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Sustainable Economic Development: An Overview

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SUSTAINABLE ECONOMIC DEVELOPMENT: AN OVERVIEW.

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CONTENTS.

1. INTRODUCTION.

In this paper the origins and the elements of the notion of sustainable development are examined. Two specific dimensions of research receive special attention, namely the regional scale and the use of dynamic models. First, a short historical background is provided, which is followed by a discussion of the new elements that sustainable development conveys. Furthermore, a concise account is given of the already large body of diverse literature on sustainable development. Next it is argued that a regional approach of sustainable development is needed. This will especially facilitate economic-ecological integration on an operational level, which is argued to be important for a successful approach in studying sustainable development. Such integration can be based on the use of dynamic integrated economic-ecological models. The advantage of dynamic models and several criteria for their structure in the context of sustainable development are discussed. On an abstract theoretical level these models are tools for aiding our thinking about sustainable development, for analyzing dynamic characteristics of long term economic-environmental interactions and evaluating intergenerational distributional consequences of specific development paths. In addition they are valuable on an operational level for studying sustainable development of national and sub-national regions, for which purpose interactions between economic and environmental phenomena have to be considered.

2. CHANGING VIEWS ON ENVIRONMENTAL PROBLEMS.

The relationship between the natural environment and economic activity and development has never been denied by economists[1]. However, the ideas on this relationship have changed over time (see Barbier, 1989). Since the time of the origin of economics in the 18th century, the role of the environment for the economy has been regarded as one of direct supply of water and land, while agriculture was seen as the sector that directly interacted with the environment. After the industrial revolution attention was also paid to physical limits of renewable (e.g., timber/forests) and non-renewable resource (e.g., coal) availability. The conscious notice of specific types of interactions has always arisen from a simultaneous occurrence of both manifestation and human or political awareness of specific environmental problems. For instance, degradation of natural ecosystems as a result of various types of pollution and disruption was perceived much later than problems of city pollution and congestion. Scarcity and sensitivity of fish resources was considered important only after several disturbances in certain world fisheries had occurred. And the importance of amenities generated by natural systems was recognized only after development had reached the level to fulfil most material needs and many additional wants.

Especially in the past decades the interest in environmental problems has drastically changed character. Concern for resource scarcity, attention for pollution problems, bio-physical and ecological views, elements of social, cultural and economic development, and ethical considerations have all entered the environmental economics sphere. Genuine and ingenious integration of all these different perspectives in theoretical or operational analyses however has not been accomplished yet, and to strive for that may even be over-ambitious. Still, a step towards this direction is necessary if one wants to contribute to a better understanding of

[1] However, in some periods this relationship was regarded with more concern than during others. And still, the larger part of economics is not concerned with it. Sub-disciplines such as agricultural and regional economics, and of course environmental economics have relatively been more successful in addressing environmental aspects of economics. The relationship of man with the natural environment has become a more distant and indirect one, caused by the various stages of production and consumption, and the separation of human settlements and natural environments, especially in more developed countries. Still many people think - and even Fisher and Peterson (1976) express this opinion in the first line of their overview of environmental economics - that therefore we are less dependent on our natural environment, although the opposite is more plausible.

structural and long term economic-environmental issues.

The first wave of profound environmental concern since 1960 has mainly focussed the attention on negative externalities (i.e., social costs) emerging from the industrial structure of our economies in the form of air and water pollution (see e.g., Mishan, 1967; Kneese and Bower, 1968; OECD, 1976) and the long term consequences of resource depletion (e.g., energy resources, minerals, fisheries). Following this, the attention was also pointed towards the disruptive impacts of various specific production processes, technologies used, and various forms of consumption (e.g., recreation, mobility behaviour; see Shechter and Lucas, 1978).

The discussion in Barbier (1989) mentions some drawbacks of the conventional theoretical approaches towards interactions between economy and environment. A partial view is chosen in which the focus is on either material scarcity, and environmental damage, or preservation versus development. No ecological elements are introduced, so that irreversible paths, qualitative changes and collapse of natural systems are not taken into account. Furthermore, relative rather than absolute scarcity is emphasized, motivated by reference to resource price adjustments, substitution between resources, backstop substitutes and technological progress. Also the material balance model approaches (starting with Kneese et al, 1969) take a limited view, as the focus is on the correlation between the quantities of material inputs to and outputs of economic (productive) systems. These approaches do not consider amenity services of natural environmental systems giving rise to direct utility, they omit other causes of environmental damage such as disturbance by noise or encroachment by land-use, and they exclude the consequences of environmental damages for the economic system. Redclift (1988) states that social science - and thus also economics - has treated the environment in an unproblematic, unsystematic and a-historical way. The approach having had most support - which he calls 'environmental managerialism' is criticized on several points. It takes the environmental problem as the starting point; it is not holistic (in the sense of allowing for interrelationships between environmental variables in the analysis); it does not include international dependencies, provides for ad hoc piecemeal solutions; it is positive in the sense of reliance on finding technical solutions; it does not consider distributional issues in relation to environmental ones; and it places environment after development. As a consequence, economic and ecological factors receive unequal weights or attention in the objective function (see Redclift, 1988).[2]

In the past decade a shift has occurred from studying relatively partial cause-effect relationships and short-term consequences of economic activities towards a more integrated approach in dealing with environmental problems. This is made explicit by the consideration of interdependencies of different production or consumption processes which are related to specific environmental problems and were often studied in isolation before. Also the perception of various environmental damages as a consequence of one economic activity or one type of resource use is indicative for this. Further integration is accomplished through simultaneous consideration of economic and ecological phenomena. A third change in focus concerns the growing attention for interdependencies between regional or national phenomena. These types of integration are indispensable stages in dealing with long term issues of development and environment. Thus trade flows, trade barriers, unequal growth, international competition, North-

[2] As alternative approaches for dealing with human-environment interactions Redclift mentions sociobiology, Neo-Malthusianism, and an ecocentric approach. Sociobiology (Wilson, 1975) highlights the biological basis for social action and behaviour. Neo-Malthusianism states that population cannot exceed resource-determined carrying capacity levels, as natural checks are counterbalancing population growth. Against this view criticisms have been put forth, such as failure of the mechanism in the case of common property resources (Hardin, 1968), and failing institutional and political feedbacks (e.g., Commoner, 1972). Finally, the ecocentric approach (O'Riordan, 1981) is concerned with the ends to which resources are put, and considers both the objectives and means of development. It makes a strict distinction between structural factors in LDC's and developed countries. LDC's have distorted development processes and the period before colonialization is regarded of great importance, while developing countries are in a 'post-industrial' stage with a focus on high-tech production, services, leisure and culture (see Redclift, 1988).

South relationships, global environmental media and phenomena have all acquired a more central position in the environmental debate. The two global environmental problems most alluded to are the rise in carbon dioxide concentration in the atmosphere leading to a rise in temperature (the so-called 'greenhouse effect'), changing weather and climatological patterns, and possibly a rise in seawater levels around the world, and the ozone depletion which may have consequences with respect to health of living organisms as a result of more intense and/or different radiation reaching the surface of the earth (for instance, skin cancer, crop damage, genetic mutations). As a third global issue may be regarded the exploitation of the common seas, in terms of exploitation of fisheries as well as dumping of waste and pollution.

'The concept of sustainable development arose as a difference between a perceived and a desired state of the world' (de Vries, 1989, p.3). To accomplish a reconciliation between these two states, the need for the above mentioned types of integration was recognized. Although in the seventies attempts have been made to study long term relationships between development and environment these have emphasized mainly the limits posed by the availability of non-renewable resources (e.g., the Forrester-Meadows type of models). The new dimension in sustainable development is the inclusion of all kinds of ecological processes - natural growth, regeneration, assimilation, ecosystem evolution, geochemical cycles, etc. - and the resulting dynamics of and feedback mechanisms between global and world-wide economic and ecological systems. Thus the environment is now seen not only as providing potential limitations and opportunities for development but also especially as changing over time, and a pool of intrinsically dynamic processes, providing dynamic opportunities and constraints.

The implications of integration for research are inter alia an explicit consideration of spatial dimensions and dynamic relationships (feedback and time-delays), and an orientation towards multidisciplinary studies. It is increasingly recognized that an integrated approach is needed in solving environmental problems, arising from e.g. land use, urban development, use of common property resources, multiple use of natural resources, spatial patterns of activity, and economic development. For both theory and operational analysis, this involves a fusion of resource and environmental economics, of economics and ecology, and of development and spatial interactions.

In terms of general policy considerations, sustainable development implies that environmental concerns must be integrated in decisionmaking at all levels, that the relationship between various environmental problems is recognized so that they are not treated as if they were independent, or that conflicting environmental questions can be answered through trade-offs or compromises.

In the context of sustainable development especially the spatial dimension has not been considered very often. The importance of the spatial element arises from a reciprocal relationship: (1) local trends cause global impacts, and (2) global trends giving rise to local effects. For example, the loss of ecosystems in some regions may have large - and very uncertain - impacts on global climatological conditions and geochemical cycles. In other cases, over-grazing and deforestation may lead to large-scale soil erosion, downstream sedimentation, flooding and salinization. A destruction of the ozone layer, acid rain, erosion, desertification, eutrofication, ocean pollution and use of extracted resources are taking place at a world-wide scale, but their impacts can clearly be observed at a local or regional scale.

The political formulation of the idea of sustainable development is most pronouncedly reflected in the publication of the World Commission on Environment and Development (1987), called 'Our Common Future' (the so-called Brundtland Report). This report strongly supports the notion of 'ecologically sustainable economic development' (further on referred to as 'sustainable development', abbreviated sometimes as SD), meaning 'a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional changes are made consistent with future as well as present needs' (WCED, p.46). Thus it is evident that the issue of SD is essentially much broader than that of environmental protection[3]. SD in this broad cultural, political and international context, presupposes a radical change of priority setting and agenda formation within the socio-economic and environmental policy institutions. It also needs a planning structure for sectoral and inter-sectoral development, and - given the global impacts of regional environmental issues - an international alignment of policy. The notion of SD calls also for a more coherent (instead of a partial) and a more long-term (instead of a short-term) oriented policy perspective. Most importantly, there should be worldwide political support for attaining a sustainable development. One cannot expect this to exist in a world of poverty, and hence SD requires a policy oriented toward spatial (including intragenerational) as well as intergenerational equity. An adequate use of this political will presupposes also a greater extent of democracy in international decision-making. Finally it is important to mention the idea of the Brundtland Commission that sustainable development is not a fixed state of harmony but rather a balanced, adaptive process of change.

3. VIEWPOINTS ON SUSTAINABLE DEVELOPMENT.

Some confusion about the meaning of sustainable development has to do with the various interpretations of the term 'sustainable'[4]. The most frequent use of it in economic-ecological settings has been in combination with use or utilization. Sustainable use (utilization) is a resource management practice that applies to renewable natural resources and is - in the strict sense - based on the rationale of keeping the stock level constant. Often, sustainability and sustainable development are used interchangeably, although we prefer the second terminology, which is more explicit about what should be sustainable and points at the relevance of change, while the first term may be taken in a more static sense. 'Sustainable development' consists of two words which both can have either a narrow or a wide interpretation. 'Sustainable' may refer to social, financial or natural bases of development, but is taken here to apply only to the natural environment. Development is restricted here to economic development which leaves broader social-cultural phenomena out of the discussion. Thus sustainable development is used here as a shorter way of saying ecologically sustainable economic development and incorporates the idea of maintaining the ecological base of economic processes (see Opschoor, 1987). In addition to sustainable development, sometimes the notion of sustainable growth is used (for instance, Archibugi and Nijkamp, 1989, and Pezzey, 1989), sometimes in an equivalent way and sometimes in a neoclassical growth view of sustainable increase of a one-dimensional indicator of growth such as GNP or man-made capital.

Sustainable development can be regarded as a means of exploring the interface between (environmental) economics, (human) ecology and (intergenerational) ethics (see Turner and Pearce, 1990). Economics deals with the allocation, production and valuation of scarce resources, goods and services. Ethics is seriously involved as soon as future generations or the approach vis-a-vis other species enter the discussion. Ecology enriches our understanding of the dynamics of potentials and constraints posed by the environment on economic activity

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[3] For instance, the WCED mentions the relationship between development, environment and safety (war and peace).

[4] In the English language one can find many synonyms and words with similar meanings for the verb 'to sustain'. The following list of verbs is illustrative: abide, accommodate, aid, assist, attend to, base, bear, board, brace, care for, carry (on), conserve, continue, cultivate, defend, endure, feed, foster, found, fuel, further, gird, go, ground, harbor, heed, help, hold (up), house, husband, insist, keep (for, up), keep into being, keep elevated/ flowing/ functioning/ going/ operating/ performing/ rolling/ running/ streaming/ working, last, linger (on), lodge, maintain, make last/ endure, mind, nourish, nurse, nurture, obey, outlast, outlive, perpetuate, persevere, persist, preserve, prevent, proceed, prolong, protect, provide for, remain, repair, rescue, retain, reserve, respect, root, safeguard, sanction, save, secure, serve, set aside, shelter, shield, shoulder, spare, stay, store, suffer, support (the life of), survive, tend, tolerate, undergo, underpin, uphold, withstand.

in general. Consequently, as a basis for agreement on sustainable development consensus on the following issues is necessary (see also Repetto, 1986): (1) scientific knowledge, (2) real world data, (3) ethical principles, (4) satisfaction of human needs and wants. Scientific knowledge consists of theoretical, experimental and empirical proofs of the existence and validity of social, environmental and economic phenomena. The main obstacle here is that much understanding of the many processes is not yet available - if it will ever be. Another difficulty arises when scientists do not agree with one another. Especially in the economic and ecological sciences severe limits are posed on finding exact relevant statements. To a certain extent, this is the consequence of the limited availability of information on processes in and present states of the economy and the environment. Furthermore, if certain information is available, it may not be accessible to everyone, or not to the same extent and of even quality. Next, acceptance of certain ethical principles is unavoidable in discussing sustainable development, and this may pertain to consideration of justice (or more limited equity[5]) between generations and concern for non-human life. The last important issue is the understanding of our needs and wants, which, to a certain degree, is also a matter of ethical choices. It involves two questions: should everyone's needs be satisfied first before we turn to wants; and, is maximizing the realization (and creation?) of wants a desirable goal. Disagreement on one or more of these issues may result in different opinions about the goal and contents of SD. Of course assuming that preferences are dynamic, that they can be manipulated, and are changed as a result of various social processes will lead to extra complications. For instance, a question of maximizing the realization of wants is not so simple then, but involves considerations of a combination of changing and satisfying them (see Daly about 'ultimate ends' and 'relative wants'[6]).

If we take an anthropocentric starting point, which is usually done, and strive for intergenerational equity, then we must focus on welfare over time and present and future generations. This means that we have to study the relationship between welfare, the environment and economic development. So, in general, for clarifying and defining ecologically sustainable economic development the following questions have to be answered: (1) is there an ultimate end?; (2) what determines it directly?; (3) what is affecting change of this determinant[7]?; and, (4) what is constraining its change? Simplified answers without details corresponding with this numbering may then be: (1) intergenerational equity in terms of social welfare (a given time pattern, a constraint concerning its time-structure, or a dynamic optimizing objective); (2) economic and environmental services and goods; (3) dynamic processes in the economy and environment and economic-environmental interactions; (4) the limited potential of the environment to generate and accept materials, and undergo physical non-material influences.

So sustainable development implies management of the mix of human, physical, financial and natural assets to increase long term wealth and well-being. It involves the ultimate recognition that the environment is not static, but dynamically reacting to inputs and outputs from an economic system. It may be illuminating to think of 'sustainable' as a constraint and

[5] Justice may apply to all living and non-living entities, and to all conditions (economic, social, legal, physical, environmental) that they are subjected to. Equity is a more narrow concept and can be thought of in terms of distribution of welfare over individuals, groups or generations of humans. See section 2.6 for a more extensive discussion.

[6] At present the discussion on sustainable development focusses on the 'ultimate means' side (in the terms of Daly, 1977), while the relevance and meaning of 'ultimate ends' and 'relative wants' is politically not very seriously addressed.

[7] One might distinguish between definitions of SD focussing on actions to be taken ('activistic', oriented towards policy-making) and those focusing on description and evaluation of development paths ('scientific approach'). This distinction is however not of much relevance for our purposes. Still, the literature uses sustainable development to denote a goal, a management strategy or an actual pattern (see Opschoor and Van der Ploeg, 1990).

not as an optimality criterion. Several futures may be sustainable; only one may be optimally sustainable - in the sense of some intergenerational criterion. The constraint will be derived from a combination of ethical and physical-ecological considerations.[8] [9] Sometimes, sustainable development is regarded identical with preventing irreversible changes. Environmental changes may be irreversible for physical, biological, ecological or economic reasons. But cautioun is needed here, as many long term indigenous ecological phenomena and socio-economic changes are irreversible in this sense as well. It may therefore be too restraining to state such a rigorous constraint a priori. It seems preferable to judge irreversible changes in their total - economic, technical and environmental - context and in relation to their impact on opportunities for present and future generations.

The use of the notion of sustainable development can be regarded as the result of a need to solve a potential or actual conflict between growth and conservation, or between cornucopian and extreme preservationist standpoints. With regard to the notion of sustainable growth the following question deserves more attention: are the objectives of economic growth and environmental improvement (or non-degradation) mutually consistent in the long term in both a global and a national-regional context? (for the project level, see Van Pelt et al., 1990). Conservation arises from anthropocentric goals, which may include concern for one's own future or that of one's descendants. It is not as strong as preservationist's opinions arising from for instance 'Deep Ecology' (see Devall and Sessions, 1984) which attribute intrinsic (existential) values and rights to non-human species. Preservation of certain natural areas and in general genetic diversity of plant and animal species can be motivated by reference to speculative use values of future potential services, especially for medicine and agriculture (food, genetic varieties, pest control, restoration of ecosystems) (see for instance WCN/IUCN, 1980; and Turner, 1988). Conservation and preservation as management objectives on micro-levels may thus both be integrated with macro-development. As Norgaard (1988) states, 'to a large extent the call for sustainable development is a call to tap into the sun for energy through constructive management of organisms, ecosystems and environmental systems'.

One central element of conservation is the maintenance of the quality and quantity of the stock(s) of natural resources, sometimes expressed as 'consumption of flows instead of capital'. If 'stock' is regarded as an abstract concept we may link it to multifunctionality of natural resources. The conservation objective then applies to the formation of useful materials, storage and assimilation of waste and pollution, and the generation of amenity services. Keeping stocks intact or even increasing them may be rational when the optimal stock is higher than the present one. Other reasons for this objective originate from risk aversion in the face of uncertainty and potential irreversibility of decreases or qualitative changes in the stock. Constancy may apply to physical measures, the economic value or productivity, or it may be expressed via a constant price over time. Pezzey (1989) mentions maintenance of the effective resource base in terms of a constant real price index for virgin materials (derived from Page, 1977) or a constant economic productivity of the whole resource base by balancing resource depletion with capital accumulation and technical progress (from Howe, 1979). The total economic value over time may be used in combination with the compensation/ 'shadow

[8] Proposals have been made for inclusion of such constraints in standard economic evaluation methods such as cost-benefit analysis (CBA), so that a constrained optimization problem has to be solved. For instance, placing constraints on depletion and degradation of stocks of natural capital combined with CBA (Pearce et al, 1988), or applying safe minimum standards in combination with CBA (Goodland and Ledec, 1987).

[9] Some possible combinations of objectives and constraints for sustainable development are the following. Maximizing a preference-based function subject to a physically/ecologically-based constraint; maximizing a preference-based function subject to an ethically-based constraint; or, maximizing a function based on private preferences subject to a constraint based on social preferences. Which of these is considered most relevant depends for instance on whether one sees the requirement of ecological sustainability as a social preference.

project' principle (see Klaassen and Botterweg, 1976). The notion of stock constancy has different implications when applied to an aggregate stock including all natural resources, or single stocks of natural resources, renewable and non-renewable (see Pearce, 1988; James et al., 1989; and Opschoor and Reijnders, 1990).

Maintenance of renewable resources is usually regarded as being equivalent to sustainable resource use. However, the latter terminology has mainly been employed to indicate only the extraction of renewable resources (see Clark, 1976, 1985), and is not related to damage effects arising from other than extraction activities such as for example pollution, land use and recreation. For renewable resources separately stock conservation means that extraction rates must be smaller than the natural or manipulated regeneration rate, and that the stock itself is not injured through pollution or physical impacts otherwise, or that these are compensated for. O'Riordan (1988) mentions a whole list of assumptions underlying this notion, related to independence, homeostasis, confinement of the resource ecosystem, and exclusion of other functions. Holling (1978) and Walters (1986) express the idea of 'adaptive learning through management experiments with the resource' as an alternative strategy to the conservation of a renewable resource through sustainable use. These ideas arise from the recognition that each natural resource system is unique and subject to environmental variability, and cannot be trusted to act like all other similar systems under all circumstances. The advantage of the latter approach is that it allows for development of potential benefits and recovery from historical depletion. To deal with some of the drawbacks of the sustainable use concept mentioned above, Siebert (1982) and Opschoor (1987) suggest the concept of a resource regenerative system which can be seen as an intermediate between a simple resource and a complex ecosystem approach. This approach allows for dealing with an integrated analysis of resource extraction, pollution and other physical impacts.

Keeping non-renewable resources constant and using them at the same time seems contradictory at first sight. However, also here we must ask the question what exactly should be kept constant, for instance, the so-called effective resource base, or the price levels. Extraction may be counterbalanced by a combination of recycling, efficient use, increases in technological efficiency, compensation (e.g., for fossil fuels) with knowledge (nuclear fusion), exploration, or other non-renewable resources (if we consider one specific type of non-renewable resource). However, neither of these will completely undo the effective decrease of the non-renewable resource stock.

A first implication of the objective of constancy of the total of renewable and non-renewables resources is the constraint that the regeneration rate of renewable resources must compensate for extraction of both renewables and non-renewables as well as physical damage otherwise to renewables (see Barbier, 1989, chapter 8). A second implication is the substitution of renewable for non-renewable resources (so that a non-renewable in this context, or the total of both, is a quasi-renewable stock; see Daly, 1990). A third implication is that renewable resources combined with man-made capital (e.g., wind and windmills with a capacity equal to that of lost reserves) may compensate for non-renewable resource use. In the latter case man-made capital is explicitly included because it could become a large - and increasing - part of the total expenses to maintain the production that is based on the original resource, for instance, in the case of energy production with alternative sources. The two latter options have been addressed to in the literature with 'compensation (projects)' (see for instance Pezzey, 1989) and 'shadow projects'[10] (see Klaassen and Botterweg, 1976, and the end of this section).

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[10] We note here that compensation and realization of shadow projects can be understood in a very general way, namely to include substitution of renewable for non-renewable resources, substitution of one renewable for another one and similarly for non-renewables, and substitution of a combination of technology or man-made capital with a natural resource to replace another natural resource. Because of these different types of compensation, this idea is expressed at various stages in the main text. Furthermore, perfect compensation in reality will not be simple to accomplish because it involves the understanding of economic and financial consequences, and time and spatial patterns of effects, in addition to natural environmental effects. And these are all surrounded with much uncertainty, especially when they have to comply with long time horizons.

If we take economic (man-made) and natural stocks of capital together, then the notion of stock constancy may be interpreted even more broadly than in the foregoing situations. One proposal is formulated as the steady state economy which - in addition to a constant stock of natural capital - includes a stabilized population level and stock of man-made capital, while it aims for minimizing or limiting the growth of throughput (see Daly, 1977). However, a less rigid interpretation of stock constancy in such a world allows for substitution over time between man-made capital and natural capital, as long as the constraint of a constant sum of both is not violated. However, what it means to have a constant sum is just as difficult to answer as it is for the total of different types of natural resources. Furthermore, by comparing the man-made and natural stocks of capital we discover differences with respect to productivity, energy efficiency, multifunctionality, independence, irreversibility of depletion, and uniqueness and substitutability of goods and services stemming from the stock. The most profound distinctions are multifunctionality and substitutability. While most natural resources are multifunctional, most man-made stocks perform only a single function. Man-made and natural capital are substitutes sometimes but non-substitutability in terms of characteristics of functions is crucial[11]. The stocks may be indicated by some aggregate measure that is close to either material, financial, or utility/welfare units. If one of the latter two is chosen, the aggregate measure should include not only services derived from the stock now but in all future times as well.

The most direct link between justice and sustainable development is through the category of intergenerational justice. Why are we, or should we be interested in future generations? This is a very basic question which we will not address in depth here. One may regard sustainable development as a concept arising from the application of the anthropocentric objective of intergenerational justice to the development of economies in a dynamic natural environment. But the concept of justice may also call attention for the socially disadvantaged in the existing generation, or for 'Nature' and especially living nature (see Pearce et al., 1988). In the latter case, an ecocentric perspective (indicated by various labels, such as 'Deep Ecology', 'Bioethics', 'Ecocentrism' or just 'Preservationism') is chosen as an alternative to the anthropocentric notion of intergenerational justice. It shows a deep concern for intrinsic or existence values in nature and is usually associated with the objective of preserving diversity of species and ecosystems.

Such an ecocentric approach can be criticized for being obstructive towards development, and therefore possibly socially costly, and for not taking passable notice of problems in developing countries. It may be argued that some human problems are so pressing that they deserve more sympathy than bioethical considerations. Besides, the need for preserving genetic diversity - both of ecosystems and of species - and a stable environmental quality can nonetheless be supported on the basis of concern for future generations and optional economic values (see World Conservation Strategy, WCN/IUCN, 1980[12]). However, the ecocentric standpoint covers all ecosystems and species while an economic perspective is more limited and focuses on ecosystems and species related to specific economic sectors (agriculture, medicine, etc.) instead of, for instance, on rare species. In addition, taking both

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[11] Moreover, natural stocks are the ultimate physical-material basis of man-made stocks, including the primary life support function for the 'stock' of population. See also the ideas of Georgescu-Roegen (1971) on the difference between stocks and flows, and between the two necessary types inputs of production, namely the resources (natural materials and energy) and the actors (labour and machines). The interesting relationship between the two types of stocks in such a context is related to the materials generative function of the first. The natural stocks provide for materials that are transformed through the production process by actions of the man-made stocks.

[12] It means that species extinction should be prevented, that as many varieties as possible should be preserved of all domesticated animals, otherwise economically valuable species and their wild relatives, together with their habitats (these include crop and forage plants, timber trees, livestock, animals for aquaculture, microbes and other); and that unique and representative ecosystems should be protected. So an important motivation for preserving genetic diversity is the existence of potential economic benefits.

existence and anthropocentric values into consideration will - as long as it is not conflicting - command a careful and risk-averse approach towards the relationship between development and nature[13].

Finally, it is clear that intergenerational equity implies a long term horizon, although the exact choice is arbitrary. However, either endless increases of entropy or a close-by supernova will make its value finite. So we do not have to take care of all future generations. If one wants to include future generations in a meaningful way, then one should aim for a period at least as long to include (part of) the next generation after the present one has disappeared. If, for instance, we reckon people above the age of 16 to the present generation, wish to depict 20 years of the next generation, and assume a maximum person's life time of 80 years, then the time horizon is at least 80-16+20=84 years.

The basic conflicts that one tries to solve are between the present and future generations, between the long and the short term objectives, between environment and economy, and between the multiple functions of the environment. As a result of its focus on future generations, sustainable development incorporates a long term horizon. The conflict between the present and future generations is characterized by the non-presence of the later ones and the uncertainty surrounding the future. Although conflicts may arise simply because some of our actions cause irreversible changes, care for our future selves and our descendants, as well as prevention of certain regenerative and reversible economic and natural processes, will diminish the potential degree of conflict.

When long term issues are studied, usually the assumption is made - in any case implicitly - that in reaching long term goals no extra complications will arise as a result of short term processes. However, there may be a conflict between controlling environmental degradation in the long run and guiding economic activity in the short run. For instance, it is assumed that overcoming instability caused by business cycle processes is not conflicting with fulfilling long term objectives of sustainable development. And if growth is inevitably related to stable economic development (as a condition or a result), then we face a real dilemma in finding a sustainable development. Simultaneous consideration of fulfilling long term goals and short term goals, or of fulfilling long term goals and accounting for short term constraints and inflexibilities, is rarely touched upon in environment-economic studies. Economic approaches towards sustainable development seem most suited to deal with this issue, because environmental-ecological viewpoints do certainly not include considerations of choosing instruments and institutions to harmonize short term and long term objectives.

To a certain extent a trade-off has to be made between the multiple type of functions of natural resources, materials' generation, providing productive conditions, waste storage and assimilation, and providing amenity and recreational services. However, much scope for trade-off is usually not available as these qualitatively different functions are interdependent via the relationships in the ecological system.

In general, ecosystems, populations and resources may provide services for both natural and economic activities. An example is a species functioning both as a prey for a natural and a human predator (e.g., the fishery sector). In this case the services provided to the different users are of the same nature. But the services may also be very different, like a forest that provides timber, recreational services, a stable flora and fauna, regulation of precipitation and evaporation of water, assimilation, diminishing pollutant levels, etc. In using or affecting a resource base, economic activities and natural processes may be independent, one-way dependent, competitive (in several degrees, like the extreme case of exclusiveness), complementary or commutative. Finally, the important question of whether a conflict exists between growth in the scale of an economy and maintenance of the scale of the natural environment has been addressed before.

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[13] See Opschoor (1989) for a general - historical, social-ethical and economic - analysis of the relationship between man and his natural environment, and its impact upon the manifestation of environmental problems.

The concepts of sustainable profit from resource use, maximum sustainable yield, harvest, extraction and pumping stem all directly from sustainable use of resources, and may all be elements of resource management. Sustainable development might also be portrayed as resource management, but then on a high aggregation level. Sustainable growth translated to the resource level would imply growth of harvest under the condition of sustainable use, which is clearly impossible. It is hard to translate development to the level of one resource without losing much of the inherent character of development. It may in any case involve the requirement that the scale of an economy, determined by the population level and economic activity per capita, must be within the carrying capacity of the region, so that the population level can be maintained without natural capital consumption (Daly, 1990).

Sustainable development can be regarded as extended resource management by taking one or a combination of two possible routes: (1) Imposing aggregate constraints that are satisfied by the application of regulations (standards and property rights) and economic incentives (subsidies, taxes, monetary policy). Additionally, resources should not be considered separately (see also second route), as this would be too restrictive and lead to inefficiency; (2) Intergenerational compensation projects, through compensating negative impacts of main projects by performing (executing or financing) one or more secondary or 'shadow' projects such that the sum of the individual project damages is zero. This can be regarded as an alternative - and improvement - to valuation of environmental damage and monetary compensation. The main characteristic is that it deals explicitly with correcting, diminishing or compensating the direct (dynamic) physical impacts of the project, while the cost of the alternate project(s) allow(s) for corrections upon the cost-benefit analysis of the original project. 'Shadow' projects may either replace lost environmental values or avoid the environmental degradation and disturbance caused by the original project, where the last option is favoured. A main advantage of such an approach is that the difficult cardinal valuation is preceded by an easier to perform ordinal valuation of suitable 'shadow' projects (see Klaassen and Botterweg, 1976).

The idea usually expressed here is that current decisions should not impair the prospects for maintaining or improving future living standards (see, for instance, WCED, 1987). When faced with the choice to invest, save or consume now and impact thereby upon the future, we have to decide how to evaluate the various alternatives. Distribution of a fixed amount of something over time is already a difficult problem. When we add to this the dynamics of investment, saving, technology, resource depletion and pollution accumulation we are confronted with a more complex choice problem. Further complications arise from uncertainty and controllability of the economic-environmental system. Do we consider the distribution of welfare[14] or do we highlight the opportunities for attaining certain welfare levels? One may start by stating conditions to the minimum or maximum levels of time paths for certain variables, for instance to ensure survival. At the other end is the search for optimal sustainable development paths based on a specific intergenerational welfare function. In between these extremes on may search for monotonous changes. Pezzey (1989) makes a distinction between the characteristics of development paths of welfare over time into optimality, sustainability and survivability, which he regards as independent criteria. Sustainability is then taken in terms of non-decreasing time paths of welfare (see Mäler and Bojö, 1989). It is noted that concern for future generations in terms of opportunities implies that in addition to endowments of natural assets also man-made capital, technology and knowledge should be considered. Finally,

[14] Welfare of a generation is a vague concept. Besides the usual problems of aggregation of individual utilities additional ones arise in a dynamic setting. The first question is whether we have to think of the welfare of a generation in terms of a value at one point in time, or to approach it continuously. In the latter case one may explicitly take into account the fact that a generation exists for a certain period. This idea can be expressed by way of a function which explicitly aggregates the flow of welfare over a generation's lifetime into an indicator which should act as an index of comparison between generations (see Riley, 1980; Nijkamp and Rouwendal, 1988). Furthermore, one may include the notion of overlapping generations.

establishing intragenerational equity is part of the solution to attaining intergenerational equity, as fewer poor now means fewer, or fewer poor descendants of the present poor. In this respect, it is worthwhile to note that one may support the conviction that we should solve present problems of poverty before turning ourselves to future generations.

It may be clear that it is very difficult to describe accurately the characteristics of sustainable development paths. Partly, this is caused by the ethical choices involved. However, to a large extent one's belief in economic and ecological flexibility, and the subjective estimation of the risks involved are determining different positions. And where an exact description is difficult, an 'anti-description' may sometimes be illuminating and inciting. We have come up with the following general examples of anti-descriptions of sustainable development:

- depleting resources without providing for compensation or alternatives;
- borrowing now and leaving fut[illegible] generations with the financial burden;
- long term national/regional im[illegible]nce between import and export of specific resources;
- growth in one part of the w[illegible] at the cost of the environment and the population in another;
- a combination of living sta[illegible]ds and population levels in a region that cannot be supported in terms of basic [illegible] like water and food in the short or medium term by the natural resources available in [illegible]gion;
- export of waste and pollution, [illegible] via economic or environmental media;
- accumulation of pollution in s[illegible]ater, air and living creatures;
- simultaneous occurrence of e[illegible]mental degradation in one part of the world as a result of too high living standards an[illegible]nother because of too impoverished living conditions;
- degradation via pollution, ex[illegible]on or encroachment of ecosystems essential to the functioning of the biosphere;
- overloading the biogeochemica[illegible]ies;
- taking unnecessary risks with th[illegible]vironment, for instance by decreasing species diversity or increasing carbondioxide [illegible]entrations in the atmosphere, when the possible consequences are manifold or s[illegible]s[illegible] threatening, and surrounded with much uncertainty, whereas ways for avoiding it do [illegible].

The last paragraph of this section w[illegible]al with the impediments to sustainable development, of which there seem to be a lot. The [illegible]st important one seems to be that economic systems cannot easily be manipulated with[illegible] disturbing their performance (efficiency) and stability. Economic crises of the seventies [illegible] eighties have strengthened the conventional, and recently much supported belief of e[illegible]omic policy agencies that free market mechanisms are most suitable for maintaining a pro[illegible]us economic system. On the other hand, the call for sustainable development gives (aga[illegible]e to discussions on governmental policies with regard to regulations and incentives to gui[illegible]e economic activities of production and consumption within ecological constraints. And e[illegible]f this latter view is especially related to a transitional stage of fundamental and structural [illegible]ges in the economy before a sustainable development pattern is 'automatically' realized w[illegible]a corrected market system, it still leads to a conflict with the conventional economic polic[illegible]w[15].

A basic problem is that of commo[illegible]perty resources where a lot of polluting or extracting, and/or damaged parties are involve[illegible]some of these cases no instrument will guarantee an improvement since it is dependent o[illegible]tracts and mutual confidence.

Furthermore, corrections exercis[illegible]on market mechanisms aiming at so-called 'right prices', that internalize external neg[illegible](and positive) effects, are difficult to realize because

[15] One may add here that inherent to s[illegible]ble development is the opinion that market mechanisms fail to take all external, environmental, optional an[illegible]tain values into account so that sustainable development can only be realized if the market system is perm[illegible] corrected. This means that the conflict will not be solved after the transitional initial period.

the knowledge on exact scarcity, precise environmental impacts, and present/future values is surrounded with much uncertainty. Difficulties arise here for instance because of ambiguity in the valuation of environmental amenity services and the deficiency of future markets.

Another obstacle to sustainable development concerns the regional differences and competition that may hinder international cooperation, provide for the wrong incentives, and cause global inefficiency.

Finally, a very general deficiency is our still limited knowledge for solving the complicated problems that we face. So, if circumscribing the goal of sustainable development is difficult, 'accomplishing it is a matter of trial and error, and conducting experiments with reality is the only way to test our ideas', to use a phrase of Norgaard (1988).

4. AN OVERVIEW OF THE LITERATURE ON SUSTAINABLE DEVELOPMENT.

Attention for the environment - as providing constraints or incentives for economic change - in long term processes has been rare, although an outstanding classical exception is found in the work of Malthus, who envisioned inescapable limitations to continuous population growth. In a more recent contribution Wilkinson (1973) argues that economic changes have always been preceded by an ecological disequilibrium of a society, causing scarcity, and activating processes of cultural and technological change. Other approaches to an integration of long term development and environmental processes can be found in the work of Daly (1977), who supports the old idea of a steady or stationary state, with a stable level of population and capital - already discussed by Ricardo as the inevitable final outcome of the social and economic transition process, and by Mill as a desirable state in which more attention could be paid to the conditions of well-being than to accumulation and economic competition. The ideas of Boulding (1978) also include an integration of development and natural environment, in a way similar to the famous work of the French anthropologist Theilhard de Chardin, namely by stressing the similarities of the processes of change in different systems - physical, biological, ecological, economic, and social/cultural - which can all be considered as evolutionary. Finally, the inconsistency of continuous growth and the existence of ultimate limits has been addressed most noticeably by Georgescu-Roegen (1971), who has criticized the urge for growth by referring to the second law of thermodynamics, which implies increasing entropy, disorder and irreversibility. The other well-known critique has been expressed in the 'Club of Rome' report (Meadows et al., 1972), in which the physical limits of resource availability, food production potential, and assimilative capacities of natural systems as well as population pressure and congestion are emphasized. Since the eighties, sustainable development is a central concept in investigations of environment and development relationships.

Some important events and statements in the past decades that have paved the way to the emergence of the concept of sustainable development are the Stockholm Conference on the Human Environment and the establishment of the UNEP in 1972, 'The limits to growth' debate (Meadows et al., 1972; and 1982 for a overview of alternative models and reactions), the 'US Global 2000 Report to the President' (Barney, 1980) and the reaction 'The resourceful earth' (Simon and Kahn, 1984), and the 'World Conservation Strategy' (WCN/IUCN, 1980).

Reports of the eighties especially important in the context of sustainable development are the OECD reports 'Environment and Economics' (1984) and 'Renewable Resources' (1989), the IIASA report 'Sustainable Development of the Biosphere' (Clark and Munn, 1986), World Bank reports (World Bank, 1979; Warford, 1986), and of course the already mentioned United Nations report 'Our Common Future' (WCED, 1987).

The latter report studied the relationship between environment and development, with regard to both industrialized and developing countries, and concern for international, global economic and global ecological phenomena. The central message was: the world resources are sufficient to meet long-term human needs; they are unevenly spread; and they are wrongly used, namely inefficiently, inequitably and irrationally. In other words, it stresses the needs of the world's poor and the environment's ability to meet present and future needs, if basic changes would occur in the fields of resource use, investment, technology and institutions.

In general, the reactions to this report have been very positive, mainly because of its political effect and stimulus for scientific research. However, some authors mention the possibility of inconsistency between its objective of growth and regard for ecological limits (see Daly, 1990; and Hueting, 1990). According to the Brundtland report growth in LDC's is necessary to overcome poverty and at the same time - because it is one of its causes - environmental degradation. Also it is argued (and in the opinion of the critics to a certain extent assumed) that growth in developed countries is beneficial to development of LDC's because financial support is easier and demand for their products will increase. Aside from the criticism that is possible on this specific argumentation (Hueting criticizes the Brundtland report conclusions more explicitly), a general critique is possible. This is most clearly expressed in the many writings by Daly (see especially Daly, 1977 and 1980). The idea is that continuous growth in the physical size of an economy - and usually going along with a rise in GNP - for a general economy is not compatible with maintaining a non-decreasing environmental quality, generation of resource inputs, and assimilation of wastes. However, when instead of a general economy the specific relationships - between and different characteristics and needs^]13^^+('^U%* and developed countries are taken into consideration such a goal may be conflicting with solving problems of poverty. A simple compromise solution might be: the global environment may not be able to sustain global continuous growth; if growth in the South is regarded as necessary to solve problems of poverty it should be compensated by a decline in the size of the economies of the North so that the physical scale of the world economy is not increasing. Of course, this is politically even less acceptable than the steady-state concept of Daly applied to each national economy, and from an international economical viewpoint also very risky.

Much of the literature related to sustainable development has a strong bias towards developing countries (see Bartelmus, 1986; Redclift, 1987, Repetto, 1986; Tolba, 1987; and Simonis, 1990). Some authors prefer a more historical or theoretical economic argument to end with proposals on sustainable development (Daly, 1977; Barbier, 1989; Collard et al., 1988; Pearce, 1988; Pezzey, 1989; NAVF, 1990). Other approaches show a variation of issues related to sustainable development and deal with scarcity of specific resources, decreasing environmental damage through technical solutions, and relate more to developed countries or avoid such a choice. Also they discuss techniques to be used for studying sustainable development (Turner, 1988; Archibugi and Nijkamp, 1989). Still other approaches do stress the ecological factors, and propose a more integrated approach between economic and ecological studies (Dasman et al., 1973; Holling, 1978; Clark and Munn, 1986). A critical study of the social and psychological need for (further) growth and development along the lines of western economic development has been undertaken by various authors (Galbraith, 1959; Mishan, 1967, 1977; Scitovsky, 1976; Daly, 1977; Hirsch, 1977). They accentuate the existence of social and psychological limits to growth, the inequality in access to and use of resources, the need to maintain a balance between material and spiritual values, and - in comparison with the other studies mentioned - they focus on 'ultimate ends' instead of 'ultimate means' (except Daly, who addresses both these concepts). Finally, some books contain very personal or environmentalistic statements (for example, Commoner, 1971; Schumacher, 1973; Lovelock, 1985). Definitions of sustainable development and related concepts abound, and some attempts have been made to a systematic approach towards a definition (for instance, Brown et al., 1987) or collect those expressing very different positions (see the appendix in Pezzey, 1989).

Finally, we mention Dutch studies dealing with sustainable development. Hueting (1974/1982) provides for a conceptual link between economic growth and the loss of environmental functions. He proposes to valuate the latter and correct for them in the GNP figure (see also Hueting, 1990). Opschoor (1987) gives an overview of the general discussion and issues involved. He supports the idea of a resource regeneration system as an intermediate level of observation and analysis to the ecosystem and resource approaches. He advocates the ecocentric approach linked to the preservation of species and ecosystem diversity. Soeteman (1988) proposes a conceptual model of economic-ecological relationships for dealing with sustainable development. This includes three levels, namely a physical (causality, effectiveness, efficiency), a subjective (temporal and spatial dimensions) and an ethical (indicators, critical variables). This conceptual model is used for looking at land use in relation to the agricultural sector for the Netherlands in more detail. De Vries (1989) examines the role of formal models for defining and applying the concept of sustainable development and thereby emphasizes the concepts analog, isomorphism and metaphor to compare formal and natural (real-world) systems, and shows several operational studies of energy analysis. A research report of the Dutch Council for Environmental and Nature Research (RMNO; de Wit, 1990) collects a set of papers showing perspectives from various disciplines, including semeiology, ethics, systems ecology, environmental economics, sociology and psychology.

5. REGIONAL APPROACHES TO SUSTAINABLE DEVELOPMENT.

In this section we will argue that the study of sustainable development in the regional system is a logical phase in the approach towards the implementation of ecologically sustainable economic development. Various considerations are relevant in that respect (see table 1):

Global developments do not uniformly and smoothly impact on all regions. Global warming of the atmosphere, for example, may have positive effects on the total of organic production in the world, but will certainly result in socio-economic and ecological disasters in parts (regions) of the world. Second, the finiteness of natural resources on a global scale may have important different consequences at a regional scale. These consequences can be understood better by recognition of several relationships between global and regional levels. Third, many global environmental problems are caused by the total of a great many small-scale and meso level activities. The fact that the level of economic processes is moving towards a global scale, with more interactions between nations, adds to these phenomena. Fourth, the effects of many global environmental problems are visible at the meso level.

Global processes can be seen as consisting of interregional processes. The study of interactions between subsystems of a global system adds to the understanding of many global processes. In order to pursue such a study, the global system has to be decomposed into a set of open systems. All processes in a global or closed system are internally determined, while for the development in a regional system many factors are determined outside (e.g., international prices of resources, competition and demand for exported goods, imported pollution, and climatic conditions). Such a (multi-)regional approach has several advantages: its analysis will become less abstract and more operational; certain issues (e.g., linked to cross-boundary flows) as well as development paths are more easily traceable; furthermore, it may even be a necessary step in obtaining any operationally useful results. Finally, on a multi-regional level of analysis and policy there is much scope for various trade-offs: interregional, global-regional and intertemporal.

While the study of a global system often necessitates the assumption of homogeneous space and processes and (implicitly) equal distributions, a multi-regional setting allows one to study heterogeneous patterns and distributional issues within the total system. Regions differ with respect to, for instance, the standard of living, type of environmental problems and potential solutions available, rate of population growth, and autonomy. Heterogeneous patterns allow for compensation between regions. An example is compensation in terms of resources - the reserves of which may be unevenly distributed over regions - by interregional flows of resources and substitution of one type of resource by another. However, such compensations will only be possible if there exists a wide diversity among regions and if the resources or resource-using activities are mobile. In the case of land (an immobile resource), the interrelation of regions may ease the mobility of human activities when the pressure on this resource becomes too high.

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1. local-global relationships
    - local impacts of global development
    - finiteness of global natural resources
    - relationship between local and global systems behaviour
    - global impacts of local activities
    - perception of global problems at the regional scale
2. interregional processes
    - way of understanding global processes
    - concentrating on critical relationships
    - drawing of boundaries
    - operational analyses
3. heterogeneity patterns in the global system
    - differences amongst regions
    - compensation between regions
    - spatial adjustment processes
    - mobility of production factors and resources
4. control, monitoring and transformation
    - regional level suitable for control
    - selection of indicators, scenarios and strategies
    - choice of concrete policy objectives
5. conceptual and theoretical basis
    - no theoretical framework for regional sustainable development
    - extension of sustainable development concept
    - basis for linking and comparing empirical studies
6. descriptive and analytical operationability
    - including specific regional dynamics and constraints
    - systems approach: time, space and multidisciplinary
    - providing interactive modules in economic-ecological models
    - design of scenarios
7. feasibility of sustainable development policies and strategies
    - link policies and effects
    - scope for trade-offs
    - reliability and measurability of indicators

Table 1: Motives for the regional scope in sustainable development analysis.

Clearly, from a management and policy point of view, a regional system is more suitable for control and transformation than the global system. This follows from the non-homogeneous character of policy systems and goals in countries around the world, which gives rise to conflicting priorities in socio-economic objectives and governmental measures. Of course, regional policies should also be based on international communication and be in coherence with supra-national policies. In addition, a regional scale allows one to choose reliable and measurable indicators, while scenarios, concrete policy objectives, and strategies can be identified and analyzed. Thus, by focussing on regions, it is possible to operationalize the sustainable development concept.

While sustainable development has been extensively discussed in general and for a global scale (see the foregoing section), the regional approach has not been adequately addressed. Consequently, it is worthwhile to provide for a conceptual-theoretical treatment of ecologically sustainable development in open economies (before operationalizing). This may complement the empirical regional and national studies on interactions between economies and environment that are already being performed. A theoretical basis for the study of regional sustainable development includes at least the following elements: defining the basic concepts; general characteristics of development of regions; difference between global and regional sustainable development; and a step-wise procedure for operational analysis of regional sustainable development.

The use of indicators, data, economic-ecological models, and scenario-analysis in the study of sustainable development can be more easily accomplished on a meso than a global level. The choice of indicators is derived from the specific regional dynamics, constraints and objectives, many of which differ between regions and therefore either cannot be aggregated into an indicator on a global scale, or can be aggregated, only with a significant loss of information. For the study of SD on a regional scale with models specific dynamic economic-ecological models are needed. In order to be able to integrate potential economic and ecological submodels - i.e., provide for an interactive module - they should be consistent with one another in terms of geographical coverage and level of aggregation. The level of aggregation in a model should be consistent with the objectives of using that model. In the context of (global) SD two important objectives are that processes modelled on a chosen level of aggregation should be linked to those on the highest (i.e., global) level of aggregation and that the model is able to generate long term patterns (see next section). Hence, to provide for the consistency mentioned above, not too much complexity must be strived for. The complexity of models for SD will tend to be high if one aims at three distinct features in the design: (1) integration of three main modules (economic, ecological and interaction); (2) a high level of completeness o^R^U^S+' iption of each module; (3) much disaggregation of descriptions. Therefore, the choice of a regional scale seems to be a logical compromise in order not to further increase the complexity.

The design of scenarios may include relevant policy options and use of instruments, local desires, specific regional patterns, and details and (in)formal information on planned developments. A global scale will not allow for such an amount of detail and a direct link between policy instruments and effects. It only makes sense to link policy instruments with effects on a global scale when those policies can be implemented actually, which is not always evident. With a scheme of interactions between regional processes one may study the a link between the use of policy instruments and global effects systematically. Furthermore, by concentrating on cross-boundary flows and external determinants of internal processes the open character of a region can be explicitly used in scenarios.

In conclusion, there seem to be many reasons for considering the regional impacts and implication of SD. And hence it is evident that the objective of SD may be achieved more easily, if the processes of socio-economic development and environmental change at a regional scale are clearly understood and properly managed (cf. Kairiukstis, 1989).

An analysis of sustainable development of regions (RSD) is therefore necessary. Figure 1 shows the most essential elements to be considered in such an analysis, namely the economic and ecological systems, the welfare derived on the basis of their performances, the flows between the economic and ecological systems, and the cross-boundary economic and ecological flows. Furthermore, one must consider for RSD the development of a regional system in relation to interactions with other regions and their respective developments, and, where relevant, the external determinants of internal economic and environmental processes. Regional sustainable development is thus related to the sustainable provision of natural resources in the region and the sustainable import of resources, goods and services, thereby taking cross-boundary flows of pollution into account.

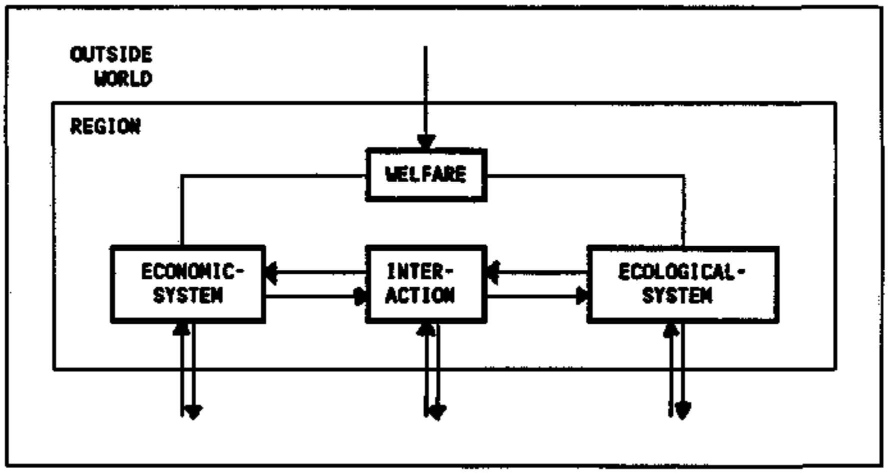

FIGURE 1: A scheme of regional economic-ecological interactions.

6. ECONOMIC-ECOLOGICAL MODELLING FOR SUSTAINABLE DEVELOPMENT.

One of the elements in the discussions around sustainable development is the integration of economics and ecology. These are not merely different objects of study, but also separate disciplines. This means that many of their theoretical concepts and methods are different. Also, the techniques used to operationalize theoretical concepts, or to perform empirical studies, and test hypotheses are dissimilar. However, some similarities can be found as well, for instance, between the sub-disciplines dealing with a rather aggregate treatment of the subjects, namely macro-economics and synecology, in both of which the method of deduction has dominated (see Van der Ploeg, 1974). Furthermore, although experimenting is limited in both fields, ecology possesses more opportunities for this than economics.

A rational approach to integration is the use of formal models, in which processes of both fields are described as far as they are related to one another. Methodological differences are circumvented to a certain extent in this way, while the specific accumulated disciplinary knowledge is used to establish the structure of the model, select the elements and specify their relationships (see Braat en van Lierop, 1986).

It was mentioned before that sustainable development entails the simultaneous consideration of (seemingly independent) environmental problems or economic-environmental interactions. Formal models again seem most adequate to deal with this.

We will argue subsequently that dynamic descriptive or analytical models, in combination with dynamic simulation techniques, scenario analysis, evaluation procedures or optimization objectives, are most suitable for dealing with sustainable development issues. It is possible to deal in such frameworks with the goals of development, and the interactions between economic and ecological-environmental systems. As an example, we can visualise this in terms of an optimal control model (see Kamien and Schwarz, 1982). In general it has four main elements:

(a) The initial conditions representing the economic capital and natural resources or ecosystems;
(b) A dynamic very simplifying description of natural and economic processes; the representations of natural processes may include functions for short term

regeneration and assimilation or changes of parameters that indicate long term changes; the economic processes described in such a framework can range from short and medium processes of extraction, recycling and emission, medium term process of investment and capital accumulation, and long term processes of technological progress and structural changes indicated by parameter changes;

(c) A description of a (generation's or individual's) utility or welfare function which may be based on consumption flows and natural resource stocks to represent natural environmental amenities.

(d) An ethical view on intergenerational justice via an evaluation of intergenerational distributions of utility/welfare that searches for the optimal value of (usually) an additive utility or maximin criteria function.

To make these analytical models suitable for dealing with sustainable development we may add constraints to limit extreme values or time-path structures, or to include ideas of various types of stock maintenance - such as those mentioned in section 3 (see Pezzey, 1989; and Barbier, 1989, 1990; and chapters 4 to 7). Furthermore, comparative static and dynamic analyses are relevant in the context of SD, as they deal with parameter changes which may result in the long term, for instance changes in tastes reflected by other parameter values in the welfare function, or evolution in the environmental sphere by changing parameters in the ecological description.

If descriptive models are used one can include uncertainty by linking probability distributions to descriptions of processes or events. Furthermore, it is then possible to add slow and fast dynamics, seasonal patterns, and economic, ecological and spatial disaggregation. Especially for dealing with the regional scale larger descriptive models are useful, because a detailed description can often be supported by available and reliable data, and region-specific concrete policies, strategies, and scenarios (see the foregoing section). In addition, it is possible to include systematically the various economic, ecological, and interactive processes in a larger descriptive model without being limited by analytical requirements. Of course, simplifying where possible is always desirable in order to keep the overview, limit the data requirements and uncertainty, perform more formal analyses (e.g., optimization), or derive simplified models.

The type of model that is relevant for gaining insight into sustainable development issues, or for tracing sustainable development paths should be checked with the following set of criteria:

(1) Does the model take a complete or general - in contrast to a partial - approach. The latter is likely to become less relevant when long term horizons are considered. The entire economic structure with both productive and non-productive uses of the environment should be included. The description of the natural environment should be compatible with it in the long run.

(2) Are the impacts included of economic productive and consumptive activities upon the natural environment, in terms of materials extraction, waste emission and pollution, and non-material disturbances. In more detail one has to pay attention to (i) extraction of non-renewable and biotic and abiotic renewable resources, (ii) agricultural activities affecting groundwater and soils like fertilizing, use of pesticides, irrigation, drainage, ploughing, (iii) the use of terrestrial and aquatic ecosystems for recreational purposes, (iv) land use, and the patterns and infrastructure involved, and (v) pollution and waste disposal, with a special view on for toxines, reactiveness, dispersion, degradability, and also specific types such as thermal, radiation and noise pollution.

(3) Is a mechanism included to describe the feedback from the ecology to the economy. This includes various elements related to for instance recreation and tourism, landscape values, quiet and annoyance. Inclusion of feedbacks of ecological impacts of general economic activity to the economic system is essential for an adequate description of long term processes in economic systems. For instance, feedback to decisionmaking with respect to productive activities may be included among other things via perception of resource scarcity, and pollution levels, or environmental damage in general.

(4) Not only material or priced services should be included, but also, as much as possible other services, such as for instance productive conditions (e.g., soil quality) and amenity services. The latter may be included in the evaluation or welfare function, but equally by way of behavioural feedback mechanisms. Furthermore, multifunctionality of ecosystems, and resource systems (as opposed to single one-dimensional resources) can be dealt with in a systems description.

(5) Concern for future generations must be included. First, this may imply that a judgement criterion is chosen for the evaluation of intergenerational distributions. Also, various conditions may be imposed on natural capital, pollution or economic capital to ensure an equitable intergenerational distribution. If the repercussions of intergenerational concern are taken in a behavioural rather than an evaluative or constraining sense it implies that behavioural or policy feedbacks aiming at intergenerational equity are endogenous.

(6) A long time horizon is a logical consequence of the foregoing point. It means that short term processes are left out where possible to simplify the picture. Also, it implies that linear models will not be adequate for a description of every process, and that risk or scenario analyses may be used for dealing with various uncertainties.

(7) It must be possible to describe qualitative (structural) change, either implicitly or explicitly. This means that one has to allow for a description of irreversible processes, thresholds, nonlinear structures and time-delays. This options may be supplemented by risk analysis (e.g., with Monte-Carlo experiments) to deal in various ways explicitly with uncertainty.

(8) The model assumptions should not conflict with physical constraints. Conceivable limitations on substitution in production and utility functions should be built in; furthermore, interdependencies between substitution of production factors, investments and technological progress have to be considered simultaneously. In addition, model assumptions should not conflict with thermodynamic laws, while material balances can be included explicitly.

These considerations point out that the dynamic element is essential. Therefore, we will focus our attention on dynamic models. They can deal with the transformation of short term processes into long term processes. They can include 'strange dynamics' associated with non-linear, feedback, stochastic and multiple interacting processes. For instance, it is necessary to describe the inherent dynamics of the fundamental chain —extraction—processing— consumption—waste generation—emission— in one framework and in a manner consistent with material balance principles. Furthermore, basic evaluation techniques such as cost benefit analyses assume that the dynamic path of the costs and benefits is known, and just this can exactly be the output of a dynamic model.

A second important implication of the above considerations is the need for incorporating environmental-ecological and economic processes in these models. The terminology 'economic-ecological' has been used to denote models that implement very different concepts of integration. It has been employed for economic process models which include environmental variables (e.g., waste emission or resource extraction) and ecological process models with economic variables (e.g., stress factors). The considerations above indicate that a stronger concept is necessary to deal with sustainable development, namely one that integrates economic and environmental-ecological processes rather than a process and a variable.

Of course, the use of models has some drawbacks. First, there are always a lot of subjective decisions involved when one establishes the crucial elements and relationships in the observed system. In addition, developing formal mathematical descriptions is one step which has to be complemented by quantifying these. Very important in building a complete and representative picture of the economic-ecological interactions is that it requires the specification of many relationships. Consequently, if as a result of lack of knowledge and data each of them is surrounded by uncertainty, this will severely impact on the reliability of the whole model in a negative way. Simple dynamic analytical models are more abstract in nature so that this drawback has less relevance there. However, to be analytically soluble they require that the form, complexity and size of the representation of the interactive economic and ecological systems, possibly supplemented by a formulation of an objective, is kept within certain boundaries (particularly related to the number of state variables and nonlinear specifications).

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