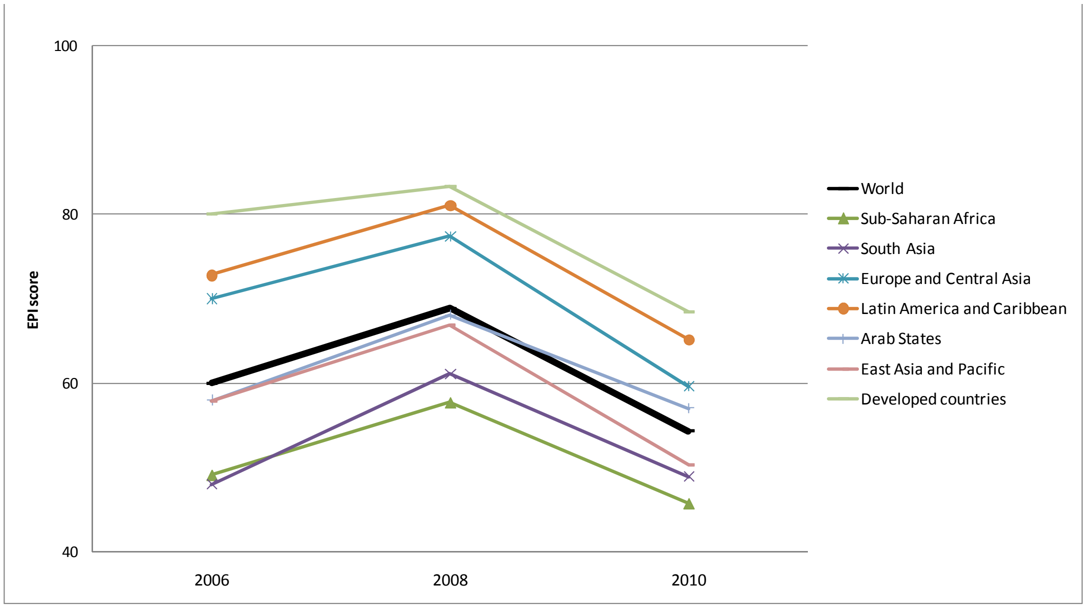
The 2 main objectives of EPI are (1) environmental health and (2) ecosystem vitality. The 10 core policy areas are (1) Environmental Burden of Disease; (2) Water Resources for Human Health; (3) Air Quality for Human Health; (4) Air Quality for Ecosystems; (5) Water Resources for Ecosystems; (6) Biodiversity and Habitat; (7) Forestry; (8) Fisheries; (9) Agriculture; and (10) Climate Change.

[14] http://epi.yale.edu/

[15] The EPI can also be interpreted as a reduced form of the Environmental Sustainability Index, created by the same partnership. See Jha and Pereira (*forthcoming*) for more information.

Using the data available for the years 2006, 2008 and 2010 (figure 4 below), it is possible to see that the world, as a whole, saw its environmental performance worsening 10 percent from 2006 to 2010: from 60 to 54. The highest decrease, 15 percent, happened in the regions of Europe and Central Asia and in the group of developed countries.

Figure 4. Trends on *Environmental Performance Index,* world and regional averages



Note: The average values are calculated based on country level data, using population as weights. Table 10B in Annex B presents the values for this graph.

The main critic to EPI is the fact that it provides information on a mix of current environmental indicators, but not whether countries are on a *sustainable* path or not. As such, the policy message is ambiguous, with very often presenting an optimistic view of developed countries performance. Arbitrary weights are also non desirable.

3.2.2. Ecological Footprint

The Ecological Footprint (EF), created by the Global Footprint Network,[16] is a composite index that tries to measure the demand that populations and activities place on biosphere each year. In

[16] www.footprintnetwork.org

simple words, it is an assessment of the pressure on the environment. EF is measured in a standardized land and sea area unit, the *global hectare*, which re-weights land areas according to their worldwide average potential productivity.

EF represents the total area of productive land or sea required for six uses of land (crops, grazing, forest, fishing grounds, carbon, built-up land) and is calculated as:

$$EF = \frac{P}{YN}.YF.EQF$$

where

- P is the amount of product harvest or waste generated (i.e., the amount of one of the six uses of land);
- YN is the national average yield for P;
- YF is the yield factor (productivity) within a country. It considers countries' differing levels of productivity for particular land use types. Each year, a country has a yield factor for cropland, grazing land, forest land and fishing grounds. The yields factor for built-up land is the same as for cropland. YF is calculated as the ratio between national and world average areas;
- EQF is the equivalent factor, which converts the actual area in hectares of different land use types into their global hectares equivalent (units of world average biologically productive area).

EF can be compared with biological productive capacity of the land and sea available (*biocapacity*), in order to produce a balance of footprint:

$$BC\ (biocapacity) = A.YF.EQF$$

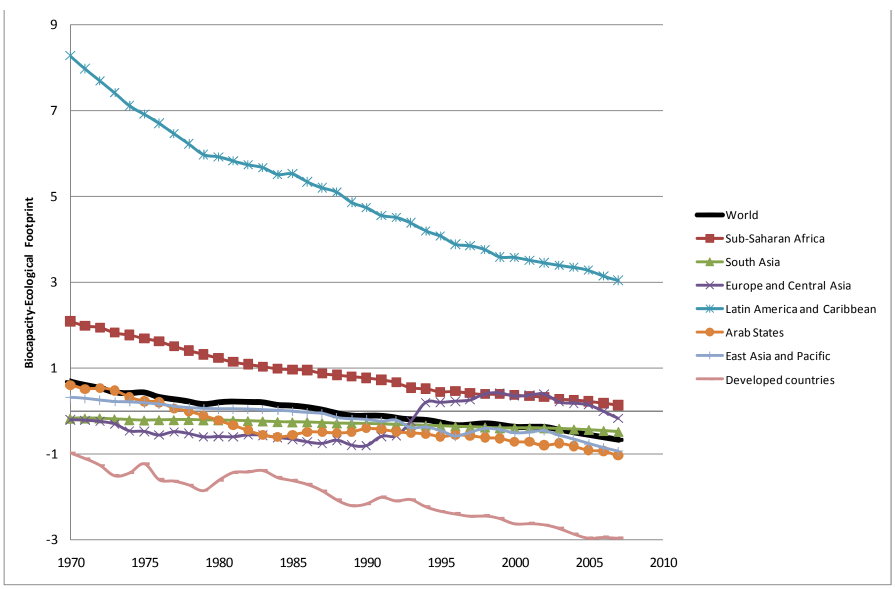
where A is the area available for a given land use type within a country.

A negative difference between BC and EF (negative *ecological balance* or *ecological deficit*) is considered a signal of unsustainable consumption of natural resources, which can be compensated by overusing local biocapacity or by using biocapacity from abroad.[17]

From their formula, it is clear that the EF and the ecological balance have a special focus on the environmental component of sustainability and are consistent with a strong concept of sustainability, where natural resources are considered critical.

Despite the conceptual difference of EF and the previous ANS, the evolution of the ecological balance shows us a trend towards unsustainability, at world and regional level (figure 5 below). In fact, for 2007 (the latest year with data available), the ecological per capita deficit achieves a negative value of 0.67. In other words, according to this measure, the world is consuming more than 50 percent more than it affords.[18]

Figure 5. Trends on *Ecological balance* (Biocapacity minus EF), world and regional per capita averages



Note: Table 11B in Annex B presents the values supporting this graph.

[17] The Ecological footprint of a country is the *demand* side (the area required for the several activities), while the biocapacity is the *supply* side (the productivity capacity to provide the necessary environmental resources).

[18] The slightly discrepancy between our results of more than 50 percent "overconsumption" and the ones of the official Global Footprint Network of approximately 50 percent (http://www.footprintnetwork.org/) is totally due to the sample of countries used. In our case, we use as a starting point a smaller sample of the countries for which we have HDI trend data.

Besides the overall negative trend, figure 5 puts in evidence a diversity of results at the regional level, with Latin America and Caribbean showing the highest (still positive) ecological balance, and the Developed countries registering the highest ecological deficit.

Some of the main critics to EF refer that:

- It assumes substitutability between the different types of natural capital, but there is no role for savings or for capital accumulation. It relies on a strong concept of sustainability since savings and accumulation of produced or human capital does not impact environmental sustainability;
- It does not weight possible technical progress, nor it includes problems of unsustainability derived from the extraction of fossil fuels, biodiversity loss, or water quality;
- Biocapacity is calculated using the real yield and not the yield necessary to leave soils with sufficient quality to ensure the same yield for the following year(s). This is inconsistent with the concept of sustainability;
- Since forests have general lower equivalence factors, the index is biased towards favouring replacing forests by culture lands. The underlying problem is that the value of forest does not include non-market benefits;
- Since an ecological deficit can be compensated by using biocapacity of other countries, EF does not take into account the benefits of trade. Countries have different population density and endowments of resources, so inequality in EF in the exploitation of natural resources and interdependencies between geographical areas is more an argument for the benefits of international trade than a signal of unsustainability;
- EF does not have clear implications for policy decision;
- Most results (changes/trends) are driven by CO_2 emissions, so an alternative would be to consider only this other indicator as a measure of over-utilization of common resources. In

fact, using our database, the value of correlation between EF and CO_2 emissions, both in per capita terms, is significantly high: 0.53.[19]

What can EF add to the Sustainable Human Development discussion?

EF is more a measure of pressure and inequality on the exploitation of resources, which obviously links with the environmental dimension of sustainability. However, since most of the results/trends and patterns of this measure are driven by the CO_2 emissions, it is not clear the value added of EF in comparison with a much simple indicator of emissions.

3.3 Single indicators, and carbon dioxide emissions per capita

Given the conceptual challenges of green national accounting measures, and the methodological critics of composite indices, it is consensually recommended that any attempt of measuring sustainable development is complemented by a list of simple indicators. In the international debate of sustainability there are many examples of such indicators, including the ones resulting from Rio Summit in 1992 (Agenda 21), and European Council's indicators developed by OECD and Eurostat (10 themes, 11 indicators of level 1, 33 of level 2, and 78 indicators of level 3; with indicators in levels 2 and 3 covering 29 sub-themes).[20]

The United Nations Department of Economic and Social Affairs, Division for Sustainable Development, is taking a lead role in advancing the debate in national and international levels. The latest revised version of indicators contains a set of 50 indicators, which are part of a larger set of 96 indicators. Indicators are classified in 14 themes: poverty, governance, health, education, demographics, natural hazards, atmosphere, land, oceans, seas and coasts, freshwater, biodiversity, economic development, global economic partnership, and consumption and

[19] In the calculus of EF, the component of carbon refers to Carbon uptake land, the amount of forest land needed to uptake anthropogenic carbon emissions; and therefore, its strong correlation with CO_2 emissions.

[20] http://epp.eurostat.ec.europa.eu/portal/page/portal/sdi/indicators/

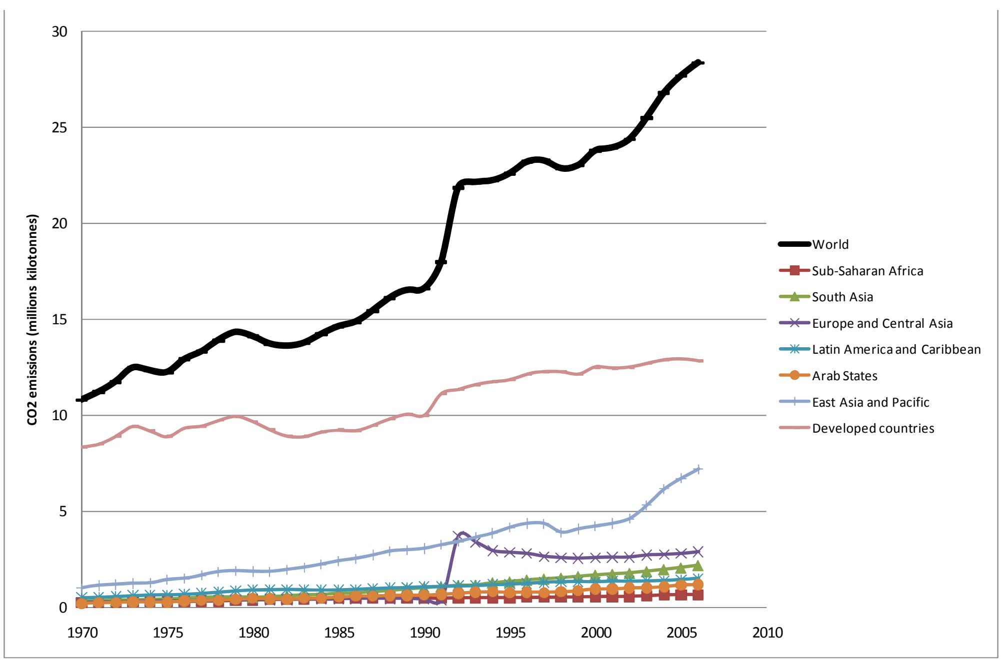
production patterns. This set of indicators is considered a reference to be used by countries to track progress towards nationally defined goals of sustainability.[21]

Despite their great flexibility, dashboards of simple indicators don't facilitate the international comparison of performances. Moreover, as we extend the list of possible indicators to include in such dashboard, there is a risk of introducing heterogeneity in terms of covering both outcomes and instruments for current and future development, making classifications and analysis of patterns and trends quite challenging.

For this reason, for purpose of international analysis it is wise that such dashboard has a relatively short list of selected indicators. Given its role in the international debate of environmental sustainability, carbon dioxide (CO_2) emissions are an indicator that may receive priority in that selected list.

Analysing the evolution of CO_2 emissions over the recent decades, it is evident that they have been increasing enormously, both totally and in per capita terms (figures 6 and 7 below).

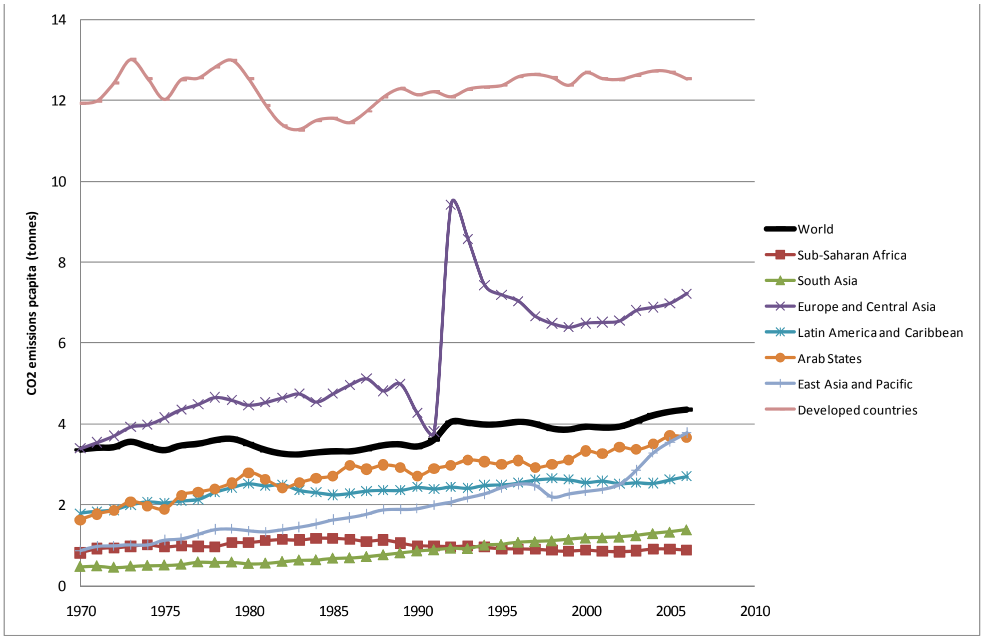
Figure 6. Trends on **CO_2 total** emissions, world and regional aggregates



Note: Table 12B in Annex B presents the values supporting this graph.

[21] http://www.un.org/esa/sustdev/natlinfo/indicators/guidelines.pdf

Figure 7. Trends on CO_2 **per capita** emissions, world and regional averages



Note: Table 13B in Annex B presents the values supporting this graph.

From the previous graphs, it is very clear that the increase in both types of indicators, total and per capita CO_2 emissions, is common to all regions in the world. However, it is also very noticeable the diversity of performances, with the developed countries being, by far, the group with higher values in both measures.

Given the role that CO_2 emissions play in a major challenge for the future progress of well-being (the change in the patterns of climate), it is never too much to study its evolution and to look for possible solutions to break the current path. However, as we discuss in the next section, measuring sustainability requires a much larger scope than just focusing on the atmosphere area of the environmental dimension.

3.4 Discussion on measurement challenges and the way forward

In the search for a measure of sustainability of human development, there are two main considerations to keep in mind: i) measuring current human development is different from measuring sustainability; ii) sustainability of human development is necessarily multidimensional and intertemporal.

Although recognizing that "human development today is also a means to human development tomorrow" (Anand and Sen, 2000), current human development has to do with the expansion of current capabilities (what they can *do* or *be*). Objective measures of the capability set of individuals relate with several aspects, among which: living a long and healthy life, being educated and knowledgeable, having access to economic resources to live a decent life, having a voice and being able to participate in the life of the community, and living within quality environmental conditions (for a more complete list of human development dimensions, please see Ranis et al., 2006). Environmental conditions determine human development through both direct and indirect ways. Aspects such as quality of air, water and sanitation, environmental amenities and biodiversity has a direct impact on health, living standards, knowledge, and they also have an intrinsic value for what people can currently *do* or *be*.

Certainly related with current human development, but necessarily different, is the possibility of expanding the capability sets of those living in the future. Making a parallel with our own personal lives, it is easily understood that one of the best things we can do today to ensure a better future for our children and ourselves, is to save and invest in "assets" which can be either tangible (e.g., invest in property, in a business, or in natural resources) or less tangible (e.g., education and health). Ultimately, by having such behaviour today, we/our children will be able to enjoy lives that we/they will value.

From an environmental perspective, sustainability implies achieving developmental results without jeopardising the natural resource base and biodiversity of the region, and without damaging the resource base for future generations above a certain critical/irreversible level. This is similar to financial sustainability, which refers to the way in which development is financed and its impact over time. Specifically, development should not lead countries into debt traps nor deplete them of their future resources.

Therefore, a measure of sustainability should consider the investment/savings that today we made in several types of "assets" that can be used for our future. This, however, is not a simple task due to the many uncertainties about what is more relevant for the future, and how to compare/value each of those assets today, trading-off their use between different time horizons. If all goods and services were traded in markets, markets were perfectly competitive and we would all have perfect forward looking knowledge of the value of the different goods and services in the future, then market prices would be perfect signs to value each component we would want to save/invest. Nevertheless, we have to recognize that in reality none of those ideal conditions are met, but rather, there is much uncertainty and ignorance about those values.

In sum, while looking for a possible measure (or set of measures), it is important to acknowledge that:

- It makes all sense to include an environmental dimension in the measurement of a current human development framework as well as in the measurement of sustainability;
- Measuring sustainability of human development would necessarily imply an intertemporal and multidimensional analysis.

Future research will need to assess if the best option for measuring sustainability of human development goes through the adoption of a single (composite) index. This choice would face all the challenges commonly presented for composite indices (e.g., aggregation, weights, and distributional aspects) and, additionally, the uncertainty and ignorance about the future. For that reason, it is specially recommended that the analysis of such potential composite index is complemented by a short list of other indicators. While future and deeper research may advocate for the use of some particular list of indicators, table 3 below presents some initial candidates.

Table 3. List of possible indicators to be included in a dashboard for sustainable HD

Indicator	
Proportion of population using improved water source	*MDG*
Proportion of population living in hazard prone areas	
Human and economic loss due to natural disasters	
CO2 emissions, total, per capita and per $1 GDP (PPP)	*MDG*
Land degradation /Land affected by desertification	
Proportion of land area covered by forests	*MDG*
Proportion of marine area protected	*MDG*
Water use intensity by economic activity	
Proportion of terrestrial area protected, total and by ecological region	*MDG*
Proportion of species threatened with extinction	*MDG*

4. Indicators of sustainability and human development

The previous section showed that existing measures of sustainability, whether based in a comprehensive index of weak sustainability, in a environmental index of strong sustainability, or in a single indicator of exhaustion of a critical natural resource, all point in the same conclusion: *over time, the world has become more unsustainable*.

The recognition of that fact lead us to two crucial (sequential) set of questions, useful for the design of policies to address that major challenge of increasing unsustainability:

1st. What does the relation between the existing measures of sustainability and human development reveal? Is it possible to have simultaneously a high human development and being unsustainable?

2nd. What can explain possible (dis)connection between indicators sustainability and human development?

4.1 Is there a (dis)connection between indicators of sustainability and human development?

The interaction between indicators of human development and sustainability can only partially reflect the concept of sustainable human development. Both the Human Development Index (HDI) and the sustainability indicators mentioned in the previous section are imperfect measures of the concepts at hand, and thus any analysis of their data is bound not to be comprehensive.

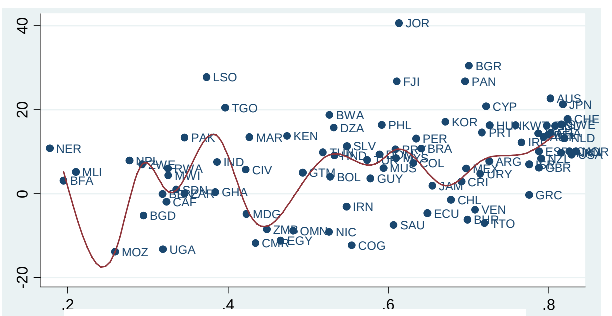
Nevertheless, studying the relation between those set of measures is an important step for understanding current challenges of sustainability and the way to address them in the near future.

4.1.1 Adjusted Net Savings and HDI

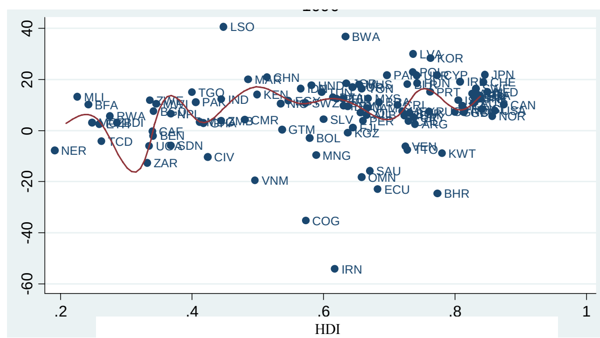
Considering the relation between ANS and HDI over time, we find a correlation that is either non-significant or slightly positive. This conclusion, shown in figure 8 below for a few illustrative years, is also confirmed by the values of the correlation between the two variables (table 4 below).

Figure 8. Distribution of ANS and HDI, in different (illustrative) years

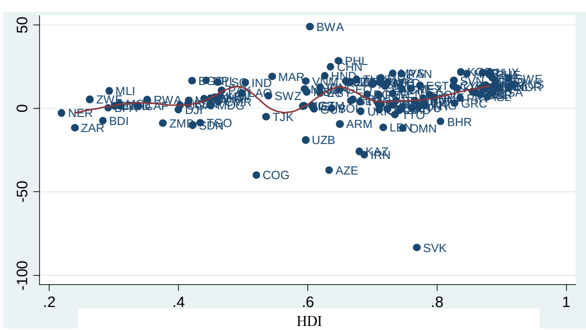
Panel A. 1980



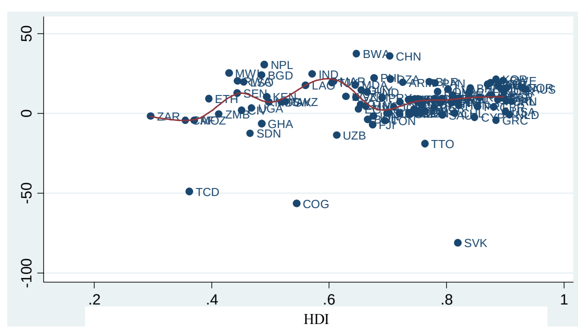
Panel B. 1990



Panel C. 2000



Panel D. 2008



Note: ANS excludes particulate emissions damage.

Table 4. Correlation between ANS and HDI, at world and regional level, over time

	1975	1980	1985	1990	1995	2000	2005	2006	2007	2008
World	**0.443**	**0.351**	**0.284**	**0.198**	**0.138**	**0.206**	**0.154**	**0.138**	**0.091**	**0.116**
(p-value)	0.000	0.001	0.005	0.043	0.133	0.021	0.085	0.129	0.326	0.235
Sub-Saharan Africa	**0.32**	**0.02**	**0.18**	**0.24**	**0.07**	**0.35**	**0.24**	**0.17**	**0.14**	**0.22**
(p-value)	0.23	0.92	0.40	0.24	0.75	0.08	0.25	0.42	0.54	0.36
South Asia	**0.60**	**-0.32**	**-0.75**	**-0.90**	**-0.76**	**-0.96**	**-0.85**	**-0.86**	**-0.71**	**-0.16**
(p-value)	0.40	0.60	0.14	0.04	0.13	0.01	0.07	0.06	0.18	0.84
Europe and Central Asia	**.**	**1.00**	**0.99**	**0.33**	**0.26**	**0.34**	**0.32**	**0.29**	**0.12**	**0.07**
(p-value)	0	1.00	0.10	0.35	0.30	0.15	0.18	0.23	0.62	0.77
Latin America and Caribbean	**-0.17**	**-0.02**	**-0.09**	**-0.16**	**0.11**	**0.14**	**-0.13**	**-0.31**	**-0.07**	**-0.02**
(p-value)	0.58	0.94	0.71	0.49	0.65	0.54	0.56	0.19	0.78	0.93
Arab States	**0.64**	**0.39**	**0.15**	**-0.30**	**-0.19**	**0.11**	**-0.14**	**-0.01**	**-0.07**	**0.31**
(p-value)	0.25	0.30	0.70	0.43	0.59	0.74	0.69	0.97	0.83	0.42
East Asia and	**-1.00**	**0.11**	**0.03**	**0.33**	**-0.33**	**0.46**	**0.15**	**0.04**	**0.15**	**-0.08**
(p-value)	1.00	0.93	0.95	0.43	0.43	0.18	0.67	0.90	0.68	0.85
Developed	**0.17**	**0.13**	**-0.02**	**-0.12**	**0.30**	**0.49**	**0.42**	**0.43**	**0.43**	**0.38**
(p-value)	0.46	0.51	0.91	0.54	0.10	0.00	0.01	0.01	0.02	0.05

Having a more detailed analysis of the relationship between the components of ANS and HDI, for the latest year where data is available, 2008 (please table 5 below), we can that:

- HDI is positively (but not too strongly) correlated with ANS and its components, being the highest correlation of 0.28 with the Education Expenditures component in ANS. Inversely, the highest correlation of ANS is with the Health and Education Indices components of HDI, but even those are relatively small (0.17 and 0.16, respectively) and almost non-significant;
- Net National Savings is weakly correlated with HDI and all its components;
- The components associated with (des)investment in natural resources present negative but not significant correlation with all HD components; similarly, damages from CO_2 emissions are not significantly correlated with HDI nor its components;
- The strongest correlations occur between Education expenditures and HDI and its components.

Table 5. Correlation between ANS and HDI, and their components, 2008

	ANS	NNS	Education Expenditures	Depletion Natural Resources (Energy, Mineral, Forest)	CO2 damages
HDI	**0.12**	**0.05**	**0.28**	**-0.08**	**0.01**
(p-value)	0.23	0.62	0.00	0.39	0.93
Health index in HDI	**0.17**	**0.05**	**0.20**	**-0.14**	**0.04**
(p-value)	0.08	0.58	0.02	0.11	0.62
Education index in HDI	**0.16**	**0.03**	**0.38**	**-0.09**	**0.10**
(p-value)	0.10	0.74	0.00	0.30	0.28
Income index in HDI	**0.06**	**0.05**	**0.29**	**-0.02**	**-0.07**
(p-value)	0.56	0.62	0.00	0.81	0.42

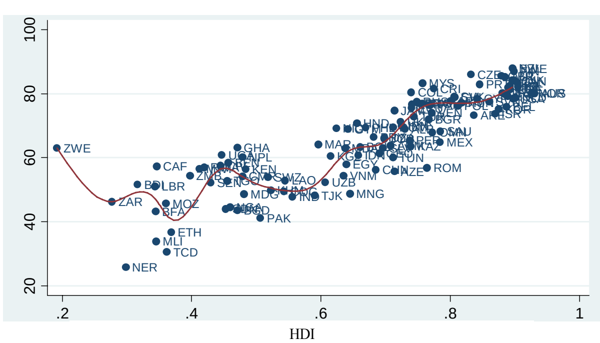
By the analysis of the correlations above, which are barely significant, it seems clear that HDI captures a process which is different from the wealth accumulation process as measured by ANS, and the only link happens through the human capital indicators.

4.1.2 Environmental Performance Index and HDI

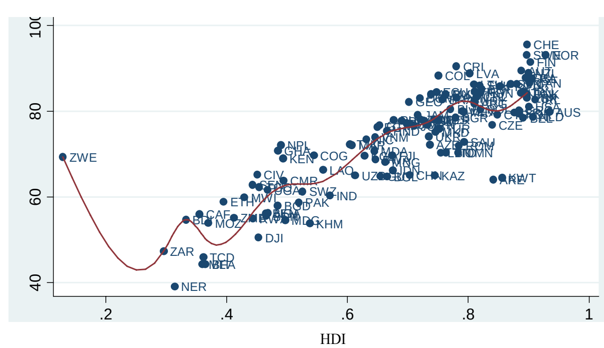
Mapping EPI and HDI for the three most recent years for which we have data, it is clear a positive association between these two composite indices, both in figure 9 and in the table 6 of correlations (please see below). In other words, this results supports the conclusion that as countries become more developed, they tend to have better environmental performance in terms of resource management and environmental pollution.

Figure 9. Distribution of EPI and HDI, in recent years

Panel A. 2006



Panel B. 2008



Panel C. 2010

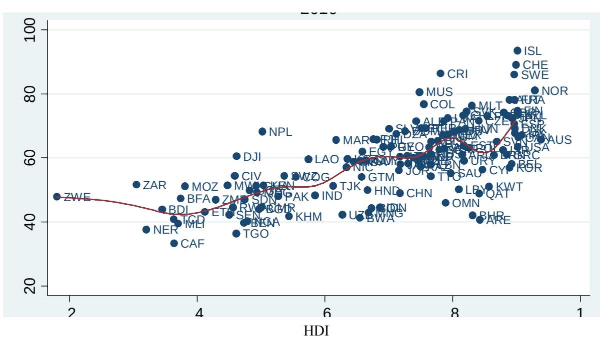


Table 6. Correlation between EPI and HDI, at world and regional level, recent years

	2006	2008	2010
World	**0.86**	**0.85**	**0.68**
(p-value)	0.00	0.00	0.00
Sub-Saharan Africa	**0.29**	**0.56**	**0.51**
(p-value)	0.15	0.00	0.01
South Asia	**0.72**	**0.64**	**0.23**
(p-value)	0.17	0.25	0.70
Europe and Central Asia	**0.68**	**0.65**	**0.75**
(p-value)	0.01	0.00	0.00
Latin America and Caribbean	**0.58**	**0.64**	**0.52**
(p-value)	0.01	0.00	0.02
Arab States	**0.84**	**0.62**	**-0.21**
(p-value)	0.00	0.04	0.50
East Asia and Pacific	**0.76**	**0.75**	**0.34**
(p-value)	0.03	0.02	0.37
Developed countries	**0.36**	**0.32**	**0.39**
(p-value)	0.05	0.07	0.02

The positive correlation between EPI and HDI is a constant for the world, as a whole, and for each individual region. However, it is worth noticing that for the group of developed countries the association is less strong.

Disaggregating HDI in its several components (table 7), the strong positive and significant correlation with EPI is still present.

Table 7. Correlation between EPI and HDI, and their components, 2010

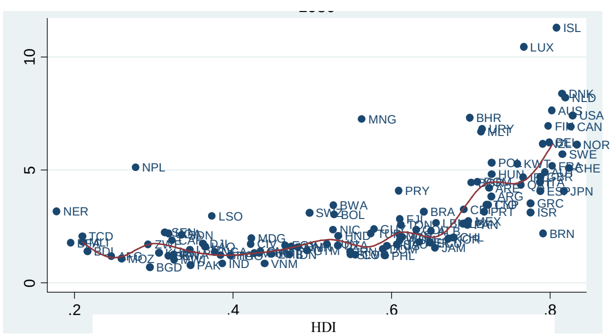
	EPI
HDI	**0.68**
(p-value)	0.00
Health index in HDI	**0.69**
(p-value)	0.00
Education index in HDI	**0.64**
(p-value)	0.00
Income index in HDI	**0.61**
(p-value)	0.00

4.1.3 Ecological Footprint and HDI

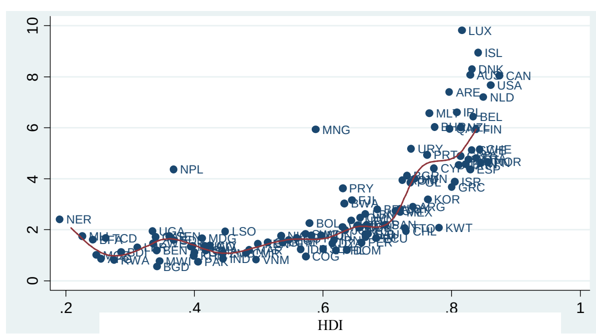
Considering now the environmental composite index, EF, it is visible a strong positive and significant relation between the pressure on environmental resources and HDI. In fact, both graphical (figure 10) and correlation analysis (table 8 below) corroborate in that same conclusion.

Figure 10. Distribution of Ecological Footprint pcapita and HDI, in different (illustrative) years

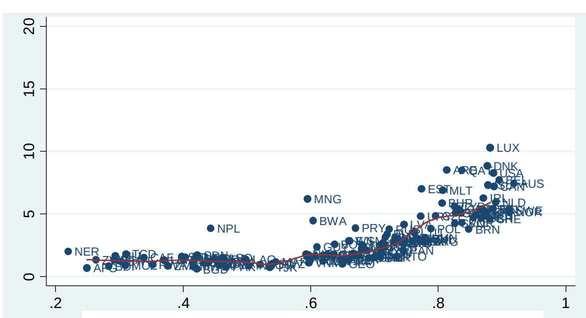
Panel A. 1980



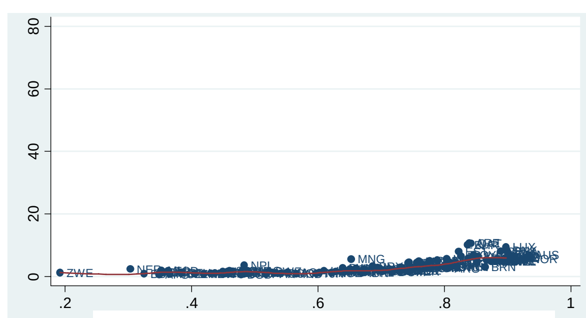
Panel B. 1990



Panel C. 2000



Panel D. 2007



The graphs in figure 10 show a positive, but non-linear association between EF and HDI.

Table 8. Correlation between EF and HDI, at world and regional level, over time

	1975	1980	1985	1990	1995	2000	2005	2006	2007
World	**0.6073**	**0.663**	**0.6561**	**0.7196**	**0.6784**	**0.7344**	**0.7476**	**0.7302**	**0.7377**
(p-value)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00
Sub-Saharan Africa	**0.04**	**0.04**	**0.02**	**0.25**	**0.33**	**0.41**	**0.53**	**0.51**	**0.54**
(p-value)	0.86	0.85	0.92	0.21	0.08	0.03	0.00	0.01	0.00
South Asia	**-0.33**	**-0.24**	**-0.10**	**0.05**	**0.23**	**0.30**	**0.37**	**0.41**	**0.42**
(p-value)	0.53	0.64	0.85	0.93	0.66	0.56	0.47	0.42	0.40
Europe and Central Asia	**0.79**	**0.88**	**0.94**	**0.92**	**0.21**	**0.83**	**0.85**	**0.82**	**0.81**
(p-value)	0.21	0.12	0.06	0.08	0.40	0.00	0.00	0.00	0.00
Latin America and Caribbean	**0.48**	**0.49**	**0.35**	**0.48**	**0.44**	**0.42**	**0.45**	**0.52**	**0.55**
(p-value)	0.03	0.03	0.13	0.03	0.05	0.07	0.05	0.02	0.01
Arab States	**0.08**	**0.68**	**0.67**	**0.70**	**0.71**	**0.72**	**0.70**	**0.72**	**0.71**
(p-value)	0.81	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
East Asia and Pacific	**0.33**	**0.35**	**0.37**	**0.39**	**0.37**	**0.31**	**0.45**	**0.47**	**0.52**
(p-value)	0.32	0.28	0.26	0.23	0.26	0.35	0.16	0.14	0.10
Developed countries	**0.50**	**0.36**	**0.31**	**0.42**	**0.33**	**0.33**	**0.23**	**0.03**	**0.00**
(p-value)	0.00	0.04	0.08	0.02	0.05	0.05	0.18	0.84	0.98

Studying the evolution of the same correlation as in table 8 above, we can conclude that as countries have a higher HDI, they tend to impose a higher pressure on environment. This applies to world, as a whole, and to individual regions as well. Interestingly, the exceptions to that general conclusion are: the developing countries in South Asia and in East Asia and Pacific for all the period in analysis; and the group of the most developed countries, for the three latest years.

When one disaggregates HDI in its components (table 8 below), we can also find a strong positive correlation with EF. The correlation is particularly high between the income dimension of HDI and EF. In other words, for the world as a whole, having a higher HDI, being healthier, more educated and (above all) richer, is associated with causing higher pressure on environment.

Table 9. Correlation between EF and HDI and its components, 2007, world average

	Ecol Footprint pc
HDI	**0.738**
(p-value)	0.00
Health index in HDI	**0.641**
(p-value)	0.00
Education index in HDI	**0.589**
(p-value)	0.00
Income index in HDI	**0.808**
(p-value)	0.00

As seen in section 3 of this paper, the indicator of sustainability in the EF framework is the *ecological balance*, i.e., the difference between the biocapacity and the footprint of each country. Nevertheless, when we study its relation with HDI, the results are very mixed (table 10 below).

Table 10. Correlation between *Ecological balance* and HDI, at world and regional level, over time

	1975	1980	1985	1990	1995	2000	2005	2006	2007
World	**0.01**	**-0.03**	**-0.06**	**-0.08**	**-0.12**	**-0.11**	**-0.13**	**-0.13**	**-0.14**
(p-value)	0.94	0.76	0.53	0.37	0.19	0.23	0.13	0.14	0.11
Sub-Saharan Africa	**0.27**	**0.26**	**0.30**	**0.38**	**0.35**	**0.22**	**0.30**	**-0.04**	**-0.04**
(p-value)	0.18	0.19	0.09	0.03	0.05	0.20	0.07	0.83	0.83
South Asia	**0.38**	**0.26**	**0.28**	**0.17**	**0.06**	**0.03**	**-0.04**	**-0.35**	**-0.37**
(p-value)	0.45	0.19	0.16	0.38	0.74	0.89	0.86	0.50	0.47
Europe and Central Asia	**-0.96**	**0.28**	**0.13**	**-0.02**	**-0.16**	**-0.24**	**-0.32**	**0.11**	**0.04**
(p-value)	0.04	0.59	0.81	0.97	0.76	0.64	0.54	0.67	0.88
Latin America and Caribbean	**-0.22**	**-1.00**	**-0.98**	**-0.97**	**0.31**	**0.31**	**0.18**	**-0.35**	**-0.35**
(p-value)	0.36	0.00	0.02	0.03	0.20	0.20	0.48	0.12	0.13
Arab States	**-0.65**	**-0.29**	**-0.34**	**-0.38**	**-0.39**	**-0.38**	**-0.35**	**-0.83**	**-0.83**
(p-value)	0.02	0.22	0.14	0.10	0.09	0.10	0.14	0.00	0.00
East Asia and Pacific	**0.18**	**-0.80**	**-0.86**	**-0.73**	**-0.79**	**-0.79**	**-0.80**	**-0.23**	**-0.21**
(p-value)	0.59	0.00	0.00	0.01	0.00	0.00	0.00	0.50	0.54
Developed countries	**0.21**	**0.18**	**0.16**	**0.08**	**-0.15**	**-0.16**	**-0.13**	**0.39**	**0.40**
(p-value)	0.24	0.60	0.64	0.82	0.65	0.65	0.70	0.02	0.02

Note: Ecological balance is the difference between biocapacity and ecological footprint.

Table 10 shows a non-significant linear correlation between the ecological balance and HDI, for the world as a whole and for most the regions, when we consider the disaggregated analysis. There are a few exceptions in the regional analysis, but those are relatively weak, mostly for a few punctual years, and showing opposite signals (e.g., the correlation is positive for the 1990s in Sub-Saharan Africa, and in the latest years for the Developed countries; while negative for Latin America in the 1980s, for Arab States in 2006 and 2007). Only for East Asia and Pacific, the correlation has been strongly negative over most of the period of analysis, i.e., for the developing countries in this region, having a higher HDI seems to be very much associated with an ecological deficit.

Table 11 below reinforces the conclusion of a non-significant correlation between HDI and the ecological balance. However, and more interestingly, there seems to be a negative correlation with the health component of HDI and, specially, with the income component. In other words, richer countries seem to simultaneously have a smaller ecological balance.

Table 11. Correlation between Ecological balance and HDI and its components, 2007, world averages

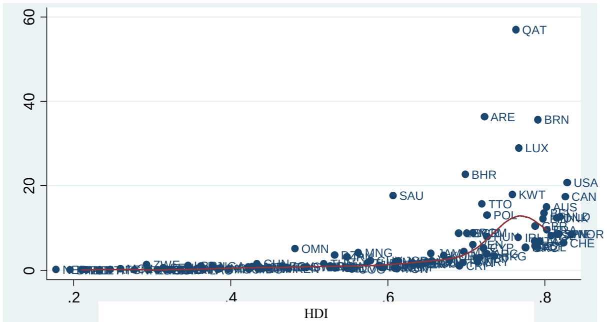
	Ecol Balance pc
HDI	**-0.140**
(p-value)	0.11
Health index in HDI	**-0.156**
(p-value)	0.08
Education index in HDI	**0.002**
(p-value)	0.98
Income index in HDI	**-0.208**
(p-value)	0.02

4.1.4 Carbon Dioxide emissions and HDI

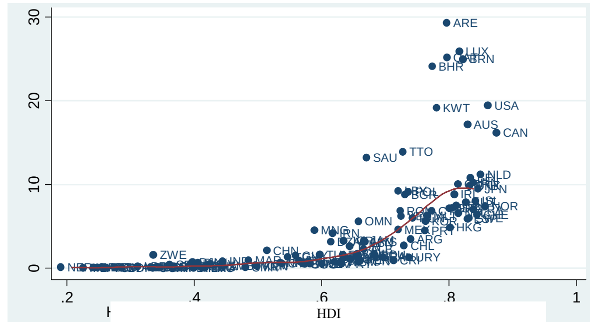
Given the high correlation between EF and CO_2 emissions, we expect that the relation between this last indicator and HDI would also be significantly positive. In fact, as shown by figure 11 and table 12 below, we confirm the general pattern that more developed countries (as measured by HDI) tend to have higher CO_2 per capita emissions. This applies both at world and regional level, with the exception of developed countries for whom no significant relation seems to exist. This puzzling finding deserves additional consideration in the next section of the paper.

Figure 11. Distribution of CO_2 pc emissions and HDI, in different (illustrative) years

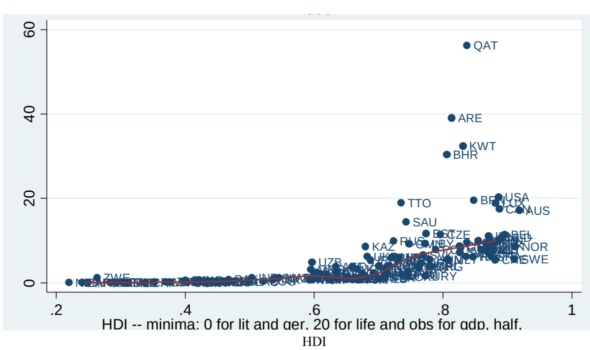
Panel A. 1980



Panel B. 1990



Panel C. 2000



Panel D. 2006

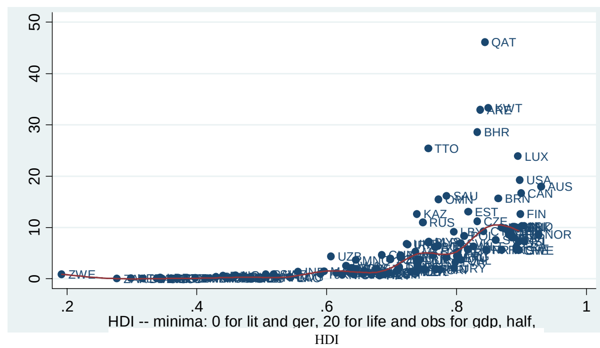


Figure 11 (visually similar to figure 10!) shows a positive and non-linear association between HDI and CO_2 per capita emissions.

When we study this same correlation, systematically over time (table 12), we confirm the positive and significant association between the two measures. However, there are a few exceptions worth noticing: for Latin America, in the last decade, and for developed countries, over all period of analysis, the correlation is non-significant.

Table 12. Correlation between CO_2 pc emissions and HDI, at world and regional level, over time

Corr(HDI, CO2 pc)	1975	1980	1985	1990	1995	2000	2005	2006
World	**0.47**	**0.54**	**0.60**	**0.65**	**0.55**	**0.55**	**0.57**	**0.58**
(p-value)	0	0	0	0	0	0	0	0
Sub-Saharan Africa	**0.47**	**0.44**	**0.63**	**0.61**	**0.63**	**0.70**	**0.70**	**0.71**
(p-value)	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00
South Asia	**0.93**	**0.94**	**0.93**	**0.91**	**0.89**	**0.86**	**0.89**	**0.90**
(p-value)	0.01	0.00	0.01	0.01	0.02	0.03	0.02	0.02
Europe and Central Asia	**0.89**	**0.88**	**0.93**	**0.95**	**0.58**	**0.45**	**0.44**	**0.43**
(p-value)	0.11	0.12	0.07	0.05	0.01	0.05	0.06	0.06
Latin America and Caribbean	**0.65**	**0.54**	**0.46**	**0.49**	**0.38**	**0.32**	**0.28**	**0.28**
(p-value)	0.00	0.01	0.04	0.02	0.09	0.16	0.23	0.21
Arab States	**0.62**	**0.68**	**0.74**	**0.76**	**0.70**	**0.69**	**0.69**	**0.70**
(p-value)	0.03	0.01	0.01	0.00	0.01	0.01	0.01	0.01
East Asia and Pacific	**0.43**	**0.40**	**0.35**	**0.42**	**0.51**	**0.59**	**0.66**	**0.66**
(p-value)	0.19	0.22	0.30	0.20	0.11	0.05	0.03	0.03
Developed countries	**-0.05**	**0.00**	**0.01**	**0.10**	**-0.05**	**-0.08**	**-0.09**	**-0.13**
(p-value)	0.78	0.98	0.96	0.57	0.77	0.64	0.62	0.46

Table 13 below considers HDI disaggregation in its components, for the world as a whole and the most recent year with data available. Again, we reinforce the overall message that being more developed is positively and significantly associated with having higher CO_2 per capita emissions.

Table 13.Correlation between CO_2 pc emissions and HDI and its components, 2006

	CO2 emissions pc
HDI	**0.576**
(p-value)	0.00
Health index in HDI	**0.478**
(p-value)	0.00
Education index in HDI	**0.407**
(p-value)	0.00
Income index in HDI	**0.689**
(p-value)	0.00

4.2 What can explain the (dis)connection between indicators of sustainability and human development?

As shown in the previous section, the relationship between HDI and several of the best known measures of sustainability is mixed (even contradictory!), depending on the selected sustainability indicator and the underlying concept of sustainability:

- There is an absence of a strong correlation between the adjusted net savings indicator of the World Bank and HDI, which is either non-significant or only slightly positive. The strongest correlation exists between Education expenditures (ANS component) and the Health and Education indices of HDI. This suggests that HDI seems to capture a process which is different from the wealth accumulation process as measured by ANS.
- There is a positive and significant correlation between HDI and EPI, meaning that more developed countries tend to have better environmental performance in terms of resource management and pollution control;
- There is a positive and significant association, though mostly non-linear, between HDI and both Ecological Footprint and CO_2 emissions. This suggests that as countries become more developed, they make higher pressure on environmental resources and, in particular, in the atmosphere. A puzzling result is the fact that this general conclusion does not seem to hold entirely for the most developed countries.

The specific case of the most developed countries is worth to explore in deeper future research. In this section, we address the general finding of higher development level being associated with higher pressure on atmosphere, namely with CO_2 emissions. In order to do it, we start by looking at the correlation between patterns of energy indicators and HDI over the last decades. Table 14 below presents the result.

Table 14. Correlation of HDI with energy indicators

Corr (HDI, .)	1975	1980	1985	1990	1995	2000	2005	2006	2007
CO2 intensity	**0.14**	**0.49**	**0.58**	**0.59**	**0.57**	**0.56**	**0.56**	**0.57**	
(p-value)	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Electric power consp pc	**0.63**	**0.64**	**0.63**	**0.65**	**0.67**	**0.66**	**0.65**	**0.64**	**0.62**
(p-value)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Electric power product pc	**0.62**	**0.63**	**0.62**	**0.62**	**0.64**	**0.63**	**0.64**	**0.63**	**0.61**
(p-value)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fossil Fuel energy (%share)	**0.75**	**0.74**	**0.70**	**0.67**	**0.66**	**0.65**	**0.65**	**0.65**	**0.64**
(p-value)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: Due to the lack of data for some of the energy indicators, by the beginning of 1970s, we present the correlations results only starting at 1975.

Carbon intensity, the amount of CO_2 emissions per unit of GDP generated, is a measure of (in)efficiency of the productive structure of the economy, in terms of environmental impact. Economies with “greener” (more efficient) technologies would be able to produce a certain level of GDP with less emissions. The consistently strong positive and significant correlation between carbon intensity and HDI over the previous decades, as presented in the table above, supports the conclusion that, on average, more developed countries have been producing their goods and services with average higher CO_2 emissions than developing countries.

A second main result of the previous table is the strong positive and significant correlation between HDI and electric power production and consumption, in per capita terms. This is an evidence that, on average, each person in a more developed country consumes more electricity power and also is associated with a higher production level than in a less developed country. As HDR2007/08 emphasized, power generation and electricity are among the main sources of CO_2 emissions in the world. Therefore, this correlation result shows that source of emissions is also associated with higher development levels, and in particular with income level.In fact, going a step further and studying the relation of these electricity power indicators with GDP levels, which has a direct link with the income dimension of HDI, it is easily to verify the close link between economic performance and energy consumption.

Table 15. Correlation bwteen GDP levels and electric power per capita consumption

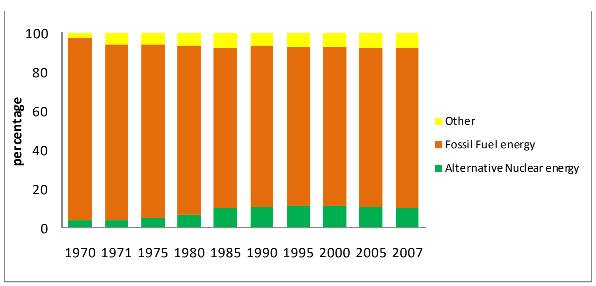
corr (GDP, .)	1975	1980	1985	1990	1995	2000	2005	2006
Electric power consumption pc	**0.41**	**0.54**	**0.71**	**0.76**	**0.81**	**0.83**	**0.85**	**0.83**
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

As shown by the results in table 15 above, that there has been a significant positive and increasing association of electric power per capita consumption and GDP level.

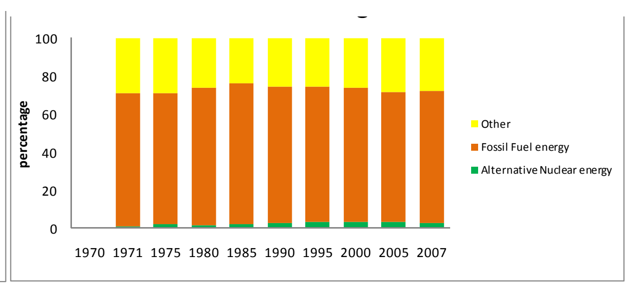
The reason why the use of more electric power and energy, in general, may have a negative impact on environment relies on the sources for that energy. In fact, the dominant source has been fossil fuels, the one with higher impact on CO2 emissions. This is true for the world as a whole, but when the analysis is broken by regional aggregates, it is particularly so for the developed countries, as shown by the several panels in the figure 12 below.

Figure 12. Trends on the Energy use per type of source, world and regional averages

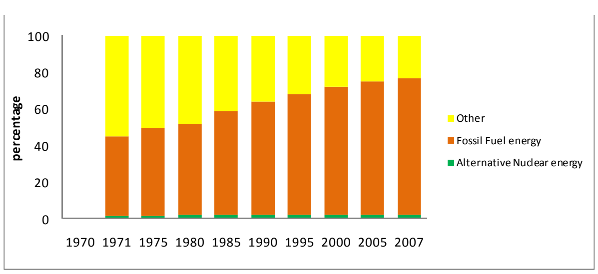
Panel A. World



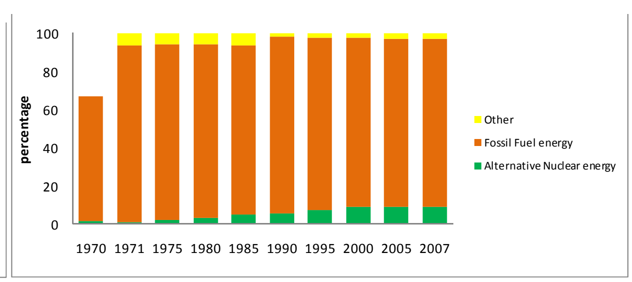
Panel B. Sub-Saharan Africa



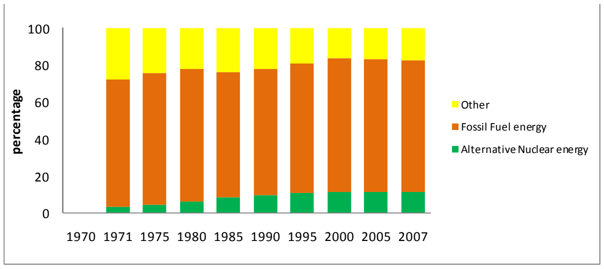
Panel C. South Asia



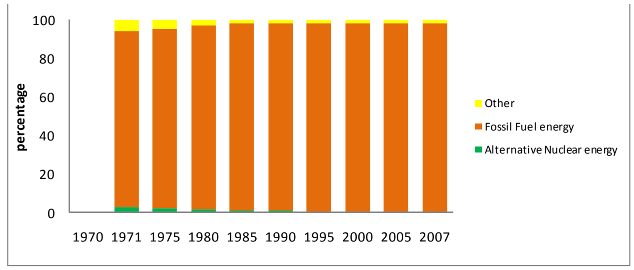
Panel D. Europe and Central Asia



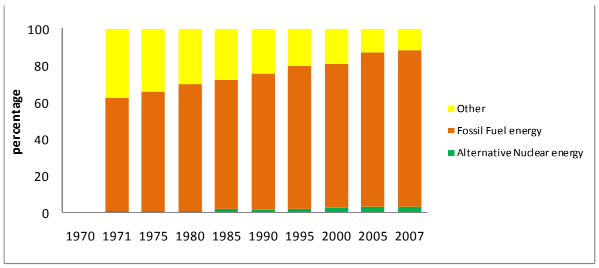
Panel E. Latin America and Caribbean



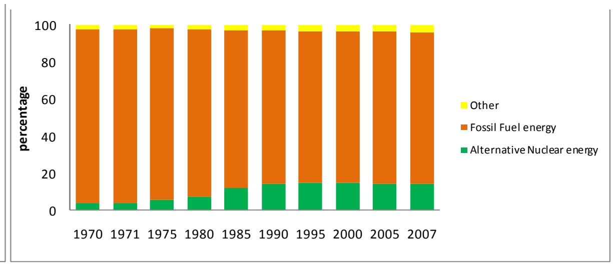
Panel F. Arab States



Panel G. East Asia and Pacific



Panel H. Developed countries



Note: Tables14B-21B in Annex B presents the values supporting these graphs.

The data analysis presented in this section is consistent with a simple message: over time, and particularly in the last decades development, there has been a close link between higher economic performance and energy consumption. However, higher use of energy has been mostly based in the use of fossil fuels, which have a huge toll in terms of CO_2 emissions and, therefore, on environmental resources.

5. Concluding Remarks

There are important synergies between human development and sustainability, but the conceptual question of how to integrate sustainability in the human development and capability approach, and how to measure and evaluate potential policy trade-offs is still not fully understood. In this paper, we try to advance the discussion and the search of more satisfactory answers for those challenges.

We use the basis of the sustainability and human development literature to show the possible advances in conceptualizing "sustainable human development". However, it remains a challenge for future research to better understand the inter-temporal aspects of human development. This is not an easy task, since human development relates to the possibilities a person has and it is, almost by definition, time and context specific. In other words, new conceptual research on how to understand "transfers" of human development over time is required.

The concept of sustainability has garnered importance over the last decades, following the publication of the Brundtland Report. Conceptual and empirical studies of the sustainability of consumption are common, and the resulting measurement exercises represent a clear connection between the theory on sustainability and the empirical possibilities given the data constraints. Nevertheless, the concept of sustainability of human development (or its sister approach, *capabilities*) is much less developed and to our knowledge, there have been very few attempts to establish a simple, transparent measure of sustainable human development.

Since sustainability is a dynamic concept, a choice rule needs to be assigned in order to prioritize different paths of human development. Three possibilities, at least, exits: the sum of discounted utilities, a minimax rule and stewardship of the earth. Additionally, a transformation between this norm and a clear, simple indicator is needed. Using as a starting point the adjusted net savings estimates produced by the World Bank, the results are mainly driven by the definition of adjusted net savings.

In terms of measurement, the debate must turn to indicators that are conceptually sound (thus avoiding the "kitchen sink" approach of amassing a large number of indicators into a catch-all number). In this sense, the adjusted net savings of the World Bank present a successful model – albeit with a different underlying theory. A successful measure of sustainable human development needs to reflect, at a minimum, how people's freedoms will change over time *given* the current paths of human development.

Our results show that current indicators of sustainability are limited in scope. Depending on the choice of an existing indicator of sustainability, one could almost conclude anything about the correlation between sustainability and human development. Truth is we do not know how to systematically assess the relationship. It has been long argued, and mostly accepted, that the carbon dioxide emissions, for instance, generated by economic production is unsustainable, and since income is part of human development and the HDI, part of the human development process is therefore unsustainable. But are countries in the upper ladder of human development better suited to sustain their development? Or are they trapped in an unsustainable lifestyle?

Future research thus should concentrate on responding these questions but it would need to do it sequentially, responding first how best to conceptualize sustainable human development and then moving on to the measurement agenda.

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Annex A - The data

The statistical analysis in this paper uses data from several sources, namely:

- the data on the HDI and its components comes from the HDRO database (2010), which covers 135 countries (90 percent of the world population) over the period 1970-2010. The indices used follow the hybrid concept, which uses the indicators of the HDI published in previous years (life expectancy; gross enrollment ratio for primary, secondary and tertiary education; literacy rate; and GDP per capita in PPP), but with a different functional form. The global HDR2010 presents detailed information on this methodology.[22]
- the Environmental Performance Index data comes from the Yale Center for Environmental Law & Policy at Yale University, and the Center for International Earth Science Information Network at Columbia University.[23] It refers to 162 countries, for the years of 2006, 2008, and 2010.
- the Ecological Footprint and the Biocapacity data comes from the Global Footprint Network. It refers to 187 countries, from 1961 till 2007;
- all the remaining data comes from the World development Indicators of the World Bank. The data refers to the period of 1970 until the most recent available for each indicator (which varies between 2006, 2007 or 2008), and for the sub-sample of countries that are also covered by the HDRO database.

Descriptive Statistics

Development Indicators	*Total nr obs non-missing*	*Mean*	*St Dev*	*Min*	*Max*
HDI value (hybrid version), 1970-2010	5535	0.62	0.19	0.12	0.94
Life index of HDI (hybrid version), 1970-2010	5535	0.71	0.17	0.10	1
Education index of HDI (hybrid version), 1970-2010	5535	0.64	0.21	0.04	1
Income index of HDI (hybrid version), 1970-2010	5535	0.53	0.20	0.01	1

[22] http://hdr.undp.org/en/reports/global/hdr2010/

[23] http://epi.yale.edu

Development Indicators (cont.)	***Total nr obs non-missing***	***Mean***	***St Dev***	***Min***	***Max***
Annual GDP, US$, constant prices 2008, PPP, 1970-2010	7436	10,295	13,365	163	106,770

Sustainability Indices	***Total nr obs non-missing***	***Mean***	***St Dev***	***Min***	***Max***
Adjusted net savings, excluding particulate emission damage (% of GNI), 1970-2008	4696	7.97	14.31	-162.65	189.17
Carbon dioxide damage (% of GNI) in ANS, 1970-2008	5991	0.59	0.77	-0.30	9.68
Consumption of fixed capital (% of GNI) in ANS, 1970-2008	5921	10.30	3.87	0.42	72.58
Education expenditure (% of GNI) in ANS, 1970-2008	6010	3.99	1.74	0.00	13.18
Energy depletion (% of GNI) in ANS, 1970-2008	5991	4.15	11.10	0.00	150.70
Mineral depletion (% of GNI) in ANS, 1970-2008	5991	0.52	1.92	0.00	34.28
Net forest depletion (% of GNI) in ANS, 1970-2008	5520	0.52	1.54	0.00	20.11
Net national savings (% of GNI) in ANS, 1970-2008	5064	9.39	13.66	-167.45	186.48
Environmental Performance Index, 2006, 2008, and 2010	442	64.64	14.22	25.70	95.5
Ecological Footprint pcapita, 1961-2007	7822	2.88	2.75	0.00	77.57
Biocapacity pcapita, 1961-2007	7822	5.61	12.49	0.00	154.55

Environmental Indicators	***Total nr obs non-missing***	***Mean***	***St Dev***	***Min***	***Max***
CO_2 emissions (kilo tonnes), total, 1960-2006	7630	97,753	439,083	-80.6	6,099,054
CO_2 emissions (metric tons), per capita, 1960-2006	7608	4.15	7.73	-0.24	105.74
CO_2 intensity (kg per kg of oil equivalent energy use), 1960-2006	4486	2.40	1.97	-1.19	53.71

Energy Indicators	***Total nr obs non-missing***	***Mean***	***St Dev***	***Min***	***Max***
Fossil fuel energy consumption (% of total),1960-2007	4770	69.37	29.62	1.64	103.55
Electric power consumption (kWh), 1960-2007	4754	81,700,000,000	301,000,000,000	11,000,000	4,110,000,000,000
Electricity production (kWh), 1970-2006	4770	88,500,000,000	320,000,000,000	0.00	4,320,000,000,000

Annex B – Data analysis

Table 1B. Trends on ANS world and regional averages weighted by GNI (% of GNI)

Year	World	nr obs	Sub-Saharan Africa	nr obs	South Asia	nr obs	Europe and Central Asia	nr obs	LAC	nr obs	Arab	nr obs	East Asia and Pacific	nr obs	Developed	nr obs
1970	17.29	59	8.28	13	8.35	4	9.99	1	12.10	11	10.51	2	13.78	5	18.03	23
1971	17.07	62	9.66	14	8.79	4	10.05	1	10.53	11	11.42	3	12.91	5	17.81	24
1975	13.64	71	9.38	19	5.89	5	11.22	1	11.91	13	14.46	5	15.08	4	14.16	24
1980	11.25	107	8.51	31	4.33	6	13.31	2	6.54	25	0.93	10	14.33	5	12.34	28
1985	10.47	118	5.50	35	7.01	6	11.88	3	4.16	26	0.25	10	14.16	10	11.28	28
1990	11.80	130	2.94	39	-3.12	6	10.88	10	7.33	25	-1.82	10	19.03	11	12.66	29
1995	11.78	145	6.87	38	12.91	7	10.06	18	7.68	26	0.77	11	26.31	11	11.54	34
2000	11.02	155	4.28	41	8.88	8	5.23	19	6.60	26	4.96	12	22.80	14	11.00	35
2005	10.24	156	1.94	41	17.92	8	4.33	19	8.27	26	7.49	12	30.70	14	8.82	36
2008	9.48	128	-5.63	31	22.26	6	5.25	19	6.24	22	4.57	10	30.81	11	7.03	29

Note: The world and regional values of ANS in this table are different from the ones published by the World Bank,[24] due to differences in the way of aggregating the country level data: World Bank calculates, first, the aggregate value for each component of ANS and then applies the ANS formula to obtain a world (or regional) figure. Here, we use the country level ANS values and calculate the world (or regional) averages, using as weight the GNI of each country. Due to differences in the number of countries for which ANS and each of its components are available, the two methodologies do not show the exact same numbers. However, using any of the two aggregating methodologies, it is clear the downward sloping trend over the years for the world and for all developing regions except South Asia and East Asia and Pacific.

24 http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/ENVIRONMENT/EXTDATASTA/0,,contentMDK:21061847~menuPK:2935516~pagePK:64168445~piPK:64168309~theSitePK:2875751~isCURL:Y,00.html

Table 2B. Trends of ANS and its components (% of GNI), **world** averages weighted by GNI

Year	ANS (exc PED)	nr obs	Net National Savings	nr obs	Education Expenditure	nr obs	Energy Depletion	nr obs	Mineral Depletion	nr obs	Net Forest Depletion	nr obs	CO2 damages	nr obs
1970	17.29	59	13.17	59	5.44	59	0.51	59	0.14	59	0.06	59	0.61	120
1971	17.07	62	12.94	62	5.56	62	0.69	62	0.10	62	0.06	62	0.60	120
1975	13.64	71	11.04	71	5.39	71	2.15	71	0.14	71	0.06	71	0.47	121
1980	11.25	107	10.70	107	5.00	107	3.82	107	0.20	107	0.06	107	0.41	133
1985	10.47	118	9.02	118	4.41	118	2.32	118	0.10	118	0.05	118	0.49	142
1990	11.80	130	9.49	130	4.37	130	1.46	130	0.11	130	0.05	130	0.45	166
1995	11.78	145	8.79	145	4.40	145	0.88	145	0.06	145	0.04	145	0.42	176
2000	11.02	155	8.90	155	4.31	155	1.65	155	0.06	155	0.03	155	0.44	179
2005	10.24	156	9.26	156	4.36	156	2.75	156	0.18	156	0.03	156	0.41	181
2008	9.48	128	10.27	128	4.23	128	4.05	128	0.53	128	0.03	128	0.39	168

Table 3B. Trends of ANS and its components (% of GNI), **Sub-Saharan Africa** averages weighted by GNI

Year	ANS (exc PED)	nr obs	Net National Savings	nr obs	Education Expenditure	nr obs	Energy Depletion	nr obs	Mineral Depletion	nr obs	Net Forest Depletion	nr obs	CO2 damages	nr obs
1970	8.28	13	7.79	13	4.10	13	0.51	13	1.44	13	0.78	13	0.65	34
1971	9.66	14	8.68	14	4.10	14	0.63	14	0.96	14	0.63	14	0.78	34
1975	9.38	19	8.52	19	4.20	19	1.18	19	0.99	19	0.50	19	0.57	33
1980	8.51	31	12.03	31	4.29	31	2.80	31	4.06	31	0.38	31	0.50	35
1985	5.50	35	8.21	35	4.30	35	3.99	35	1.42	35	0.55	35	1.05	38
1990	2.94	39	3.93	39	4.76	39	2.98	39	1.19	39	0.76	39	0.83	41
1995	6.87	38	5.52	38	5.25	38	1.52	38	0.46	38	1.02	38	0.89	42
2000	4.28	41	5.70	41	4.39	41	3.71	41	0.26	41	0.82	41	1.04	43
2005	1.94	41	6.62	41	4.56	41	7.13	41	0.82	41	0.56	41	0.74	44
2008	-5.63	31	6.68	31	4.31	31	13.32	31	1.84	31	0.76	31	0.60	43

Table 4B. Trends of ANS and its components (% of GNI), **South Asian** averages weighted by GNI

Year	ANS (exc PED)	nr obs	Net National Savings	nr obs	Education Expenditure	nr obs	Energy Depletion	nr obs	Mineral Depletion	nr obs	Net Forest Depletion	nr obs	CO2 damages	nr obs
1970	8.35	4	8.96	4	2.82	4	1.58	4	0.11	4	1.12	4	0.60	6
1971	8.79	4	9.90	4	2.98	4	2.25	4	0.11	4	1.10	4	0.61	6
1975	5.89	5	12.37	5	3.43	5	8.10	5	0.12	5	1.16	5	0.52	7
1980	4.33	6	7.44	6	3.72	6	4.96	6	0.11	6	1.25	6	0.50	8
1985	7.01	6	9.37	6	3.15	6	4.10	6	0.09	6	0.69	6	0.64	8
1990	-3.12	6	-0.26	6	3.42	6	4.18	6	0.14	6	1.02	6	0.95	8
1995	12.91	7	15.88	7	3.03	7	3.59	7	0.09	7	1.04	7	1.28	8
2000	8.88	8	12.37	8	3.87	8	5.07	8	0.14	8	0.74	8	1.41	8
2005	17.92	8	23.97	8	3.19	8	7.17	8	0.44	8	0.49	8	1.13	9
2008	22.26	6	26.85	6	2.97	6	4.64	6	1.12	6	0.77	6	1.01	8

Table 5B. Trends of ANS and its components (% of GNI), **Europe and Central Asia** averages weighted by GNI

Year	ANS (exc PED)	nr obs	Net National Savings	nr obs	Education Expenditure	nr obs	Energy Depletion	nr obs	Mineral Depletion	nr obs	Net Forest Depletion	nr obs	CO2 damages	nr obs
1970	9.99	1	8.70	1	1.86	1	0.10	1	0.13	1	0.00	1	0.35	1
1971	10.05	1	8.70	1	1.86	1	0.11	1	0.06	1	0.00	1	0.34	1
1975	11.22	1	9.88	1	1.86	1	0.26	1	0.03	1	0.00	1	0.23	1
1980	13.31	2	12.27	2	2.44	2	0.68	2	0.12	2	0.00	2	0.59	2
1985	11.88	3	11.52	3	2.22	3	0.68	3	0.12	3	0.02	3	1.03	3
1990	10.88	10	18.08	10	3.35	10	8.45	10	0.03	10	0.00	10	2.15	16
1995	10.06	18	14.68	18	3.65	18	6.06	18	0.17	18	0.02	18	2.04	21
2000	5.23	19	16.72	19	3.56	19	12.73	19	0.17	19	0.03	19	2.15	21
2005	4.33	19	15.92	19	3.79	19	13.91	19	0.37	19	0.02	19	1.10	21
2008	5.25	19	15.84	19	3.84	19	13.07	19	0.60	19	0.01	19	0.78	21

Table 6B. Trends of ANS and its components (% of GNI), **Latin America and Caribbean** averages weighted by GNI

Year	ANS (exc PED)	nr obs	Net National Savings	nr obs	Education Expenditure	nr obs	Energy Depletion	nr obs	Mineral Depletion	nr obs	Net Forest Depletion	nr obs	CO2 damages	nr obs
1970	12.10	11	12.13	11	3.01	11	2.14	11	0.21	11	0.07	11	0.49	25
1971	10.53	11	10.99	11	3.07	11	2.71	11	0.16	11	0.07	11	0.49	25
1975	11.91	13	13.03	13	3.38	13	3.62	13	0.47	13	0.03	13	0.38	25
1980	6.54	25	11.97	25	3.22	25	7.63	25	0.61	25	0.03	25	0.39	29
1985	4.16	26	8.39	26	2.98	26	6.16	26	0.50	26	0.02	26	0.54	29
1990	7.33	25	8.70	25	3.23	25	3.46	25	0.64	25	0.02	25	0.47	30
1995	7.68	26	6.11	26	4.14	26	1.83	26	0.34	26	0.02	26	0.37	30
2000	6.60	26	6.75	26	4.17	26	3.53	26	0.39	26	0.02	26	0.39	30
2005	8.27	26	11.26	26	4.55	26	6.13	26	1.02	26	0.02	26	0.37	30
2008	6.24	22	10.62	22	4.36	22	6.63	22	1.81	22	0.01	22	0.29	29

Table 7B. Trends of ANS and its components (% of GNI), **Arab States** averages weighted by GNI

Year	ANS (exc PED)	nr obs	Net National Savings	nr obs	Education Expenditure	nr obs	Energy Depletion	nr obs	Mineral Depletion	nr obs	Net Forest Depletion	nr obs	CO2 damages	nr obs
1970	10.51	2	7.73	2	3.35	2	0.03	2	0.20	2	0.00	2	0.76	12
1971	11.42	3	22.78	3	3.08	3	13.42	3	0.06	3	0.00	3	0.82	12
1975	14.46	5	42.54	5	2.79	5	29.93	5	0.56	5	0.00	5	0.41	12
1980	0.93	10	34.93	10	3.25	10	36.73	10	0.10	10	0.05	10	0.36	12
1985	0.25	10	10.87	10	4.94	10	14.86	10	0.07	10	0.05	10	0.57	12
1990	-1.82	10	10.43	10	4.75	10	16.12	10	0.04	10	0.10	10	0.71	14
1995	0.77	11	10.49	11	4.74	11	13.55	11	0.01	11	0.07	11	0.89	14
2000	4.96	12	18.94	12	5.39	12	18.37	12	0.03	12	0.05	12	0.91	14
2005	7.49	12	29.88	12	5.40	12	26.89	12	0.03	12	0.04	12	0.82	15
2008	4.57	10	29.94	10	5.18	10	29.11	10	0.80	10	0.03	10	0.60	13

Table 8B. Trends of ANS and its components (% of GNI), **East Asia and Pacific** averages weighted by GNI

Year	ANS (exc PED)	nr obs	Net National Savings	nr obs	Education Expenditure	nr obs	Energy Depletion	nr obs	Mineral Depletion	nr obs	Net Forest Depletion	nr obs	CO2 damages	nr obs
1970	13.78	5	12.81	5	3.23	5	0.03	5	0.72	5	1.02	5	1.17	9
1971	12.91	5	12.10	5	3.07	5	0.12	5	0.56	5	1.02	5	1.30	9
1975	15.08	4	13.70	4	3.68	4	0.88	4	0.54	4	0.49	4	1.23	9
1980	14.33	5	16.99	5	2.96	5	3.08	5	1.18	5	0.98	5	1.52	11
1985	14.16	10	21.53	10	2.17	10	7.17	10	0.28	10	0.22	10	1.84	14
1990	19.03	11	25.36	11	2.00	11	5.52	11	0.41	11	0.33	11	2.07	16
1995	26.31	11	28.87	11	2.14	11	2.56	11	0.24	11	0.22	11	1.66	18
2000	22.80	14	25.88	14	2.15	14	3.40	14	0.23	14	0.14	14	1.47	20
2005	30.70	14	35.90	14	2.12	14	5.19	14	0.61	14	0.04	14	1.48	20
2008	30.81	11	38.65	11	1.93	11	7.03	11	1.58	11	0.02	11	1.13	19

Table 9B. Trends of ANS and its components (% of GNI), **Developed countries'** averages weighted by GNI

Year	ANS (exc PED)	nr obs	Net National Savings	nr obs	Education Expenditure	nr obs	Energy Depletion	nr obs	Mineral Depletion	nr obs	Net Forest Depletion	nr obs	CO2 damages	nr obs
1970	18.03	23	13.49	23	5.68	23	0.43	23	0.12	23	0.01	23	0.59	33
1971	17.81	24	13.17	24	5.82	24	0.52	24	0.08	24	0.00	24	0.57	33
1975	14.16	24	10.35	24	5.73	24	1.37	24	0.10	24	0.00	24	0.44	34
1980	12.34	28	9.66	28	5.34	28	2.21	28	0.08	28	0.00	28	0.36	36
1985	11.28	28	8.32	28	4.69	28	1.30	28	0.04	28	0.00	28	0.39	38
1990	12.66	29	8.88	29	4.59	29	0.48	29	0.05	29	0.01	29	0.28	41
1995	11.54	34	7.57	34	4.58	34	0.31	34	0.03	34	0.00	34	0.27	43
2000	11.00	35	7.48	35	4.47	35	0.64	35	0.02	35	0.00	35	0.29	43
2005	8.82	36	5.54	36	4.58	36	0.99	36	0.06	36	0.00	36	0.25	42
2008	7.03	29	4.42	29	4.60	29	1.56	29	0.18	29	0.00	29	0.23	35

Table 10B. Trends on *Environmental Performance Index*, world and regional averages

	World	nr obs	Sub-Saharan Africa	nr obs	South Asia	nr obs	Europe and Central Asia	nr obs	Latin America and Caribbean	nr obs	Arab States	nr obs	East Asia and Pacific	nr obs	Developed countries	nr obs
2006	59.98	132	49.12	36	48.02	6	70.00	15	72.77	22	57.96	11	57.95	11	80.09	31
2008	68.86	148	57.72	37	61.09	6	77.41	21	81.04	24	68.08	14	66.91	13	83.29	33
2010	54.33	161	45.76	40	48.92	8	59.61	22	65.12	25	56.99	15	50.34	14	68.44	37

Table 11B. Trends on *Ecological balance*, world and regional per capita averages

Year	World	nr obs	Sub-Saharan Africa	nr obs	South Asia	nr obs	Europe and Central Asia	nr obs	LAC	nr obs	Arab States	nr obs	East Asia and Pacific	nr obs	Developed	nr obs
1970	0.67	146	2.09	40	-0.18	8	-0.21	4	8.27	27	0.60	16	0.30	17	-0.98	34
1971	0.59	148	1.98	40	-0.18	9	-0.22	4	7.97	27	0.51	16	0.28	17	-1.12	35
1975	0.42	148	1.68	40	-0.22	9	-0.48	4	6.91	27	0.22	16	0.17	17	-1.23	35
1980	0.19	148	1.22	40	-0.22	9	-0.60	4	5.92	27	-0.23	16	0.04	17	-1.63	35
1985	0.12	148	0.96	40	-0.27	9	-0.67	4	5.52	27	-0.57	16	-0.02	17	-1.63	35
1990	-0.12	149	0.76	40	-0.30	9	-0.82	4	4.73	27	-0.41	16	-0.21	18	-2.17	35
1995	-0.27	171	0.44	42	-0.35	9	0.19	20	4.07	27	-0.60	16	-0.47	18	-2.34	39
2000	-0.38	171	0.37	42	-0.40	9	0.34	20	3.57	27	-0.72	16	-0.52	18	-2.63	39
2005	-0.56	172	0.22	42	-0.44	9	0.13	20	3.27	27	-0.92	17	-0.78	18	-2.97	39
2007	-0.67	174	0.13	42	-0.49	9	-0.18	22	3.04	27	-1.05	17	-0.95	18	-2.97	39

Table 12B. Trends on CO_2 **total** emissions, world and regional aggregates (kilo tones)

Year	World	nr obs	Sub-Saharan Africa	nr obs	South Asia	nr obs	Europe and Central Asia	nr obs	LAC	nr obs	Arab States	nr obs	East Asia and Pacific	nr obs	Developed	nr obs
1970	10.78	152	0.22	41	0.32	7	0.23	4	0.50	31	0.19	15	0.97	18	8.35	36
1971	11.19	153	0.25	41	0.34	8	0.24	4	0.53	31	0.21	15	1.12	18	8.49	36
1975	12.22	155	0.29	42	0.42	9	0.31	4	0.65	31	0.26	15	1.42	18	8.88	36
1980	14.09	155	0.37	42	0.51	9	0.36	4	0.90	31	0.45	15	1.85	18	9.66	36
1985	14.60	156	0.47	42	0.72	9	0.41	4	0.89	32	0.50	15	2.40	18	9.22	36
1990	16.57	158	0.46	43	1.01	9	0.39	4	1.06	32	0.61	15	3.04	19	10.00	36
1995	22.57	183	0.48	44	1.32	9	2.84	21	1.19	32	0.76	16	4.14	20	11.83	41
2000	23.76	184	0.55	44	1.67	9	2.57	21	1.31	32	0.94	17	4.21	20	12.50	41
2005	27.66	185	0.64	44	2.05	9	2.77	21	1.43	32	1.15	17	6.70	21	12.91	41
2006	28.34	185	0.63	44	2.18	9	2.87	21	1.50	32	1.16	17	7.18	21	12.81	41

Table 13B. Trends on CO_2 **per capita** emissions, world and regional averages (metric tones)

Year	World	nr obs	Sub-Saharan Africa	nr obs	South Asia	nr obs	Europe and Central Asia	nr obs	LAC	nr obs	Arab States	nr obs	East Asia and Pacific	nr obs	Developed	nr obs
1970	3.36	147	0.81	39	0.47	7	3.39	4	1.79	29	1.62	15	0.87	17	11.92	36
1971	3.40	148	0.91	39	0.49	8	3.54	4	1.83	29	1.76	15	0.98	17	11.98	36
1975	3.34	150	0.96	40	0.51	9	4.15	4	2.04	29	1.89	15	1.13	17	12.02	36
1980	3.51	151	1.06	41	0.55	9	4.46	4	2.53	29	2.79	15	1.36	17	12.53	36
1985	3.32	151	1.17	41	0.68	9	4.74	4	2.25	29	2.72	15	1.63	17	11.54	36
1990	3.43	153	0.99	42	0.86	9	4.27	4	2.43	29	2.71	16	1.91	17	12.13	36
1995	3.99	176	0.91	43	1.02	9	7.19	21	2.50	29	3.00	16	2.42	17	12.36	41
2000	3.93	177	0.88	43	1.18	9	6.49	21	2.56	29	3.33	17	2.33	17	12.68	41
2005	4.30	178	0.91	43	1.33	9	6.98	21	2.62	29	3.70	17	3.55	18	12.70	41
2006	4.35	178	0.88	43	1.39	9	7.22	21	2.71	29	3.67	17	3.78	18	12.52	41

Table 14B-21B. Trends on the Energy use per type of source, world and regionalaverages

World, % energy use

	Altern Nuclear	nr obs	Ffuel	nr obs	Other
1970	3.76	26	93.94	26	2.30
1971	3.72	109	90.31	109	5.97
1975	5.41	109	88.61	109	5.98
1980	6.76	109	86.70	109	6.53
1985	10.59	111	81.94	111	7.46
1990	10.85	131	82.50	131	6.66
1995	11.70	133	81.07	133	7.23
2000	11.61	133	81.13	133	7.26
2005	10.83	133	81.79	133	7.38
2007	10.30	133	82.12	133	7.59

Sub-Saharan Africa, % energy use

	Alternative & Nuclear	nr obs	Ffuel	nr obs	Other
1970	.	0	.	0	.
1971	0.96	18	70.06	18	28.99
1975	2.00	18	69.15	18	28.85
1980	1.79	18	71.84	18	26.37
1985	2.45	19	73.81	19	23.74
1990	3.02	19	71.71	19	25.27
1995	3.16	20	71.38	20	25.46
2000	3.43	20	70.75	20	25.82
2005	3.15	20	68.72	20	28.12
2007	3.04	20	68.86	20	28.10

South Asia, % energy use

	Alternative & Nuclear	nr obs	Ffuel	nr obs	Other
1970	.	0	.	0	.
1971	1.71	6	43.31	6	54.98
1975	1.89	6	47.49	6	50.62
1980	2.18	6	49.94	6	47.88
1985	2.10	6	56.78	6	41.13
1990	2.26	6	61.75	6	35.99
1995	2.11	6	66.18	6	31.71
2000	2.06	6	69.90	6	28.03
2005	2.39	6	72.40	6	25.21
2007	2.42	6	74.20	6	23.38

Europe and Central Asia, % energy use

	Alternative & Nuclear	nr obs	Ffuel	nr obs	Other
1970	1.56	1	65.65	1	.
1971	1.05	4	92.53	4	6.42
1975	2.41	4	91.47	4	6.12
1980	3.57	4	90.49	4	5.94
1985	4.97	4	88.60	4	6.43
1990	5.48	22	92.73	22	1.79
1995	7.70	22	90.09	22	2.20
2000	9.05	22	88.49	22	2.46
2005	9.34	22	87.82	22	2.84
2007	9.09	22	88.20	22	2.71

	LAC, % energy use				
	Alternative & Nuclear	nr obs	Ffuel	nr obs	Other
1970	.	0	.	0	.
1971	3.37	22	68.68	22	27.95
1975	4.58	22	71.09	22	24.32
1980	6.19	22	72.04	22	21.77
1985	8.59	22	67.53	22	23.88
1990	9.86	22	68.37	22	21.78
1995	10.94	22	70.08	22	18.98
2000	11.30	22	72.54	22	16.17
2005	11.39	22	71.55	22	17.06
2007	11.37	22	70.97	22	17.66

	Arab States, % energy use				
	Alternative & Nuclear	nr obs	Ffuel	nr obs	Other
1970	.	0	.	0	.
1971	2.63	14	91.45	14	5.92
1975	2.17	14	92.94	14	4.89
1980	1.67	14	95.41	14	2.92
1985	0.83	14	97.09	14	2.08
1990	0.87	14	97.29	14	1.84
1995	0.68	14	97.59	14	1.74
2000	0.70	14	97.43	14	1.87
2005	0.61	14	97.75	14	1.64
2007	0.65	14	97.64	14	1.71

	East Asia and Pacific, % energy use				
	Alternative & Nuclear	nr obs	Ffuel	nr obs	Other
1970	.	0	.	0	.
1971	0.99	8	61.35	8	37.65
1975	1.06	8	64.73	8	34.20
1980	1.38	8	68.23	8	30.39
1985	2.03	9	69.94	9	28.04
1990	1.93	9	73.54	9	24.52
1995	2.26	10	77.14	10	20.60
2000	2.79	10	77.82	10	19.38
2005	3.25	10	83.66	10	13.09
2007	3.40	10	85.13	10	11.47

	Developed countries, % energy use				
	Alternative & Nuclear	nr obs	Ffuel	nr obs	Other
1970	3.77	25	94.00	25	2.23
1971	4.01	37	93.83	37	2.16
1975	5.94	37	92.02	37	2.04
1980	7.56	37	89.93	37	2.51
1985	12.32	37	84.51	37	3.17
1990	14.12	39	82.75	39	3.13
1995	15.03	39	81.62	39	3.35
2000	14.83	39	81.79	39	3.38
2005	14.57	39	81.73	39	3.70
2007	14.32	39	81.56	39	4.12