Environmental Economics, Ecological Economics, and the Concept of Sustainable Development

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ABSTRACT: This paper presents a systematic discussion, mainly for non-economists, on economic approaches to the concept of sustainable development. As a first step, the concept of sustainability is extensively discussed. As a second step, the argument that it is not possible to consider sustainability only from an economic or ecological point of view is defended; issues such as economic-ecological integration, inter-generational and intra-generational equity are considered of fundamental importance. Two different economic approaches to environmental issues, i.e. neo-classical environmental economics and ecological economics, are compared. Some key differences such as weak versus strong sustainability, commensurability versus incommensurability and ethical neutrality versus different values acceptance are pointed out.

KEYWORDS: ecological economics, post-normal science, co-evolution, institutional economics, sustainability, incommensurability

1. INTRODUCTION

The growth of world population and the rapid growth of economic activity have caused environmental stress in all socio-economic systems. There is a wide scientific consensus that problems such as the greenhouse effect (and climate change), ozone depletion, acid rain, loss of biodiversity, toxic pollution and renewable and non-renewable resource depletion are clear symptoms of environmental unsustainability.

Traditional neo-classical economics analyses the process of price formation by considering the economy as a *closed system*: firms sell goods and services, and then they remunerate the production factors (land, labour and capital). It is interesting to note that while classical economists such as Malthus (1798), Ricardo (1817), Mill (1857) and Marx (1867) had clear in their minds that

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economic activity is bounded by the environment, neo-classical economics completely forgot this important characteristic of real world economies up till the seventies when the debate was started on social and environmental limits to economic growth.[1] The real economy started to be seen as an *open system* that in order to function must extract resources from the environment and dispose of large amounts of waste back into the environment (Ayres and Kneese, 1969; Kneese et al., 1970).

The life support function of ecosystems (de Groot, 1992) is connected to their physical, chemical, and biological role in the overall system. Ecosystems can be divided into three categories (Odum, 1989):

- natural environments or natural solar-powered ecosystems (open oceans, wetlands, rain forests, etc.);
- domesticated environments or man-subsidised solar-powered ecosystems (agriculture lands, aquaculture, woodlands, etc.); and
- fabricated environments or fuel-powered urban-industrial systems (cities, industrial areas, airports, etc.).

It is evident that fabricated environments are not self-supporting or self-maintaining. To be sustained they are dependent on the solar-powered natural and domesticated environments (life-supporting ecosystems). *Stress* caused by the disposal of wastes and pollutants negatively affects recycling, feed-back loops and control mechanisms in the life-supporting ecosystem and thereby the production and maintenance of environmental goods and services. In the eighties, the awareness of actual and potential conflicts between economic growth and the environment led to the concept of *'sustainable development'*.

2. THE CONCEPT OF SUSTAINABLE DEVELOPMENT

Traditionally, Gross National Product (GNP) has been considered as the best performance indicator for measuring national economy and welfare. But if resource depletion and degradation are factored into economic trends, what emerges is a radically different picture from that depicted by conventional methods (Daly and Cobb,1990). In environmental terms, the GNP measure is plainly defective because (Faucheux and O'Connor, 1997):

- no account is taken of environmental destruction or degradation;
- natural resources as such are valued at zero; and
- repair and remedial expenditure such as pollution abatement measures, health care, etc., are counted as positive contribution to GNP inasmuch as they involve expenditures of economic goods and services.

Let us try to clarify some fundamental points of the concept of 'sustainable development'. In economics by 'development' is meant 'the set of changes in the economical, social, institutional and political structure needed to implement the transition from a pre-capitalistic economy based on agriculture, to an industrial capitalistic economy' (Bresso, 1993). Such a definition of development presents two main characteristics:

- the changes needed are not only quantitative (GNP growth), but qualitative too (social, institutional and political); and
- the only possible model of development is that of western industrialised countries. This implies that the concept of development is viewed as a process of cultural fusion toward the best knowledge, the best set of values, the best organisation and the best set of technologies.

The concept of sustainable development has wide appeal, partly because, in contrast with the 'zero growth' idea of Daly (1977; 1991a), it does not set economic growth and environmental preservation in sharp opposition. Rather, sustainable development carries the ideal of a harmonisation or *simultaneous realisation* of economic growth and environmental concerns. For example, Barbier (1987, p. 103) writes that sustainable development implies:

> *to maximise simultaneously* the biological system goals (genetic diversity, resilience, biological productivity), economic system goals (satisfaction of basic needs, enhancement of equity, increasing useful goods and services), and social system goals (cultural diversity, institutional sustainability, social justice, participation).

This definition correctly points out that sustainable development is a *multidimensional* concept, but as multicriteria decision analysis teaches us (see Munda 1995) it is impossible to maximise different objectives at the same time.

For example, according to actual social values in western countries, having a car per two or three persons could be considered a reasonable objective in less developed countries. This would imply a number of cars ten times greater than at present, with enormous consequences for global warming, exhaustion of petroleum, loss of agricultural land, noise, production of CO_2 and NO_x. Let us consider a study by the United Nations cited in Bresso (1993). In 1980, the total world energy consumption was 10 terawatt-hours (TW-h). With no increase in consumption in less developed countries, by 2025 the whole world population would need 14 TW-h. If the consumption of the whole world population were at the level of western countries, then by 2025 it would be 55 TW-h. It is clear that while the first hypothesis is socially unsustainable (zero growth in less developed countries), the second one is environmentally unsustainable (in terms of exhaustion of natural resources and global pollution).

It is evident how difficult it is to implement the idea of sustainable development. From an economic point of view, the costs and benefits of economic growth are *incommensurable*. Furthermore, ecology alone cannot explain (e.g. by using the concept of carrying capacity) an important characteristic of human beings: the enormous differences in the use of materials and energy among different people and territories. Geographical distribution is determined historically, not biologically (Martinez-Alier, 1987, 1994; Martinez-Alier and O'Connor, 1996).

We can synthesise the main features of sustainable development as follows. First, an important characteristic is the issue of *distributional equity*, both within the same generation (intra-generational equity, e.g. the North-South divide) and between different generations (inter-generational equity). Second, an economic-ecological integration is needed, above all in terms of resource use and pollution emissions.

We could put the question, 'sustainable development of whom?' Norgaard (1994, p.11) writes, 'consumers want consumption sustained, workers want jobs sustained. Capitalists and socialists have their "isms", while aristocrats and technocrats have their "cracies".' We can conclude that environmental management is effectively *conflict analysis* characterised by technical, socio-economic, environmental and political value judgments. The concept of ecological distribution refers to the social, spatial, and temporal asymmetries or inequalities in the use by humans of environmental resources and services. Thus, the territorial asymmetries between SO_2 emissions and the burdens of acid rain is an example of *spatial ecological distribution*; the inter-generational inequalities between the enjoyment of nuclear energy and the burdens of radioactive waste is an example of *temporal ecological distribution*. In the USA, 'environmental racism' is a term used to describe the location of polluting industries or toxic waste disposal sites in areas where poor people live. This is an example of *social ecological distribution* (Martinez-Alier and O'Connor,1996).

In the following sections we will examine how traditional neo-classical environmental economics and ecological economics differ in tackling the issue of sustainable development. In particular, the difference between *weak* and *strong* sustainability will be stressed.

3. NEO-CLASSICAL ENVIRONMENTAL ECONOMICS

3.1. Basic Principles

Environmental economics can be considered as a particular specialisation of neo-classical economics studying two fundamental questions:

(i) the problem of environmental externalities; and

(ii) the correct management of natural resources (in particular, the optimal inter-generational allocation of non-renewable resources).

From an epistemological point of view, economists belonging to the Neo-classical school take inspiration from Newton's mechanics. They tend to believe in value neutrality and objectivity and regard their arguments as 'scientific'. Rational decisions are connected with the existence of optimal solutions based on calculations in *monetary* or other *unidimensional* terms (the assumption of complete commensurability). It has to be noted that to put a precise monetary value to an environmental externality implies the solution of very important problems, e.g., uncertainty connected to the environmental impact, correct time horizon and correct discount rate.

Neo-classical economists have a quite optimistic view of technological progress and economic growth. They generally recognise that even if the production technologies of an economy can potentially yield increases in output commensurate with increases in inputs, overall output will be constrained by limited supplies of resources (growth theory with exhaustible resources). But these limits can be overcome by *technological progress*: if the rate of technological progress is high enough to offset the decline in the per capita quantity of natural resource services available, output per worker can rise indefinitely. A stronger statement is the following: *even in the absence of any technological progress exhaustible resources do not pose a fundamental problem if reproducible man-made capital is sufficiently 'substitutable' for natural resources* (Dasgupta and Heal, 1979; Hartwick, 1977, 1978; Solow, 1974a and 1974b; Stiglitz, 1979).

This concept of substitution of more productive man-made capital for natural capital can be criticised from many sides.

(i) If capital depreciates by a constant proportion, the exhaustible resources are essential, since consumption should eventually fall to zero (assuming no technical change).

(ii) Man-made capital is not independent of natural capital; since resources are required to manufacture capital goods the success of any attempt to substitute capital for resources will be limited by the extent to which the increase in capital requires an input of resources. 'The idea of substitution might be rescued if we can demonstrate that the extra productivity in K_M (man-made capital) outweighs the extra natural resources that get used up in the production of K_M. At this stage all we can say is that this is not obvious' (Pearce and Turner, 1990, p. 49).

(iii) A limit to the substitutability between man-made capital and natural capital is that natural capital has the feature of multifunctionality (all the life support functions), such a feature is not shared by man-made capital (Pearce and Turner, 1990).

The so called weak sustainability concept (Pearce and Atkinson, 1993) states that an economy can be considered sustainable if it saves more than the combined depreciation of natural and man-made capital. 'We can pass on less environment so long as we offset this loss by increasing the stock of roads and machinery, or other man-made (physical) capital. Alternatively, we can have fewer roads and factories so long as we compensate by having more wetlands or mixed woodlands or more education' (Turner et al., 1994, p. 56). Weak sustainability is based on a very strong assumption, *perfect substitutability* between the different forms of capital, so all the criticism presented above also applies in this case.

Under weak sustainability conditions, sustainability is equivalent to leaving future generations with a total stock of capital not smaller than the one enjoyed by the present generation. Cabeza (1996) notes that the concept of weak sustainability is nothing but a by-product of growth theory with exhaustible resources when:

(i) the definition of inter-generational equity is restricted to a non-declining level of consumption per capita; and

(ii) the environment-economy relationship is restricted to the introduction of an aggregate input called natural capital into the production function.

Indeed, weak sustainability is simply a different statement of the so called Hartwick-Solow rule (Hartwick, 1977, 1978; Solow, 1974b, 1986), stating that in order to have a stream of constant level of consumption per capita to infinity, society should invest all current returns from the utilisation of the flows from the stock of exhaustible resources. Criticism of the empirical results of Pearce and Atkinson's calculations can be found in Martinez-Alier (1995).

3.2. The Pearce-Turner Constant Natural Capital Rule

Pearce and Turner (1990) although they are inside the framework of conventional economics,[2] have a 'different position' in approaching environmental problems. They devote their attention to the desirability and meaning of maintaining the natural capital stock as a condition for sustainable development. Maintaining the natural capital stock is considered *desirable* mainly because the role which natural environments play in supporting and sustaining economic systems is covered by scientific uncertainty. Since uncertainty exists about the way in which environments function, either internally or in terms of their interactions with the economy, a trade-off of the benefits of substituting man-made capital for natural capital is not a realistic one. Moreover, most environmental decisions are characterised by irreversibility: if a mistake is made, it is not possible to correct it afterwards (it is quite difficult to create a tropical forest again). Thus the presence of uncertainty and irreversibility together should make human beings more circumspect about giving up natural capital.

But what does a constant natural capital stock mean? Pearce and Turner (1990, p. 53) give four possibilities:

- the physical quantity of natural resource stocks should remain unchanged;

- the total value of the natural resource stocks should remain constant in real terms (standard economic approach);
- the unit value of the services of the natural resources, as measured by the prices of natural resources, should remain constant in real terms; and
- the value of the resource which flows from the natural resource stock should remain constant in real terms. Where resource flow is the product of price and quantity used, it is possible to allow quantity to decline but the price to rise, keeping value constant.

Pearce and Turner recognise some of the shortcomings of each of these definitions of a constant stock of natural capital, and other weak points have been indicated by Victor (1991). Measurements of natural capital stock made exclusively in physical terms are problematic, according to these authors, because of the difficulty in adding up different physical quantities expressed in different units. For this reason the second interpretation is offered. By valuing each resource stock in money terms, the total value of natural capital can be measured. One obvious problem here is that many natural resources (e.g., air, water, wilderness) do not have observable prices. Thus one would need to find implicit or shadow prices in some way. Even those prices that do exist may not be useful; they may be affected by market imperfections and taxes, and they may exclude externalities involved with the production and use of the resource.

> There are additional problems in using market prices to value the aggregate stock of natural capital. Resource prices or net prices reflect conditions at the margin and to use these to value entire stocks can give perverse results. For example, it is possible for the real price or net price of a resource to rise over time at the same rate as (or faster than) the rate of decrease in the physical stock of the resource..... This possibility is of more than theoretical interest. If price or net price rises as resource quantity is declining, the value of resource stocks as an indicator of sustainability can give precisely the wrong policy signal to government. As long as the value of the stock remains constant or rises, the government, through this indicator, will not perceive a problem even though the flow of resource is becoming increasingly valuable (as measured by price) and the physical stock is declining. (Victor, 1991, p. 204)

Pearce and Turner's third and fourth interpretations of a constant stock of natural capital also utilise market prices and so similar criticisms made in relation to keeping the value of the capital stock constant apply. Although the idea of a constant natural capital stock is quite important and desirable (maintaining natural capital is an important prerequisite for sustainability), one has to admit that the above considerations demonstrate that the development of relevant indicators of sustainable development connected to this idea is quite difficult. This is mainly because it is based on the assumption of *complete monetary commensurability*.

4. ECOLOGICAL ECONOMICS

The linkages between ecosystems and economic systems are the focus of ecological economics. A good definition of what is meant by Ecological Economics is the following.

> Increasing awareness that our global ecological life support system is endangered, is forcing us to realise that decisions made on the basis of local, narrow, short-term criteria can produce disastrous results globally and in the long run. We are also beginning to realise that traditional economic and ecological models and concepts fall short in their ability to deal with global ecological problems. *Ecological economics* is a new *trans-disciplinary* field of study that addresses the relationships between ecosystems and economic systems in the broadest sense..... Ecological economics (EE) differs from both conventional economics and conventional ecology in terms of breadth of its perception of the problem, and the importance it attaches to *environment-economy interactions*. (Costanza et al., 1991, pp. 2-3)

A simplified scheme of the possible scientific approaches to environment-economy interactions can be found in Figure 1. The left half concerns those approaches using several evaluation criteria for analysing the interactions between ecological and economic systems, and the right half those using a common denominator for this evaluation, such as money or energy. Ecological economics explicitly refuses the complete commensurability paradigm and recognises the existence of *incommensurability* between economic and environmental aspects. Thus a new scientific paradigm is needed.

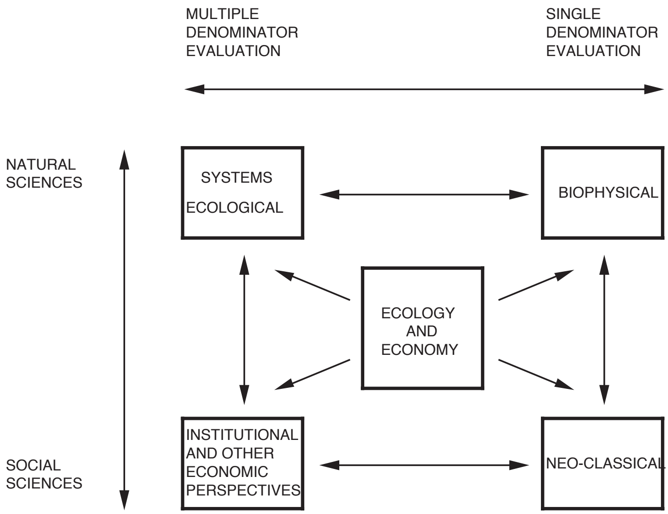

FIGURE 1. A simplified conceptual model of ecological and economic perspectives and approaches to environmental issues (from Folke and Kaberger 1991, p. 275)

4.1. Epistemological Foundations of Ecological Economics

4.1.1. Post-normal science and institutional economics

In any science a paradigm or pre-analytic vision exists; research has to start somewhere, thus something is given by a pre-analytic cognitive act. Everybody starts his own research from the work of his predecessors. According to Kuhn (1962), scientists normally are just ordinary people (so neither the impeccable truth-gathers of the positivist tradition, nor the heroic conjecturalists of Popper) concerned only in solving research puzzles within an unquestioned framework of concepts and methods.

Global environmental issues present new tasks for science: scientists now tackle problems introduced through policy issues where typically, *facts are uncertain, values in dispute, stakes high, and decisions urgent* (Funtowicz and Ravetz, 1990, 1991, 1994). Thus Funtowicz and Ravetz have developed a new epistemological framework called 'post-normal science', where it is possible to make use of two crucial aspects of science in the policy domain: *uncertainty* and *value conflict*. The name 'post-normal' indicates that the puzzle-solving exercises of normal science, in the Kuhnian sense, which were so successfully extended from the laboratory of core science to the conquest of nature through applied science, are no longer appropriate for the solution of environmental problems.

Neo-classical economics has traditionally been able to maintain its credibility by relegating uncertainties in knowledge and complexities in ethics firmly to the sidelines. But, uncertainties in input information produce irreducible uncertainty in conclusions; the relevant question of quality is the degree to which the recommended policy choices are robust against those underlying uncertainties. As a post-normal science, ecological economics recognises the presence, importance and legitimacy of different value-commitments for the appropriate management of uncertainty. *It does not claim ethical neutrality*, nor an indifference to the policy consequences of its arguments.

As science became used in policy, it was discovered that lay-persons (e.g. judges, journalists, scientists from another field, or just citizens) could master enough of the methodology to become effective participants in the dialogue. A basic principle of post-normal science is that these new participants are indispensable. This extension of the peer community is essential for maintaining the quality of the process of resolution of complex systems. Thus the appropriate management of *quality* is enriched to include this multiplicity of participants and perspectives. The criteria of quality in this new context will, as in traditional science, presuppose ethical principles. But in this case, *the principles will be explicit and will become part of the dialogue*.

According to Funtowicz and Ravetz (1994), the traditional analytical approach, implicitly or explicitly reducing all goods to commodities, can be recognised as one perspective among several, legitimate as a point of view and as a reflection of real power structures, but not the whole story. To choose any particular operational definition for value involves making a decision about what is important and real; other definitions will reflect the commitments of other stakeholders.

One should note that the view that, concerning environmental issues, conflicts between interests and interested parties are the normal state of affairs is also shared by institutional economics (Bromley, 1989, Myrdal, 1973, 1978). 'Institutional economics focuses on actors, their world views, habits, etc., and on institutional arrangements. The latter term refers to organisation, rules of game, power relationships, entitlements and other types of control over resources' (Söderbaum, 1992, p. 131).

Some relationships between ecological economics and institutional economics have been investigated by Aguilera-Klink (1994; 1996), Klaassen and Opschoor (1991), Opschoor and van der Straaten (1993) and Söderbaum (1992). The main common points are recognition of the impossibility of a value free science, emphasis on the importance of the distribution of property rights, and strong criticism of monetary reductionism. How much is a songbird worth? To answer this question represents a new problem of valuation, one where measurements cannot pretend to be independent of methodology and ethics.

> The issue is not whether it is only the marketplace that can determine value, for economists have long debated other means of valuation; our concern is with the assumption that in any dialogue, all valuations or 'numeraires' should be reducible to a single one-dimension standard. (Funtowicz and Ravetz, 1994, p. 198)

William Kapp, probably the first institutional economist with environmental interests, wrote in 1970:

> To place a monetary value on and apply a discount rate (which?) to future utilities or disutilities in order to express their present capitalised value may give us a precise monetary calculation, but it does not get us out of the dilemma of a choice and the fact that we take a risk with human health and survival. For this reason, I am inclined to consider the attempt at measuring social costs and social benefits simply in terms of monetary or market values as doomed to failure. Social costs and social benefits have to be considered as extra-market phenomena; they are borne and accrue to society as a whole; they are heterogeneous and cannot be compared quantitatively among themselves and with each other, not even in principle.

From a philosophical perspective, it is possible to distinguish between the concepts of strong commensurability (common measure of the different consequences of an action based on a cardinal scale of measurement), weak commensurability (common measure based on an ordinal scale of measurement), strong comparability (there exist a single comparative term by which all different actions can be ranked) and weak comparability (one has to accept the existence of conflicts between all different consequences of an action) (O'Neill, 1993).

Clearly, traditional cost-benefit analysis is based on the assumption of strong comparability, whereas weak comparability can be considered the philosophical foundation of multicriteria evaluation (Martinez-Alier et al., 1996; Munda et al., 1994; Munda, 1995).

The methods used in multicriteria evaluation are based on (necessarily restrictive) mathematical assumptions as well as on information gathered from the decision-maker. Thus the concept of 'decision process' has an essential importance. According to Simon (1972, 1978, 1983), a distinction must be made between the general notion of rationality as an adaptation of available means to ends, and the various theories and models based on a rationality which is either substantive or procedural. This terminology can be used to distinguish between the rationality of a decision considered independently of the manner in which it is made (in the case of substantive rationality, the rationality of evaluation refers exclusively to the results of the choice) and the rationality of a decision in terms of the manner in which it is made (in the case of procedural rationality, the rationality of evaluation refers to the decision-making process itself) (Froger and Munda, 1997).

To be sure, the analyst can greatly influence the results of a decision analysis, but the advantage of multicriteria evaluation is that the black-box effects are reduced to a minimum level: thus in principle it is always possible to justify or defend the decisions taken. Of course a defensible decision is not the same as the best possible decision, but at least it is a transparent decision. The analyst is generally subject to pressures of politicians or stake holders who want to influence the outcome of the evaluation process.

4.1.2. The coevolutionary paradigm

There is a constant and active interaction of the organisms with their environment; organisms are not simply the results but they are also the causes of their own environments: this is the main thesis of the *coevolutionary paradigm* (Norgaard, 1994; Gowdy, 1994). Economic development can be viewed as a process of adaptation to a changing environment while itself being a source of environmental change. However, coevolution does not imply change in a particular direction (i.e., progress).

In biology, coevolution refers to the pattern of evolutionary change of two closely interacting species where the fitness of the genetic traits within each species is largely governed by the dominant genetic traits of the other. So-called 'coevolutionary biology' was started with a study on the reciprocal adaptation of butterflies and plants (Ehrlich and Raven, 1964).

In real world societies,

> people survive to a large extent as members of groups. Group success depends on culture: the system of values, beliefs, artifacts, and art forms which sustain social

> organisation and rationalise action. Values and beliefs which fit the ecosystem survive and multiply; less fit ones eventually disappear. And thus cultural traits are selected much like genetic traits. At the same time, cultural values and beliefs influence how people interact with their ecosystem and apply selective pressure on species. Not only have people and their environment coevolved, but social systems and environmental systems have coevolved. (Norgaard, 1994, p.41)

Agriculture began between five and ten thousand years ago when there were approximately five million people in the world. The incredible increasing of population was only possible through an increase in the effectiveness with which people interacted with their environment through changes in knowledge, technology and social organisation. According to Norgaard, the increase in material well-being and in the rate of population during the past century can be understood as a process of coevolution. With industrialisation, social systems evolved to facilitate development through the exploitation of coal and petroleum.[3] Social systems no longer coevolved to interact more effectively with environmental systems.

> Hydrocarbons freed societies from immediate environmental constraints but not from ultimate environmental constraints – the limits of the hydrocarbons themselves and of the atmosphere and oceans to absorb carbon dioxide and other greenhouse gases associated with fossil fuel economies. (Norgaard, 1994, p.44)

From the coevolutionary paradigm the following lessons can be learned:

(i) A priori, different models of coevolution are possible, then no unique optimal development path exists. The spatial dimension is a key feature of sustainable development.

(ii) The respect of cultural diversity is of a fundamental importance. In environmental management local knowledge and expertise (being the result of a long coevolutionary process) sometimes are more useful than experts' opinions.

(iii) Coevolving systems have parts and relations which change in unforeseeable ways. At any point in time, they can be described like an ecosystem, but over time they are as unpredictable as the evolution of life itself.

It has to be noted that the principles of the coevolutionary paradigm, institutional economics and post-normal science reinforce one another. They share the issues of value conflicts, democratisation of science and uncertainty. Post-normal science and institutional economics emphasise the importance of incommensurability and decision making processes; coevolution underlines the importance of economy-environment interactions.

4.2. Economy-Environment Interactions

4.2.1. The issue of scale

Systemic approaches to environmental issues consider the relationships between three systems: the economic system, the human system and the natural system (Passet, 1979). The *economic system* includes the economic activities of man, such as production, exchange and consumption. Given the scarcity phenomenon, such a system is efficiency oriented. The *human system* comprises all activities of human beings on our planet. It includes the spheres of biological human elements, of inspiration, of aesthetics, and of morality which constitute the frame of human life. Since it is clear that the economic system does not constitute the entire human system, one may assume that the economic system is a subsystem of the human system. Finally, the *natural system* includes both the human system and the economic system (Nijkamp and Bithas, 1995).

From the ecological economic perspective, the expansion of the economic subsystem is limited by the size of the overall finite global ecosystem, by its dependence on the life support sustained by intricate ecological connections which are more easily disrupted as the scale of the economic subsystem grows relative to the overall system. Since the human expansion, with the associated exploitation and disposal of waste and pollutants, not only affects the natural environment as such, but also the level and composition of environmentally produced goods and services required to sustain society, the economic subsystem will be limited by the impacts of its own actions on the environment (Folke, 1991). A central issue then is: does any '*optimal' scale* exist for the economy? This point has especially been tackled by Daly.

The term 'scale' is shorthand for 'the physical scale or size of the human presence in the ecosystem, as measured by population times per capita resource use' (Daly, 1991b, p. 35). The standard economics point of view about economic growth seems quite optimistic. But as an economy grows, it increases in scale. Scale has a maximum limit defined either by the *regenerative or absorptive capacity of the ecosystem*, therefore 'until the surface of the earth begins to grow at a rate equal to the rate of interest' (Daly, 1991b, p. 40), one should not take this optimistic attitude too seriously. Thus the concept of '*strong sustainability* 'is needed. Such a definition is based on the assumption that certain sorts of natural capital are deemed critical, and not readily substitutable by man-made capital (Barbier and Markandya, 1990). In particular, the characterisation of sustainability in terms of the 'strong' criterion of non-negative change over time in stocks of specified natural capital provides a strong justification for development of non-monetary indicators of ecological sustainability based on *direct physical measurement* of important stocks and flows (Faucheux and O'Connor, 1997; Faucheux and Noël, 1995).

By means of this concept, we are left with bio-physical indicators, or 'satellite accounts' of variations in natural patrimony, not integrated in money terms within national income accounting. However, behind a list of indicators there would always be a history of scientific research and political controversy. Moreover, one should note that a list of indicators is far from being a list of targets or limits for those indicators. Also, a question arises, how could such indicators be aggregated? Often, some indicators improve while others deteriorate. It has to be noted that this is the classical conflictual situation studied in multicriteria evaluation theory, in particular noncompensatory methods are quite relevant, since compensability implies substitutability between different types of capital (Faucheux et al. 1994; Munda, 1996).

4.2.2. The entropy law and the economic process

Energy analysis is very important for studying the relationships between economy and environment. Energy-based valuation may appear to be a newcomer in the field of economics: some people would find its origins in the 1973 energy crisis; others identify it with Georgescu-Roegen's *The entropy law and the economic process*. Yet in actual fact, attempts to base theories of economic measurement or value on various concepts of energy have a long history behind them. Martinez-Alier (1987) shows that there is a tradition of cross-fertilisation between economics, thermodynamics and ecology, due to the work of scientists such as Jevons, Clausius, Podolinski, Geddes, Soddy and others. However, energy is not a substitute for money in order to reach a new concept of commensurability, as it was theorised by the 'energy theories of value' in the seventies and in the eighties (on this point see Faucheux and Pilet (1994); Mirowski (1989)).

Since the meaning of the entropy law for the economic process is a much discussed subject, here we will follow closely Georgescu-Roegen's terminology. Classical thermodynamics deals with energy but only with energy in bulk. No thermodynamic concept makes any sense if applied to a microscopic element. An electron has no heat, no temperature, no pressure, and no entropy. The entropy concept can be defined as follows: 'in an isolated thermodynamic system the available energy continuously and irrevocably degrades into an equal quantity of unavailable energy, so that the total energy remains constant while the unavailable energy tends to a maximum' (Georgescu-Roegen, 1993, p. 187), where available energy is the one that humans could use for their purposes; unavailable energy is energy that humans cannot use in any way; and an *isolated system* is the one that can exchange neither energy nor matter with its environment. The entropy law can be applied neither to a *closed system* that can exchange only energy with the environment nor to an *open system* that can exchange both energy and matter with its surroundings.

As matter exists, like energy, in two states: available and non-available, and since matter-energy enters the economic process in a state of low entropy and comes out of it in a state of high entropy, Roegen states his controversial fourth law as follows: ‘in a closed system (as the Earth practically is) mechanical work cannot proceed at a constant rate forever’ (Georgescu-Roegen, 1993, p. 198), or more simply, matter cannot be completely recycled. A consequence of this law is that a programme based on the substitution of terrestrial energy by solar energy such as Daly’s steady state, cannot work. Interesting discussions of the meaning and consequences of the so-called fourth law can be found in Mayumi (1991, 1992, 1993).

Regarding technological progress, Georgescu-Roegen is quite pessimistic. He defines ‘Promethean techniques’ as those that allow obtaining a surplus of *accessible* energy (getting more accessible energy than that used in the operation). A new technology requires a new Promethean technique, not just one already familiar alternative. The Promethean technique that saved the wood crisis was the steam engine, but nowadays neither controlled fusion nor direct harmessed solar energy have the characteristics of a Promethean technique.

According to Georgescu-Roegen (1984), a technology is viable if and only if it can maintain the corresponding material structure which supports its resource and sink functions, and consequently the human species.

> A technology that draws down irreplaceable stocks, or generates irreducible pollution, or violates the ability of funds to provide assimilative and restorative services, is not viable. The relevance of all this to weak sustainability is that all production processes are characterised by inflows fron Nature and outflows of waste to Nature which are limitational. (Gowdy and O’Hara, 1996)

Figure 2 illustrates the ecological economics conception of the economic system as a part of the overall ecosystem.

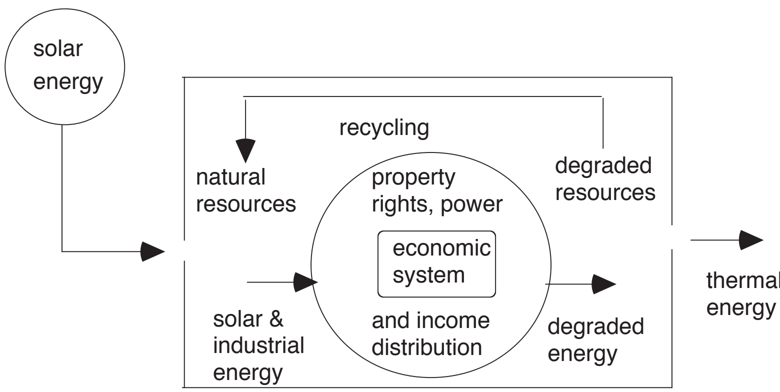

FIGURE 2. The economy embedded in social institutions and in the ecosystem (Source: discussions with J. Martinez-Alier)

5. CONCLUSIONS

From the above discussion, the following conclusions may be drawn:

(i) Natural life-supporting ecosystems are negatively affected by the disposal of wastes from the economic system. If the economy-environment interactions are taken into account, immediately a broad question about the capability of the natural environments to sustain the economy arises.

(ii) Substitution of more productive man-made capital for natural capital is not an acceptable answer to environmental problems.

(iii) The idea of maintaining the natural capital stock is important and desirable; unfortunately it is very difficult to operationalise. Its main problem is connected with the possibility of valuing environmental goods in money terms (strong commensurability).

(iv) Environmental problems are very complex and characterised by scientific uncertainty. Any method trying to operationalise the concept of sustainable development is necessarily a second best approach.

(v) In economic theory, three main conflictual values can be identified: allocation, distribution and scale. In an operational framework, this means that an exhaustive analysis has to take into consideration efficiency criteria, ethical criteria and ecological criteria, so a multidimensional paradigm is needed.

(vi) Ecological economics recognises that ecological and economical rationality are not sufficient to lead to correct decisions, thus environmental decisions must be taken by using a democratic scientific-political decision process.

We can identify the main differences between conventional environmental economics and ecological economics in relation to the concept of sustainable development as follows:

ENVIRONMENTAL ECONOMICS	ECOLOGICAL ECONOMICS
pretends to be value free	values are always inherent interdisciplinarity and transdisciplinarity are key principles
there is a precise world-wide meaning of economic development	co-evolution and diversity are the key issues of sustainability
strong comparability based on weak or strong commensurability is a key principle	incommensurability, multidimensionality and weak comparability are key guiding principles
weak sustainability is the only possible operationalisation of the concept of sustainable development	strong sustainability operationalised by means of bio-physical indicators

Traditional monetary evaluation methods such as cost-benefit analysis are based on phenomena such as consumer's surpluses, market failures, demand curves which are just a partial point of view, since connected with one institution only: markets. From an ecological economics point of view, issues connected with actions outside of markets and behaviour of people different from the class of consumers should be taken into account. (Duchin and Lange, 1994)

In a post-normal science framework, any recommendations which emerge should be defensible to the technical expert, but also to politicians, the media and the various stakeholders. This does not imply that a consensus will be reached. Indeed, the possibility of irreconcilable differences is recognised and catered for by promoting a plurality of approaches. Ecological economics may be understood as cross-disciplinary in the horizontal axis, integrating disciplinary perspectives on the issue at stake, and as pluri-participatory on the vertical axis, integrating the evenly legitimate perspectives of the different stake-holders and social actors concerned by the issue (see Figure 3).

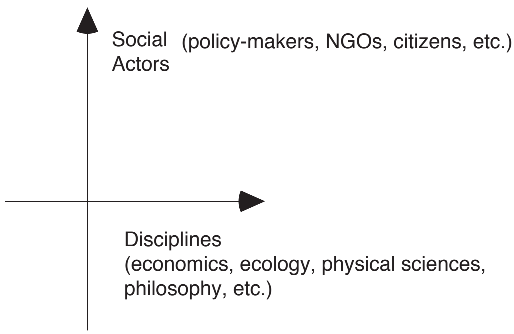

FIGURE 3. Vertical and Horizontal Integration in Ecological Economics (Source: Castells and Munda, 1996)

One should note that the issue of 'value-free science' is important in real-world environmental policy. For example, David Pearce claims that his work for the intergovernmental Panel on Climate Change (IPCC), where lives of people in rich nations are valued up to fifteen times higher than those in poor countries, is a matter of scientific correcteness versus political correctness! (*New Scientist*, 19 August, 1995). Is it really a matter of value-free scientific correctness to use valuations based on assessments of a community's willingness and ability to pay to avoid risks of death? The impossibility of eliminating value conflicts in environmental policy and the call for a plurality of approaches creates a clear need for environmental philosophers and ethicists to play an important role in ecological economics.

NOTES

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[1] Here we do not enter in details regarding the so called ‘growth debate’. The interested reader can refer to: Galbraith, 1959; Hirsch, 1977; Hueting, 1980; Meadows et al., 1972; Mishan, 1967 and 1976; Nordhaus and Tobin, 1972; Scitovsky, 1976.
[2] ‘In this textbook we show how we can use the main body of economic thought to derive important propositions about the linkages between the economy and the environment. Rather than looking for some “different economics”, we are seeking to expand the horizons of economic thought’ (Pearce and Turner, 1990, p. 30).
[3] Martinez-Alier (1987) shows that the increase in productivity of modern agriculture depends on the underestimation of energetic inputs from fossil fuels, the low value given to the contamination caused by pesticides and the loss of biodiversity.

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