Operationalising ecologically sustainable development at the microlevel: Pareto optimality and the preservation of biologically crucial levels

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Abstract: The concept of Ecologically Sustainable Economic Development (ESED) has led to relentlessly heated debate. Yet, it still remains without a clear operational framework. At the micro level where a multitude of projects and programmes are designed, the absence of operational principles has serious repercussions. In order to tackle this ineffectiveness, ESED may be viewed as a pattern of economic process and evolution that takes into account the constraints imposed by the natural environment. In effect, the economic process should ensure the preservation of the human race by maintaining the biological basis responsible for the healthy evolution of the race. In addition, economic development should not lead to Pareto suboptimal positions by precluding production potentials. Based on these principles, the present paper outlines an operational framework for ESED at the micro level of projects and programmes.

Keywords: intergenerational Pareto optimality; safe minimum standards; project appraisal; sustainable development.

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1 Introduction

Since the emergence of the concept of Ecologically Sustainable Economic Development (ESED), a great deal of effort has been devoted to the scientific interpretation of the ESED. The ESED emerged as a political objective to deal with the everincreasing intensification of environmental degradation. The scientific community, acutely aware of the severity of environmental problems, hailed the objectives of this political goal as welcome news. Yet, were the ESED to be adopted by scientists and decision makers alike as a meaningful tenet, a context less vague than that of a mere political bargaining tool had to be sought.

In this context, the scientific community established a fruitful exchange of ideas which, though creative and productive, seems so far to have reached no rigid conclusion as to the scientific meaning of the ESED. Essentially, the debate has veered towards two prevalent directions: the direction of ‘strong’ sustainability and that of ‘weak’ sustainability. Although not alike in terms of philosophy and methodology, these approaches seem to have two characteristics in common. For one thing, both are well established within their methodological framework and scientific paradigms. For another, in both approaches, the operational framework appears somewhat wobbly especially as the approaches are in dire need of practical principles at the levels of project and programme design and appraisal. This conspicuous absence of practical principles constitutes a cause for concern for nearly all parties who busy themselves with practical issues, especially since the practical principles that owe their existence to the emergence of the ESED concept are few and far between. In fact, it appears that the only practical result that the ESED may have had at the project and programme level is the increasing awareness of the impact that economic activities have brought on the environment and the attempt at either managing or eliminating this impact. Still, in the clear light of day, could this awareness, however vital, encompass all the elements of the ESED such as its philosophy, aspirations and rationale? What is more, to what degree does this awareness differ from the traditional environmental impact assessment approach and the relevant mainstream environmental economics analysis? Granted, the ESED concept has offered but a marginal influence at the practical level of design and appraisal of projects and programs. However, projects and programmes are instrumental in the evolution of environmental and economic systems. Environmental deterioration is the combined and cumulative outcome of numerous projects and programmes and their impact on the environment. This is why the ESED proposes in no uncertain terms, the fundamental principle of “thinking globally and acting locally”. Within the context of this principle, and if the ESED were to present a practical framework that offers itself to policy design, it should propose guidelines that are both practical and applicable at project and programme levels. A set of operational principles applicable to everyday business situations should be defined for the ESED. A set of scientific tenets transforming the political agenda into testable and applicable objectives is required. These principles and tenets should be adequately clear so as to fit the needs of ongoing business situations and sufficiently meaningful so as to reflect the essential requirements of the ESED.

In that sense, the present paper aspires to trace and offer an operational framework for the ESED: a framework that can be used in a scientific manner for project and programme design and appraisal. Bearing this target in mind, the paper avails itself of the traditional Pareto Criterion and the particular form it takes under the requirements of the ESED and, in that manner, concedes that a meaningful interpretation of the ESED covering all current and future generations, can be obtained by means of applying the Pareto criterion in the intergenerational context. Consequently, the paper undertakes to trace the practical conditions for operationalising the ESED and in doing so it reaches the conclusion that the preservation of certain, quantitative and qualitative traits of the natural ecosystems and species may could lead to the achievement of ESED at micro level.

The proposal for preservation of certain thresholds in nature is not new: it made its appearance in economics quite a few years ago. Within the boundaries of this proposal, the concept ‘safe minimum standards’ proposes that this type of preservation may be feasible as long as it is not overly expensive and hence restrictive for economic growth (Bishop, 1978). On the contrary, this paper’s approach does not accept any tradeoff in the preservation of the natural and ecological thresholds at the micro project and programme level. Therefore, it seems that our approach challenges the economic rationale for preserving ‘safe’ minimum standards as well as the Norgaard (1994, 1995) approach which decrees that the natural and ecological thresholds are *socially* defined in the coevolutionary process if the Norgaard’s implication is that the socially defined thresholds do not take into account certain biological facts which irrevocably constrain the spectrum.

The present paper asserts that normative environmental preservation levels can be determined by the natural sciences and the preservation of these levels is appropriate, at least at the micro level, for operationalising the ESED. In the long run, after all, their preservation ensures that the Pareto optimality is attained as far as the involvement of all future generations is concerned.

Recent studies offer methodological frameworks for the determination and preservation of natural thresholds, pinning upon the latter the label of Critical Natural Capital. Furthermore, these studies regard the preservation of Critical Natural Capital as an operational condition for achieving Sustainable Development (Ekins 2003). In this respect, our approach for identification and preservation of crucial natural thresholds may prove to be an operational framework for defining the Critical Natural Capital at the microlevel of projects and programmes.

2 The background

The concept of the ESED emerged in the publications of the World Conservation Strategy (IUCN, 1980) as a policy framework to combat the environmental decay afflicting our planet; a decay mainly owing to the increasing levels of pollution and the alarming surge in the extraction of natural resources. The ESED has grown in popularity since the publication of the Bruntland report (WECD, 1987). In it, the ESED is defined as

> "the development that meets the need of present generations without compromising the ability of the future generations to meet their own needs" or as "a pattern of social and structural economic transformations which increase the benefits available in the present without jeopardising the likely potentials for similar benefits in the future." (WECD, 1987)

From these definitions it is clear that the ESED sets a meaningful social target which, however, requires further elaboration in order to assume an operational dimension. A somewhat more precise operational definition, addressing policy issues, can be found at a later point in the Brunt land report:

> "in essence sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potentials to meet human needs and aspirations." (WECD, 1987)

All three definitions share a common trait: the needs of present and future generations should be potentially fulfiled without tradeoffs between the fulfilment of present generations' needs and fulfilment of future generations' needs. The word 'potentially' applies to the needs of future generations that cannot be brought under scrutiny at present since the priorities of future generations have not arisen as yet, and consequently, are unknown to us; therefore, the only readily available strategy would be to waive, the potential for fulfilment of the needs of future generations, irrespective of the characteristics that these needs may assume (Norgaard, 1994).

Two different scientific approaches dealing with the ESED were the result of two different considerations regarding the needs of future generations. These approaches are widely known as 'strong' sustainability and 'weak' sustainability.

'Strong' sustainability views the needs of future generations as independent of the needs of present generations and maintains that any needs arising at and belonging to a future point may have to be formulated in a manner entirely independent of the way that present needs are currently formulated. After all, the needs of future generations may take a different shape than that assumed by the needs of present generations or even be wholly irrelevant to them. In this sense, a rational policy should aim at eliminating the barriers that stifle the formulation and fulfilment of future needs. The ESED, offering itself as a rational policy, must therefore eliminate those barriers whose cause may lie in environmental degradation and inexorable exploitation of natural resources. For, once these calamities have gathered momentum, they decrease any potential future that generations in times to come may have. With that consideration in mind, Christensen (1989) outlines sustainable development as the development permitting the existence of a natural environment, which acts as a basis for human welfare. Similarly, Goodland and Ladec (1987) states that

> "sustainable development implies using renewable resources in a manner which does not eliminate, or degrade them, or otherwise diminish their usefulness for future generations also implies using non renewable mineral resources in a manner which does not unnecessarily preclude easy access to them by future generations."

Once finally, Allen (1980) argues that

> "sustainable utilisation is a simple idea: we should utilise species and ecosystems at levels and in ways that allow them to go on renewing themselves."

Veering towards a different direction, the approach of 'weak' sustainability accepts that the needs of future generations will be similar and in any case contingent on the needs of present generations. The needs of future generations can be foreseen by extrapolating the evolution of current needs. The essential characteristic of this approach is the assumption that future generations can substitute the fulfilment of needs pertinent to the natural environment with the fulfilment of needs pertinent to manmade elements, as long as one takes into account that such a substitution also holds true for both past and present generations. The assumption goes on to maintain that, because of the degradation of the natural environment, the foregone utility can be substituted by the utility attained by using manmade assets, and since this substitution did occur in the past it can continue to occur in the future as well. In this context, the indicator of sustainability is the per capita utility, and as long as the per capita utility does not decline, the sustainability to be enjoyed by future generations is ensured. This rationale is based on an extension of the existing mainstream welfare criteria to future generations. Indeed, past and present generations accept a lesser fulfilment of preferences regarding the natural environment, on condition that other preferences regarding manmade elements are fulfilled to a higher level. It is thus implied that environmental degradation can be sustained if accompanied by other activities which increase welfare, to an extent greater than the extent to which welfare is lost due to the degraded environment. Such an evolution, argues this approach, can constitute a sustainable development path. As a result, future generations can do with a reduced environment as long as manmade assets can guarantee a nondeclining per capita utility. The implicit assumption underlying this argument is that future generations have similar patterns of values as the present generation and hence are able to adopt a similar tradeoff ratio between environmental utility and manmade utility. In this context, Pezzey (1989) and Barbier and Markandya (1990) firmly states that

> "our standard definition of sustainable development will be the criterion of a non-declining per capita utility, because of its self-evident appeal as a criterion of intergenerational equity."

Pearce et al. (1989) and Pearce and Atkinson (1993) defines sustainable development as a situation in which "the development vector increases monotonically over time".

It is, therefore, evident that there exist two fundamentally different directions in the scientific interpretation of the political concept of the ESED. The direction of strong sustainability supports the maintenance of a natural system as a condition for the formulation and fulfilment of future generations' needs while the direction of weak sustainability endorses the economic condition of the nondeclining utility which implicitly permits substitution of the natural environment with manmade capital and/or assets and hence opens the way to further environmental deterioration.

Between the two directions interpreting the ESED one may detect several valuable approaches which, however, are already deficient in operability, at least at the micro level. Indicatively, Van De Bergh and Nijkamp (1991) define the ESED as those dynamics of economic activities, social perceptions and population which provide acceptable levels of life for every human being by ensuring availability of natural resources and ecosystems. Daly (1999) speaks of uneconomic growth and proposes physical limits in the economic process and in economic growth so that the latter may be a lasting one. The 'steady state' approach proposes explicitly that economic process and production should not overcome the carrying capacity of ecosystems. Georgescu-Roegen (1971) envisages grave and irreversible scarcities of natural resources and an exacerbated pollution problem if economic production continues at its current pace. Additionally, he foresees irrevocable unsustainability by which future generations will be dealt a far heavier blow.

It is clear from the above, that there exists a lively scientific dialogue over the ESED and an inexhaustible effort to make the concept operational, and decision making relevant. Sadly, considerable lack of operability at the micro level, where projects and programmes are evaluated, still remains. This is because of the difficulty involved in identifying operational criteria, which may be applied at micro levels, and which differ substantially in their effectiveness from those that were applied before the emergence of the ESED. Indeed, at the micro level the operational framework works in tandem with cost-benefit analysis and environmental impact assessment, and rarely does it involve 'safe minimum standards'.

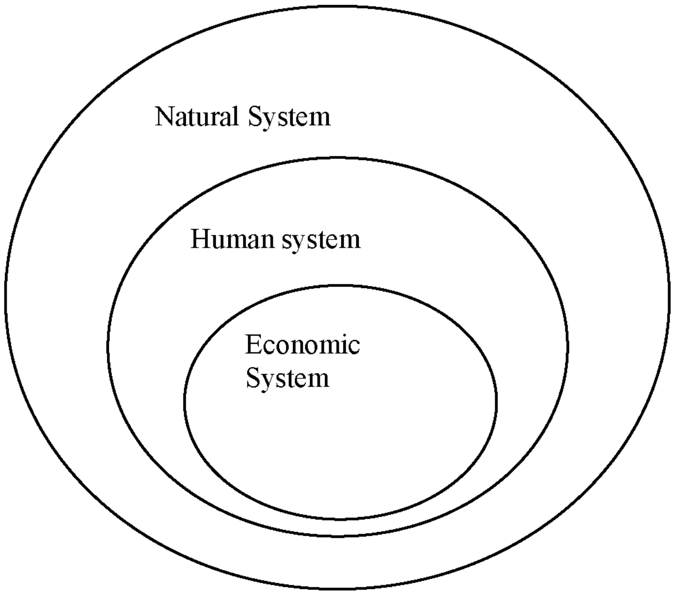
In this context, the paper aims at delineating and proposing a framework that may operationalise the ESED at the micro level.

3 Exploring the ESED

Before seeking the operational conditions of the ESED on the programme and project level, it is necessary to further explore its scientific implications. Literally speaking, the ESED refers to two discrete concepts: the natural environment and economic development. The natural environment consists of all elements, biotic and unbiotic, that can be found in the earth's biosphere system and, in spatial terms, it includes the earth and its surrounding atmospheric systems. In contrast, economic development refers to one and only one specific stage of the economic system. Economic development implies that the output of the economic system is continuously increasing. The output of the economic system is the production of 'goods' that are purchased on markets and yield welfare. These 'goods' should be explicitly produced by means of a deliberate production process. Needless to say, welfare can be created by other processes as well, such as philosophical contemplation or erotic activities not to be found for sale in any market. These activities are not 'economic' and the welfare resulting thereof is not the outcome of an economic system. The most common operational unit for measuring the output of the economic system is the Gross National Product (GNP) and the general concession is that what matters is the per capita GNP, an indicator of the average goods enjoyed by individuals and hence an indicator of the average per capita economic welfare. In effect, economic development connotes an increasing per capita GNP and, by extension, increasing per capita economic welfare.

Having forayed into the literal content of both fundamental terms of the ESED, one is then able to explore their relationship. For the purpose of exploring the relationship between the natural environment and the economic development, it seems that Passet's model, based on the systemic theory, is an appropriate scientific tool. Passet's model focuses on the relationship between the natural, the social and the economic system (Passet, 1979). As indicated in Figure 1, the essential relationship between the three systems, where their physiology is concerned, is that the economic system is a subsystem of the social one, whereas the social system is a subsystem of the natural system.

Figure 1 The fundamental systems



Clearly then, the ESED concerns the fundamental relationship between the natural environment and the economic system and, in essence, prescribes an evolution during which the natural environment is capable of supporting economic development in both the short and the long run and thus does not impose any constraints on economic development. Although this description is rather austere and stripped of all finery, it seems that it can, and does, offer an essential starting point for the query that ensues: What sort of 'support' does the natural system offer to economic development? In answer, we should further explore the fundamental relationship between the natural system and economic development. The section that follows endeavours to answer this query in a systematic manner so as to offer a more operational content for the ESED.

4 Operationalising the ESED

Passet's model and its ability to offer an essential depiction of the physiology of the economic, social and natural systems can serve in exploring those systems' relationships and in identifying the 'support' permeating and affecting all, from the natural to the economic system.

First, the economic system, being a subsystem of the human system, requires the existence of human beings who are the agents responsible for any economic processes. In its turn, the human system, being a subsystem of the natural one, requires that the natural system functions properly so that it may secure the natural conditions necessary for the biological existence and evolution of the human race. As a result, the economic system requires the existence of the natural system in order to exist itself and, to that purpose it must look to the proper function of the natural system that serves as a provider of the biological necessities vital to human beings. In effect, the natural system sets the biological foundation for the human race and its evolution, and should continue to do so in order for any future evolution to be biologically viable. Thus, if such an evolution is desired, the human race must solely rely on the natural system, in order to look forward to a biologically 'hale' future. Let us, for instance, consider such fundamental and indispensable human processes as breath and digestion, processes exclusively supported by the natural system which was once dubbed the 'living room' for Homo Sapiens (James et al., 1989). Homo Sapiens do remain both the fundamental and indispensable actor running the economic system. With good reason then, the smooth function and evolution of the natural system pose themselves as a prime condition for the existence and function of the economic system, a condition that should also be regarded as the indispensable requisite for the ESED. Indeed, in order to reach economic development, in other words, to obtain an increase in the outcome of the economic system, the economic system and especially human beings, its actors, should exist in a biologically sound form. It would be pointless to speak of the ESED without ascertaining first that the biologically robust status and evolution of human beings have been safeguarded by means of the proper function of the natural system. The relationships interwoven between the three major systems inevitably lead to the foregone conclusion that any major and crucial disturbance in the broadest system of all, that is, the natural system, will indubitably result in biological impacts bearing on the human system, thus certainly undermining the biological welfare and potentially endangering the existence of human beings, the soloists responsible for economic virtuosity. Hence the realisation that preservation of the smooth function and evolution of the natural system constitutes the one prime condition for the ESED that cannot be dispensed with.

Another substantially different 'support' is offered directly by the natural system to the economic one. Economic processes require natural inputs as any process of production uses mass and energy taken directly from the natural system. What we call 'natural resources' is a surefooted path to offering natural inputs to any economic process. The debate on natural inputs is paramount to economic process, and the substantially different approaches that have been proposed are well known. Indicatively, Solow (1986) speaks of a substantial decrease in the indispensability of natural inputs caused by the technological boom while Georgescu-Roegen (1979) asserts that, as the earth's population and economic production increase, natural inputs in the economic process will also increase. For the time being, any practical consideration should be based on the current evidence and data concerning natural inputs to the economic process worldwide. International statistics show substantially high and even increasing levels of natural inputs and therefore there is no indication of any fundamental reduction trends (Atkinson and Halvorsen, 1984; Hudson and Jorgenson, 1974). Consequently, it seems that natural inputs are indispensable for economic progress, at least for the foreseeable future. What is more, natural inputs are necessary for an increase in the outcome of the economic system, that is to say, for economic development.

Although the exact magnitude of natural inputs and the relevant trends may be debatable it is clear that natural inputs should be incorporated in economic processes and support economic development. This necessity essentially forms the second condition of the ESED. An economic process being a material process, requires mass and energy that eventually come from natural resources. Essentially, the ESED requires that economic development is sufficiently provided with natural inputs. The term 'sufficient provision' implies that scarcity of natural resources does not necessarily impose any indispensable constraint on economic development, if one is to take into account substitution potentials, technological advancements and recycling alternatives.

The two conditions of the ESED discussed above correspond to two discrete fundamental 'supports' offered by the natural system to the economic one and are identified on the basis of the fundamental relationship adopted in Passet's model. It goes without saying that there exist other forms of 'support' offered by the natural system to the human and economic ones, such as natural aesthetic welfare, arising from the sound ecological stage of the natural system. Although such welfare is a direct contribution of the natural system to human beings, it is not considered an indispensable condition for the ESED. Aesthetic welfare depends on the preferences of human beings and therefore, as preferences may vary, it is possible to substitute aesthetic welfare with other welfare forms. On the contrary, other elements that are manmade cannot serve as substitutes for either natural inputs or the biologically sound function of humans since they are both, respectively, indispensable for economic development to occur and for the economic system to exist.

5 The operational conditions for ESED at micro level

The previous section identified the two major 'supports' that the natural system has to offer to the economic one, and through them it also identified the conditions for ESED. However, the analysis of the issues that these 'supports' deal with does not bring forth any practical tenets, that is, any conditions that can be applied to everyday decisions and especially to the evaluation of programmes and projects. And it is precisely those very programme and project levels that prove so instrumental in revealing the practical facet of the ESED. From time to time, global and general environmental policies are drawn up at international and national forums and set general tenets. All too often, these tenets are quite vague and fail to form any particular action plan. On the contrary, there is nothing vague about the great number of programmes and projects designed and applied every single day. They result in the economic processes that are in force today and codetermine the state of the natural system. And it is precisely the importance of such programmes and projects that has prompted economic science, in an effort to promote economic development and social welfare, to offer very practical instruments and methods to assist in their evaluation. Such methods in the framework of standard economics include the two most prevalent ones and, specifically, the cost benefit method and the cost effective one. However, environmental policy aiming at achieving the ESED lacks practical tenets and their respective evaluation methods that may have ensured appropriate protection of the natural environment and hence establish the ESED at the micro level. These sort of practical tenets that may further assist in specifying the two major conditions of the ESED, are to be traced in the present section.

5.1 The first condition: 'biological sustainability'

The proper biological function and evolution of the natural system has been identified as the prime condition of the ESED since it ensures the biologically healthy status and evolution of the human race. The smooth biological functioning and evolution of the natural system could be given the name 'biological sustainability' or 'biosphere sustainability'. How can 'biological sustainability' be ensured? The natural biosphere system consists of all biotic and unbiotic elements comprising the earth's system as well as the atmospheric levels surrounding the earth. Each natural element participates in numerous natural functions and all natural functions determine ecological balance and the evolution of the natural system. In order to preserve ecological balance and evolution of the natural system, natural functions should be maintained in a proper form. In turn, such maintenance requires that the natural elements and species that perform the natural functions be present at a satisfactory level.

Are all natural functions indispensable to biological sustainability? Do all the natural elements and species play a decisive role in the maintenance of the natural functions? The first question cannot be answered in an explicit way. Our knowledge of the natural system is not only limited at present, but will probably be found sadly wanting and far behind the current needs to form an effective environmental policy. In this context probably we could try to choose certain natural functions as more fundamental since they are directly contribute to human beings biological status. Although such an approach may be proven ineffective, it seems that it could be a good starting point. Certainly an alternative, more effective and risk averse approach could preserve all natural functions. This risk adverse approach will be adopted for our further analysis for the rest of the paper.

In the matter of natural elements and species, throughout earth's history it should be admitted that there have been several natural species which disappeared or became extinct without causing any decisive disturbance in the natural system functions. As it turns out, there seems to be resilience in natural functions, which are not always jeopardised by the extinction of any one species or element. In this context the crucial question is, how could this resilience be estimated in operational terms? How far and to what extent could the natural elements and species be eliminated without disturbing the natural functions? Again, at this point, it should be admitted that our knowledge concerning the natural system and its evolution is actually scant. Ecology is a relatively new science and our knowledge about the science of biology is not sufficient to describe and predict the conditions for the 'healthy' evolution of the natural system (Norgaard, 1984).

In this scientific penumbra and based on our limited knowledge and experience, we should eventually come down and design an effective protection of natural functions. In fact, one may realise that during the past few years, certain fundamental natural functions are not working properly: change in climate and global warming; biodiversity disturbances; oceans and ground water pollution; desertification; these are but a few of the problems standing out for their severity as crucial environmental problems. Bearing those prime examples in mind, one may conclude that in the past few years there has been a systematic disturbance in major natural functions, a disturbance that could be attributed to the quantitative elimination and qualitative deterioration of certain natural elements and species. For example, let us consider global warming. It is caused by the qualitative deterioration of the earth's atmosphere because of the accumulation of certain pollutants (CO_2). The example, deliberately chosen, indicates that it is not only the extinction or elimination of natural species that should be blamed for disturbing natural functions. Increases in, and accumulation of, certain elements (natural or manmade) can also be the culprit behind the substantial exacerbation observed in natural functions. These elements, known as pollutants, may be necessary up to a certain level for the natural functions, but their accumulation beyond certain levels results in crucial, ecological disturbances. In consequence, certain natural functions are currently jeopardised because some natural elements are crucially over eliminated or over concentrated.

In the past, there were fluctuations in these natural elements, which wrought no serious impact on the natural functions. However, the evidence now before us is indicating further elimination or increase, thereby overcoming the relevant resilience levels.

With this in mind, one may assert that in order to ensure the 'wellness' status of natural functions, the relevant natural elements should be kept within certain limits reflecting either stock levels, concentration levels or quality characteristics. The preservation of the natural functions requires the conservation of certain crucial levels of natural elements and the confinement of pollutants to below crucial thresholds. The crucial levels of the natural – biotic and unbiotic – species and pollutants that determine the healthy existence and evolution of natural functions could be indicatively termed 'biologically crucial levels'. Therefore, a 'biologically crucial level' could be the one defining the upper limit of the concentration of a pollutant or determining the lower, quality or stock level of a natural species/element, which ensures the respective proper environmental functioning. Obviously, such a consideration may give rise to the following questions:

- for which natural elements should the 'biologically crucial levels' (BCLs) be preserved?
- how can the relevant BCLs be defined?

In order to determine the natural elements and species whose respective 'biologically crucial levels' should be preserved, two criteria seem appropriate for application. The first criterion derives directly from the ESED and its long-term perception: all natural elements should be preserved from extinction in order to keep open the prospects of future generations to form their own preferences and to pursue their own welfare. Future generations should be able to enjoy the same opportunities as present generations in shaping their preferences and should therefore be 'equipped' with the same natural elements and/or species that display the same genetic variety as the current ones (Rammel and Van Den Bergh, 2003). In operational terms, the first criterion is quite easy in application and capable of preserving any species from extinction. In essence, what it entails is that when the first criterion is applied, the minimum viable populations and magnitudes should be preserved (Clark, 1976). In the context of the first criterion, the minimum viable populations are tantamount to the 'biologically crucial levels'.

The second criterion applies to those natural elements and species that should be preserved at a level higher than the minimum sustainable population. These species are those that participate in those natural functions that provide the biological basis for a biologically healthy existence and evolution of the human race. Yet, when it comes to the BCLs of those natural elements and/or species, the issue is far more complex. Which are these elements and species and how can their BCLs be defined? The limiting factor in answering this question is our knowledge on the natural system and the respective processes taking place within it. Although knowledge and experience on natural processes has advanced by leaps and bounds in recent years, it is still far beneath a level adequate enough to enable us to define clearly the indispensable natural elements and to estimate their respective BCLs. Be that as it may, a rational society should be able to resolve the problems stemming from this uncertainty; especially, since solutions concern the very essence of its biological existence and evolution. It then appears that a rational policy should be a policy averting risk. It is thus evident, that such a policy would necessitate preserving those natural elements and species that are *potentially* indispensable for the natural functions relevant to humans' biological existence and evolution. To identify the BCLs for these natural assets, a risk averse policy, taking into account existing knowledge, should call for maintenance of satisfactory buffering levels. As scientific knowledge increases, the relevant buffering levels could be readjusted should they prove relatively strict.

In conclusion, an operational framework for the first condition of the ESED, 'biological sustainability', consists, on the one hand, of preserving the 'biologically crucial levels' of certain natural elements and species and, on the other hand, of avoiding overstepping the 'biologically crucial levels' of pollutants. The 'biologically crucial levels' emerge as those crucial thresholds ensuring the proper operation of (fundamental) natural functions and the existence of all natural species.

Needless to say, BCLs define the minimum levels of environmental protection and therefore higher levels of protection could be defined on the basis of the mainstream rationale or other socioeconomic criteria.

Could such a concept be considered a newcomer in economic science? BCLs bear striking similarities to 'safe minimum standards' (Bishop, 1978). Yet, 'safe minimum standards' call for preservation of the crucial levels of natural species and functions whenever preservation does not prove too costly for economic development. In the framework of standard economics, the prime objective is economic development and the target of environmental protection is pursued as long as it does not overly affect the prime objective. In quite a different manner, the ESED calls for an economic development within the limits imposed by the natural system, or at least within the limits imposed by the maintenance of the biological basis of human beings. These limits are operationally expressed by the term 'biologically crucial levels' which should be preserved regardless of the rising short term economic costs.

5.2 The second condition: availability of natural resources

The second condition for the ESED involves sufficiently providing the economic process with natural inputs. A production process requires natural inputs in the forms of mass and energy in order to take place. What is more, economic development necessitates increasing production, which, in turn, relies on increasing natural inputs. However, the availability of natural inputs is limited and defined by the accessibility of natural resources (Georgescu-Roegen, 1976). Will the accessibility of natural resources be sufficient in supporting economic development in the long run? To answer this question, one should examine the factors that determine, on the one hand, the accessibility of natural resources and on the other hand, the requirements of economic development. There has been heated scientific debate regarding the requirements for natural inputs by economic development. The debate indicates the very fact that natural scarcity plays a leading role indeed in the economic process. However, although no one can forecast with any degree of satisfaction the exact requirements for natural inputs that will be necessary for economic production, one could draw some reasonable conclusions, as follows. Since human beings need certain goods with a material basis of considerable physical dimensions, material inputs are necessary for economic production. Furthermore, since 100% recycling is practically impossible, natural resources will continue to play a decisive role in providing these material inputs (Georgescu-Roegen, 1979). Moreover, energy inputs are indispensable for any kind of action, and hence for economic production to take place. Therefore, energy resources are crucial to the production process.

The ESED targets the task of leaving open the potential for economic development in the long run. It implies that material and energy natural resources should be sufficient to 'support' economic development now, as well as in the future. Owing to several practical and technical reasons, the requirements for natural inputs in the future cannot be estimated. In addition, the preferences that future generations may exhibit are unfathomable at present. Given this uncertainty, an operational and rational interpretation of the ESED is that it targets future accessibility of natural resources that can support 'a reasonable' economic development in the future. The future maximum accessibility of natural resources depends on their natural characteristics and on the current patterns of use. Let us examine systematically, both natural characteristics and current patterns of use.

Natural resources can be classified in three major categories:

- nonrenewable
- renewable exhaustible
- renewable nonexhaustible.

Exhaustible are those renewable resources, which are exploited when their utilisation permanently exceeds their regeneration rate; while nonexhaustible renewable resources cannot be exploited, since utilisation is confined, by nature, within their regeneration rate.

The current use of nonrenewable resources shows in no uncertain terms that their future availability will decrease. Any exogenous constraint in the current use of nonrenewable resources is an exogenous limit on current economic development. In that sense, 'supporting' any future development necessitates confining the current one. Which type of development counts more, the current or the future one? This question has been answered in practice by human society, which finds the current development, more preferable as after all, it increases the utility of current generations. Yet, in the context of competition between current and future development and when they are mutually excluded, one can hardly summon an ethical criterion in support of future development. It seems that the biological instincts of the human race (similar to other natural species) lead to a higher ranking of the present utility (Georgescu-Roegen, 1971). As a result, one cannot propose an operational criterion for constraining the current use of nonrenewable natural resources at present for the sake of future use. However, the criterion of a 'wise' use, which would advocate avoidance of any unnecessary waste of nonrenewable resources, should be applied.

As far as nonexhaustible renewable resources are concerned, the current patterns of use do not influence their future accessibility. Therefore, it is pointless to propose a restrictive criterion in the context of the ESED. On the contrary, the current pattern of use of exhaustible renewable resources influences their future accessibility when the rate of current use exceeds the natural regeneration rate. A rate exceeding the respective regeneration rate reduces the available stock of resources; furthermore, if the rate of use permanently exceeds the respective regeneration rate, the resource is led into depletion (Clark, 1976). In this context, could an operational criterion ensuring the ESED be proposed? The criterion of Pareto optimality, as modified by Hick-Kaldor, is an answer to this question and once applied in an intergenerational framework, can lead to an appropriate operational principle (Pareto, 1964). The essence of Modified Pareto criterion is that an allocation of resources is optimal whenever there is no an alterative allocation that increases the utility of some individuals more than it decreases the utility of another individual. So, the optimal allocation is the one maximising the sum of individual utilities and can, therefore, be called 'efficient allocation'. The application of this Modified Pareto Criterion in the intergenerational context can attribute an operational principle for the use of exhaustible renewable resources. We will call the Modified Pareto Criterion in the intergenerational context as the 'Intergenerational Modified Pareto Criterion' ('IMPC'). Let us reconsider the use of renewable exhaustible resources within the prism of the IMPC. Any pattern of use, that reduces irreversibly, or even depletes, the stock of exhaustible renewable resources essentially deprives future generations of their potential use and hence of the relevant potentials for utility. This situation is not a Pareto optimal one. Although the potential future utility decreases as a result of a more extensive current use, resulting in higher current utility, the potential foregone future benefits, by far exceed the current benefits. If B_0 stands for the current benefits, arising from the use that exceeds the regeneration rate and irreversibly depletes the stock of the resource, and B_n the respective potential foregone future benefits, then B_n seen to be greater than B_0. Indeed, $B_n = \sum B_i$, where B_i stands for the foregone potential future benefits of the future year i, then B_n by far exceeds B_0 being the benefits in a limited time period. In effect, where all future time periods are concerned, it is a potential Pareto optimal to ensure the potential future benefits B_n instead of procuring the current benefits B_0. This does not imply that the current generation should totally sacrifice the benefits stemming from the use of the resource; the use of the resource can take place as far as it does not exceed its generation rate. It stems down to the fact that the application of the Pareto optimality criterion is suitable in establishing, even within the mainstream economics, a pattern of use proposed by several scientists as a condition of the ESED: a use of renewable (exhaustible) resources that should not exceed the relevant natural generation rate (Allen, 1980; Goodland and Ledec, 1987), so that the stock of the resources and their potential use is not irreversibly reduced.

In a nutshell, as far as the accessibility of natural resources for economic production is concerned, two practical criteria for operationalising ESED could be proposed:

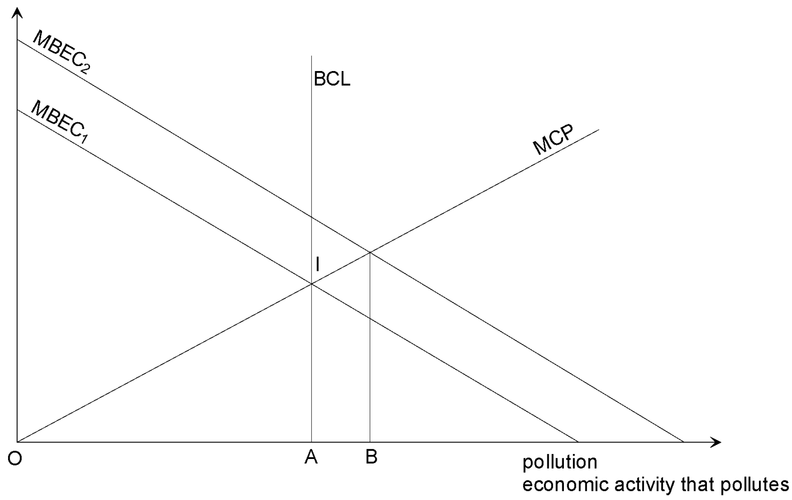
- to use non renewable resources in a 'wise' way that works at avoiding any unnecessary decrease in their stock
- to use renewable exhaustible resources in such a way so that their harvest rate does not exceed the regeneration rate.

Despite the first criterion's inability to come up with any clearly practical guidelines, it does offer a framework for action. The second criterion does lead to explicit guidelines which stem from the Potential Pareto optimality when applied in an intergenerational context.

6 The political economy of preserving the BCLs

The preservation of the BCLs has been proposed as the normative criterion for attaining the ESED. The ensuing question pertains to those actors and institutions that have the power to adopt such a normative criterion. Could such an actor be an individual or a private firm? It has been drummed into us by economic theory that whenever an individual or a firm decides on the level of environmental protection, they take into account and compare the relevant private costs and benefits. Figure 2 depicts the pertinent rationale.

Figure 2 The optimum level of environmental protection and BCL



The horizontal axis represents not only the economic activity that causes pollution, but the magnitude of pollution as well. Curve $MBEC_1$ indicates the marginal benefits arising from the economic activity that pollutes; hence curve $MBEC_1$ could be perceived as representing the marginal benefits arising from pollution. The MCP gives the marginal cost to individuals, imposed by pollution. Interaction between individuals and firms is expected to confine economic activity and pollution at the OA level (Coase, 1968). In absence of effective self regulation, OA is the environmental protection target adopted by the authorities on the basis of welfare maximisation (Pearce and Turner, 1991). Thus, the optimum level of environmental protection is determined so that environmental deterioration does not exceed OA. Assuming that the relevant biologically crucial level (BCL) does coincide with OA pollution levels, the relevant BCL is preserved thereto as long as pollution does not overcome OA. Could the BCL be systematically preserved or are there any conditions that may lead to its violation? Consider an increase in private benefits arising from the polluting activity; it shifts the respective marginal benefits curve upwards to the $MBEC_2$ location. Such an evolution could be the outcome of a change in the preferences of the present generation that may suddenly come to like the product of the polluting activity more than they previously did. In effect, the new optimum level of pollution is defined at OB. Evidently, by confining pollution at OB, pollution does not manage to preserve the relevant BCL. That leads to the conclusion that an increase in the benefits of the polluting activity may lead to violation of the corresponding, previously preserved BCL. By and large, protection of the BCLs by individuals and firms can constitute only a chance occurrence and is susceptible to the preferences that the current generation has.

In compliance with the conditions of Figure 2, BCLs are systematically preserved if, and only if, the curve of pollution costs becomes vertical at those pollution levels indicated by BCL. Indeed, in Figure 2, if and only if the curve OI BCL represents the marginal costs of pollution can BCL be irrevocably safeguarded. The OIBCL curve shapes a technical condition for biological sustainability. In socioeconomic terms this technical condition implies that the costs of violating BCL are unacceptably high. In essence, the crux of the matter lies in the hypothesis that when pollution wreaks deterioration on the environment beyond BCL, the relevant costs tend to infinity, and consequently the respective marginal costs curve becomes vertical. The violation of BCL results in biological unsustainability and since such an evolution is considered unacceptable, the vertical cost curve is defined.

The question arising at this point is: who are the actors and institutions that could adopt the modified vertical costs curve? And again, who are the parties that may evaluate the costs of biological unsustainability as unacceptably high? Society emerges as the only institution capable of rating the costs resulting from the violation of biological sustainability as unacceptably high. Society's long-term consideration, in tandem with society's holistic spatial perception, leads to an evaluation that corresponds to the technical condition of the vertical marginal costs curve. On the contrary, individuals are agents who are rather shortsighted and therefore, can only partially perceive the alarming sum of all costs stemming from the violation of biological sustainability. Systematically, one may identify four factors inducing individuals to adopt a 'shortsighted' perception. The first one is the time factor. Despite the conspicuous presence, in both the short and the long term, of repercussions owed to biological unsustainability, individuals can perceive only the short term ones. As a matter of fact individuals assess, evaluate and rate only those repercussions that are valid during their own life span and probably for an additional period accounting for the life span of direct descendants, dismissing long term, albeit imminent, repercussions that may affect future generations. In that sense, the term 'time span effect' may be an apt label for this deepseated, intrinsically myopic outlook on environmental impacts. The second factor asserts that individuals are incapable of perceiving impacts spatially holistic; rather, they see impacts as occurring within their own narrow and limited surroundings which functionally serve those individuals' biological needs. However, environmental impacts could also be found happening in 'remote' places, affecting others individuals as well as their descendants. Thus, another apt term defining this second factor may be 'space span effect' and by that to mean the shortsighted outlook on environmental ramifications owing its existence to the inborn limited capacity of shortsighted individuals to consider space in its entirety. The third factor pertains to the economic evaluation of pollution impacts; a subjective process dependent on individual preferences. Any change in the preferences signals changes in the protection level, and since the preservation of BCL is susceptible to the changes in individual preferences, it runs the risk of being overstepped. The fourth factor concerns another characteristic of economic evaluations: income distribution and wealth endowment. Any change in either income distribution or wealth endowment results in a different protection level.

Out of these four factors one may draw the conclusion that individual evaluations may not systematically preserve BCLs and, in consequence, lead to violation of biological sustainability, the prime condition of the ESED. With that in mind, it is evident that society is shown to be the only institution that should be entrusted with the task of turning out the appropriate estimations for the overall costs of biological unsustainability and as such, it should also make those decisions that preserve BCLs in a binding, final manner. For society, the preservation of BCLs emerges as an indisputable social preference which provides the boundaries for the spectrum of individual preferences of contemporary generations.

Does the constraint on individual preferences, imposed in the name of BCL preservation, violate democratic processes and freedom of the individual to shape preferences and to make choices? As long as social preferences increase the potential for social welfare, they will rank social preferences higher than individual preferences, which should then be confined within the spectrum boundaries drawn by the social ones. This tenet is quite old and firmly established within even the most direct of democratic societies. One may seek proof as far back as Aristotle who writes:

> "The priority belongs to the 'city's society' with society coming first, 'before' individuals whose preferences bow to the city's priorities." (Aristotle, *Politica*, p.125a, 18, authors translation, in English see Barnes (1984))

At another time in history, Heraclitus (1993) states that

> "first comes the common-social rationale and individual rationales are determined by this social one." (Heraclitus '*About Nature*' (23), authors translation, in English see Kahn (1979))

The historian, Thucidides corroborates:

> "The society-city is far abler to be beneficial towards its individuals when it is prosperous, than individuals who are prosperous while their city is poor." (Thucidides History B' presenting a speech of Pericles the Athenian. In English see Edinger (1979), authors translation)

As a result, what remains to be proven is that the preservation of BCLs, and hence of biological sustainability, does lead to an increase in social welfare and therefore it could be defined as a social priority of paramount significance. Indeed, the preservation of BCLs leads to Potential Pareto optimality by increasing the prospects for social welfare. In the framework of the ESED, social welfare should be defined as the sum of the welfare of all individuals of all generations. Let us denote W_j the welfare of generation j, consisting of the sum of the welfare of all individuals belonging to generation j. W_j consists of two factors: the welfare arising from a healthy biological existence and evolution of human beings denoted by B_j and the welfare arising from conventional economic goods denoted by U_j. As a result,

$$W_j = f(B_j, U_j). \tag{1}$$

Evidently, the biologically 'healthy' status emerges as a prior and necessary condition for the realisation of U_j. Formally, this can be denoted as:

$$W_j = B_j U_j. \quad (2)$$

Therefore, when $B_j = 0$ then $W_j = 0$.

The violation of BCLs and hence the biological unsustainability results in $B_j = 0$ for future generations. The trade-off for this loss is an increase in the welfare U_j for current generations. The increase in U_j leads to an increase in W_j of the respective current generations. However, this occurs at the expense of B_j and, hence, of W_j for future generations. Taking into account that biological non-sustainability is an irreversible evolution it is clearly observed that $\sum_1^j W_j$ is greater when $W_j > 0$ for every generation j, in comparison with $\sum_1^j W_j$ when some W_j tends to zero after a certain time period when biological non-sustainability occurs (because $B_j = 0$ after this time period).

So, $\sum_1^j W_j$ with $B_j > 0$ is greater than $\sum_1^j W_j$ with B_j tending to zero after a certain time period. Therefore, $\sum_1^j W_j$ with $B_j > 0$ is a Potentially Pareto preferable position in comparison to $\sum_1^j W_j$ with some B_j tending to zero after a time period.

In a nutshell, it appears that the preservation of BCLs and hence of biological sustainability increases social welfare and establishes a potential Pareto optimality in the long run, where all generations are concerned. It seems that, in traditional welfare terms, the preservation of BCL as a social preference confining individual preferences is justified. Indeed the traditional Pareto criterion can establish the preservation of BCLs as a prime social preference if applied across an intergenerational spectrum.

7 Concluding remarks

The concept of the ESED may still be vague at the aggregate level, yet, the intensity of the environmental problems and environmental impacts, caused by a plethora of projects and development programmes, is such that the ESED stands in urgent need of an operational framework at the micro level, demanding practicality. After all, the micro level is where everyday decisions largely determine the evolution of both the natural and the economic system, and that is precisely where the ESED actually calls for sustaining the natural system. One may identify two distinct contributions of the natural system to economic development. As its first contribution, the natural system provides the biological basis for human existence and evolution, since humans are indispensable actors on the economic system. Nowhere, throughout human history, has environmental deterioration resulted in fundamental biological disturbances. Nevertheless, the current ecological status indicates that contemporary environmental impacts create nonreversible negative biological evolutions. Thus it appears that the Biologically Crucial Levels of natural species and elements should be preserved at all costs in order to ensure the biologically sound evolution and function of the biosphere and, by extension, of the human species. This normative operational condition of the ESED could be justified through the application of a Pareto criterion in the intergenerational framework. Needless to say that environmental protection higher than the biologically crucial levels could be pursued by societies. The biologically crucial levels simply constrain the spectrum for the protection which should not be lower than BCLs.

On the other hand, what remains open is the creation of those social institutions that can adopt this normative principle since individuals acting out of sheer self-interest can preserve biological sustainability purely accidentally. Social preferences should prevail and confine individual ones so that the potential for social welfare increases. In effect, the preservation of biological sustainability can be adopted as a social priority since it increases the prospects for social welfare. When social institutions preserve biological sustainability, they are acting on behalf of the biological rights of future generations who cannot be present in decisions made today anyway. Indeed, biological sustainability is beneficial for both current and future generations although the impact of biological unsustainability may be heavier in the future because of the accumulated irreversibility.

The second contribution of the natural system to economic development refers to the accessibility of material and energy resources. This accessibility involves a competition between contemporary and future generations. The competition entails the use of nonrenewable resources as inputs to economic production. This competition precludes the establishment of a normative criterion well grounded inside the standard welfare framework. As far as nonrenewable resources are concerned, the only plausible tenet which could be proposed, is to avoid their unnecessary use and depletion. Furthermore, the substitution of nonrenewable with renewable resources as well as the development of efficient technologies may also be proposed. However, it seems that no criterion based on the standard welfare grounds could be proposed as a clearcut, quantitative, specification of these tenets.

On the contrary, a normative criterion can be proposed for the use of renewable exhaustible resources Indeed, a pattern of use that eliminates and even depletes their stock leads to a nonoptimal Pareto evolution path. In effect, an operational condition could be proposed, defining a pattern of use that does not exceed the natural regeneration rate.

As a result and where all future generations are concerned, it seems that the ESED can indeed be considered to be a framework that ensures the potential for a Pareto optimality. Specifically, the ESED may be viewed as a pattern of development that does not preclude the achievement of Pareto optimal positions with reference to the welfare resulting, directly or indirectly, from the natural environment. This position can lead to two analytically distinct operational conditions for economic action at the microlevel. First, unless we wish to jeopardise the biological basis and evolution of the human race, we do not transgress the Biological Crucial Levels of the natural functions, processes and species. This evolution could be called ‘biological sustainability’. Secondly, we do not use renewable exhaustible resources at a rate that permanently exceeds the respective natural regeneration rate, if we desire resources to yield a harvest in the long run.

In this context, what is needed is a bioeconomic institutional setting that adopts and applies these operational principles. Society should design and establish appropriate social institutions that can suitably confine individual preferences within those boundaries that ensure Pareto Optimality in the long run.

Admittedly, the proposed approach and especially the concept of the Biological Crucial Levels need further elaboration and research. BCLs will have to stay and be defined according to the uncertainty under which we work, as well as the present limits on our knowledge about natural functions and interactions. Proper methodologies and interdisciplinary methods should be developed to lead into practical guidelines for decision makers. The concept of BCLs should be traced within the joint framework of coevolution of nature, society and economy. Quite probably BCLs form the prerequisite for such an evolution to occur and be environmentally sustainable. What is more, BCLs ought to be evaluated against safe minimum standards, thus forming a popular concept in environmental protection. Granted, safe minimum standards were accepted as appropriate in the 1970s when environmental problems were less severe and irreversibilities few and far between. Today, and under the influence of severe environmental problems as well as the urgency for the ESED, BCLs may form the precondition for effective environmental protection in the long run.

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