Sustainability: A mantra or a moral choice? An ecological and economic approach

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"Bringing the laws of economics into conformity with biophysical laws, no matter how trivially true the latter, is no trivial task!"
(Herman Daly, 2007, p.3)

Growth and Unsustainability

THERE IS a widespread notion that to meet the basic needs of the population requires accelerated economic growth. The insistence on this belief has increased even further since the onset of the global economic crisis in 2008 – which would have arisen precisely from a growth bubble. On the matter, for example, the prudent and respected British newspaper *The Economist* states in its Bagehot column (2011, p.62): "Without growth, a lot of the coalition's reforms [of the UK government] will not work. That would be tragic." But how to grow? What growth rate is acceptable in an economy? And what is the optimal size of the macroeconomic scale vis-à-vis what nature can bear? Well, this is of course assuming that one is talking about a situation in which the economy (economic activity) is seen as a subsystem of the ecosystem. It is from this perspective – which ecological economics postulates and which is not part of the dominant view of mainstream economists - that the concept of ecological sustainability is defined. At this point it would be appropriate to mention the irreversible environmental impact of economic growth on nature's resources and sinks. Or, in other words, to think about the size of the footprint left on nature by human activities in the light of the potential use offered by the latter. A topic parallel to the issue and which has been developed by political ecology is identifying who will appropriate the benefits of growth and who will pay for the destruction of environmental resources (Martínez Alier, 2007).

At the same time, the notion of sustainability seems to have become a kind of mantra of the present days. It is repeated almost to exhaustion in all types of discourses related to economic development (and growth). As noted by Leonar-

do Boff (2011), "It is fashionable these days to talk of sustainability." But the sustainability that one has in mind does not entail a clear commitment to what it represents in essence. Worse: it is associated with an economic model that aims exclusively to achieve unlimited material progress, assuming - often due to an oversimplification of reasoning (Solow, 1974, p.11, for example) – that they do not compromise nature's resource base. It's as if nothing, no human action would alter the biophysical reality of the ecosystem in which the economic system is embedded. Hence the universal adherence to the discourse or rhetoric of sustainable development (obviously, nobody advocates unsustainable development). However, argues Boff (2011), "sustainability as a noun demands a change in the relationship with nature, with life and with the Earth. This change begins with a different vision of reality."

In that regard, I was approached in 2009 by a university student from Rio Grande do Norte, Jessicleide Dantas, who asked me: "How do you see sustainable development?" I answered: "Actually, there can only be a development that is sustainable. Because if it is unsustainable, it will end. It is not therefore development, but something like a spasm of society. Sustainable development is that which lasts. It is supported first of all by nature, the ecosystem on which we depend for everything. Thus, to sustain itself, it has to take into account the rules and limits of nature, without neglecting human well-being, cultural values, the full realization of citizenship." I explained further: "Ultimately, it is about minimizing the use of nature and obtaining maximum social well-being." It is about achieving maximum well-being with minimum consumption, according to the Buddhist philosophy (Schumacher, 1973 chap.4).

Jessicleide Dantas argued: "As we know, in the eternal quest for economic growth humanity has neglected the balance society needs to grow sustainably. Will we one day have a society shaped like that? Which experiences could point us in that direction?" I explained: "There has never been an 'eternal quest for economic growth'. In fact, civilization is 5,000 years old, and growth started only in the last 250 years.[1] Today one thinks and acts as if economic growth was the rule for Humanity. It never has been. Growth necessarily means depletion of resources, destruction of something in the environment. There is not a single example of a developed society that is ecologically sustainable, simply because developed societies (Great Britain, United States, Germany, Japan, etc.) reached this level less than 250 years ago. Sustainable, we could say, were the indigenous societies in Brazil that had been around for 12,000 years when the Portuguese arrived here." Who can guarantee that in 2250 American society will be what it is today? Or Chinese society, for that matter? Nobody can guarantee that; not even what it will be like in twenty years' time! Now, 12,000?

It would then be appropriate to ask whether it is possible to balance unlimited economic growth ("the spectacle of growth", as the then future president of Brazil, Luiz Inácio Lula da Silva, foolishly – in my opinion – used to say in

2002. Or, as in Jessicleide's question "to grow sustainably") with an environment that does not deteriorate or collapse. From the economic-ecological perspective, the answer is *no*. Growth always entails 'less environment'. In fact, the planet (the global ecosystem) does not grow; if the economy grows - and it is part of the planet - obviously 'less environment' will remain. The more people on Earth, the more economic production; the more goods produced, the less nature. In other words, as the economists say - though oddly in this case they do not recognize it - there is an environmental "opportunity cost".

Development, the economy and nature

What can actually happen is an environmentally sustainable *development*. The issue is that development (which means *change*, *evolution*, *progress*) is not growth (which is understood as *increase* or *expansion*). The topic is very appropriately addressed by Daly (1990), to whom growth is a quantitative increase in the physical scale, while development is a qualitative improvement or unfolding of potentialities. Amartya Sen (1999) defines development as "the expansion of freedoms": more citizenship. Something similar to what the United Nations Development Program (UNDP) said in the Human Development Report 1990: Human development is a process of enlarging people's choices. "The most critical of these choices are to live a long and healthy life, to be educated and to have access to resources needed for a decent standard of living" (Draper III, 1990, p.1). This does not irrevocably imply material growth; but, of course, can include it. Sen, winner of the 1998 Nobel Prize in Economics, and the UNDP director (William Draper III) were clear. The same can be said of Celso Furtado (1967, p.19), to whom development is the "persistent increase in the productivity of the labor factor and its repercussions in the organization of production and in the way the social product is used and distributed." In this sense, development means more than simple economic growth and capital accumulation because, besides representing an increase in productive capacity, it also implies radiating progress to the bulk of society. Thus, "the concept of development comprises the idea of growth, but exceeds it" (Furtado, 1967, p.102).

From the standpoint of nature, it makes no sense to talk about *growing* – note: growing – sustainably. This possibility is simply not part of the natural processes. In fact, in the ecosystem continuous growth processes - which are always exponential - inevitably end in disaster. They stop, wreaking havoc. Like the steam that accumulated in the reactors of the Fukushima Dai-ichi plant, in Japan, and tragically caused them to explod in March 2011. Or like in the (classical) example offered by engineer Carlos Gabaglia Penna (2008), a professor of the Pontifical Catholic University in Rio who died in 2011:

> Imagine a lake that contains a species of algae that, by covering the entire surface of the water body will choke the life out of it. The algae community doubles in size every day. Say that in 30 days the algae will have taken the entire lake. On day 21 the algae cover only 0.2% of the surface (less than 0.0001% in day 10).

> In just another eight days half the lake will have been covered and the next day the lake will have been completely taken over by the algae, depleting the water's available oxygen.

Develop sustainably, on the contrary, is possible. This is what happens to human beings and all living organisms: they grow; they stop growing; and they never cease to develop (sustainably) until the inevitable end. Sen (1999) and Furtado (1967), with their reasoning, enable admitting the condition of sustainability - although they were not addressing it when they wrote their books.

The reality of development evinces an almost unsolvable clash between aggressive economic promotion and defenseless natural heritage. If ecology was taken really seriously as an instrument for the lasting well-being of society, many actions in the economic sphere would be in full danger. It just happens that nature provides the scale of what society can do. Meanwhile, in the economic model that governs the formulation of economic policies and development actions around the world, the resources of the ecosystem are not addressed as a constraint; they simply do not show up in the calculations. Just look, for example, at what economists use in their normal reasoning under the name of "production function". It is the relationship between the quantities of productive factors (capital, *K*, and labor, *L* - the only ones that are actually included in the economic calculus) used in carrying out the economic activity and the corresponding amount of product obtained (Υ). This function can be understood as a recipe. So Y = f (K, L). And it applies to the economy as a whole, to sectors of activities, to groups of firms. It excludes altogether the nature input (or natural resources, *N*). The rationale of the neoclassical theory of economic growth – which is associated with names such as Robert Solow (1957), winner of the 1987 Nobel Prize in Economics, and which prevails in the analysis - accepts a production function of the "constant returns to scale" type, the so-called Cobb-Douglas function (named after its proponents) being the one that actually appears in the models. This function can be expressed mathematically as follows:

$$Y = \lambda K^{\alpha} L^{\beta.}$$

The constant (positive) λ is the technology factor. The exponents α and β are the respective shares of *K* and *L* in the output (Υ), and $\alpha+\beta = 1$. This is macroeconomics (and microeconomics) 101. An extremely simplified view of the real world. What it means is that with *x* capital units and *y* labor units, one can obtain *z* product units. In other words, it is as if a person (labor factor *L*) could bake a Devil's Food Cake (product Υ) using only (capital factor *K*) his/her kitchen, a wooden spoon and a bowl with nothing in it (*N* is excluded)! How would that be possible without flour, eggs, salt, sugar, butter, chocolate (the natural resources) that make the Devil's Food cake so good? Weird. In the words of Nicholas Georgescu-Roegen, excluding *N* from the production function means ignoring the difference between the real world and the Garden of Eden, as noted by Daly (2007, p.134) and Veiga (2005, p.129).

The situation that arises without *N* gives the economic system the consistency of an *isolated* system – i.e., with no surroundings to relate to. It is independent of nature; nothing constrains it. Assuming that the economy does not have the condition of an isolated system (where would electricity come from?), a change in perspective should occur, showing the macroeconomy as an open subsystem, embedded in the finite natural ecosystem, namely the environment (see Cavalcanti, 2010). In thermodynamics – the chapter of physics that studies energy transformation - the only concrete case of an isolated system is the universe. The other systems are either *closed* (like the Earth, which exchanges energy but not matter with the outside system) or *open* (like the human body, a forest or a river in whicht here is exchange both of matter and energy with an outside system). Thinking of the economy as an isolated system is the same as imagining a body with just the circulatory system (in which what will be circulating is money, i.e., a medium of exchange, a symbol which in itself is worth nothing from the standpoint of meeting human needs). In it, there would not be the digestive tract - which, by processing the resources (the ingredients of the cake), is what gives sustenance to the body.

With such an abstraction, the reality of economic reasoning allows one to imagine the world without an ecosystem. Or to consider the latter as an externality. Yes, the environment exists; but it is on another plane (galaxy, planet). If anything, one thinks of the ecosystem as a kind of trinket or bauble, the bells and whistles of the economy; as a pantry or a storeroom from where one takes whatever one wants and also where one disposes of waste (Cavalcanti, 2010). That is why in the prevailing economic model there is no concern for the environment, natural resources, pollution and depletion. But the hard fact is that the economic process needs to be seen within the system – i.e., nature - that involves it. That's what a recent study by the management consulting firm McKinsey (Dobbs, 2011) surprisingly proposes. Thus, the ecosystem cannot be thought of as an externality. Its condition is that of the greater whole to which the economy must inevitably report. That is, with such a vision the economic system comes to be thought of as having a digestive tract: in it, matter and energy (of a high quality or low entropy, the true wealth of the world) are swallowed up, become artifacts and finally end up as (high entropy) waste. That is, what we ultimately produce is waste - not lasting wealth. A new car is pre-scrap. The supposed wealth (contained in Y) that it represents is but a transition between the gifts of nature and the final waste that seeps into nature. In this transition, "wealth" provides the enjoyment of life, well-being, an immaterial flow - just like a glass of good wine, when swallowed, ceases to exist (the tongue clicks, but the wine will not come back; it has turned into waste).

Extraction, production, discarding

The economy in its physical dimensions - those that account for food, clothing, housing etc. for humans - is made of things, people, machines, buil-

dings, artifacts of all kinds. All this is what physicists call "dissipative structures", which are maintained against the forces of disorder, decline or entropy by a throughput or metabolic flow of the environment. This understanding has environmental and economic implications such as those arising, for example, from the principle of mass and energy balance that prevails in nature: the quantity of matter and energy in and out of a process is exactly the same. Or those relating to the importance of energy in the structure and dynamics of the co-evolution of ecological and economic systems. Or those arising from the application to the economy of the foundations of far-from-equilibrium living systems (Prigogine, 1969 and White, 1999). A closed physical system – e.g. nature - should meet the mass conservation condition. Thus, with economic growth the extraction of environmental resources necessarily increases simultaneously with the amount of waste deposited in the lithosphere: more negative externalities are always being generated. The process digs a hole and gathers degraded matter. That is, it produces an entropic metabolic flow (Daly, 2007, p.9), as shown in Figure 1. This greatly simplifies reality. But it clearly exposes the character of the process that takes place in the modern economic system. A linear process, of the extract-produce-discard type. In it, recycling is minimal (zero, in fact, in the case of non-renewable resources such as oil and iron ore). It is understood as what Georgescu-Roegen (1971, p.19) meant when he wrote that "'bigger and better' washing machines, automobiles, and superjets must lead to 'bigger and better' pollution."

Figure 1 shows that what the modern economy ultimately does is to dig a perennial hole that becomes deeper and deeper (extraction of low entropy matter and energy). Once the throughput process is completed, the resources will have inevitably turned into waste - neutral matter, debris, dust, ashes, scrap, dissipated energy – which are virtually useless (high entropy matter and energy). They pile up forming a dump yard, also perennial, that won't stop growing. Thus, resource extraction and waste disposal leave as a legacy an ever bigger ecological footprint. An illustration of the process is offered - casually, in fact - by a book that has other purposes: it addresses unusual means of transport (McPhee, 2006 p.185s). The book describes a coal train in the United States that every eight hours, 365 days a year, carries 115 tons of ore from a mine in the Powder River Basin, state of Wyoming, to the Scherer thermoelectric plant (the largest coal-fired plant in the world), located in the State of Georgia, 2,880 km away. The convoy consists of 133 buckets and is 2.5 km long. It leaves full and comes back empty. As a result, potholes are incessantly dug on the ground in Wyoming, leaving an eternal and growing void. In Georgia, the amount of debris (also perennial) continues to grow. According to the First Law of Thermodynamics, the mass of the hole in Wyoming is the same as the mass of the heap in Georgia. And what is all that for? Well, to provide the population on the east coast of the country with a safe (sustainable?) supply of electricity, thus

ensuring the wasteful standard of living of their American way of life. The stark fact presented here does not concern exhaustible resources such as fossil fuels alone. Renewable resources face the same threat, to the extent that extraction rates exceed replacement rates. That is what happened to the (fresh) water of the Aral Sea in Uzbekistan-Kazakhstan, causing the water body there to be reduced to half its original size - a terrible environmental disaster. It happens to fishing grounds that are exploited above their regenerative capacity – as is the case of the Canadian cod in Newfoundland, the Mediterranean blue fin tuna, and lobster in Pernambuco (Brazil).

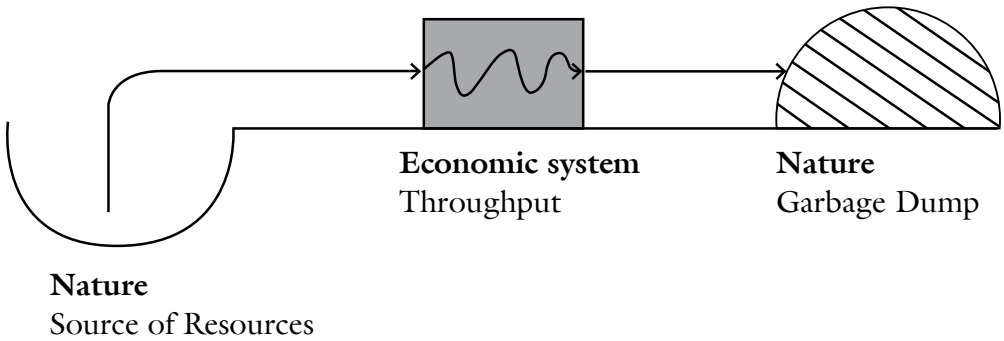

Figure 1 – Resource extraction (nature as source) and waste disposal (nature as sink) by the economic system.

In Brazil, what has been done to the Atlantic Forest (Dean, 1996) since the year 1500 is a clear example of how renewable resources - flora and fauna species, and ultimately biodiversity – become non-renewable resources. It is obvious, therefore, that a growing economy (and even one that does not grow but uses non-renewable resources) leads to continuous change and somehow disrupts the environment. The fact is not addressed in conventional economic analysis because the market does not record this change appropriately (information on resource depletion and degradation, which are externalities of the economic process, are not reflected in market prices). But that does not mean they do not exist. It is precisely to tackle the problem that WWF (2010) produces its biennial Living Planet Report, a document in which the ecological footprint is compared to biocapacity. Developed in collaboration with the Zoological Society of London and the Global Footprint Network, the document uses the Living Planet Index to assess the health of nearly 8,000 populations of more than 2,500 species. This global index shows a 30 percent decrease since 1970. The decline is more pronounced in the tropics, where a fall of 60 percent has been recorded in less than 40 years. That is, the extraction-production-discarding rule heads in the opposite direction of sustainability. It's like the fishing that compromises the reproduction of stocks (cf. Veiga, 2010, p.11).

Scales of sustainability

Strictly speaking, an industrial-based economy will be more often than not on the verge of unsustainability - if it is not already fully in it. This is indeed the position of Georgescu-Roegen - "an inconvenient position", as defined by José Eli da Veiga (2005, p.121) – to whom growth, even zero growth, always represents depletion "and therefore shortens the life expectancy of the human species. "This conclusion is presented with scientific rigor, although not always with literary poise, in the book *The Entropy law and the economic process* (Georgescu-Roegen, 1971). In his book, Georgescu-Roegen (1971, p.303), speaking for example of the mechanization of agriculture, states that contrary to what some of its enthusiasts believe and propagate, it has a price. The advantages of mechanization can be obtained "only by eating more quickly into the 'capital' of low entropy with which our planet is endowed." And he concludes: «That, indeed, is the price we have paid and still pay not only for the mechanization of agriculture, but for every instance of technological progress». Further in the argument he offers a view to be reflected upon (Georgescu-Roegen, 1971, p.304): "If we stampede over the details, we can say that every baby born now means one human life less in the future. But also every Cadillac produced at any time means fewer lives in the future. "

Then, would there be a way out? For someone who like me has read Georgescu-Roegen (1971) – the foundation of ecological-economic thought - with admiration, attended his classes, had an office next to his at Vanderbilt University in the United States in 1970, translated a lecture he delivered in Recife in July 1973 and accepted his solid argument, the answer should be "No". However, I believe that the challenge can be met. Situations of more or less (un)sustainability that nurture the idea of finding reasonable solutions to the quest for progress of humanity can actually be conceived. One of them, which has come up recently, is "prosperity without growth" (Jackson, 2009). British economist Tim Jackson insists that despite the finding that questioning the dogma of growth is deemed to be the act of lunatics, idealists and revolutionaries, growth must be questioned. The problem is that the idea of a non-growing economy may be anathema to the economist; just like the idea of a continually growing economy is anathema to the ecologist (Jackson, 2009, p.4).

In Jackson's (2009, p.4-5) elaborate view, what really matters is the fact that prosperity does not mean GDP (and economic) growth but rather building a more just and better society; it means achieving a good life and the opposite of adversity and grief. Thinking of prosperity without growth, in turn, is also an imposition of nature's limits, a topic that Jackson recognizes as being controversial. However, among other things, the severity of climate change and the "oil peak" require reflecting upon the unsustainability of a model the outcome of which could be the collapse of civilization. Incidentally, on this topic Celso Furtado expressed similar concern three and a half decades before, by stating

that development understood as the "idea that *poor people* can someday enjoy the ways of life of today's *rich people*" is simply unrealistic. The reasons for that would be of an ecological nature: nature's system would not bear the destruction implicit in the proposal (Furtado, 1974, p.75). That is why, according to Furtado (1995, p.76), "Generalizing [industrial civilization and the way of life engendered by it] to all humanity, which is the promise of the so-called economic development, would accelerate a planetary catastrophe which, anyway, seems inevitable unless we change the course of this civilization."

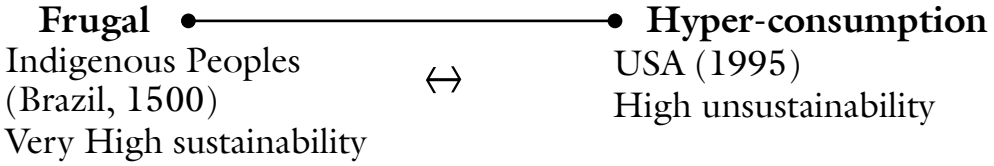

Figure 2 – Levels of sustainability of the lifestyles of Brazilian indigenous peoples and American Citizens

Another solution would be to look for different, real situations in terms of sustainability in the experience of different societies, to see what they suggest. Thinking about it, in the early 1990s it occurred to me to compare lifestyles (Cavalcanti, 1995). When measuring my ecological footprint and comparing it, for example, with that of a woman who worked as a housekeeper in my ranch (Josefa Severina, a small landowner who lives in the rural area of the municipality of Gravatá, in Pernambuco, and worked for me between 1976-2011), the unsustainability of my lifestyle and the great sustainability of hers become evident. Doing the same thing with a ranch neighbor (Severina de Dezinho, a 65 year-old woman who had nine children and only had electricity at home in 2005 and describes herself as the happiest person in the world), I wondered about the cost-benefit ratio of the process that enables my well-being and that of those women, especially the second one. Back to the issue of clash of lifestyles, what I did in the early 1990s was to compare the Brazilian indigenous peoples and American citizens (Cavalcanti, 1995, 1997). The criteria I used as reference were energy consumption, economic characteristics, demographics, culture and worldview in both groups. For that purpose I used the available material, especially that produced by economists, anthropologists and ethno-scientists. The summary result is shown in Figure 2.

In other words, it is possible to build a scale of sustainability whose minimum value (i.e., maximum unsustainability) corresponds to the American Way of Life of the present time and whose maximum (or minimum unsustainability) would be among the indigenous peoples who lived in Brazil in 1500 and today still live in isolated groups in the Amazon. The American paradigm corresponds to unconscious and exaggerated consumption, i.e., to waste. The paradigm of Brazilian indigenous peoples corresponds to frugality, sobriety, thermodynamic

parsimony (Cavalcanti, 1995, p. 171). These would be two extremes of the planet's reality.

Based on Figure 2, it is possible to classify societies according to their presumed level of sustainability. This is what we see in Figure 3, in which the distance between the points that correspond to different groups has no cardinal significance. It is only an order of magnitude of actual cases of sustainability. That is what WWF (2010) does with greater accuracy - using numerical values based on rigorous methods. It is worth remembering that the first WWF Living Planet Report dates back to 1998. A rough idea of my comparison (from 1992, published in 1995) was to suggest that there are possibilities or solutions for meeting the challenge of how to promote the art of life, prosperity, the well--being of people while being aware that the economy will always be "eating" into nature, as suggested by Georgescu-Roegen (1971, p.303). And doing that requires respecting limits. Limits that are bio-physical from the standpoint of natural resources, which is what matters when discussing sustainability. But without neglecting ethical limits - because not always what is ecologically possible is morally desirable – such as catching baby lobsters, an activity that is prohibited in Brazil, or disrespecting the catch-quotas for the noble Atlantic and the Mediterranean blue fin tuna set by the International Commission for the Conservation of Atlantic Tuna (ICCAT). Sustainability, in short, means maintaining the life support system; it means behaving in tune with the laws of nature (Cavalcanti, 1995, p.165).

Figure 3 – Levels of (un)sustainability of countries

The limits of the economy

Material growth (quantitative increase of artifacts) is undoubtedly a considerable necessity for many genuine human development situations, especially at certain stages of society's evolution (the obvious case of the Democratic Republic of Congo, Liberia or Haiti, for example, in 2011), in which the composition of GDP needs to include a large share of food, clothing and housing. By applying the instruments of conventional economic theory to these situations, it can be said that the additional benefits ("marginal" benefits in the words of economists) of growth, in this case largely outweigh the additional costs of the process. As we know, microeconomics, which deals with how to compare the costs and benefits of activities in the economic system, determines when the expansion of activities should stop. By expanding, an activity displaces other activities. It generates "opportunity costs." The rule is to stop when the new costs match the new benefits obtained (marginal cost = marginal benefit). That is, it is

not worth spending an additional dollar on pizza, when that same dollar ensures greater pleasure when spent on something else. In a finite biosphere, increasing the production of *essential* goods, with their corresponding additional ecological costs, is justified by the large additional social benefits these goods will bring to those who need them. As we move on to less essential goods, however, the comparison weakens. Marginal benefits tend to drop (a law of economics), while marginal costs (another law) rise. Thus, when production increases, the trend is that at some point decreasing marginal benefits will be the same as increasing marginal costs. Thereafter, new costs will outweigh additional benefits. Growth will have become *uneconomical* (Daly, 2007, p.17). It no longer makes sense.

A case of poor growth is when production processes based on fossil fuels or that cause irreversible damage to rare natural systems are used: these are extremely high costs for returns that can be frustrating. An illustration of that is the project for the Suape Port, in Pernambuco, whose flagship is an oil refinery. The project envisages the construction of a huge fuel oil power plant. Most of the current economic policies in the world are largely based on the underlying assumption of endless material growth, whatever that may be. However, it makes no sense to accept increases in the economy at any cost. In Brazil, as a result of the top priority assigned to the Growth Acceleration Program (PAC), the idea is to grow in every possible way. And simply growing is not enough; the pace of expansion needs to be accelerated. Severe environmental changes, such as seen in the Amazon, resulting from the construction of hydroelectric plants (Belo Monte is a good example) stem therefrom. If there are "barriers to growth" created by the imagination, then environmental protection laws, e.g. the Forest Code, need to be changed so that these "barriers" are overcome. When Michel Camdessus (1990) was managing director of the International Monetary Fund (IMF), he offered a rationale for that: "Our primary objective is growth. In my view, there is no longer any ambiguity about this. It is toward growth that our programs and their conditionality are aimed." Privileged economic actors say the same. One of them is Paul Sankey, an analyst with Deutsche Bank, who stated shortly before the outbreak of the global crisis of the past three years: "The market wants growth, growth, growth".[3] More than that, one actually often speaks of "sustainable growth"[4] - which strictly is a biophysical impossibility, given that there is nothing in nature that grows continuously in a healthy way (Georgescu-Roegen, 1971, Pearce, 1988; Penna, 2008.)

It is further alleged, as part of conventional wisdom, that poverty is fought through more growth. Just like a rising tide that raises all boats, the benefits of growth will be ultimately poured out upon the poor. However, experience shows the misleading content of this assumption.[5] More and more growth may be something desirable; however, what level of growth will be possible or acceptable? This is a problem that leads to the determination of the optimal sustainable scale by the ecosystem. It is usually assumed that problems of depletion of sour-

ces of energy and resources, pollution and other limits to growth can be eliminated by technological progress. There are situations - such as the severity of the water problem in the world today, for example, or climate change and the loss of biological diversity - for which technological progress ends up being irrelevant. Indeed, how to increase the stock of water on the planet, how to make global temperature stop rising or neutralize the effects of species extinction? The great British economist Barbara Ward (1976), among other authors, says that the needs of many poor people cannot be met by the free play of the market, since the market is sensitive to purchasing power, and a market system totally devoid of control by institutions of justice, sharing and solidarity makes the strong stronger and the weak weaker. Thence, one cannot expect that left to itself the market will be able to generate sustainability from the human standpoint, ensuring the poor of today long-term benefits; or to preserve ecosystem productivity for the benefit of distant future generations. After all, it is environmental, technological and economic limits that impose on us the conscious search for sustainability, the search for a safe future, without any threat of collapse.

Conclusion

Sustainable (responsible) development is construed as a socio-economic process in which: (i) the use of matter and energy (depletion) is minimized, thus containing the advance of the hole show in Figure 1; (ii) environmental impacts (waste disposal), i.e., the formation of the mound shown in Figure 1, are minimized; (iii) well-being or social utility is maximized, with no threat of setbacks; and (iv) a situation of maximum efficiency in the use of resources is achieved – similarly to the operating model of nature, i.e., as seen in Figure 3, a movement towards the maximum sustainability of the frugal lifestyle of the Brazilian indigenous peoples, fleeing the profligacy of the U.S. model, of the elites, of the super-rich. In fact, which of these models can be reproduced without severe environmental stress? As explained by the venerable development economist Paul Streeten (1995), the meaning of sustainability that concerns the human species - because it is their survival that is at stake, not the planet's – lies in the maintenance, replacement and growth of capital assets, both physical and human; in the maintenance of the physical environmental conditions of the constituents of well-being; in the increased resilience of terrestrial systems, so that they can adjust to shocks and crises; and in avoiding transferring debts of any character, whether ecological or financial to future generations. Doing the opposite of that is the same as promoting unsustainability.

Changes in the economic system are unavoidable as a way of adapting to the restrictions the economic process faces and can no longer ignore. These changes can be conscious (transition to a new era in tune with nature's limits) or abrupt (chaotic responses to changes in life-support systems). At this point it is worth asking what one wants to sustain: standards of living (well-being) or the means that ensure human fulfillment? As the single source of all things, nature

(through the entropic metabolic flow that provides throughput) must come first. The challenge is to find the optimal scale of the economy that ensures its sustainability by the ecosystem. This optimal scale is the sustainable scale. It corresponds to the maximum economy compatible with the availability of natural resources (air, water, soil, minerals, photosynthesis, etc.). Certainly, not just any scale will do. Just like it is possible to determine (a) how many passengers can travel safely on an Airbus 320; (b) what would be the optimal size of a school class; (c) how many people can live comfortably in a two-bedroom apartment; (d) how many people would fit in a city like Recife without causing excessive stress on the environment; (e) how many spectators can be seated in the Maracanã stadium.

In addition, the size of the economy depends on the time scale used. How long can an economy grow at 8 percent a year? Brazil in 2010, for example, had an economy of 1.8 trillion dollars; 8 percent a year would mean 8.4 trillion in 2020. Is that possible? And if so, until when? It is essential to know to what temporal perspective the concept of sustainable development should refer. To the immediate perspective? To a long-term perspective or to one centuries or millennia from now? We should not forget that the Mayan civilization, which merits to be mentioned, lasted 2,900 years. And that our modern industrial civilization has been around for only 250 years, while the Australian aborigines are 60,000 years old. The case is clear, but the options are open. It is impossible to go back to the life of Brazilian indigenous peoples. At least this would not be a conscious choice for today's society. But if imposed by ecological reasons, it is not unthinkable. Maybe it would do us good to reflect on a thought by Henry Thoreau (1906):

> This world is a place of business… If a man walks in the woods for love of them half of each day, he is in danger of being regarded as a loafer. But if he spends his days as a speculator, shearing off those woods and making the earth bald before her time, he is deemed an industrious and enterprising citizen.

It is up to society to determine the kind of person that is worth valuing – in other words, a moral choice

Tao Farm☯, December 10, 2011.

Notes

1 Data provided by Keith Sill (2008) show a nearly zero growth in per capita income in the world from the year 1 AD to 1750.

2 Nauru is a tiny islan d country in the Pacific; a phosphate mountain until 1915, the place has been transformed into massive craters, with no future at all. A complete disaster (see McDaniel & Gowdy, 2000).

3 *Newsweek* magazine, 12.5.2008, p.5.

4 As in Bagehot' comment (2011, p.62) on British government initiatives (adjustment

of public finances), emphasizing the purpose of "putting Great Britain on a path to sustainable growth."

5 In Brazil, the number of people without access to basic sanitation (situation that illustrates a scenario of extreme poverty) in 2010 was much higher than the entire population of the country in 1940 (the year I was born). In the United States between 1979 and 2007 - years of good growth in the U.S. economy, as it is known - while the average income of the 1 percent richest households grew 275 percent, the income of the poorest 10 percent "increased" 20 percent (*The Economist*, Oct. 29, 2011, p. 10).

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Abstract – What is the optimum scale of the economy compatible with nature? This question asks for consideration of the economy as a subsystem of the ecosystem. Ecological economics adopts that perspective, thus enabling the concept of environmental sustainability to be established. This implies that the environmental impact of growth on the source and sink functions of nature have to be contained within limits. The usual notion of sustainability, however, seems to have been converted into a kind of today's mantra, without serious obligations. Changes in the economic system are unavoidable as a means of adaptation to the restrictions facing the economic process. This requires knowing what is to be sustained and at which time scale. It is up to society to choose the change to be made: a moral choice.

Keywords: Sustainability, Optimum scale of the economy, Ecological limits, Extraction-production-discarding model.

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