Sustainable development: an ecological economics perspective

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Introduction

THIS PAPER aims to provide a definition of sustainable development from an ecological economics perspective. Since the term emerged in the 1970s under the name of eco-development, its most accurate definition has been the object of controversy (Veiga, 2005). To be sustainable, development must be economically sustainable (or efficient), socially desirable (or inclusive) and ecologically prudent (or balanced). The first two criteria were present in the debate on economic development started in the post-war period. The third is new. The terms "sustained economic growth" and "exclusionary economic growth" opposed the neoclassical mainstream current to the heterodox, Marxist and structuralist currents. To the first, sustained economic growth[1] was open as a possibility to all countries, being a necessary and sufficient condition for social inclusion. To the second, on the contrary, economic growth and its benefits were for the few, the core capitalist countries. Marxists and structuralists disagreed among themselves, however, about the causes of the fact. Nonetheless, they have all rejected the idea of environmental limits to growth as proposed by the Club of Rome.

The environmental criterion proposed by eco-developmentalists was acceptable to these currents, but the way they integrated it to the other criteria put them in a unique position in this debate. The goal of the second section of this paper is to analyze this trajectory of formulation and evolution of the concept of eco-development. Due to their assumptions and propositions, eco-developmentalists have taken a unique position vis-à-vis other currents under debate: they shared the rejections of the idea of zero growth; but differentiated themselves from each of them: in relation to the mainstream, because of their concern for potentially important environmental losses and poverty and income concentration; in relation to Marxism and structuralism, for assuming that the situation of poor countries resulted from predominantly endogenous factors.

The emergence of the global warming issue in the 1990s had a major impact on the debate about sustainable development in two fundamental aspects:

the approach to environmental risk and, again, the issue of trade-off between economic growth and the environment. Regarding the first aspect, the notion of prudence gives way to the most appropriate and accurate concept of Precaution, which has been raised to the condition of principle and was formally adopted at the Rio 92 Conference. The issue of ecosystem uncertainty in the case of global warming and its mitigation based on the Precautionary Principle (as proposed by the Kyoto Protocol) highlights the second aspect mentioned, since the rapid reduction of emissions is costly. Although eco-developmentalists did not deny the existence of some sort of "trade-off" between economic growth and the environment, the assumption was that this would be negligible provided that the set of proposed policies was adopted.

The concept of sustainable development in its most recent disguise of *green economy* reflects this problem in that it incorporates the need for adopting sustainability parameters while taking into account the environmental risk. Regarding the alleged "trade-off" between economic growth and the environment, its inexistence is reaffirmed, but reinforcing especially the arguments that justify this assumption based on expectations of advances in the generation of "triple winner" technologies: in social, economic and environment terms.

The third section of the paper presents the theoretical foundations that justify the position of the mainstream rejection of the conclusions of the Club of Rome report and of optimism about the ability to overcome only relative environmental limits to economic growth. This optimism stems from two assumptions: there are almost no limits to increased efficiency in the use of natural resources, and these can be largely replaced by capital. The environmental problem is seen primarily as a market failure due to the nature of natural resources such as air and water as public goods, thus generating a negative externality problem.

In this sense, the most efficient environmental policy is one that creates the conditions for economic agents to "internalize" the costs of the degradation they cause. State action is necessary only to correct this market failure, either through privatization or the pricing of natural resources. Once these failures have been resolved to ensure the correct economic signals of the relative scarcity of these environmental services, the dynamic of intertemporal allocation of resources based on cost-benefit assessments would tend to be processed efficiently, with no problems such as uncertainty and risk of irreversible losses. It must be said however, that not everyone in this current has accepted these logical conclusions based on the assumptions made, considering that there are many situations in which one should opt for the preservation of a given ecosystem due to its importance and irreplaceability.

In the fourth and fifth sections the paper elaborates on the argument for defining sustainable development from an ecological economics perspective. In the fourth section, initially the criticism of environmental economics

assumptions enables developing a concept of ecological sustainability that does not exist in the various definitions of sustainable development. It is not possible to increase indefinitely the efficient use of natural resources (second law of thermodynamics), and capital is essentially complementary to natural resources, which are represented especially by complex ecosystems that are vital for human survival. Therefore, the production of materials/energy cannot be indefinitely increased, and this will require the end of economic growth at some point, to prevent the carrying capacity of the planet – which science in unable to accurately estimate - from being exceeded.

From these assumptions, the central issue for ecological economics is how to get the economy to work while accepting the existence of these limits. Two action plans need to be considered: (1) one concerns specific policies for each type of environmental problem to be tackled; (2) the other is related to the stabilization of the system's expansion at a sustainable level - zero growth. Regarding the first action plan, in the case of ecological economics, reversing the rationale behind the decision of environmental economics would suffice: the amount of natural resources to be used - *scale* - must be previously defined based on ecological sustainability parameters. Setting limits to the use of natural resources raises the problem of their *distribution* among the various actors, which should be based on the criterion of justice. Finally, the market will be responsible for the efficient *allocation* of investments within the framework of these ecological and social constraints.

As for the second action plan, which is the topic of the fifth and final section, the paper briefly examines the two problems to be addressed for achieving zero growth: (a) stopping economic growth without generating a crisis; (b) consumer expectations in consumer societies. The technical solution to the first problem is especially the formulation of macroeconomic policies, an environmental macroeconomics. Specifically, it entails facing, for example, the issue of employment, inequality and incentive to technological innovation.

The legitimacy for implementing these policies depends on the solution to the second problem, the one about consumer expectations that legitimates economic growth policies. The acceptance by the population of consumption constraints for the benefit of the populations of other countries and/or of a distant future necessarily implies a certain amount of altruism. However, this necessary altruism that legitimizes zero growth policies can be enhanced by the growing realization that the current level of material comfort is more than enough, and that continuing growth efforts will produce more harm than good. A definition of sustainable development is therefore proposed.

The concept of sustainable development

The concept of *sustainable development* emerged under the name of eco-*development*[2] in the 1970s. It resulted from the effort to find a third alternative path to those that put developmentalists on the one side and advocates of zero

growth on the other. For the latter, called "zeroists" or (pejoratively) "neo-Malthusians", environmental limits would lead to catastrophes if economic growth was not stopped.

The controversy that put developmentalists against "zeroists" began with the publication of the report prepared by the Meadows couple, from MIT, under the auspices of the Club of Rome, on environmental limits to economic growth (Meadows et al., 1972)[3], whose conclusion was that economic growth needed to be stopped to prevent the depletion of natural resources and pollution from causing a sharp drop in living standards. The first United Nations Conference on Environment held in Stockholm in 1972 was the stage of this polarization that tended to generate deadlocks. This conclusion came at a time of strong global economic growth driven by the recovery from the post-war chaos ("The Glorious Thirty") and the rise of some emerging nations such as the "Asian Tigers" and of Brazil as the country of the "economic miracle". In turn, the vast majority of countries remained poor, with problems to start a process of sustained economic growth.

Until then the great controversy about economic development put on the one side those who saw the scenario of global inequality as a problem of historical stages in the process of economic growth, i.e., each country would be able, at a given time, to start a trajectory of sustained economic growth, which was seen as a necessary and sufficient condition for social development.[4] The difficulties that many countries faced in order to meet the conditions necessary to take off towards the process of sustained economic growth resulted primarily from *endogenous factors* (Rostow, 1960). On the other side were those who saw both international inequality and national inequality (concentrated income distribution in poor countries) as a result of some form of perverse articulation between rich and poor countries for the benefit of the first and of a minority, a small elite, in the latter. In other words, inequality stemmed primarily from *exogenous factors* related to the form of unfavorable inclusion of poor countries in the international division of labor[5]

Initially, all currents rejected the conclusions of the Club of Rome report.[6] To mainstream economists firstly because there were theoretical reasons (which will be discussed in the next section) to reject the idea that natural resources could represent an absolute limit to economic growth; and secondly because of the socioeconomic and political[7] consequences of zero growth for both poor and rich countries. To the representatives of the second current there were no theoretical reasons to justify defending the lack of environmental limits to economic growth. The problem was also in the socio-economic implications of this idea, but related to the perpetuation of exclusion in favor of central capitalist countries.[8]

The first UN reactions following the Stockholm Conference, with the support of eco-developmentalists, were not only to defend the need for economic

growth in poor countries, but also to consider poverty itself as one of the root causes of environmental problems in those countries. According to the Cocoyok Declaration (1974),[9] the population boom would be the result of the lack of all types of resources, which in turn would lead this population to overuse the land, water and other natural resources. The responsibility of industrialized countries to the problems of underdevelopment would lie in over-consumption. They would have to reduce their consumption levels and disproportionate participation in the pollution of the biosphere. The positions taken in Cocoyok were consolidated in the Dag-Hammarskjöld Report (1975),[10] which goes further to pinpoint the responsibilities of industrialized countries resulting from the legacy of colonialism. The colonial system would have concentrated the land suitable for agriculture in the hands of a social minority and European settlers. Consequently, large masses of the original population were expelled and marginalized, and forced to use less suitable land.[11]

The conciliatory proposition of eco-developmentalists is based on a normative concept of what development can and should be: it is possible to maintain efficient (sustainable) economic growth in the long term alongside improved social conditions (by distributing income) while respecting the environment. However, efficient economic growth is seen as a necessary but not sufficient condition for improving human welfare: the desired income distribution (the primary indicator of social inclusion) does not automatically result from economic growth, which can be socially exclusionary; specific public policies designed to prevent growth from benefiting only a minority are necessary; likewise, the ecological balance can be adversely affected by economic growth and limit it in the long run without the help of ecologically prudent policies that encourage the increase of eco-efficiency and reduce the risk of potentially important environmental losses.

In the case of poor countries, this set of policies would provide an opportunity for them to start a process of sustained economic growth, distributing income and avoiding repeating the trajectory of environmental impacts of developed countries. More than an opportunity, these policies would be the very condition for a development based chiefly on the endogenous forces of those countries ("self reliance").

Because of their assumptions and propositions, eco-developmentalists have taken a unique position in relation to other currents under debate: they share with all of them the rejection of the zero growth idea, but differentiate themselves from each of them: in relation to the mainstream for its concern about potentially important environmental losses and poverty and income concentration; in relation to Marxism and structuralism, because they assumed that the situation of poor countries resulted from essentially endogenous factors, although they also pointed to the need for developed countries to show solidarity in the struggle to overcome international inequality - either by increasing

foreign aid or by correcting business and financial mechanisms that are unfavorable to developing countries (see Sachs, 1981, 1986).

At the beginning of the following decade, UNEP organized the Nairobi Conference in 1982, when the decision was made to create a World Commission on Environment and Development under the leadership of the Prime Minister of Norway, Gro Harlem Brundtland. The results of the effort were made public in 1987, in a document entitled *Our Common Future, a*lso known as the Brundtland Report (1991). Similarly to eco-developmentalists, the authors of the report considered that the environmental risk of economic growth should be taken seriously, a concern that was expressed in the motto defining what should be understood as sustainable development:[12] "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable development can be achieved through a set of policies capable of simultaneously guaranteeing the increase in national income and access to basic social rights (economic security, access to health and education) and reducing the impact of increased production and consumption on the environment. Thereafter, the term "sustainable development" has replaced almost completely the term "eco-development", while expressing the same normative concept.

The second UN Conference on the environment took place in Rio de Janeiro, Brazil, the same year in which an update of the first Club of Rome report was published ratifying the key conclusions of the original document. Interestingly, twenty years after the first conference, it had become clearer that technical progress - the magic wand of optimistic developmentalists - had been much more efficient in addressing the issue of the environment as (a) a provider of raw materials than in confronting the issue of the environment as (b) a provider of ecosystem services: (a) the prices of raw materials had fallen, t*hanks to technical progress* in the exploitation of natural resources, in the replacement of expensive inputs for cheaper ones, and in the (ecological) efficiency of their use; (b) however, pollution and the degradation of ecosystems had increased *despite technical progress.*

This second fact (b) is reflected in the updated report of the Club of Rome, whose main highlight is the destruction of ecosystems and its implications in the carrying capacity of the planet, to the extent that ecosystems as a whole provide the main ecosystem service, i.e., the ability to absorb and recycle the waste generated by human activities. The risk of depletion of non-renewable raw materials, especially oil, pales before this. In any event, the conclusion of the analysis remains the same: economic growth needs to be stopped.[13]

Another important fact to note in the socioeconomic context of that time was the realization - taking Brazil was an iconic case - that economic growth by itself could be highly exclusionary. High income concentrations could persist despite years of strong economic growth, because of structural problems that

could only be solved through more active State intervention. These facts have contributed to strengthen the position of advocates of the concept of sustainable development: there is a risk of important environmental losses, and economic growth can be socially exclusionary; the solution is a set of public policies that remove structural obstacles to the dynamic redistribution of income and address environmental problems with caution and ecological efficiency (technical progress).

The emergence of the global warming issue in the 1990s, however, ultimately brougth the debate to a new level in relation to two key aspects: (a) the assessment of environmental risk; (b) the "trade-off" between economic growth and the environment. Regarding the first aspect, the notion of prudence gives way to the most appropriate and accurate concept of Precaution, raised to the condition of principle - formally adopted at the Rio 92 Conference. Prudence applies to situations of risk in which the distribution of probabilities is known. Precaution applies when there is uncertainty. In the first case, safety procedures can be defined with probable margins of precision, thus enabling maintaining a given course of action. In the second case there is only one safety procedure: stopping or reducing the course of action in order to buy time for the acquisition of new knowledge that reduces or eliminates uncertainty (Hourcade, 1997).

In the case of global warming and its confrontation based on the Precautionary Principle (as proposed by the Kyoto Protocol), the issue of ecosystem uncertainty highlights the second aspect, since the rapid reduction of emissions is costly. Although eco-developmentalists have not denied the existence of some sort of "trade-off" between economic growth and the environment, the assumption was that this trade-off would be negligible provided that the set of proposed policies was adopted. Policies that supposedly addressed the risk of environmental losses in a proper way, based on prudence. Actually this "trade--off" has become the main reason for results to have fallen short of what was expected in the successive conferences on the environment after Rio-92.

The difficulties in implementing the Kyoto Protocol[14] have reinforced the position - based on the work of William Nordhaus[15] – of the advocates of smooth, low cost induction of change in the energy matrix (decarbonization) through moderate fees on fossil fuels, which minimizes or ignores the uncertainty about the possibility of potentially catastrophic, irreversible losses. In turn, the reports of the Intergovernmental Panel on Climate Change (IPCC) have reinforced the arguments of environmentalists in favor of stronger action to reduce emissions. The Stern Review (2006) represented something of an effort to respond to the recurring deadlock: by agreeing with environmentalists (and ecological economists), it accepts upfront the need to identify a sustainable scale (it considers a maximum temperature rise of 2°C). Stern criticizes the gradualism of Nordhaus, considering the risk of important environmental losses if the temperature rises above that limit. Once a limit has been established - which represents a scale of

use of natural resources – it will be then necessary to seek a cost-effective solution. His decision rule is that of environmental efficacy and cost-effectiveness. To him, gradualist models such as that of Nordhaus do not reckon a number of impacts and, in particular, catastrophic impacts. Regarding the latter, Stern works with subjective probability distributions although, as pointed out by Vale (2011, p.127), he recognizes not being sure about which probability distribution he should use and so he arbitrarily increases the estimated costs of inaction.

The explicit concern about intergenerational distribution (and justice) leads him also to adopt a very low, close to zero discount rate. However, he explicitly rejects the idea of zero growth as the ultimate solution to the environmental problem. Similarly to eco-developmentalists, he proposes a set of environmental policies capable of taking the environmental risk into account, but with low "trade-off" between economic growth and the environment. In contrast, however, he structures these policies based on a framework of macroeconomic scenarios where the environmental costs of inaction are estimated.

In the recent report of the United Nations Environment Program on Green Economy (UNEP, 2011), the fundamental eco-developmental premise is explicitly stated,[16], but similar to the Stern Review it is included in a stricter macro-economic analytical framework. Two key aspects of this analytical scheme deserve to be highlighted: firstly, environmental risks can be estimated, therefore enabling the simulation of scenarios showing the cost-benefit of adopting a particular set of policies;[17] secondly, the problems stem primarily from the inefficient allocation of production factors; this inefficiency, in turn, results from market failures related to ecosystem services, as well as from wrong incentives arising from existing public policies. Also worth noting is the explicit adoption of the "unorthodox" premise that capital and natural resources are not perfect substitutes; ecosystem services in particular would be very limitedly replaced by capital.

Policy proposals are a mix of command and control policies and with policies based on economic instruments. In relation to the first, an aggressive environmental regulation is also recommended to anticipate future scarcity. As for the second, beyond the pricing of ecosystem services, it will be necessary to virtually reverse the signals of an economic incentive structure which, in key--sectors such as energy and transport favor the use of fossil fuels and individual transport. Developing countries have specificities - such as large portions of the population still living on forestry activities and small subsistence agriculture - that need to be addressed through specific policies. Supposedly, the "greening" of these activities would be capable of simultaneously increasing the supply of jobs and labor productivity and therefore of income. There is no "trade-off" between economic growth and the environment. The issue of environmental limits raised by the Club of Rome would be nothing but a "myth".[18]

There is a great expectation towards the role of technology: "green" te-

chnologies which are "triple winner": environmentally friendly, socially appropriate and economically efficient. Another UN report (DESA, 2011), whose title precisely expresses this expectation, indicates the policies required to stimulate technological change, especially so that emerging countries may be able to "leapfrog" directly into these new triple-winner technologies. The technological revolution of the green economy would be different for three reasons: (a) the short period of time within which it should occur given the pressure on ecosystems; (b) because of that and the limitations of market mechanisms, governments will have to play a much more active role in the production and dissemination of technology; (c) the need for international cooperation, since the main environmental problems are global in nature.

Environmental economics: the thermodynamic Saci[TN] and the capitalist Midas

From the point of view of *environmental economics* (neoclassical mainstream), natural resources (as a source of both inputs and ecosystem services) do not represent, in the long run, an absolute limit to economic growth.

This position is based on two premises: (a) there are almost no limits for scientific / technological progress to increase efficiency in the use of natural resources (eco-efficiency); and (b) capital, labor and natural resources can perfectly replace one another.[19] Thus, on the one hand waste emission would tend towards zero with the endless increase in the efficient use of natural resources, causing the progressive decoupling of the economic growth process from its materials/energy base; the economy operates in a world as if the second law of thermodynamics, the Law of Entropy, does not apply. In turn, natural ecosystems that are inevitably lost due to human expansion would be easily replaced by capital. Therefore, it is a world where a *thermodynamic saci pererê* and a *capitalist king Midas* working together would guarantee perpetual economic growth.[20]

Thus, the availability of natural resources (NR) can be a constraint to economic growth, but only a relative constraint that can be *indefinitely* overcome by scientific and technological progress. It all happens as if the economic system could move smoothly from a resource base to another as each of them is exhausted, with scientific and technological progress as the key variable to ensure that the replacement process will not limit economic growth, thus guaranteeing its sustainability in the long term. At the limit, as provocatively stated by Solow (1974),[21] the economy could get by along without natural resources!

In the literature this idea became known through the concept of *weak sustainability*. An economy is considered "non-sustainable" if gross savings are less than the combined depreciation of produced and non-produced assets - natural

[TN] In Brazilian folklore, a one-legged black or mulatto youngster with holes in the palms of his hands, who smokes a pipe and wears a magical red cap that enables him to disappear and reappear wherever and whenever he wishes.

resources (Atkinson et al., 1997). The underlying idea is that investment compensates future generations for asset losses caused by curr[2]ent consumption and production (formally presented by the "Hartwick rule").

According to this current, the incentive mechanisms through which this indefinite expansion of environmental limits to economic growth occurs should be especially market mechanisms. In the case of environmental goods traded in markets (material and energy inputs), the growing shortage of a particular good would translate easily into an increase in its price, thus leading to the introduction of innovations that enable saving it (eco-efficiency), and, at the limit, replacing it with another more abundant resource. In the case of environmental services generally not traded in the market due to their nature as public goods (air, water, global biochemical life support cycles, ability to absorb waste, etc.), this market mechanism fails. Correcting this failure requires interventions, so that the willingness to pay for these environmental services can be expressed as their scarcity increases.

It would have been empirically observed that the natural evolution of the individuals' preferences resulting from the economic growth process itself would be towards lower tolerance of this growing shortage of these services due to pollution, representing what can be expressed as an Environmental Kuznets Curve (Figure 1): as per capita income rises with economic growth, environmental degradation increases up to a point from which the environmental quality starts to improve. The explanation for this would be that in the early stages of the economic development process, increasing environmental degradation is accepted as a negative, but inevitable, side effect. However, after a certain level of economic well-being, people become more sensitive and willing to pay for the improvement of environmental quality, which would have led to the introduction of institutional innovations and organizational measures to correct market failures arising from the public nature of most environmental services. These institutional and organizational innovations, in turn, guarantee a pace of introduction of technical innovations in production processes capable of compensating for the pressure of economic activities on the environment (Grossman and Krueger, 1995).

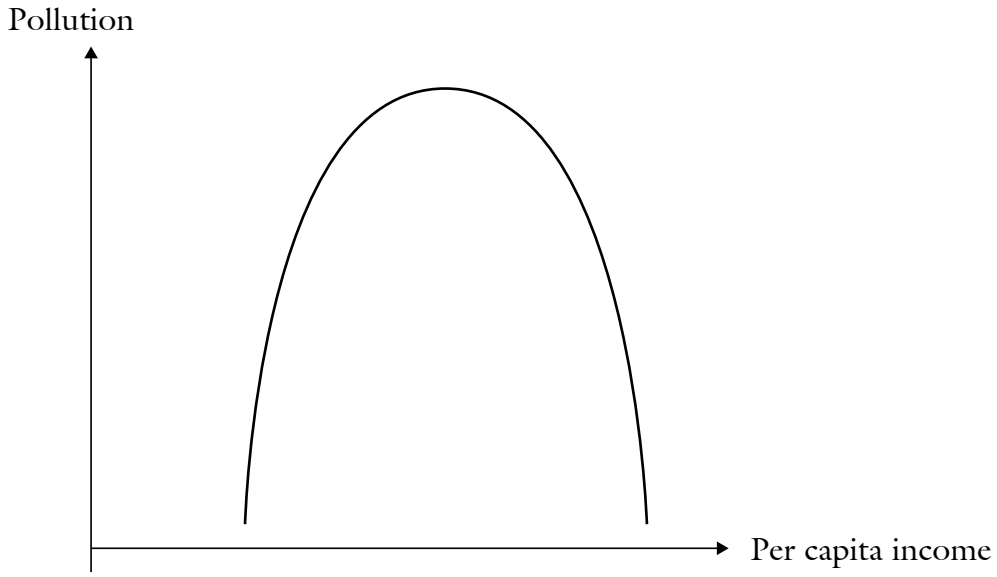


Figure 1 – The Environmental Kuznets Curve

The optimal solution would be that which could somehow create the conditions for the free operation of market mechanisms: either directly, through the elimination of the public nature of these goods and services by defining property rights over them (Coasian bargaining), or indirectly through the economic valuation of the deterioration of these goods and the application of these values by the state through taxes (Pigouvian tax). The first would entail privatizing resources such as water, air etc. which, among other obstacles, would collide with the high transaction costs arising from bargaining processes involving hundreds or even thousands of agents.

The second assumes that it is possible to calculate the values from a marginal curve of environmental degradation. Thus, economic agents would enjoy a "trade-off" between their (marginal) pollution control costs and the (marginal) costs of environmental impacts (externalities) caused by their production activities, which they would be forced to "internalize" by paying the corresponding taxes (prices) (Figure 2): economic agents will seek to minimize the total cost resulting from the sum of how much they will spend to control pollution (control cost) with the amount to be paid for pollution taxes (degradation cost). The optimization point is called "optimal pollution", in which the total cost is minimized.

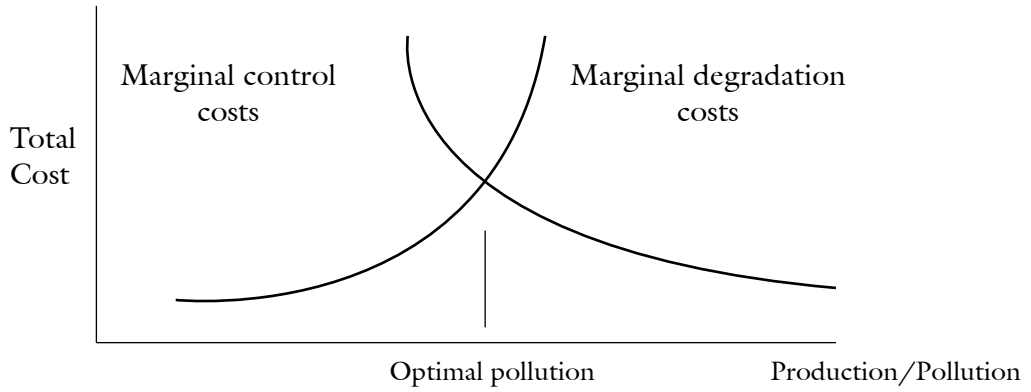


Figure 2 – Optimal pollution

The most efficient environmental policy is that which creates the conditions through pricing for economic agents to "internalize" the costs of the degradation they cause. Ensuring "sustainability" would be ultimately a problem of intertemporal *allocation* of resources between consumption and investment by rational economic agents whose motivations basically maximize utility. Collective action (through the State) is necessary only to correct market failures that occur because most environmental services are public goods (air, water, ability to absorb waste, etc.) and therefore have no price. Once these failures have been resolved to ensure the correct economic signals of the relative scarcity of these environmental services, the dynamics of the intertemporal allocation of resources based on cost-benefit assessments would tend to be processed efficiently, with no problems of uncertainty and risk of irreversible losses.

Not everyone, however, has accepted that this logical conclusion based on the assumptions made. For long, economists participating in this current have been concerned about the risk of potentially important irreversible environmental losses; important in that they can cause significant losses of well-being that could be prevented. This dilemma between the conservation and exhaustion of a given ecosystem has been structured as a discrete choice issue, which recognizes that there are many situations in which the full conservation or the irreversible transformation of a given ecosystem can be legitimately claimed. The problem is defining which one. And economists, as noted by Pearce & Turner (1990), have not solved this problem. However, they have proposed some pioneering methods that could contribute to that, such as those by Krutilla & Fisher (1985), Ciriacy-Wantrup (1952) and Bishop (1978).

Krutilla & Fisher have developed an algorithm to ensure that the benefits of the conservation option are correctly factored into the basic equation of a cost-benefit analysis applied to the environmental problem. Thus, the estimated value of the benefits that the conservation of a given resource would entail begins to be treated as part of the costs of the development project. This value, in turn, takes into account the fact that the price of this natural resource (δ) would

tend to increase over time, as it becomes progressively scarcer. Furthermore, it is believed that technical progress (φ) can have a negative effect on the economic viability of the development project in question (or of maintaining a given course of action) by making other investment options attractive.[22] The introduction of the price factor and the technology factor differentiates the Krutilla-Fisher algorithm from more conventional analysis by moving the "benefit of the doubt" to the conservation side. Thus, the risks inherent in the cost-benefit analysis would be reduced in situations in which the losses can be very importantes.[23]

The pioneering work of William Nordhaus (1993, 2008) is the main reference in the "mainstream" effort to treat with rigor a problem that in theory should not require special treatment. Theoretically, the problem of global warming could be solved like that of any other environmental externality resulting from a market failure in the use of public natural resources, by pricing the ecosystem service of climate regulation. Thus, as the cost of warming increases progressively, the market would induce the introduction of technological solutions that reduce the cost of controlling greenhouse gas emissions (mitigation).

Initially, as pointed out by Vale (2011), Nordhaus found that the *laissez-faire* would not be enough, and that State intervention beyond pricing would be required (as in the establishment of minimum efficiency standards for engines), in order to force a faster adjustment of emissions to adequate safety levels.[24] However, he abandoned this idea, which is alien to neoclassical orthodoxy, to favor a strictly orthodox treatment of internalization of a global environmental externality. The big challenge, then, would be to estimate marginal curves of control cost (mitigation) and pollution cost for a complex and very long term global problem. Nordhaus' feat was precisely that, i.e., to estimate a very long-term marginal cost curve for global warming based on the optimization of an intertemporal economic growth model, which would enable putting a price on the ecosystem service of CO_2 absorption capable of, when added to the prices of fossil fuels, *internalizing* (and solving) the global warming issue.[25]

Considering the structure of the Krutilla-Fisher algorithm, Nordhaus' model has the effect of making clear to economic agents the benefits of changing the current energy mix based on fossil fuels: over time, the present value of the benefits of the current energy mix falls due to technical progress (κ) in alternative sources (mitigation costs), while the value (δ) of the service ecosystem of CO_2 absorption, as measured by the cost of emissions, increases because of its growing scarcity, until it is completely replaced by another energy mix ("backstop technology"). These movements characterize a 'ramp': between 1990 and 2010 carbon prices should rise slightly because environmental damages would be few and technological options would be costly. As of 2010, prices should rise sharply. Thus, Nordhaus manages to maintain allocative efficiency as a rule of decision in terms of marginal cost-benefit to address an environmental problem that he had singled out initially as deserving special, non-marginalist State action.

Ecological economics: sustainable scale and the law of entropy

From the standpoint of *ecological economics,* the environment represents an absolute limit to the expansion of the economy, which is one of its subsystems. However, if by definition a subsystem cannot be larger than the system that contains it, its size in relation to the whole does not have the system as its maximum limit, but rather its carrying capacity, which is defined by thresholds of ecosystem resilience. This is one of the fundamental premises of ecological economics that has its origin in the work of Kenneth E. Boulding. To illustrate this idea, Boulding (1966) uses the analogy of the "cowboy economy" and the "spaceship economy". In the first, the economic subsystem - the cowboy in the great plains – does not have enough critical mass to cause some important irreversible ecosystem impact; in the latter, the size of the economic subsystem - the spaceship crew - is large enough to endanger its own survival if the resources available are not handled carefully. It is not possible to replace essential ecosystem services with capital. Natural resources (natural capital) are complementary to capital and/or labor. The current size of the economic subsystem and its rapid expansion bring the planet ("Spaceship Earth") closer to the second.[26]

With regard to population growth, the idea of limits of "Spaceship Earth" is generally accepted by all, including neoclassical environmental economists. The difficulty lies in the idea that economic growth, increasing production and per capita income are also limited by the size of Spaceship Earth.

This limitation is due to the law of entropy, according to which no productive matter and energy change activity (first law of thermodynamics) is possible without an irreversible entropic degradation process that generates waste (second law of thermodynamics); it is possible to reduce the amount of waste by increasing eco-efficiency, but beyond a certain point there are insurmountable entropic limits. This is another fundamental premise of Ecological Economics which has its origin especially in the work of N. Georgescu-Roegen (1971).

Based on these two assumptions, Herman Daly (1996), the pioneer responsible for incorporating these ideas into a theoretical body that founded ecological economics, concludes that the total waste inevitably generated by the extraction, processing and consumption of natural resources in a given period of time (which he calls "throughput") cannot exceed the carrying capacity of the Earth and that, therefore, zero growth is the only way to prevent that from happening.

The thermodynamic destabilizing effects of human activities result from two sources. The first source of imbalance is the expansion of human occupation of the space. Rich estuarine ecosystems give way to cities and ports; huge natural spaces are radically transformed by agriculture, forestry and animal husbandry. The second is the introduction of materials and energy from sources exogenous to the system. The minerals found in the Earth's crust at concentration levels (mines) that economically justify their exploitation are inert, i.e.,

they either do not interact or interact only marginally with biological activities in the ecosphere.[27] The mining, processing and consumption of these materials result in the production of waste that will be dispersed in the ecosphere, forcing ecosystems to adapt in order to absorb them. Depending on the amount, this waste represents a source of pollution that can affect or even destroy the ability of ecosystems to provide services.

These activities have impacts similar to those of volcanoes, with the difference, however, of being selective: the volcanoes spew especially relatively high entropy materials such as silica, which are abundant in nature, so that their assimilation by ecosystems is easier (besides the fact that ecosystems have co-evolved with volcanic activities for hundreds of millions of years); human mineral extraction practices, on the contrary, are focused on low-entropy materials concentrated in certain places by telluric forces for million years, thus hindering their assimilation by ecosystems. Added to these materials are those produced artificially, an already huge number of new substances whose impacts on ecosystems and directly on humans are not well known, such as POPs (Persistent Organic Pollutants), hormone-mimicking molecules, etc. In the long term, therefore, the sustainability of the economic system is not possible without the stabilization of waste (and heat)[28] production levels according to the carrying capacity of the planet. This is the biggest limiting factor: the environment as a producer of ecosystem services and not as a producer of non-renewable raw materials. Services that cannot be replaced by capital and that the market is incapable of adequately taking into account.[29]

Once the existence of a carrying capacity that cannot be exceeded is recognized, the next issue is its size. To what extent human pressure on ecosystems can be absorbed by these without a catastrophic rupture? Great efforts have been made in this regard. According to Rockstrom et al. (2009a, 2009b), for example, the current scale of human activities would have already exceeded the limits of ecosystem services of biodiversity, nitrogen cycle and climate regulation. However, although these efforts are required, it must be recognized that these ecosystem services result from complex ecosystems that have, *inter alia*, the property of resilience, i.e., the ability to rebalance without rupturing (or phase shift, to use a more precise thermodynamics language), whose *threshold* cannot be fully known. It is a radical uncertainty that science is unable to solve.[30]

From these assumptions, the central question for ecological economics is how to get the economy to operate while accepting the existence of these limits. Two action plans need to be considered: (a) one relates to specific policies for each type of environmental problem to be addressed; (b) the other to the stabilization of global waste production at sustainable levels - zero growth. Conventional environmental economics, as we saw earlier, only takes into account the first action plan, in that it ignores the existence of environmental limits to growth, based on the possibility of unlimited replacement of scarce resources

with abundant resources and/or capital. In the case of environmental goods traded in the markets (material and energy inputs), it is assumed that the growing shortage of a particular good raises its price, thus leading to the introduction of innovations that enable saving it and, at the limit, replacing it with other, more abundant resources, whose stocks the economic agents are supposed to know, along with quality differences, the future course of technological progress, and demand itself. In fact, as pointed out by Daly (1996), the prices reflect the availability of each resource regardless of the total stock of resources, thus preventing them from being used to signal an optimal extraction process from the standpoint of sustainability.

In the case of environmental services not traded in the market due to their nature as public goods, the adjustment mechanism proposed does not take into account key ecological principles to ensure sustainability, in that this mechanism is based on cost-benefit calculation by economic agents with a view to *allocating* resources between investments in pollution control and payment of pollution fees to minimize the total cost. The fees, in turn, will be calculated based on a set of economic valuation methodologies that measure either directly or indirectly the willingness of individuals to pay for environmental goods and services.[31]

Therefore, the point of equilibrium, known as "optimal pollution", is about economic and not ecological balance since, as pointed out by Godard (1992), one cannot talk about balance in economic terms when the assimilative capacity of the medium is exceeded, which is the case in point considering that pollution remains. The fact that the assimilative capacity is exceeded in a given period (t) reduces the assimilative capacity in the following period and so forth, and may result in *irreversible* loss. There is therefore a "net destruction", and only their second order effects are taken into account, i.e., those that affect the level of well-being of other agents in the short term. This adjustment mechanism implies that technology and preferences (and, implicitly, income distribution) are used as nonphysical *parameters* that determine a position of equilibrium in which the physical *variables* of the quantities of goods and services used (*scale*) are adjusted. Thus, it is the *allocation* of investments in pollution control and payment, according to the technology and optimizing preferences of the agents, that determines the scale of use of natural resources.

In the case of the ecological economics this process needs to be reversed, starting by determining the sustainable scale of use of natural resources. Thus, what used to be process adjustment variables (amount of ecosystem goods and services to be used) are now being treated as physical parameters of ecological sustainability, to which the (now) nonphysical variables of technology and preferences should adjust. Because of the technology, the latter begin to be limited by the scale. Determining a *sustainable scale,* in turn, involves other values besides the individual pursuit of maximizing gain or well-being, such as solidarity between and within generations. These values have to be affirmed in the context

of scientific controversies and uncertainties in complex cases such as those of global environmental problems. In such cases, the scale deemed sustainable can only be determined through collective decision-making processes, from perspective of application of the *Precautionary Principle*.

Thus, without a collective intervention to define the scale that society deems sustainable, the improvement of environmental quality induced by environmental degradation (the Environmental Kuznets Curve) tends to be limited to the degradation that affects the level of well-being of the very agents making the decision (such as that caused by the emission of sulfurous gases, particulates, disposal of domestic sewage, etc.), leaving aside that whose effects involve more dispersed and long-term costs as is the case, for example, of the degradation caused by the emission of carbon dioxide responsible for the greenhouse effect (Arrow et al. 1995).[32]

Once the sustainable *scale* has been determined, the issue of distribution of the right of access - which has become restricted - to a particular ecosystem good or service follows suit. This issue does not exist in the conventional analytical scheme, since there are no environmental limits. The basic distribution criterion should be one that society considers fair. Once the distribution of the right of access based on a fairness criterion accepted by all has been defined, the *allocation* of available resources between investments in pollution control and investments in pollution payment should be made based on market criteria.

In the case of global warming, the policies proposed by the Kyoto Protocol followed this analytical framework. A sustainable scale of use regarding the capacity to absorb greenhouse gases was defined[33] based on ecological criteria; then the *distribution* of the use of this capacity among signatory countries was established based on criteria considered fair (emission reduction based on the contribution of each country); and finally the *allocation* of investments was left to the carbon market, with the addition of the ingenious Clean Development Mechanism (CDM).[34]

Regarding the second action plan - stabilization of the level of heat and waste emissions in developed countries, which implies stopping economic growth (zero growth) - the problem is how to do it without generating a socioeconomic crisis (to be discussed in a coming section). In the case of developing countries, economic growth is essential to eliminate poverty and inequality. For those, policies like the ones advocated by UNEP (2011) and by eco-developmentalists in general are the ones that should be implemented.[35] Politically and operationally, as seen in a previous section, it is possible to develop a set of policies that lead to institutional, organizational and technological innovations capable of putting these countries on a path of sustainable growth until they achieve levels of material comfort similar to those of developed countries.

Final Remarks: steady state and welfare

The debate about zero growth or even degrowth[36] has gained momentum in recent years. There are two problems to be tackled simultaneously for achieving what Daly (1996) called *steady state:* [37] (a) the problem of stopping growth without generating a socio-economic crisis; (b) the problem of consumer expectations in consumer societies.

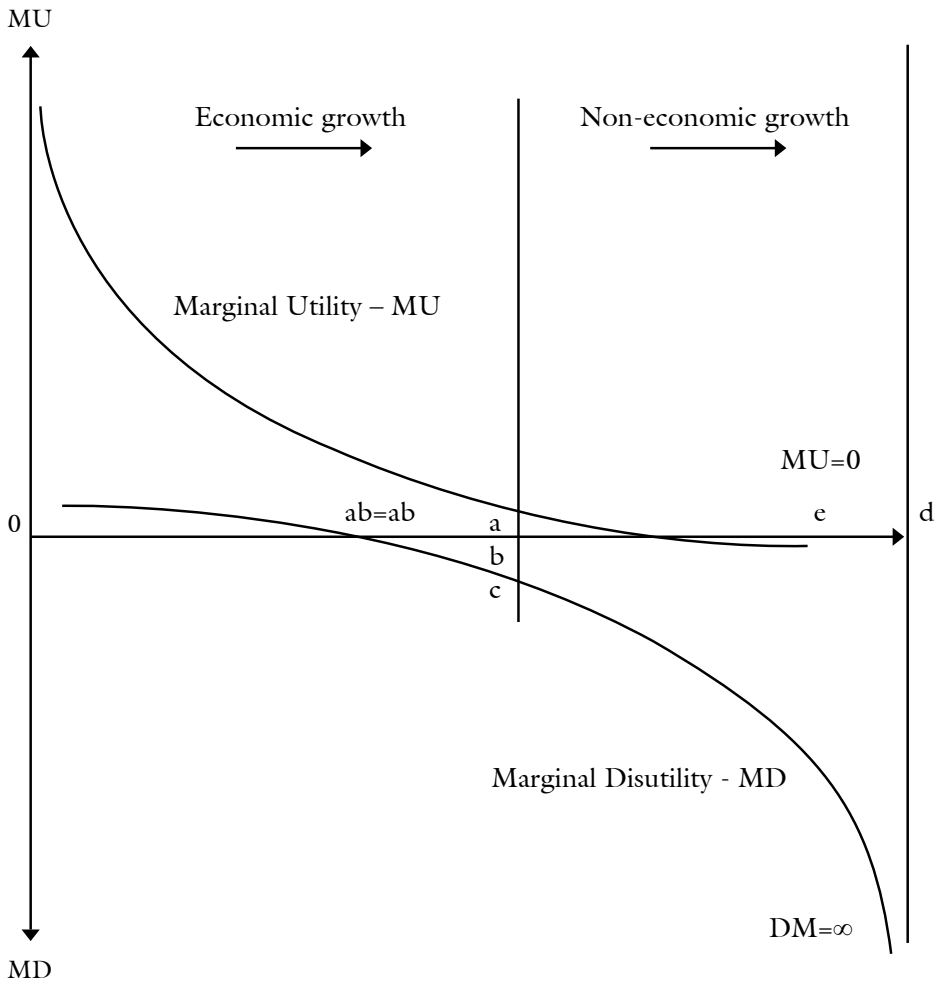
The technical solution to the first problem is mainly the formulation of macroeconomic policies – an environmental macroeconomics. Specifically, it is about tackling, for example, the problem of employment, of inequality and of incentive to technological innovation. The pioneering work of Victor (2008) for the Canadian economy, and of Jackson (2009) for the British economy, present options of macroeconomic policies that would enable stabilizing production growth considering the following issues: variations in the proportions between investment and consumption, changes in investment nature and conditions, greater public investment, greater environmental restrictions, increased employment by reducing working hours, and a neutral tax reform that penalizes the intensive use of natural resources, among other policies.

The legitimacy for the implementation of these policies depends on the solution of the second problem, the one regarding consumer expectations that give legitimacy to the opposing, growth incentive policies. One must not lose sight of the fact that the emergence of mass consumer societies was unprecedented in human history and released the great mass of the population from the oppression of poverty. It was the result of a process of sustained economic growth. This, in turn, was only possible when certain cultural/institutional conditions coincided in Medieval Europe, with certain political/geographical conditions that enabled the systematic introduction of technological, organizational and institutional innovations, giving rise to what Braudel (1979) termed *Mutant Civilization*.[38]

The acceptance by the population of environmental restrictions involving some sort of sacrifice for the benefit of the populations of other countries and/or of a distant future necessarily implies a certain dose of altruism, particularly if these restrictions aim to stop economic growth (Romeiro, 2000). However, this necessary legitimizing altruism of zero growth policies may be enhanced by the growing realization that the current level of material comfort is more than enough, and that continuing growth efforts will produce more harm than good. A feeling that one could be moving towards what Daly & Farley (2004) called non-economic growth (Figure 3), in which the increase in satisfaction (utility) brought by economic growth is lower than the increase in dissatisfaction (disutility).

The curve of marginal disutility is increasing because it reflects the negative effects of economic growth on well-being, including the effect of environmental degradation and other risk factors, as well as the increase in social

entropy.[39] The curve of marginal utility, in turn, is decreasing to the extent that the initial satisfaction of more basic needs generates a utility greater than the subsequent consumption of less essential goods. Daly & Farley (2004) draw attention to the fact that the basic rule of neoclassical economics has not been part of an intergenerational dialogue. As the current generation starts from an already high level of material comfort, increased incomes and the consequent increase in consumption would result in a utility gain lower than that obtained by the previous generation. Actually, it was found that this gain tended to be null! Surveys of the sense of happiness of the population conducted in the United States on a regular basis by polling firms like Gallup and the National Opinion Research Center show that income growth had not been accompanied by an increase in the happiness of people as they perceived it. There was a positive correlation in the same period of time between income level and the reported degree of happiness – i.e., the number of self-declared happy people was higher in higher income brackets; however, in time series this correlation disappeared: the number of self-declared happy people remained constant.



The first case is not surprising, to some extent, since stepping out of poverty and having increased access to goods and services is always a source of relief and satisfaction. The second result, apparently paradoxical (the "Easterlin Paradox"), shows that the fact that people consume more than the previous generation does not bring greater satisfaction. According to Abramovitz (1989), this fact could be explained by a set of psycho-cultural reasons, of which one of the most important would be the fact that the satisfaction each individual gets by increasing his consumption capacity is related to the consumption capacity of his fellow citizens; that is, if income increases for society as a whole, the perception of increased consumption capacity vanishes. Thus, the American citizen of the 1990s - although his consumption capacity is much higher than that of his grandfather or great-grandfather – does not see it as something that can make him happier.

In summary, from the point of view of ecological economics, sustainable development should be understood as a process of improvement of human well--being based on a material/energy production that ensures the comfort that is deemed appropriate and that has been stabilized at a level consistent with the thermodynamic limits of the planet. Therefore, it implies a Steady State in which consumption growth as a factor of social emulation gives way to cultural, psychological and spiritual growth; a development process with as freedom, as defined by Sen (1999), a process of permanent improvement in the conditions necessary for the full realization of "an individual's capacity to flourish."

Notes

1 Sustained growth understood as a long-term growth process that results from a virtuous cycle of savings and investment that increases employment and income, which, in turn, expand opportunities for new investments.

2 This name had been suggested by Maurice Strong, director of UNEP, but Professor Ignacy Sachs, from the EHESS of Paris University is recognized historically as the leading theoretician of this concept.

3 The modeling performed was a system dynamics that had just been developed by Jay Forrester. A simulation based on system dynamics is essential if we want to know, for example, what happens in a given system when the flow of input or output of an exogenous source of energy or matter increases or decreases. But it cannot be used for "forecasting" situations involving the expansion of the system under analysis. This was precisely the weakness of the model, because the technological variable implies the possibility of relative magnification of the system (Planet Earth) under analysis.

4 Economic growth would tend to improve income distribution by increasing scarcity and labor productivity, as it would have been observed historically in developed countries - the Kuznets Curve.

5 The various sub-currents sharing this view could be divided, in turn, into two groups: a) the group that understood international inequality as resulting from some form of imperialism in by the capitalist countries (Santos, 2000; Frank, 1967; Arrighi, 1997); b) the ECLAC group, whose main intuition was to identify in the structural differen-

ces between mainly exporting poor countries and rich industrial countries, the causes for the disadvantageous insertion of the first in the international division of labor: deterioration in Prebisch's (1982) terms of trade and Furtado's (1961) structural imbalance of production factors.

6 With the (perhaps single) exception of Furtado (1974) in *The myth of economic development*. For Furtado, the conclusion of the Club of Rome report would be proof that economic development was not for everyone, though in his analytical scheme, exclusion mechanisms are not directly related to environmental issues.

7 And we could say moral, as argued by Friedman (2005), in a well-documented review of development theories and major historical experiences. Moral in the sense that no growth would ultimately mean a return to barbarism. Environmental limits to growth, as hopefully (and poorly) argued by Friedman, could be overcome by technical progress.

8 Altvater (1992) was one of the first, if not the sole author of this current that seeks to integrate this fact of environmental limits to growth into a theoretical framework that explains international inequality; he advocates the thesis that central countries, aware of the limits to the availability of resources, perpetuate the underdevelopment of other countries (especially by manipulating external debt), with the aim of maintaining them only as producers of raw materials, thus preventing them from becoming consumers competing for scarce resources!

9 The Cocoyok Declaration resulted in a meeting organized by the United Nations Conference on Trade and Development (UNCTAD) and the United Nations Environment Program (UNEP).

10 This is the final report of a project by the Dag Hammarskjöld Foundation, which counted on the participation of researchers and politicians from dozens of countries. UNEP and another 13 UN organizations have also contributed.

11 Note the difference in the position of the Marxist and structuralist currents: the liability is more for situations created by the colonial past, which have become endogenous, and less for active exogenous mechanisms embedded in international relations between center and periphery that benefit the first.

12 The term "sustainable development" had already appeared in the late 1970s in some studies that fueled the debate, but in the academia the term eco-development still prevailed.

13 In the first report, the conclusion was that if the observed trends - in relation to the increase in world population, industrialization, pollution, use of natural resources etc. –remained unchanged, the limits of the planet would be reached within a hundred years. In the second, the conclusion is even more extreme, in that the rates of use of many essential resources and of generation of various types of pollution would have already exceeded the rates that would be physically sustainable. And the remedy as well, because it will not only be necessary to achieve zero growth as soon as possible, but also to significantly reduce the flows of matter and energy by rapidly increasing eco-efficiency. Recognizing the epic nature of the proposed changes, it considers that facing this challenge requires more than productivity and technology; it also requires "maturity, compassion and wisdom" (Meadows et al., 1992).

14 The policy proposal to reduce emissions under the Kyoto Protocol represents the theoretically optimal solution advocated by Ecological Economics, as will be discussed in

the next section.

15 The work of Nordhaus is noteworthy for its pioneering nature (dating back to the 1970s) in addressing this global warming problem and for its neoclassical orthodoxy.

16 The assumption is that the "environmental and social goals of a green economy can also generate increases in income, growth, and enhanced welfare" (UNEP, 2011, p.16).

17 For example, it is estimated how much annual investment in renewable energy and energy efficiency is required (between $50-170 billion) to avoid an environmental cost of climate change of $500 billion! Or yet, when it is estimated that the opportunity cost of deforestation is three times greater than its benefits.

18 "One of the major findings of this report is that a green economy supports growth, income and jobs, and that the so called trade-off between economic progress and environmental sustainability is a myth, especially if one measures wealth as a stock of useful assets, inclusive natural assets, and not narrowly as flows of produced output" (UNEP, 2001, p.622).

19 Initially natural resources (R) didn't even appear in the production function. In its subsequent inclusion the function type - first-degree homogeneous - Y = f(K, L, R) was maintained, implying that the amount of resources (R) required can be as small as is desired, provided that the amount of capital (K) is large enough. Georgescu-Roegen criticized this version of the neoclassical production function (which he dubs Solow--Stiglitz variant) calling it "magic." For an analysis of Georgescu-Roegen's work, see Chechin (2010).

20 Baumol (1986) admits the thermodynamic restriction that the efficiency of real systems cannot be increased indefinitely, but the replaceability between capital and natural resources would ensure perpetual economic growth. That is, the thermodynamic *saci* does not exist, but the capitalist Midas does and could handle the problem by himself. For an internal critique of the Baumol thesis, see Amado & Sauer (2010).

21 "The world can, in effect, get along without natural resources, so exhaustion is just an event, not a catastrophe" (Solow, 1974, p.11).

22 The present value of a given development project D is deducted from the benefits of preservation P.

$$VP\,(D) = -1 + \int_0^{\infty} De^{-(\pi+\varphi)t}\,dt - \int_0^{\infty} Pe^{-(\pi-\delta)t}\,dt$$

where

π is the discount rate;

δ is the variation rate in the resource's price;

φ is the "decadence" rate given by technological progress.

23 In cases where these uncertainties are even greater and the benefits of the development alternative are dubious, the criteria of the Krutilla-Fisher approach would not be sufficient to prevent irreversible losses of resources whose conservation would prove *a posteriori* to be invaluable. In this case, an alternative would be the so-called safe minimum standards approach (SMS), developed especially by Bishop (1978) based on the work of Ciriacy-Wantrup (1952). However, the need to define these standards

contradicts the assumptions mainstream economists work with. Randall & Farmer (1995) consider that the cost-benefit analysis provides a good idea of the satisfaction of human preferences (individual), but admit that there are good reasons to impose a minimum safeguard standard (SMS), unless the cost of that is intolerably high. The definition according to which the intolerably high cost of conservation should be in accordance with the standard economic thinking based especially in sustaining adequate levels of consumption by human populations.

24 "One persistent concern has been that man's economic activities would reach a scale where the global climate would be significantly affected. Unlike many of the wolf cries, this one, in my opinion, should be taken very seriously" (Nordhaus, 1977, p.341, apud Vale, 2011, p.198).

25 See Vale (2011) for a detailed analysis of the evolution of Nordhaus's work and its comparison with the Stern Report.

26 In the last two decades, the expansion of economic activities led by the Asian giants, China and India have entailed an exponential growth of human pressure on the environment, despite the increase in eco-efficiency. Definitely, humanity has become an almost geological factor of change. We have gone for Holocene to Anthropocene! (see Andrade & Romeiro, to be published).

27 Ecosphere is the name given to the space where life on Earth is concentrated: from a few meters underground to a few hundred meters into the atmosphere.

28 The dissipation of heat generated by the nuclear power park in France uses about a third of the country's surface water.

29 It takes an "economics of ecosystems." See Andrade & Romeiro (2011).

30 Several factors explain the absence of a distribution of probabilities of a given phenomenon: cognitive or computational deficiency, lack of information, lack of knowledge, which theoretically can be overcome at some point; but there are cases of ignorance that cannot be eliminated. The threshold of complex ecosystems fits into the latter situation (see Dequech, 2011).

31 Methodologies that have their specific limitations and are applied without an adequate ecosystem evaluation. For a critical analysis of these methodologies, see Romeiro & Maia (2010).

32 In general, therefore, the decline of pollution associated with the increase in income was due to local institutional reforms, such as environmental legislation and incentives based on market mechanisms, which do not consider international and intergenerational consequences. In other words, these reforms do not help to avoid problems when their costs are borne by the populations (usually poor) of other countries or by future generations, i.e., they do not take into account the problems related to distributive justice and scale.

33 Certainly economic considerations (cost of adjustment) intervened in the definition of what should have been determined only by scientific considerations.

34 This mechanism, proposed by the Brazilian delegation, enables non-signatory developing countries to participate in the official carbon market; a triple winner solution: environmental efficiency (reduced emissions), economic efficiency (lower cost of adjustment in developed countries) and social efficiency (creation of jobs and income in developing countries).

35 See the latest works of Professor Sachs (2002, 2006, 2007).

36 Georgescu-Roegen believed that degrowth would be necessary for humanity to extend its life on Earth. The hypothesis is that the current level of production and consumption in developed countries cannot be generalized to all countries; these therefore need to progressively degrow to make room for the necessary growth of poor countries (see www.degrowth.org) .

37 Daly's (1996) idea of Steady-State was inspired by John Stuart Mill who, in view of the potential of the industrial revolution to overcome the historical poverty of humanity in the 19th century, envisioned the need to stabilize material production because of environmental limits, emphasizing that, after all, the most important activities, such as "education, art, religion, basic research, sports and human relations" did not depended on perpetual economic growth.

38 In the medieval West, the anthropocentric view of the meaning of human presence on Earth derived from the Judeo-Christian cosmology, in which human beings were created by God in his image and likeness and to whom the entire Earth and its resources are subject, coincided with territorial fragmentation and, within regions, the division of power between the center (the crown) and the local lord, implying the existence of multiple centers of decision. The first represented a remarkable change of mind in human history and contributed to a strongly proactive attitude in the sense of manipulating and transforming nature, by inventing new methods and procedures. The second enabled expressing the first, insofar as it allowed innovative agents to bargain their ideas with leaders in a mutual competition (see White, 1970, 1978; Jones, 1993; Mokyr, 1990; Landes, 1998, among others).

39 The term "social entropy" is being used to define situations of social degradation such as family breakdown, loneliness, teenage pregnancy, etc.

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Abstract – This paper offers a definition of sustainable development from an ecological economics perspective. For this, it begins with a historical analysis of the sustainable development concept from its origins as *eco-development* to its present formulation as *green economy*. It follows an assessment of the *weak sustainability* concept premises which allows for the neoclassical environmental economics not to take into full account the natural reality in its environmental policy proposals. The analysis of the ecological economics theoretical foundations, in turn, has made it possible to conceive a *strictly ecological definition of sustainability*, a necessary condition for the sustainable development definition proposed. Finally, the paper deals with the problem of slowing down the economy to zero growth without causing a crisis and the problem of changing the consumption expectations in consumption societies. A definition of sustainable development is then proposed.

Keywords: Sustainable development, Ecological sustainability, Thermodynamic equilibrium, Zero growth, Steady-state.

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