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## Defining and Measuring Sustainability

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## DEFINING AND MEASURING SUSTAINABILITY

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Especially following the Brundtland report *Our common future* (WCED, 1987), the interest in the question of how to treat the natural environment in economic theory has increased considerably. An important new element in recent contributions -in comparison to the literature published in particularly the 1970s and early 1980s (see for instance Mäler, 1985; Seneca and Taussig, 1984, Nijkamp, 1977; Hueting, 1980)- refers to the notion of sustainable development. The number of definitions is overwhelming (for an excellent overview see Pezzey, 1989), but the interpretation in the Brundtland report is still one of the clearest. It says that sustainable development is a development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Whereas "needs" may be translated into social welfare, "ability" is especially concerned with the availability of ecological resources ("ecological sustainability"). Sustainable development requires that the use of such resources by the present generation remains below certain levels. In other words, sustainability imposes a constraint on development patterns. Especially in developing countries, the sustainability concept provides a linkage between poverty, distribution and environment.

As the WCED definition of sustainable development appeals to many, we feel that it should be the guiding principle for the design of environmentally sound socio-economic policies. At the same time, its limitations in practical decision-making should be acknowledged. The Brundtland definition of sustainable development does not satisfactorily answer the question of how sustainability can be *defined* and *measured* in practice. Operationalization of the sustainability concept is a prerequisite for incorporating sustainability concerns in economic approaches. In an earlier article (van Pelt, Kuyvenhoven and Nijkamp, 1990) we explored possibilities to address such concerns in two methods for project appraisal, viz. cost-benefit analysis and multi-criteria analysis. Similarly, sustainability should be given a role in, for instance, input-output analysis and regional and macro-economic modelling. This article is aimed at contributing to an operationalization of the sustainability concept for such purposes. Special reference is made to issues particularly relevant to developing countries.

The following questions will be treated:

- what are key ethical issues on the basis of which sustainability policies can be developed? It is important to acknowledge that defining a sustainable level of environmental resource use is a normative affair.
- what are the basic parameters in the definition of sustainability?

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- which normative interpretations of sustainability might be distinguished? Using the findings of the issues above, several recent proposals for sustainability policies are reviewed. An outline is given of the contours of an approach to the formulation of sustainability conditions that is flexible to both policy environments and economic and ecological circumstances.
- on which scales can sustainability be measured? Measurement may be confined to assessing whether or not development is sustainable. More useful information is provided by measuring the degree of sustainability on ordinal or cardinal scales.
- which methods might be applied in measuring sustainability?

### Underlying policy factors

A sustainability constraint is a normative notion. Its format, to be discussed below, depends on views on several policy variables. These factors are: a) attributes of the social welfare function, b) weights assigned to present and future generations' social welfare levels, and c) judgements on substitution possibilities within production functions.

#### *Attributes of the social welfare function*

In neo-classical economics, social welfare tends to be equated with the consumption of man-made material goods and services. Increasingly, shortcomings of the narrow welfare concept are acknowledged (see for instance Hueting, 1980; van Pelt, Kuyvenhoven and Nijkamp, 1990). Assuming a broader interpretation of welfare, the availability of environmental amenities with a direct impact on the well-being of men (like clean air, clean drinking water, essential ecosystems such as the ozon layer) may also be considered a social welfare attribute. Whereas incorporation of environmental amenities in a welfare function by itself already is an important decision, sustainability concerns may further contribute to a more dominating role of environmental issues in economic policies. Sustainability being defined as compliance with ecological constraints, the question arises whether a limit is put on the overall use of ecological resources (including inputs in production processes, see below) only, or whether a separate threshold is formulated regarding the level of environmental amenities. In the latter case opportunities to compensate environmental decay by increasing material production are much more limited than in the former case.

#### *Weighting of social welfare of present and future generations*

In view of the long-term focus implied by sustainability concerns, judgements on the optimal distribution of welfare among successive generations are essential. In other words, how important is welfare of the present generation compared to welfare of future generations? How much welfare are those who are living now willing to sacrifice in order to safeguard the

interests of future generations? Moreover, what are views on the possibility to compensate future generations for a lower level of environmental amenities by higher material welfare levels? Finally, what are acceptable long-run ecological risks? Hence, the welfare of present and future generations should be weighted (see for instance Pearce and Turner, 1990; Collard et al., 1988; Toman and Crosson, 1991). The larger the weight assigned to future generations, the more resources should be at their avail, and the more stringent constraints should be on the present generations' resource use.

*Substitution and compensation in production functions*

Views on how sustainability should be formulated depend critically on views on how unique and indispensable the natural environment is. Environmental capital has two functions to mankind. First, as argued above, social welfare depends on consumption of environmental amenities, besides the consumption of man-made goods and services. Second, to produce goods and services certain amounts of both man-made capital and environmental inputs are required. Hence, two production functions are involved:

- the environment production function: the extent to which the environment system can provide amenities and services to mankind depends on quantitative and qualitative aspects of (and relationships between) specific ecosystems,
- the economic production function: the availability of man-made goods and services depends (inter alia) on the availability of man-made capital and natural capital, and how they can be used in combination.

Views on these two production functions, and especially on the scope for trade-offs between attributes, are at the core of sustainability analysis.

With respect to the environmental production function the discussion centers on questions such as the extent to which ecosystems are unique, ecological changes are irreversible and mankind can "create" environmental systems themselves to compensate for degraded "natural" ecosystems (compare Pearce et al., 1990 and Dasgupta and Mäler, 1990). An extreme position would be to rule out any trade-offs: all ecosystems are unique, changes in ecosystems are irreversible and mankind is unable to create nature itself. It has also been argued however, that in time ecosystems tend to recuperate, and that, perhaps at high costs, men have shown that environmental damage can be restored. The former view necessarily leads to much stronger constraints on the use of natural resources than the latter.

Similarly, the question of the extent to which man-made capital can substitute for natural capital in the economic production function needs to be treated. One extreme position emphasizes that they are complements, which rules out any trade-offs. On the other hand, it can be argued that increasing the capital stock and technological progress and know-how development may offer opportunities to replace natural capital inputs by man-made inputs. Neo-classical

economists would argue that the market mechanism will reflect changing scarcities of production factors in relative price adjustments. Such views stress substitution opportunities at the production side, which would ensure a stable quantity of consumption goods even if the stock of environmental capital would decline. In the former approach sustainability constraints will be much stronger than in the latter approach.

The issue of substitutability in production functions may be illustrated by various theories of agricultural development, summarized in Hayami and Ruttan (1985). Such theories express different views on possibilities to substitute capital and labour for land. Technology plays a pivot role in this respect. Hayami and Ruttan distinguish between mechanical technology, implying substitution of capital and land for labour, and biological technology, involving the substitution of labour and/or industrial inputs for land. The latter is most interesting from a sustainability point of view and may refer to labour-intensive conservation strategies, use of chemical fertilizers, and use of insecticides.

The "conservation model" of agricultural development stresses that the organic (and in a later version also the mineral) content of soil should be maintained at a definite level, usually the level natural to the particular soil. Such constraints play a minor role in theories with an emphasis on technological progress. The "diffusion model" rests on the view that effective dissemination of technical knowledge is a critical factor to growth. Advocates of the "high-payoff input model" argue that agricultural development requires investments in a) agricultural experiment stations producing new technological knowledge, b) the development and production of technical inputs, and c) the capacity of farmers to use modern inputs effectively. Conservation of soils at "natural levels" does not play a role in these approaches.

The nature of views on trade-offs regarding production functions differs from policy issues discussed in relation to the formulation of the social welfare function. Opinions regarding trade-offs between factors in welfare functions are by definition ethically determined. Views on trade-offs within production functions may be derived from empirical research. Due to shortcomings in our knowledge of ecosystems and how they interact with economic systems however, a significant element of value judgements remains. Particularly, attitudes towards risk and uncertainty matter. How significant are ecological risks and uncertainty and how should they affect decision-making? Considering the possibility of extremely damaging consequences of mistakes, however small the probability, a risk-averse person might want to base policies on the assumption that there are no substitution possibilities. He may be willing to sacrifice some social welfare opportunities for such a cautious approach.

Format of a sustainability condition

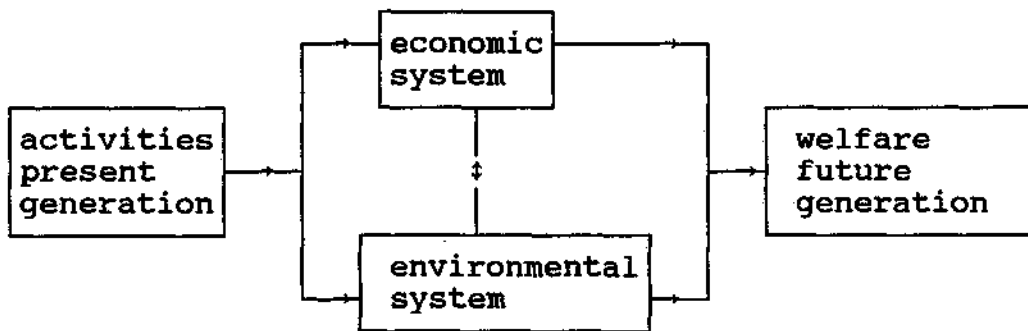
We now turn to the format of a sustainability constraint. Such a constraint has at least four dimensions:

- it is expressed in a certain parameter,
- for which a target (sustainability) level is defined,
- at a specific spatial level,
- as well as a time path for achieving that level.

*Sustainability parameter*

To ensure sustainable development, activities of the present generation should use a limited amount of scarce environmental services. A first question is whether this concerns an aggregated environmental parameter ("the total stock of environmental resources") or a set of specified environmental parameters. The former approach is hard to operationalize, because of lack of a common denominator. In the second case, sustainability constraints may be expressed in terms of use of renewable and non-renewable resources, generation of waste which cannot be recycled, etc, or even more disaggregated variables (see Opschoor and Reijnders, 1990). Constraints may be expressed in stock as well as flow variables.

A second question is whether the ecological parameter is translated into an economic parameter which is directly related to it. The logic behind this can be illustrated by the diagram below.



Following the vertical arrow, constraints on the use of environmental resources may be transformed in corresponding constraints on economic processes. It may be estimated how many economic activities and of what kind would be commensurate with the ecological limits referred to above (source-oriented). This might refer to constraints regarding production processes, volumes of end products, etc.

Economic constraints as a translation of ecological limits should not be confused with production and income targets derived from economic policies.

### *Target level*

The second question with respect to the formulation of the sustainability criterion refers to the target or satisficing level (both in quantitative and qualitative terms) of the sustainability parameter. Thus, assuming an ecological parameter, within which ecological limits should production and consumption take place to ensure sustainable development? Various choices may be made, such as:

- present environmental levels, as an expression of the view that future generations should have access to the same environmental resources as the present generation,
- levels at which irreversible environmental decay occurs (which may be higher or lower than present levels),
- levels which are considered necessary from the view point of, for instance, human health,
- extremely strict levels, commensurate with risk adverse strategies ("to remain on the safe side").

The choice of the sustainability level depends to a large extent on policy issues discussed above. The following points of view give rise to strict levels:

- the formulation of separate objectives for social welfare attributes (including risk aspects),
- a strong concern with future generations,
- a lack of confidence in possibilities for substitution within economic and environmental production functions.

Especially the latter factor plays a crucial role, as will be shown in the next section. Sustainability levels may be expressed in critical levels, quality standards, maximum sustainable yield or carrying capacity, resilience, vulnerability, fragility, etc. (Munn, 1989).

### *Spatial level*

Besides specifying normative limits to resource use, the sustainability criterion should specify a certain spatial level as a point of reference. Is sustainability defined and to be achieved at the local/project level, the programme level, the national level, or the global level? Choices in this field crucially affect the role of sustainability concerns in decision-making. A recent proposal of Dutch suppliers of electricity may serve as an example. They were willing to contribute to reforestation in Brazil to compensate for emissions of greenhouse gases by a new Dutch power station. In theory, global environmental stabilization might be achieved in this way (although many ecologists will think otherwise), but this might be of little comfort to people living close to the power station. Should sustainability be required at all levels, the proposal would have to be rejected.

### *Time path*

An important question is whether sustainability is to be assured in every year starting from the present year, or after a period of several years. If unsustainable development patterns prevail, it may be undesirable to demand sustainable



practices immediately. A transition period may be established after which sustainability must have been achieved. Reasons for a gradual approach may be political, for instance to avoid resistance of affected parties. Economic resource mobilization motives might also prevail: financing investments in resource preservation infrastructure might take some time.

In general, time may be accounted for through a distinction between successive generations. Hence starting from an intergenerational welfare function, sustainability levels can be defined for each generation. The larger the weight assigned to future welfare and the greater the emphasis on environmental amenities, the faster target levels should be achieved.

An example of how targets are chosen, also in terms of time paths, is provided by recent Dutch environmental policy (Ministry of Housing, Physical Planning and Environment, 1989). The government wants to curb further growth in concentrations of greenhouse gases in the short run and achieve stabilization after several decades. With respect to the ozone layer, stabilization should be achieved by the end of the present century. The next stage would be to further improve the quality of the atmosphere in order to reduce risks to animals and people to negligible levels, and to avoid deterioration of agricultural land and natural resources. This may take hundreds of years, which reflects the fact that atmospheric concentrations of some gases adjust slower to changes in emissions than others. Hence, policies tend to become ecosystems-specific in terms of target levels and time paths.

Views on how fast sustainability levels should be achieved may diverge extremely. From a purely ecological view, it might be argued that any delay in the implementation of policies only causes further unacceptable environmental degradation and that economic sacrifices are unavoidable. Many economists and policy-makers would support a more gradual transformation process. They would be more inclined to take economic-ecological trade-offs into consideration.

### Three interpretations of conditions for sustainability

Especially the choice of target level for sustainability has been the subject of lively discussion in literature. Three fundamental ways of interpreting a sustainability condition will be reviewed. Each approach will be associated with scientists who have advocated it, to understand underlying value judgements. The three approaches can be summarized as follows:

- *constancy of the natural stock*. Klaassen and Botterweg (1976) seem to be the first economists who have proposed to impose non-negative constraints on environmental capital. Recently, Pearce, Barbier and Markandya (1990), to be referred to henceforth as PBM, have done much to clarify the concept, its underlying factors and the role of economics.

This approach has also been advocated by Nentjes (1989) and Barbier (1989). A non-declining natural capital stock is considered a necessary condition for sustainable development. If in addition no deterioration of the man-made capital stock is allowed, a sufficient condition for sustainability is achieved. A strategy that sets non-negative constraints on natural and man-made capital separately is termed "strong sustainability" (SS) by Foy and Daly (1990).

- constancy of the total capital stock, i.e the total of man-made and natural capital. This most economically-oriented concept of those discussed here has been favoured by many economists such as recently Bøjo, Måler and Unemo (1990), to be referred to as BMU. Besides natural and man-made capital they include other capital factors (such as human capital) in the sustainability constraint, but this does not change the basic idea behind their criterion. Foy and Daly (1990) refer to the strategy of keeping the total of natural and man-made capital intact as "weak sustainability" (WS).
- ecological goals, i.e. improvement of the various components of the environmental system to ecologically acceptable levels, without any reference to economic factors or comprehensive welfare concepts. Reijnders (1990) is among the authors who have developed proposals from a purely ecological point of view. He focuses on pollution problems, but his approach could easily be generalized to cover all classes of environmental problems.

We will first compare the WS and SS approaches, which can be summarized as follows:

dN	dM
$<0$	$\geq 0$
$<0$	WS*
$\geq 0$	WS*, SS

\*: provided positive change outweighs negative change

dN : changes in the stock of natural capital

dM : changes in the stock of man-made capital

$<0, \geq 0$ : new levels are lower than; equal to or higher than; existing levels

Both the WS and SS approach aim at (at least) maintaining present welfare levels over time, and existing levels of stocks of production factors are therefore taken as a point of reference for sustainability. This involves a strong arbitrary element, and it has the drawback that the sustainability

concept may change from year to year. Sustainability defined in 1991 applies to a different social welfare level and corresponding environmental stocks compared to sustainability defined in 1995. Moreover, present conditions may be unacceptable from ecological and economic points of view.

The "constancy of natural capital stock" constraint is expressed in an ecological variable ("natural capital stock"). The possibility of compensating a deterioration of the environmental stock by investing in man-made capital is ruled out. Therefore an absolute constraint is imposed on production and consumption processes.

With respect to time paths, PBM distinguish between two strategies. If the goal is to realize a generally positive trend of welfare development over some selected time horizon, the approach the authors themselves favour, short term constraints on resource use are less stringent than if welfare is to increase every year.

The sS approach adds an economic variable to the sustainability constraint, but this does not affect the basic format. A practical problem however, is where to draw the dividing line between man-made and natural capital. Given the mixture of numerous inputs in land development (use of chemicals, terracing, irrigation channels), for instance, this line may be hard to draw.

The wS indicator is expressed in a mixed ecological-economic parameter ("sum of natural and man-made capital"). It also takes existing sizes of capital stocks as satisficing level, without evaluating their acceptability. Under wS strategies only a relative constraint is imposed on development patterns.

The wS approach is more data-demanding than the sS approach. Both require that changes in both the natural capital stock and the man-made capital stock be administered. In addition, the wS approach involves aggregation of changes in both stocks, which is hampered by the lack of a common valuation basis.

Authors who have argued in favour of either sS or wS, have used the following underlying views and assumptions:

#### *Attributes of social welfare*

PBM use a broad welfare function, referring to for instance income distribution and basic freedoms, without however, making explicit reference to the direct impact of the environment on welfare. BMU as well do not elaborate on this question.

Both sustainability conditions aim at preserving the size of aggregated stocks. Consequently, they cannot address objectives regarding the two welfare attributes separately. The fact that present levels, as argued above always an arbitrary choice, are taken as benchmark adds to this problem. From a health point of view, for instance, present air and water pollution may be unacceptable.

The wS approach applied to the two-attribute welfare function effectively assures non-negative welfare changes over

time only under certain assumptions. WS allows that a loss of productive environmental capital is compensated for by building more man-made capital. Consequently, the output of man-made consumption goods, which affects welfare directly, can be kept at reference levels. A degraded environmental stock, however, may involve not only production-related environmental amenities (which affect welfare indirectly), but consumption-related amenities (affecting welfare directly) as well. If the latter situation occurs, maintaining present welfare levels presupposes that a) the production of man-made goods and services will rise above present levels, and b) within the social welfare function a lower environmental quality (with effects on health, recreation possibilities, etc) can be compensated for by the availability of more man-made goods and services. Such optimism regarding trade-offs may cease to be warranted in view of rapidly worsening environmental amenities in many parts of the world.

The SS approach requires a less strong assumption in this respect, viz. that within an overall constant environmental stock, the quality of environmental amenities is not affected.

*Weighting of social welfare of present and future generations*  
With respect to intergenerational equity, both approaches aim at allowing future generations access to the same resource base as the present generation. Assuming constant productivity of resource stocks, social welfare levels would at least remain at present levels. As PBM explain, such an approach can be justified by Rawls' theory of intergenerational equity (Rawls, 1972).

This does not mean that generations are assigned equal weights. As long as activities tend not to comply with the sustainability constraint, the interests of future generations are assigned a weight of one. Once it has been fulfilled, however, the present generation is given a larger weight and activities are undertaken to maximize net present welfare. In other words, intergenerational welfare trade-offs are allowed only in a certain range.

A major problem associated with both SS and WS, which is not treated by their supporters, is that without further assumptions, these approaches will not necessarily maintain per capita welfare levels over time. In the case of growing populations, keeping capital stocks intact over time results in decreasing capital per capita, and consequently decreasing welfare per capita. Assuming a growing population, maintaining per capita welfare levels hence presupposes either a growing capital stock or a reduction in per capita resource use. In developing countries both options may not be feasible in the short term in terms of economic (opportunity) costs.

*Substitution and compensation in production functions*

The major differences between WS and SS approaches refer to assumptions regarding substitution possibilities within

production functions, including assessments of risk and uncertainty.

With respect to the economic production function, advocates of SS stress the complementary nature of man-made and natural capital, whereas WS is justified by reference to substitution possibilities.

PBM argue that especially in countries at an early stage of development, natural and man-made capital are likely to be complements. In more developed countries substitution might be possible in more cases. Nevertheless, according to PBM, policies should be based on the assumption that the two stocks are fully complementary. The main motive for this choice is a risk-adversive attitude. Our knowledge of ecosystems is limited, and natural capital can be decreased but often not increased (lack of replicability). Other environmental functions are replicable only at unacceptable high costs, whereas degradation of parts of a resource system might lead to a breakdown of the integrity of a whole system (Barbier, 1989).

When ecological damage occurs, the SS approach can only be complied with by creation of an equal quantity of environmental capital of similar quality. PBM do not elaborate on substitution opportunities within environmental production functions. At the same time they devote much attention to the notion of environmentally compensating projects. Such projects involve the creation of improvement of natural capital to compensate for unacceptable resource use elsewhere. Given their cautious approach to substitutability between man-made and natural capital, a similar approach would have been expected with respect to compensating environmental losses by human intervention.

Whereas uncertainty regarding ecosystems is a main motive of PBM to advocate the SS approach, they do not elaborate on how risk and uncertainty should be treated in assessing whether or not actual stress on the environment remains within acceptable limits. We feel this to be a key issue in decision-making: we often do not know how, when and where our activities will negatively affect ecological capital stocks, nor whether or when compensating activities will really compensate. Ecological risks require a rather different treatment than other types of risk; see for instance Quiggin and Anderson (1990).

A justification for the WS criterion is that income derived from natural resource use may be invested to the advantage of future generations. Substitutability within production functions is stressed. Environmental decay can in principle be compensated for by creation of new environmental capital, but also by investments in man-made capital. No ex ante constraints are put on trade-offs between man-made and natural capital. BMU emphasize that empirical information on substitution possibilities is insufficient, and argue that most economists share the view that there are no economic signs of increased resource scarcity.

The "ecological goal" approach to sustainability, as represented by Reijnders, is rather different from the two approaches outlined above.

Like in the SS approach, Reijnders' sustainability criterion is expressed in ecological variables. Reijnders' criterion, however, is not based on existing levels but on normative, ecologically acceptable levels. This can be concluded from the following steps in his approach:

- He sets out to argue that policies should follow the steady-state principle, viz. concentrations of environmental pollutants should not increase (in other words, present levels are marginally acceptable).
- This strategy may be inadequate, however, when stabilization of concentrations does not immediately lead to stabilization of environmental effects. Reijnders refers to time lags involved in adjustments of global temperature to changes in emissions of greenhouse gases. To avoid further temperature rises (and their consequences for mankind), concentrations should decrease, which calls for more drastic reductions of emissions than would be commensurate with a policy of stabilizing concentrations.
- Ultimately, effects stabilization may not continue to be the guiding principle. Reijnders argues that the present hole in the ozone layer is generally considered unacceptable and should therefore disappear completely. Apparently, in such cases policies should comply with constraints derived from what are considered ecologically acceptable standards. And such standards may imply that specific types of environmental problems are not acceptable at all.

Reijnders' three-step approach may hence be reduced to a one-step approach: long-run environmental problems should be reduced to environmentally acceptable levels. Probably it may be added that these levels should be achieved as soon as possible. This leaves several questions, such as who should define acceptable levels and on what grounds, and how effects are defined, but the general idea behind the approach is clear. Reijnders approach is strongly normative: ecologists should define acceptable states of the environment for future generations, and human activities should remain within the corresponding ecological boundaries (for comparable views of ecologists and biologists see Rees, 1990; Tisdell, 1988).

SS and WS approaches aim at providing successive generations similar welfare opportunities, including material aspects. Reijnders, who does not define a comprehensive social welfare function, confines himself to ecological welfare attributes. Future generations should be safeguarded against any long-term environmental risk and long-term negative environmental effects. He argues against assigning future generations a lower or even equal weight as present generations in these two respects. He proposes to assign future generations a higher weight, and in fact implicitly a weight of one. Hence whereas WS and SS approaches take present stocks as satisficing levels, Reijnders aims at enhancing the environment system. Effects on welfare in general are not a part of his

considerations. In our view this is the weak part in every ecologically determined approach, especially in the context of developing countries.

Reijnders does not exclude the possibility of compensating future generations for risks or long-term ecological damage, but he considers it a rather theoretical issue and does not elaborate on how compensation might be effectuated.

Although all approaches summarized above may be considered an expression of the WCED sustainability definition, the underlying analysis and their implications vary significantly. The overall conclusion is that significant steps towards operational sustainability concepts have been made, but that present approaches have some important drawbacks. These are summarized below (see also van Pelt, Kuyvenhoven and Nijkamp, 1990).

The basic problem, which underlies most other of our comments, is that the sustainability interpretations presented here are a reflection of value judgements of individual authors. The greater the rigidity of terms incorporated by a sustainability condition, the more important this aspect becomes. Normative views of individual scientists need not coincide with views and policies of governments or any other party.

SS is a much more strict approach than WS. At a global level, SS approaches make most sense. But it is doubtful whether an indiscriminate application at lower levels and within developing countries in particular should be recommended. SS sets constraints on policies irrespective of location-, sector- or time-specific environmental potentials and constraints. Whatever prevailing environmental conditions, absolute ecological constraints should be satisfied. This implies that in the case environmental systems at a particular site are very robust and untouched, socio-economic development based on intensive natural resource use would not be allowed, even if it would be for a limited period of time or if the resulting income would be used to invest in long-term income-generating activities. The SS condition seems especially appropriate in some specific developing countries where the environment has seriously been deteriorated. It should be acknowledged, however, that the WS approach in such cases would often lead to the same kind of recommendations. A WS approach merely acknowledges the possibility of substitution, but does not imply that compensation is actually always feasible. This leaves more room for location-specific analysis. At the same time, however, concerns which led PBM to follow a strict approach should be acknowledged. For instance, instead of translating risk into an overall constraint irrespective of the size of actual risks (sS), it would be preferable to deal with it in practice as one of the decision criteria, particularly in relation to substitution within production functions.

An important consequence of all, and especially the SS and ecological approaches, is that trade-offs between ecology and

(narrowly defined) economy tend to become obscured. Ecological constraints should be complied with irrespective of prevailing economic conditions and policies. We fear that such an interpretation of sustainable development may cause much and perhaps unnecessary resistance in developing countries. Developing countries need sustainability frameworks that assist decision-makers in their efforts to simultaneously develop long-term policies, in which ecological factors are dominating, and short-term policies, focused on combatting existing poverty. Such frameworks should clarify conflicts between the two classes of policies. Sustainable development may, for instance, occur at an absolute income level incompatible with government priorities. The sustainable development goal therefore might not be the only or even overriding policy goal, and trade-offs with other goals may have to be considered. And if a strong version of sustainability would be a key target, income distribution effects would need to be a part of considerations. Transitions from non-sustainable to sustainable development may often be costly, and policies should focus on the question of who will carry the financial burden. Imposing sustainability policies on poor farmers who have few options for non-sustainable practices, may not be feasible without cost-sharing schemes. Particularly in developing countries we would not favour an a priori exclusion of any degree of environmental degradation.

These comments can be considered an agenda for further research. We doubt whether governments in developing countries should make an a priori choice between one of the normative approaches outlined above. Preferably, sustainability concepts should be both comprehensive, i.e. allowing coverage of all relevant issues, and flexible, i.e. allowing for different appreciations of these issues. In the next section we explore the contents of such a flexible and comprehensive framework for the formulation of sustainability conditions.

### **Towards a flexible framework**

The WCED emphasizes that sustainable development should be considered a global objective and that "no blueprint of sustainability will be found as economic and social systems and ecological conditions differ widely among countries". Conditions for sustainable development are not uniform, but eco-system-, culture- and even site-specific (see Sachs, 1989). Moreover, conditions are likely to change over time. In this section we set out to outline the contours of a flexible sustainability framework. The framework covers basic value judgements regarding attributes of development, equity as well as views on underlying relationships. It is to be adaptable to specific circumstances, including varying policies and interests of decision-makers and social groups. It stresses issues prevailing in developing countries.



The sustainability framework would have three main, interrelated parts, each divided in several components.

*1. Welfare levels, and socio-economic and ecological systems*

A first, descriptive, step is to provide insight in welfare patterns in the area under consideration. Specific attention should be given to:

- the state of social welfare attributes, including an assessment of levels of consumption of man-made goods and services and of environmental amenities (poverty levels); welfare differences between specific levels and among social population groups; and expected changes in social welfare and its distribution over time, acknowledging risk and uncertainty.
- conditions and relationships within the economic system. This includes an assessment of technology levels, use of man-made capital, distribution of production assets, etc,
- conditions and relationships within the environment system. This includes an assessment of substitution possibilities in the environmental production function and risks and uncertainty involved,
- relationships between economic and environment systems. This includes an analysis of the question of the extent to which the environment system may allow continuation of current production and consumption trends in the long run. The answer to this question depends on a) the evolution of the ecological system and risks and uncertainty involved, b) the dependency of the socio-economic system on the environment and c) technological progress and possibilities to substitute man-made capital for natural capital, including an assessment of risk and uncertainty.
- an assessment of critical environmental levels in relation to specific economic activities, including an indication of risk and uncertainty involved.
- an assessment of how compliance with these critical environmental levels would affect social welfare levels in the short and long run. Welfare effects of not complying with environmental levels should also be investigated.

These questions should take intragenerational distribution aspects into consideration.

*2. Social welfare conditions and objectives*

Sustainability concepts are normative and prior to formulating the concept itself, underlying value judgements should be addressed. This involves the formulation of social welfare objectives. These will partly depend on prevailing social welfare conditions (see step 1.). The second, normative, step concerns various objectives regarding social welfare and its distribution:

- what are the priorities regarding social welfare attributes and possibilities for trade-offs between these attributes?
- what are short term objectives regarding social welfare of different social groups at various spatial levels? Possible trade-offs should be addressed. Hence, this refers to

objectives regarding combat of poverty, and the willingness to make sacrifices to achieve these goals. Moreover, goals regarding environmental amenities should be made explicit for specific groups and levels.

- what are long-term objectives regarding social welfare, what short term sacrifices may be made to achieve these objectives and how are risk and uncertainty related to these objectives? What are acceptable levels of risk and uncertainty for successive generations and for specific groups and levels? How may compensation of present (for short term economic costs) or future generations (for long-term ecological costs or risks) be effectuated?

### *3. Formulation of sustainability conditions*

On the basis of findings under 1. and 2. the general WCED sustainability concept may be transformed into a sustainability condition in terms of a sustainability parameter, target levels, spatial level and time path. Depending on value judgements treated above, stronger or weaker versions could emerge. Compensation measures should be designed to avoid conflicts with specified social welfare goals.

If policy makers do not want to select a particular sustainability concept *ex ante*, they can be presented the consequences of various concepts in terms of short term and long term economic and ecological effects, including risks and uncertainty involved, and possible implicit weights. In this respect the major role of sustainability analysis may be more in terms of providing information and clarifying consequences than a direct basis for decision-making.

The three stages are obviously related to each other, and various feed-back loops exist. If social welfare goals appear not to be commensurate with the analysis under 1., adjustments should be made.

### **Sustainability measurement**

Once sustainability constraints have been defined, particularly in terms of acceptable levels of resource use, application involves a comparison between this *normative level* of resource use and actual resource use. Measuring sustainability in this way may address two types of policy questions. First, are existing ecological conditions in an area (continent, country, region, etc) commensurate with sustainability objectives? How have resource use patterns evolved and what are expected changes? Land degradation indices are an example, linking existing physical degradation to desired land conditions. Second, what is the impact on existing sustainability conditions of certain policy alternatives? Such alternatives may be projects, programmes, national or regional policies, the introduction of policy instruments like taxes or regulations, etc. In terms of

projects: one would like to know the difference between sustainability indicators in the situation with the project and without the project.

Measuring sustainability, i.e assessing the difference between normative and actual resource use levels, may involve several types of measurement scales. Scales are summarized below:

scale	example of scores
<hr/>	
DISCRETE	
binary	yes (sustainability is achieved) no (sustainability is not achieved)
ordinal	actual resource use far exceeds\slightly exceeds\is equal to\is slightly below\is far below sustainable levels
cardinal	actual resource use is in the range of 100-150% of sustainable resource use
CONTINUOUS	
cardinal	actual resource use amounts to 120%\90%\20% of sustainable resource use

A distinction is made between discrete scales, involving a limited number of intervals of sustainability scores, and continuous scales, where the number of sustainability scores is infinite. Furthermore, scales may be binary (with only two possible outcomes, 0/1), ordinal (qualitative ranking) and cardinal (quantitative). These sustainability measurement scales are elaborated below. They can be used whatever approach to sustainability (wS, sS, etc) is applied. The choice of measurement scale is mainly a practical issue, as data requirements differ significantly, and does not add any normative elements to those already included in the sustainability condition.

In the most simple approach, sustainability will be measured on a *binary* scale. Such a scale by definition is discrete as it allows just two possible outcomes (effects): "the sustainability condition is complied with" (S+) and "the sustainability condition is not complied with" (S-). Consequently, sustainability conceived in this way, development cannot be "a little sustainable" or "almost sustainable". Risk and uncertainty can be incorporated, however: "the probability of S+ is..", "S+ is likely but the possibility of harmful events and the consequent S- score cannot be ruled out".

The disadvantage of binary measurement is that information on sustainability may be lost. A more sophisticated form of

sustainability measurement involves the determination of the degree of sustainability on a continuous, cardinal scale. Opschoor and Reijnders (1989) have elaborated on how such a cardinal sustainability indicator could be developed for the Netherlands. Their approach is summarized here first.

According to Opschoor and Reijnders a sustainability indicator shows the degree to which the actual use of environmental resources deviates from the sustainability levels as elaborated above. The greater the distance between sustainability and actual levels is, the lower the degree of sustainability. The value of the indicator is zero when actual and target levels overlap. It is positive if actual resource is below target level (=sustainable), and it is negative, if actual resource use exceeds the target level (=unsustainable).

A formal expression of a dimensionless sustainability indicator (SI) would be:

$$SI = \frac{SL - AL}{SL} = 1 - \frac{AL}{SL}$$

(SL=sustainability level; AL=actual level)

If  $SI > 0$ , development is sustainable, if  $SI < 0$  it is unsustainable.

Opschoor and Reijnders indicate that a dynamic approach to the sustainability indicator may be achieved by developing a separate indicator, showing the speed at which the distance between target and actual levels changes over time.

Changes over time could be captured by the formula:

$$dSI_t = (SI_t - SI_{t-1})/SI_t$$

If  $dSI > 0$ , development is becoming closer to sustainable levels; if  $dSI < 0$ , its distance towards sustainable levels is increasing.

Opschoor and Reijnders propose to develop separate indicators at fairly high levels of aggregation: pollution, use of renewable resources, use of non-renewable resources, and biological diversity. Problems involved in aggregating these separate indicators are treated below.

In short, the basic elements in developing a cardinal sustainability indicator would be:

- development of sustainability constraints, expressed in certain parameters, levels and time path,
- assessment of actual levels and changes in these levels of sustainability parameters,
- calculation of value of problem-specific cardinal sustainability indicators,

- weighting separate sustainability indicators to arrive at overall indicator.

Application of the continuous, cardinal sustainability indicator would greatly add to the operationalization of sustainability policies. It provides much more information than binary sustainability indicators. Consequently, development policies can be made more targeted and precise. At the same time, data problems are formidable. Assessing the impact on the value of sustainability indicators is even more cumbersome. One of the means to collect necessary data may be Geographical Information Systems (GIS, see Jagannathan et al., 1990; and in relation to land development: Fresco et al., 1989). If insufficient means are available to collect "hard" data, discrete approaches to sustainability measurement may be very useful. For instance, measurement may be on an ordinal scale, involving qualitative assessments of the distance between target and actual levels in terms of: "great distance", "very close", etc. Similarly, estimates may be in the form of quantitative intervals (cardinal).

Depending on the choice of measurement scale, several methods may be used in estimating sustainability indicators. A distinction should be made between two types of sustainability indicators, viz. single sustainability indicators and multi-attribute indicators. In the first case methods may assist in assessing the difference between actual and normative resource use levels. The second case involves a weighting system to derive a measure of overall sustainability from a number of sustainability indicators for separate environmental dimensions, like use of renewable resources, waste generation, etc. For each environmental attribute a sustainable level, the ideal point (Nijkamp, 1979), is determined. In such cases methods are required a) to assess the degree of sustainability for separate environmental attributes (like above), b) to determine weights and c) to arrive at conclusions regarding overall sustainability on the basis of disaggregated sustainability indicators and weights. Given the impossibility of achieving all ideal points, i.e. sustainability levels, simultaneously, a compromise solution minimizes the weighted differences between objectives and actual performance. This type of problem is commensurate with the format of multi-criteria analysis (MCA) or multi-objective decision-making models (MODM)(see for an overview Nijkamp, 1979, and Nijkamp, Rietveld and Voogd, 1990). These approaches, which cover a large number of techniques, share the feature of starting from a number of policy objectives. In the case of sustainability analysis, these objectives refer to the levels of sustainable resource use specified for environmental attributes. Qualitative or quantitative weights are used to derive overall conclusions regarding sustainability. Where physical aggregation is impossible, determination of weights implies a second type of normative factors, in addition to the choice of the sustainability level itself. Several ways might be

followed to determine weights. One is to ask policy makers to express their preferences, or to derive their implicit preferences from past policies. Another would directly search for preferences in society. Through questionnaires representative samples of people might rank environmental problems like for instance, acidification and the greenhouse effect. They might even be asked to express their willingness-to-pay to achieve sustainability in various environmental fields. Economic approaches would involve the estimation of shadow prices.

Some examples of potentially useful methods are presented below:

- in the case of continuous sustainability measurement, it may be feasible to apply penalty models, originally developed by Theil (1964). Any discrepancy between actual and normative resource use would be penalized by means of a penalty function. Higher deviations can be penalized more heavily by including a quadratic specification. Alternatively, application of multiple goal programming might be considered. This involves linear programming with multiple objectives, viz environmental attributes.
- for discrete sustainability indicators, the Goal Achievement Method (Hill, 1973) may be considered. Starting from a quantitative objective, in our case sustainable levels of resource use, performance is expressed as the ratio between actual resource use and the objective. The separate sustainability indicators would be multiplied by the relative weight assigned to environmental attributes to arrive at the overall sustainability score.
- especially if only ordinal or mixed quantitative-qualitative information is available, MCA approaches like the Regime method (Hinloopen and Nijkamp, 1987) or Qualiflex (Ancot and Pealinck, 1976) may be particularly useful.

## Conclusions

This article shows that the operationalization of the sustainability concept involves numerous types of value judgements. Incorporating sustainability systematically in development policies is impossible without explicit recognition of these ethical issues. Considering the fact that in addition to sustainability several other and possibly conflicting criteria may be a part of development policies, we would not favour an approach that strongly relies on one particular set of value judgements regarding sustainability. The sustainability concept calls for location-specific approaches. The usefulness of information about sustainability would greatly enhance if performance could be measured on cardinal or ordinal scales instead of a binary scale. Several types of MCA methods can be applied, especially if separate sustainability indicators are developed for groups of environmental attributes.

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