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Tracing operational conditions for the Ecologically Sustainable Economic Development: the Pareto optimality and the preservation of the biological crucial levels

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Abstract The operational designing of Environmentally Sustainable Economic Development (ESED) emerges as an urgent and demanding task. Even though ESED has paved the way for thought-provoking and constructive scientific dialogue, appeal for designing an operational ESED is still lagging behind the needs of contemporary societies, leaving much to be desired. With this in mind, the present paper will aim at delineating principles for the operational application of ESED. First, the preservation of crucial properties of environmental functions and ecosystems, emerges as a prime condition of ESED. The second condition concerns the provision of the economic process with sufficient natural inputs; in this context, the paper intends to trace certain operational tenets governing the use of natural resources. Finally, the appropriate institutional settings for the operational design of ESED are traced.

Keywords Sustainable development · Co-evolutionary development · Intergenerational Pareto optimality · Safe minimum standards · Critical natural capital · Conditions of sustainable development · Institutional economics

1 Introduction

The scientific dialogue that has been triggered by the Environmentally Sustainable Economic Development, has led to two schools of thought debating over the interpretation and application of the ESED. The school of strong sustainability maintains that it is crucial to preserve the existing natural capital and hand it down to future generations. Only through this natural capital bequest, argues this partic-

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ular school of thought, will future generations be able to maximize their welfare under similar natural endowment conditions as current generations enjoy. In contrast, the school of weak sustainability comes to maintain that the criterion for ESED is based on long-term non-declining per capita utility.

It is to be observed that both schools offer a rather weak ground for an operational application of ESED. The school in favour of strong sustainability proposes a criterion that might be extremely restrictive for economic development, without proving that such a restriction is necessary for an operational ESED. At the same time, the arguments proposed by the school in favour of weak sustainability are deprived of any operational appeal whatsoever since there are no indicators available in order to estimate the utility future generations may make; let alone gauge their preferences which so far remain to be seen.

Having thus set forth the circumstances salient to ESED at this time, the present paper aspires at exploring and proposing certain operational conditions for the achievement of ESED. It is towards this end, that the ‘‘supports’’ offered by the natural environment to the economic process are identified in a systematic way as, once these ‘‘supports’’ are ensured, ESED is eventually achieved. Specifically, there are two ‘‘supports’’ provided to the economic process by the natural environment that the present paper identifies.

First, the natural environment offers the biological conditions for the healthy biological existence and evolution of the human race, as human beings are the main actor and commander of the economic process.

Second, the natural environment provides the economic process with the inputs of mass and energy. However, providing the economic process with sufficient inputs of mass and energy constitutes a delicate issue triggering extensive and heated dialogue within the economic science (Georgescu-Roegen, 1971; Solow, 1974). The present paper's contribution to this debate is the investigation of certain principles, for the use of natural resources, with a view to sufficient provision of the economic process in the long run. The proposed principles in the present paper do not differ substantially from those of other scientists.

However, this paper comes to propose a condition substantially different from those proposed by other scientists and experts in order to ensure the long-term health, biological existence as well as evolution of the human race. What the present paper suggests in essence is that the preservation of crucial, quantitative and qualitative characteristics of the natural elements and functions is a prime condition for ecological balance and evolution of the natural environment and hence of human beings. Therefore, the preservation of such crucial properties of natural elements and functions emerges as a prime condition for ESED.

The adoption of the target of the preservation of the crucial properties of natural environments by a society is also examined in institutional terms. The inference drawn is that a democratic society may well adopt such a target without disturbing the fundamental principles of individuals freedom.

The proposal for preservation of certain ecological/biological 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 the preservation of crucial/minimum ecological standards may be feasible as long as is not overly costly and hence restrictive for economic growth (Bishop, 1978). On the contrary, this paper's approach does not accept any trade-off in the preservation of the crucial natural and ecological thresholds. Therefore, it seems that our approach contends the economic rationale for preserving "safe" minimum standards. The same holds for Norgaard's approach which decrees that the natural and ecological thresholds are socially defined in the co-evolutionary process if he implies that the socially defined thresholds are not take into account certain biological levels/facts which irrevocably impose constrains to the spectrum for the socially defined thresholds (Norgaard, 1994, 1995).

The present paper asserts that certain environmental thresholds/levels can be determined by the natural sciences and the preservation of these levels is appropriate, for operationalizing the ESED.

Recent studies delineate methodological frameworks for the determination and preservation of natural thresholds pinning upon the latter the label Critical Natural Capital (Ekins, Folke, & De Groot, 2003).

2 The Ecologically Sustainable Economic Development

The concept of the Ecologically Sustainable Economic Development (ESED) emerged in the publications of the World Conservation Strategy as a policy framework to combat the environmental decay afflicting our planet, a decay mainly owed to the increasing 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 jeopardizing the likely potentials for similar benefits in the future" (WECD, 1987). From these definitions it is patently 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 definition, addressing policy issues, can be found also in the Bruntland 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 fulfilled without trade-offs between fulfilment of present generations needs and fulfilment of future generations needs. The word "potentially" applies exclusively for the needs of future generations that cannot be brought under scrutiny at present since the preferences of future generations have not arisen as yet, and, consequently, are unknown to us; therefore the only readily available strategy would be to waive, for the time being, the potential for fulfilment of the needs of future generations, irrespective of the shape these needs may assume (Norgaard, 1994).

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

"Strong" sustainability views the needs of future generations as independent of the needs/preferences of present generations and maintains that any needs arising at and belonging to a future period may have to be formulated in a manner entirely independent of the way present needs/preferences are currently formulated. After all, the needs and preferences of future generations may take a different shape than that assumed by the needs and preferences of present generations or even be wholly irrelevant to them. In this context, a rational policy should aim at eliminating the boundaries that stifle the formulation and fulfilment of future generations needs and preferences. As a result the ''strong'' sustainability approach asserts that the ESED, offering itself as a rational policy, must, eliminate those boundaries whose cause may lie in advanced environmental degradation and inexorable exploitation of natural resources. For, once these calamities have gathered momentum, they decrease the potential welfare that generations in times to come may have. With that consideration in mind, Christensen outlines sustainable development as the development ensuring the existence of the natural environment, which acts as a basis for human welfare (Christensen, 1989). Similarly, Goodland and Ledec 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'' (Goodland & Ledec, 1987). Further, Allen argues that ''sustainable utilization is a simple idea: we should utilize species and ecosystems at levels and in ways that allow them to go on renewing themselves'' (Allen, 1980).

Veering towards a different direction, the approach of ''weak'' sustainability accepts that the needs and preferences of future generations will be similar and in any case contingent on the needs and preferences of present generations. Furthermore, the needs/preferences of future generations can be foreseen by extrapolating the evolution of current and past needs/preferences. The essential characteristic of this approach is the assumption that future generations can substitute the fulfilment of needs and preferences pertinent to the natural environment with the fulfilment of needs and preferences 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 natural environment's degradation, 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 in the future as well. In this context, the criterion of sustainable development is the per capita utility. As long as the per capita utility is not declining, welfare to be enjoyed by future generations, is ensured and therefore sustainability prevails. 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 continuing if accompanied by other activities which increase welfare to an extent greater than the extent to which welfare, caused by the degraded environment, is lost. Such an evolution, argues the ''weak'' sustainability approach, can constitute a sustainable development path. As a result, future generations can do with less environment as long as manmade assets can guarantee a non-declining per capita utility. The implicit assumption underling this argument is that future generations have similar patterns of values with present generations and hence adopt a similar trade-off ratio between environmental utility and manmade utility. In this context, Pezzey 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'' (Pezzey, 1989). Pearce et al. defines that sustainable development is a situation in which ''the development vector increases monotonically over time'' (Pearce et al. 1989; Pearce & Atkinson, 1993; Barbier & Markandaya, 1990).

It is, therefore, evident that there exist two fundamentally different directions in the scientific interpretation of the ESED. The direction of strong sustainability supports the maintenance of the existing natural ''capital'' as a condition for the formulation and fulfilment of future generations needs and preferences while the direction of weak sustainability endorses the mainstream criterion of the non-declining 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 approaches valuable indeed which, however, are already deficient in operationability. 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 speaks of uneconomic growth and proposes physical limits in economic process and in economic growth so that the latter may be a lasting one. This ''steady state'' approach proposes explicitly that economic process and production should not overcome the carrying capacity of ecosystems (Daly, 1999). Georgescu-Roegen envisages grave and irreversible scarcities of natural resources and an exacerbated pollution problem if economic production continues at its current pace. In this context, he foresees irrevocable unsustainability by which future generations will be dealt a far heavier blow (Georgescu-Roegen, 1971, 1976).

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 operationability still remains.

3 Exploring the operational meaning of the ESED

Literally speaking, the ESED refers to two discrete entities: 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. Economic development refers to a 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. Needless to say, welfare can be created by other processes as well, such as philosophical contemplation or erotic activities not to be bought in any market. These activities are not ''economic'' and the welfare resulting thereof is not the outcome of the 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 Fig. 1 the essential relationship between the three systems, where their physiology is concerned, is that economic system is a subsystem of the social one, whereas a social system is a subsystem of the natural system.

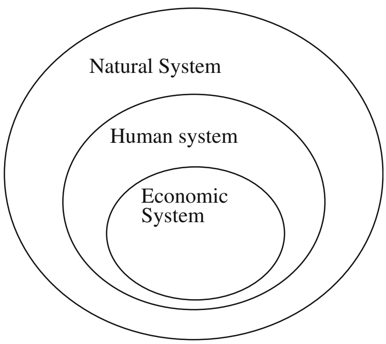
Clearly then, the ESED concerns the fundamental relationship between the natural environment and the economic system and, in essence, prescribes an evolution during which the natural environment is capable of supporting economic development in both the short and the long run and thus does not impose any serious 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 Identifying the crucial "supports" from the environment to the economic process

Passet' s model and its ability to offer an essential depiction of the physiology of the economic, social as well as natural systems, can serve in exploring the 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 and the beneficiaries of any economic processes. In its turn, the human system, being a subsystem of the natural one, requires that the natural system function properly so that it may secure the natural conditions necessary for the biological existence and evolution of the human race. 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 biological "hale" future. Let us, for

Fig. 1 The fundamental systems



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, Nijkamp, & Opschoor, 1989). With good reason then, do the smooth function and evolution of the natural system pose themselves as a prime condition for operation 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 and evolve 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 conclusion that any major and crucial disturbance in the system broader of all, that is, the natural system, will indubitably result in biological impacts bearing on the human system, thus certainly undermining the biological status and potentially endangering the existence of human beings, the soloists responsible for economic virtuosity (Von Bartalanffy, 1972). Hence the realization that the preservation of the proper 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 sure-footed path to offering natural inputs to any economic process. The debate on the scarcity of natural resources being paramount to economic process and the substantially different approaches that have been proposed are well-known. Indicatively, Solow speaks of a substantial decrease in the indispensability of natural inputs owed to the technological boom while Georgescu-Roegen asserts that, as the earth population and economic production increase, natural inputs in economic process will also be increasing (Georgescu-Roegen, 1979; Solow, 1986). For the time being, any practical consideration should be based on the current evidence and data concerning natural inputs to 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 & Halvorsen, 1984; Hudson & Jorgenson, 1974). Consequently, it seems that natural inputs are indispensable for economic process 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 participate in economic processes and hence in economic development. This necessity essentially forms the second condition of the ESED. 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. 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 existence and evolution of human race since they are both, respectively, indispensable for economic development to occur and for the economic system to exist.

Concluding this section identified the two major ''supports'' the natural system offers to the economic one and, through them, it also identified the conditions for the ESED. However, the analysis does not bring forth any practical tenets, that is, any conditions that can be applied to everyday decisions. This sort of practical tenets—the operational conditions of the ESED—are to be traced in the following sections.

5 The first condition of ESED: the ''biological sustainability''. Identifying and preserving the ''biological crucial levels''

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 proper 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 composing the earth's system as well as the atmospheric levels surrounding earth. Each natural element participates in numerous natural functions and all natural functions determine the ecological balance and 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 participate in the natural functions be present at a satisfactory quantitative and qualitative level.

- Are all natural functions indispensable to biological sustainability? This 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 (Obum, 1971). In this context, probably we could try to choose certain natural functions as more fundamental since they are directly contributing to human beings biological status. It seems that such an approach could be a good starting point for defining an effective policy. An alternative, risk averse approach, delineating a more effective policy, prescribes to preserve all natural functions. This risk adverse approach will be adopted for our further analysis for the rest of the paper.
- Do all the natural elements and species play a decisive role in the maintenance of the natural functions?

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 jeopardized 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 realize that the last years certain fundamental natural functions are not working properly: climate change 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 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 (Obum, 1971). In addition the accumulation beyond certain levels of some natural and/or manmade elements can also be the culprit behind the substantial deterioration 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 these levels results in crucial ecological disturbances. In consequence, certain natural functions are currently jeopardized because some natural elements (and manmade) are crucially over eliminated or over concentrated (pollutants).

In the past, there were fluctuations in these natural elements, which wrought no serious impact on the natural functions. However currently, the evidence now before us is indicating that the current trends overcome the relevant resilience levels.

With this in mind, one may assert that in order to ensure the wellness status of natural functions the natural elements should be kept within certain limits reflecting either stock 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 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". A "biologically crucial level" is 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 proper status and evolution for the respective environmental functions. Obviously, such a consideration may give rise to the following questions:

- Whose natural elements the "biological crucial levels" (BCLs) should be preserved of?
- How can the relevant BCLs be defined?

In order to determine the natural elements and species whose respective ‘‘biological crucial levels’’ should be preserved, two criteria seem appropriate for application. The first criterion derives directly from the content of 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 with present generations in shaping their preferences and should therefore be ‘‘equipped’’ with the same genetic variety of natural elements and/or species as the current ones (Rammel et al., 2003). In operational terms, the first criterion is quite easy in application: preserving any species from extinction. In essence, what it entails is that when the first criterion is applies 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 ‘‘biological crucial levels’’.

The second criterion applies to those natural elements and species that should be preserved at a level higher than the minimum viable population. These species might be those that participate in the natural functions that provide the biological basis for a biologically healthy existence and evolution of the human race. And probably this participation requires the existence of higher level than these indicating by the minimum viable population. Yet, to the definition of the BCLs of those natural elements and/or species, 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 again, 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, the preservation of ‘‘biological sustainability’’, consists, on the one hand, of preserving the ‘‘biological crucial levels’’ of certain natural elements and species and, on the other hand, of avoiding overstepping the ‘‘biological crucial levels’’ of pollutants. The ‘‘biological 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 that 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 (Pearce & Turner, 1991, Tietenbergh, 1996).

Could such a concept be considered a newcomer in economic science? It seems that 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 for a biologically healthy existence and evolution of human beings. These limits are operationally expressed by the term ‘‘biological crucial levels’’ which should be preserved regardless of the rising short-term economic costs.

6 The second condition of ESED: the sufficient provision of economic process with natural inputs

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 accessible of natural resources (Georgescu-Roegen, 1976). Will the accessible 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. In this context, 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 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. 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 potentials 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 methodological reasons, the requirements for natural inputs in the future cannot be estimated (Georgescu-Roegen, 1976). 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.

To estimate the future maximum accessibility of natural resources one should depend 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:

- Non-renewable
- Renewable exhaustible. Exhaustible are those renewable resources, which are exploited when their utilization permanently exceeds their regeneration rate (e.g. water resources).
- Renewable non-exhaustible. Non-exhaustible renewable resources cannot be exploited since utilization is confined by nature within their regeneration rate (e.g. solar energy).

The current use of non-renewable resources shows in no uncertain terms that their future availability will decrease. Any exogenous constraint in the current use of non-renewable 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 a 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 non-renewable natural resources at present for the sake of future use. The only criterion that could be applied is, the criterion of a ‘‘wise’’ use, which would advocate avoidance of any unnecessary waste of non-renewable resources.

As far as non-exhaustible 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 lead to an appropriate operational principle for using exhaustible renewable resources. This Pareto criterion, as modified by Kaldor and Hicks, defines the optimal allocation is the one maximizing the sum of individual utilities and can, therefore, be called ‘‘efficient allocation’’ (Hicks, 1939; Kaldor, 1939; Tietenbergh, 1996 pp. 19–30). The application of this criterion in the intergenerational context can attribute an operational principle for the use of exhaustible renewable resources. In the intergenerational context, the optimal/efficient allocation can be defined as the one maximizing the benefits of all individuals of all generations. 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. 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 since future periods of use tend to infinity. The foregone future benefits sum up the foregone benefits of numerous future generations. Let us denote the utility that arises from the use of exhaustible renewable resources in a given period as u_i.

Evidently, Σu_i where $u_i > 0$ for every one i is greater than Σu_i when $u_i = 0$ after a certain time period indicated by the depletion of the resources at hand.

As a result the use of renewable exhaustible resources within the limits defined by their regeneration rate can lead to a Potential Pareto Improvement—a Potential Pareto Optimal Status—in comparison with a use that depletes exhaustible resources. It stems down 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 & 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 operationalyzing ESED have been identified:

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

7 The institutions for preserving the BCLs and ensuring biological sustainability

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 decide on the level of environmental protection they take into account and compare the relevant private costs and benefits. Figure 2 depicts the pertinent rationale.

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. The MCP gives the marginal costs of pollution. Interaction between individuals or/and firm is expected to confine economic activity and pollution at the OA level (Coase, 1960). In absence of effective self-regulation, OA is the environmental protection target adopted by the authorities on the basis of welfare maximization (Pearce & Turner, 1991, Tietenbergh, 1996 p.329). Thus, the optimum level of environmental protection is determined so that environmental deterioration does not exceed OA. Assuming that the relevant biological crucial level (BCL) does coincide with OA pollution, the relevant BCL is preserved as long as pollution does not overcome OA.

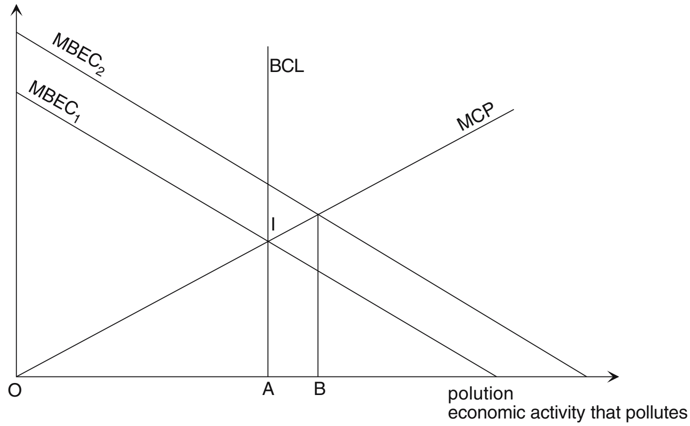


Fig. 2 The optimum level of environmental protection and the BCL

Could the BCL be systematically preserved or are there any conditions that may lead to its violation? Consider an increase in private benefits of the polluting activity; it shifts the respective marginal benefits curve upwards to the $MBEC_2$. Indicatively such an evolution could be the outcome of a change in the preferences of the present generation; evidently, other reasons may induce such a change as well. In effect, the new optimum level of pollution is defined at OB. By confining pollution at OB level does not manage to preserve the relevant BCL. That leads to the conclusion that an increase on the benefits of the polluting activity may lead to violation of the respective 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 perceptions and preferences the current generation has.

In the diagrammatic conditions of Fig. 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 Fig. 2, if and only if the curve OI BCL represents the marginal costs of pollution can BCL be irrevocably safeguarded. 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 trend to infinity and in consequence the respective marginal costs curve becomes vertical. This implies that the violation of BCL results in biological unsustainability and, since such an evolution is considered unacceptable, the vertical cost curve is defined when BCL is not preserved.

The arising question at this point: who are the actors and institutions that could adopt the modified vertical costs curve? Eventually, who are the actors 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 total spatial perception lead to an evaluation that corresponds to the technical condition of the vertical marginal costs curve. On the contrary, individuals are agents who are rather short-sighted 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 ‘‘short-sighted’’ 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 and 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 deep-seated, intrinsically myopic outlook of individuals on environmental impacts. The second factor asserts that individuals are incapable of perceiving impacts spatially broadly. Rather, they consider 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, the second factor, termed as ‘‘space span effect’’ indicates the short-sighted outlook on environmental ramifications owing its existence to the inborn limited capacity of short-sighted individuals to consider space in its entirety. The third factor pertains to the subjective 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 of individuals. Indeed, the economic evaluation of pollution depends on 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, on the environment, 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 adequate 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.

The Pareto criterion, as modified by Hick–Kaldor, may be used for proving that the preservation of biological sustainability forms a superior social objective since it increases the prospects of social welfare.

The preservation of BCLs leads to Pareto Optimum Status by increasing the social welfare, in comparison with a state of biological unsustainability.

In the framework of the ESED social welfare should be defined as the sum of the welfare of all individuals of all generations. In this context, the Potential Pareto Optimality could be defined as a status where the social welfare is maximized; similarly, the Potential Pareto Improvement defines an increase of social welfare.

Let us denote W_j the welfare of generation j, consisting of the sum of the welfare of all individuals belonging to j generation. We assert that W_j is consisting of two factors: the welfare arising from a healthy biological existence and evolution of human beings denoted by B_j and the economic welfare arising from conventional economic goods denoted by U_j. This could be denoted as:

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

The biological ‘‘healthy’’ status emerges as a necessary condition for the realization of U_j. Formally, this could be denoted as:

$$W_j = B_j U_j. \tag{2}$$

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

The violation of BCL_S and hence the biological unsustainability results in $B_j = 0$ for the generations to come after BCLs have been violated. The trade-off for this loss is an increase in the welfare U_j for some current generations. The increase in U_j leads to an increase in W_j of these current generations. However, this increase of U_j 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 trends to zero after a certain time period when BCLs are violated and hence biological non-sustainability occurs, (because $B_j = 0$ after the period of unsustainability occurrence).

So, $\sum_1^j W_j$ with $B_j > 0$ for every one generation is greater than $\sum_1^j W_j$ with B_j trending to zero after a certain time period. Therefore, $\sum_1^j W_j$ with $B_j > 0$ for every one generation is a Potentially Pareto Improvement in comparison to $\sum_1^j W_j$ with some B_j trending to zero after a time period indicated by the violation of BCLs.

In a nutshell, it appears that the preservation of BCLs and hence of biological sustainability increases social welfare and establishes a Potential Pareto Improvement in the long run where the welfare of all generations is systematically taken into account.

As a result, according to the traditional welfare criteria, 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.

8 Concluding remarks

The identification of an operational framework for ESED is a complex and demanding task. An operational framework should simultaneously pursue two distinctively discrete targets. First, the operational framework should essentially reflect the rationale, the requests, the inspirations and the targets of ESED. Second, the same operational framework ought to offer a practical context in order to assist in the decision-making process appropriate to the task.

It is precisely this type of operational framework that the present paper wishes to delineate. To this purpose, the concept of ESED comes under scrutiny in order to define its operational content. ESED proposes a pattern of economic development that can be supported by the natural environment in the long run. The issue at hand is to define the ‘‘supports’’ stemming from the natural environment and contributing to the economic process and development. There are two distinct ‘‘supports’’ that may be identified:

– The healthy biological existence and evolution of human beings.
– The provision of the economic process with sufficient natural inputs.

It is worth noting that the policy context required for the fulfilment of these two ‘‘supports’’ is not the same. On the one hand, safeguarding the healthy biological existence and evolution of the human race is a decisive issue weighing heavily for both current and future generations, as it is a policy ensuring a biological status beneficial for both. On the other hand, sufficient provision of natural inputs raises an idiosyncratic intergenerational competition on the use of natural resources and especially of non-renewable ones

In this context, the paper traces the operational conditions for the two ‘‘supports’’ arising from the natural environment and contributing to the economic process. In order to ensure the healthy biological existence and evolution of human beings it seems that one should preserve crucial, quantitative and qualitative levels/thresholds of natural assets–elements and limit or restrict pollutants below their crucial thresholds. Such a policy would lead to ecosystems functioning properly in the long run and permit the biologically robust co-evolution of both human beings and the environment.

The biological crucial levels/thresholds (BCLs) are to be defined after taking into account the particular conditions prevailing in each ecosystem with its own geographical, climatological and other characteristics. Indeed, BCLs are case-specific and their definition requires case-oriented research.

On the other hand, the preservation of BCLs cannot always be the target of environmental policy. There may be cases when the current biological status of an ecosystem is far below the specific status as delineated by BCLs. In those instances, it is probable that the socioeconomic conditions cannot facilitate an environmental policy aiming directly at the restoration of BCLs. Given these conditions, a gradual approach to BCLs may be followed by setting appropriate environmental policy targets. Under these conditions, BCLs evidently form the eventual targets of environmental policy in the long run, while the short-term targets are set to gradually approach the long-term ones.

The provision of the economic process with sufficient natural inputs is a more complicated condition to achieve. The intergenerational competition for scarce natural resources makes the identification of operational conditions far more difficult. Nevertheless, some basic principles can be proposed:

– Using renewable exhaustible resources with the limits defined by their natural regeneration rate.
– ‘‘Wisely’’ using non-renewable resources.

For identifying the operational conditions of ESED the Pareto Criterion could be used as an evaluation criterion when the welfare of all future generations is taken into account. And society is the appropriate institution that adopts such a long run evaluation of welfare and therefore ensures the conditions of ESED.

It goes without saying that the operational conditions proposed by the present paper form the basis for further investigations both on methodological and operational directions.

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