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Linking Weak and Strong Sustainability Indicators: The Case of Global Warming

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Abstract
The aim of this paper is to describe and discuss the weak and strong sustainability approach of assessing climate change and to show reasonable applications, weaknesses, possible improvements and linkages of both approaches. Main features of „weak“ and „strong“ sustainability approaches are characterized. Damage cost studies of global warming representing weak sustainability indicators are discussed. Further, the examples of the „inverse scenario“ approach of the German Advisory Council on Global Change (WBGU) and the environmental space concept of the Dutch Advisory Council for Research on Nature and Environment (RMNO) are described and discussed for illustrating advantages and weaknesses of strong sustainability indicators. Finally, the integration of damage cost modules into a broader methodological framework of strong sustainability is recommended.

Key words: weak sustainability, strong sustainability, environmental space, invers scenario, external costs, climate change, global wearming, damage costs

Non-technical summary
The Framework Convention on Climate Change (FCCC) has been one of the results of the global summit on environment and development in Rio 1992. Within the negotiation process following the Rio-conference, the need for a protocol in which the parties commit themselves to reduction targets for the different greenhouse gases (or for many developing countries: targets to limit increases) has become evident. The role of scientific research in this process is helping decision makers to derive reasonable reduction targets. However, the appropriate decision rule depends on the underlying paradigm of sustainability which can follow an ecological or an economic approach.

- From an ecological perspective, the („strong“) sustainability rule requires that the total sum of greenhouse gas emissions should not exceed the assimilative capacity of the atmosphere and that, at least, irreversible and catastrophic effects on the global ecosystem should be avoided.

- From a welfare theoretic perspective, a („weak“) sustainability approach is based on the principle that social welfare should be maximised and the total costs of climate change (abatement, adaptation and damage costs) should be minimised.

In order to bring ecological and economic requirements together, it is necessary to enhance integrated scientific assessments of climate change. During the past years, several approaches for integrating ecological aspects into economic theory have been conducted by models of integrated assessment of climate change. However, these models can still be divided into two groups: economic approaches based on cost-benefit analysis, and ecological approaches based on environmental targets.

Against this background, this paper explains the weak and strong sustainability approach of climate protection and shows reasonable applications, weaknesses, possible improvements and linkages of both approaches. In a first step, main features of „weak“ and „strong“ sustainability approaches towards climate stability are characterized. Then damage cost studies of global warming are discussed which represent indicators of the weak sustainability approach. Further, the examples of the „inverse scenario“ approach of the German Advisory Council on Global Change (WBGU) and the environmental space concept of the Dutch Advisory Council for Research on Nature and Environment (RMNO) are described and discussed for illustrating operational indicators of strong sustainability.

Finally, the integration of damage cost modules into a broader methodological framework of strong sustainability is recommended. Economic impact assessment should be improved and included into integrated models for assessing climate change policy. Weak and strong sustainability indicators can be used

complementarily in the assessment of climate change. Both can be understood as parts of broader approaches of integrated assessment models.

1 Introduction

The philosophy of a sustainable management of natural resources has been derived from the theory of environmental and resource economics. Originally the concept was developed for renewable resources, especially forests, for which maximum sustainable yields have been calculated. Hartwick (1978) has widened the sustainability principle to applications for exhaustible resources. The concept of a circular economy, as developed by Pearce and Turner (1990, p. 35), has established a broader concept which includes the function of the natural environment as a sink for emissions and waste.[1]

With regard to the assimilative capacity of the environment, ecosystem health is threatened by the greenhouse effect. The Conference of the Parties to the Framework Convention on Climate Change in Berlin 1995 has shown once more the need for a protocol in which the parties commit themselves to reduction targets for the different greenhouse gases (or for many developing countries: targets to limit increases). With regard to Article 3.1 of the Convention, targets for individual states should be defined „in accordance with their common but differentiated responsibilities and respective capabilities“.

The role of scientific research in this process is helping decision makers to derive reasonable reduction targets. However, the appropriate decision rule depends on the underlying interpretation of the sustainability paradigm which can follow an ecological or an economic approach.

- From an ecological perspective, the („strong“) sustainability rule requires that the total sum of greenhouse gas emissions should not exceed the assimilative capacity of the atmosphere and that, at least, irreversible and catastrophic effects on the global ecosystem should be avoided.

- From a welfare theoretic perspective, a („weak“) sustainability approach is based on the principle that social welfare should be maximised and the total costs of climate change (abatement, adaptation and damage costs) should be minimised.

[1] Beyond that some additional issues are discussed within the sustainability paradigm. For example, Daly emphasizes the role of eco-efficiency as a basic management rule: “Improving end use efficiency of resources is desirable regardless whether the resource is renewable or non-renewable” (Daly, 1990, p. 5). Additionaly, the German Council of Environmental Advisors (SRU, 1994, p. 48) stresses that the aspect of protecting human health is neglected by many proponents of sustainability, and introduces health as a further important goal.

In order to bring ecological and economic requirements together, it is necessary to enhance integrated scientific assessments of climate change. During the past years, several approaches for integrating ecological aspects into economic theory have been conducted by models of integrated assessment of climate change. However, these models can still be divided into two groups: economic approaches based on cost-benefit analysis, and ecological approaches based on environmental targets (Weyant et al. 1996).[2]

Against this background, the aim of this paper is to explain the weak and strong sustainability approach of climate protection and to show reasonable applications, weaknesses, possible improvements and linkages of both approaches. In a first step, main features of „weak“ and „strong“ sustainability approaches towards climate stability will be characterized. Then damage cost studies of global warming will be discussed which represent indicators of the weak sustainability approach.[3] Further, the examples of the „inverse scenario“ approach of the German Advisory Council on Global Change (WBGU) and the environmental space concept of the Dutch Advisory Council for Research on Nature and Environment (RMNO) will be described and discussed for illustrating operational indicators of strong sustainability. Finally, the integration of damage cost modules into a broader methodological framework of strong sustainability is recommended.

2 Weak and Strong Sustainability Approaches for Assessing Climate Change

2.1 Definition of Weak and Strong Sustainability

In several contributions, damage cost calculations of climate change like that of Nordhaus (1991), Cline (1991) and Fankhauser (1995) were criticised especially from an ecological perspective. It had been argued that mere neoclassical optimisation concepts tend to ignore the ecological, ethical and

[2] Some contributions towards a more ecological-oriented target-setting have been made by advocates of ecological economics, e.g. general contributions to integrated ecological and economic models like the one of Common and Perrings, 1992, and special contributions to the consideration of sustainability aspects of climate change into economic analysis, like the ones of Spash, 1994, and Hohmeyer, 1996.

[3] Since a detailled description of the contents and results of existing studies has already been done in the IPCC Second Assessment Report (Pearce et al., 1996), this paper focuses on the critical issues of the studies and the further development of their methodological framework.

social dimension of the greenhouse effect, especially issues of an equitable distribution and a sustainable use of non-substitutable, essential functions of ecosystems.[4]

The ecological argument addresses the use of damage cost values for computing optimal levels of emission abatement neglecting the special function of the atmosphere as a sink for greenhouse gases. This function is absolutely scarce and essential for the global ecosystem. It is feared that, by putting certain monetary values on this essential natural function, politicians may be encouraged to „sell“ it in exchange for goods being possibly of higher value in a short time horizon (e.g. income).

An early proposal for considering sustainability constraints in cost-benefit analysis has been made by Barbier, Markandya and Pearce (1990, pp. 1260 - 1261). They formulate a sustainability criterion requesting that the sum of damages done by a certain amount of projects should be zero. If E_i is the damage done by the i-th project, the criterion is

$$\sum_i E_i \leq 0 \qquad (1)$$

The idea of the criterion is that any environmental damage should "be compensated by projects specifically designed to improve the environment" (Markandya and Pearce, 1991, p. 150). In terms of welfare economics, the compensation criterion is shifted from hypothetical to actual compensation.

However, the sustainability criterion of Barbier, Markandya and Pearce is "weak" because it allows for unconstrained elasticities of substitution between different types of natural capital. For example, a further depletion of the ozone layer can be compensated by projects supporting the protection of panda bears. Such a weak sustainability criterion should be supplemented by "strong" sustainability criteria which stress more the limitations of substitutability. In this sense, „strong sustainability regards natural capital as providing some functions that are not substitutable by man-made capital. These functions, labeled ‘critical natural capital’, are stressed by defining sustainability as

[4] Most of the critical arguments pointing out the limits of traditional cost-benefit-analysis can be found in the IPCC Second Assessment Report (IPCC 1995, WG III).

leaving the future generations a stock of natural capital not smaller than the one enjoyed by the present generation“ (Cabeza Gutés 1996, p. 147).[5]

2.2 Elements of a Theoretical Foundation of Weak and Strong Sustainability

2.2.1 Sustainable Preferences and Adjusted Discount Rates

Strong sustainability, as defined above, is defined in physical terms. This definition is hardly compatible with neoclassical economics having pushed physical factors into the background. What counts in neoclassical welfare theory are subjective perceptions and preferences of people. This preferences of individuals give a certain value to man-made or natural capital. Following this logic, climate stability is a limiting factor of human development if and only if some individuals have an aversion against observed climate risks. As long as individuals do not care about climate change, climate protection does not produce any benefit for them and has, therefore, no economic value. In other words: strong sustainable development can only be translated into neoclassical economics by introducing individual preferences for the long-term protection of life-support functions of ecosystems. Thus, the protection of critical natural capital can be achieved if revealed preferences for intact ecosystems exist.

Such a translation of sustainable development into terms of welfare economics has been suggested by Chichilnisky (1996a). Chichilnisky introduces „sustainable preferences“ which are defined by two axioms to rule out „dictatorial“ solutions. In her approach, neither the present nor future generations should be dictatorial. The axioms are:

- no dicatorship of the present (no finite set of generations should be dictatorial), and
- no dictatorship of the future („the very long run“ should not be dictatorial).

The axioms can easily be related to the strong and weak sustainability paradigms. While the weak sustainability approach of discounted utilitarianism can be characterized as a dictatorship of the present, the strong sustainability

[5]Similar definitions can be found in Pearce and Atkinson (1993) and Pearce, Hamilton and Atkinson (1996), pp. 85 - 87. It should be added that critical elements of natural capital can neither be subsituted by man-made capital nor by other elements of natural capital, as the example of the ozone layer and the panda bear may illustrate.

approach can be regarded as dictatorship of the future.[6] The non-dictatorial solution are the so called „sustainable preferences“ or the „Chichilnisky criterion“. Sustainable preferences are sensitive to the welfare of all generations. This means that:

- the conventional way of discounting future preferences may lead to unsustainable development paths and catastrophic outcomes for future generations, so special weight has to be given to future generations.

- On the other hand, zero discounting may discriminate against the present generation. If consumption in all periods would be weighted equally on an endless time scale, weights would sum to infinity.

Chichilnisky (1996b, p. 2) sees empirical evidence that sustainable preferences exist already within the present generation. If such empirical evidence can be found, the conventional way of measuring and discounting peoples values for the future have to be adjusted. Such adjustments will be described more detailled in chapter 3 of this paper.

2.2.2 Uncertainty and Multi Criteria Analysis

Even if sustainable preferences are assumed, the question is whether the costs and benefits of climate change are quantifiable. In a complex and uncertain situation where irreversible damages can occur, Faucheux and Froger (1994) argue that the conventional Bayesian approach of assuming known risk probabilities is not appropriate. According to Faucheux and Froger, the assumption of bounded rationality[7] is more adequate to the problem. Bounded rationality means limited ability of the human mind to collect, remember and evaluate informations. Assuming uncertainty and bounded rationality supports the strong sustainability paradigm, since the optimisation of outcomes can be judged as over-ambitious in situations where even valid estimates of rough future trends are hard to find. Faucheux and Froger refer to Simon (1972, p. 410) who explains the consequences of assuming bounded rationality as follows: „The decision question has been switched to the question of how much of the actor’s resources should be allocated to search“. Intitiating such a process

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[6]In the terminology of Beltratti, Chichilnisky and Heal (1994), the strong sustainability criterion is called the „green golden rule“. They define it as the configuration of the economy which gives the highest indefinitely maintainable level of long run utilities. In principle, the green golden rule requires a zero functional consumption of exhaustible resources.

[7] Bounded rationality is an established assumption among new institutional economists, see e.g. Simon (1972) and Rennings (1992), p. 16.

of search is called procedural rationality. The methodological consequence is that satisfactory choices may become more relevant than optimal choices, and safe minimum standards may function as rules of thumb during the process of search. It is nevertheless necessary to classify and evaluate alternative outcomes in a weighting scheme. Faucheux and Froger (1994, p. 62) suggest the multicriteria analysis as an analytical tool for decision making based on procedural rationality.

2.2.3 Scale Issues and Ecological Carrying Capacity

Daly (1992) has adressed the categories of weak and strong sustainability by separating the policy goals of sustainable scale, just distribution and efficient allocation. Scale refers to the ecological carrying capacity requiring that economic activities should not jeopardize the stability of ecosystems. According to Daly, processes which are relevant to the level of entropy, as e.g. resource use or flows of matter-energy, should be restricted according to a sustainable scale. Scale has to be measured in absolute physical units. A good scale is one that is at least sustainable, that does not erode environmental carrying capacity over time. In other words, future environmental carrying capacity should not be discounted in present value calculations. An optimal scale is at least sustainable, but beyond that it is a scale at which we have not yet sacrificed ecosystem services that are at present worth more at the margin than the production benefits derived from further growth in the scale of resource use" (Daly 1992, pp. 186 - 187). Hence, economic growth should be adjusted to the absolute carrying capacity of ecological systems. This is seen as a prerequisite for dealing with questions of distribution and allocation of natural resources.

Using Daly’s categories, the valuation of external costs seems to be useful to gather indicators of efficient allocation. However, correcting market failure by estimating the „right“ social costs is only the third and last step within the sequential process of adressing policy issues of sustainability, equity and efficiency. Obviously, additional ecological and social indicators are needed for the first two steps. Pursuing this, pressures endangering the long-term stability of ecosystems have to be identified and transformed into critical thresholds. Such thresholds function as "safe minimum standards" (Hampicke, 1993, p. 149; Bishop, 1978, pp. 10 - 18) for essential parts of ecosystems. Daly has used the metaphor of „plimsoll lines“ to describe this function of scale limits (Daly, 1992, p. 192).[8]

[8] While the concept of Daly is strictly based on the law of entropy, the relevance of entropy processes to explain interactions in open economic and ecological systems seems to be

2.3 Indicators of Weak and Strong Sustainability

The weak sustainability approach is represented by external cost estimates of climate change being closely related to the economic rule of maximising welfare. Thus, external costs can be interpreted as indicators of weak sustainability. They indicate the amount of money that has to be spent for the compensation of the estimated welfare losses. The question discussed in this paper is whether these indicators are useful and which role external costs may play in a broader concept of strong sustainability.

In comparison with that, indicators of strong sustainability should offer information about critical elements of the natural capital. Firstly, they should inform about changes in quantity and quality of essential natural resources and functions. Secondly, they should reflect how far the actual use of natural resources is away from a sustainable scale.

Although the process of specifying and quantifying critical elements and thresholds evokes several problems, some progress has been made in developing physical sustainability indicators during the last years (Billharz/Moldan 1995). Rennings and Wiggering (1997) have focussed on the assimilative capacity concerning acidification and eutrophication. While critical thresholds can be observed and measured for these problems, the issue becomes more difficult for linear or uncertain risks where no safe levels are abvious. With regard to climate change, the question has to be answered if and how acceptable levels of greenhouse gas emissions can be quantified.

3 Assessment of Weak Sustainability Indicators of Climate Change

3.1 Handling of Global Warming in External Cost of Energy Studies

Due to methodological and empirical problems, the major valuation studies estimating external costs in the energy sector refused to integrate damage costs of climate change into their results. Two different options have been used alternatively:

- The first alternative is the calculation of abatement costs (for specificied CO2-reduction targets) instead of damage costs. Most advocates of an

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vague and is still disputed (Rennings 1994, pp. 106 - 110; Binswanger 1993, pp. 220 - 229). Alternative approaches are more oriented on ecological criteria like the "resilience and stability of ecosystems" (Common and Perrings, 1992, pp. 15 - 21).

ecological paradigm of sustainable development prefer the use of abatement costs because they are normally related to CO2-reduction targets leading to sustainable future emission paths. The abatement cost option has been choosen e.g. by studies from de Boer/Bosch (1995), Bernow et al. (1996) and Ott (1996).

- Other research teams, being more obliged to a neoclassical paradigm of external costs, decided to renounce the use of damage cost values until more comprehensive studies and methodologies are available. Amongst this groups are the research teams of the valuation studies of the European Commission (ExternE) and of the U.S. Department of Energy (DOE-Study). As Lee (1996, p. 16), one of the authors of the DOE-Study, states: „The earlier studies include estimates of damages from climate change; the more recent studies do not include them in their summary tabulations.“ And in a footnote he remarks that „this conclusion does not say that damages from climate change are zero, but that precise estimates of these damages do not have a sound scientific basis because of great uncertainty“.

3.2 Problems of Valuing Global Warming Damages

The report of phase II of the ExternE project (EC 1994, pp. 159 - 162) does not recommend the use of any monetary value for global warming, but describes the state of the art concerning the valuation of damages. The main results have been that:

- greenhouse gas emissions from each fuel cycle are known accurately,
- the impacts of global warming are complex, scenario dependant, very uncertain, long term and potentially very large,
- the regional variation of climatic change is poorly understood,
- the most comprehensive impact assessments (IPCC) are largely qualitative,
- the results are very sensitive to scenarios considering secondary effects, especially starvation in developing countries,
- serious ethical questions are touched which go beyond mere allocation questions of welfare theory and

there is no consensus about these fundamental ethical questions.

Similar conclusions have been drawn by the Intergovernmental Panel of Climate Change (IPCC) in it’s Second Assessment Report being finished in the end of 1995.[9] The report cites the range of estimates of marginal damage at 5 - 125 $ per ton of carbon emitted now (Pearce et al., 1996, p. 218). The Working Group III of the IPCC has given special attention to the assessment of cost-benefit analysis and the incorporation of intra- and intergenerational equity aspects. It has identified some key problems being not adequately adressed by applying traditional cost-benefit-analysis to climate change (IPCC 1995, WG III, pp. 7 - 16; Arrow/Parikh/Pillet et al. 1996, p. 59):

- large uncertainties,
- long time horizons,
- global, regional and and intergenerational nature of the problem,
- wide variations of the cost estimates of potential physical damages due to climate change,
- wide variations of the cost estimates of mitigation options,
- low confidence in monetary estimates for important consequences (especially non-market impacts),
- possible catastrophes with very small probabilities and

issues of intragenerational equity (especially lower values for statistical lives of people in developing countries than those in developed countries).

Besides these weaknesses, some additional methodological problems are still unsolved. While normally marginal impacts of single power plants are calculated in recent damage cost studies, marginal impacts of one power plant on the global climate seem to be insignificant (Plambeck/Hope, 1996, p. 784). Also Hohmeyer (1996) points out that valid cost-benefit optimisation is impossible because future marginal costs are impossible to derive for long term climate change. For that reason, average values have to be used. Thus, the

[9] The structure of the IPCC includes three Working Groups: Working Group I (WGI) assessed the science of climate change, Working Group II (WGII) focused on the analysis of impacts and response strategies, and Working Group III (WG III) studied the socio-economic implications of impacts, adaptation, and mitigation and prepared future emissions scenarios (Arris 1996, p. 1). Each Working Group prepared a final report and a summary for policymakers (SPM) (IPCC 1995, WG I - III). The summaries are supplemented by a synthesis report covering the issues of all the three Working Groups (IPCC 1995).

„bottom up"-approach and the estimation of marginal, site-specific effects has to be modified for the global warming issue.

The issue of serious ethical questions refers to normative assumptions of external cost studies which are not transparent for the user of the results. One assumption is that economic welfare is measured by people's willingness to pay or willingness to accept compensation. Thus, the welfare of rich people and nations has a greater weight in the results than the welfare of poor ones. Especially the common way of valuing human lives in developing countries lower than those in developed countries is highly disputed. Another implicit, but central judgement concerns the possibility of compensating future individuals for climate damages. Such assumptions have to be made transparent, and a representative range of assumptions should be used in the form of an ethical sensitivity analysis.

3.3 Improvements of Damage Cost Valuation

3.3.1 Intragenerational Equity

Responding to the IPCC criticism, Fankhauser and Tol (1995) and Tol (1996b) have derived a research agenda for the economic assessment of climate change impacts including:

- improved damage estimates for less developed countries;
- improved estimates for non-market losses, especially morbidity and ecosystem effects;
- assessment of the importance of variability and extreme events;
- models of the process of adaptation and the dynamics of vulnerability;
- formal uncertainty assessments and analyses of the outcomes;
- improved comparison and aggregation of estimates between countries;
- improved comparison and aggregation of estimates between generations;

ensuring consistency between economic and non-economic impact assessment.

Following this research agenda, first progress can be observed, especially concerning the handling of intra- and intertemporal equity questions.[10] Intragenerational equity questions have been adressed by contributions from Fankhauser, Tol and Pearce (1996) and Azar and Sterner (1996). Both use an approach of equity weighting: on the basis of the existing estimates of global warming damages, willingness to pay values are adjusted in the aggregation process. While aggregating estimates for single countries or world regions to a global value, the damages are weighted by the inverse of income. Damages of rich countries are weighted down and damages of poor countries are weighted up by adjusting these damages to the average annual per capita world income. The reason for the adjustment is „decreasing marginal utility of money and for the same reason we can argue that a given (say one dollar) cost which affects a poor person (in a poor country) should be valued as a higher welfare cost than an equivalent cost affecting an average OECD citizen“ (Azar and Sterner, 1996, p. 178). Thus, equity weighting leads to the result that damages and deaths in developed countries do not count more than in developing countries. Due to the fact that the annual world income does not rise is constant, it has to be used as a bugdet restriction.

Beyond issues on intragenerational distribution, improvements concerning intergenerational equity have been made by several authors and will be described more detailled in the next section.

3.3.2 Intergenerational Equity

The results of monetary values of climate change damages depend substantially upon the choice of the discount rate. The higher the discount rate, the lower the present value of future damages. Thus, discounting is often criticized because it produces incentives to shift environmental risks from the present to the future. However, the relationship between discount rate and climate change is very ambiguous. Lowering the discount rate induces an increasing level of economic activity and investment. This would probably lead to further emissions of greenhouse gases (CEC/US Joint Study, 1993, S. 2-19). The relationship between the discount rate and environmental deterioration is known as the "conservationist’s dilemma", since both, high and low discount rates, can favour environmental conservation (Norgaard/Howarth, 1991, p. 90).

Commonly, a range of discount rates is used in cost-benefit-analyses. Following Markandya, discount rates of 0, 3 and 10 percent represent an adequate range of

[10] Additionally, some efforts have been made towards a more dynamic modelling of climate change damages which will de not discussed within this paper. See for details Tol (1996a; 1996c).

parameters for the European Union (CEC/US Joint study, 1993, p. 2-22). 3 percent are taken as a rate for social time preference, 0 percent and 10 percent as extreme parameters for sensitivity analysis.[11] With regard to climate change, none of the three rates is satisfying: while rates of 3 to 10 percent lead to nearly zero costs for long term damages, a rate of 0 percent may evoke infinite costs.

3.3.2.1 Time-variant discount rates

The rate of 3 percent can be derived from the concept of social time preference (STP), a measure of the decline of social welfare or utility of consumption over time (Markandya/Pearce, 1991, p. 142). The social time preference depends on the rate of pure individual time preference (ITP) or impatience, on the growth rate of real consumption per capita (W), and on the elasticity of the marginal utility of consumption (U). The equation is:

$$STP = ITP + W \times U \qquad (2)$$

An important argument against the STP concept is that ecological "limits to (economic) growth" will set biophysical constraints on W in the long run. When choosing the rate of W, such constraints should be taken into consideration. For the EU, Markandya recommends a rate for W of around 1 or 2 percent as a low sustainable rate (CEC/US Joint study, 1993, p. 2-20).

It is argued from an environmental perspective that ITP should be refused in social investment decisions. This position takes the perspective of society as a whole and criticizes impatience for being irrational. For a society - contrary to the individual view - it seems to be unreasonable to privilege present preferences above future preferences. However, a collective view conflicts with methodological individualism being a fundamental element of welfare economics.

Rabl (1993) argues that a discount rate for intergenerational effects should be defined by taking the perspective of future generations. From Rabls point of view, market interest rates can only be taken to the extent that a market exists. Following Rabl, the longest time horizon of market transactions is 30 to 40 years. Thus, there is no inconsistency in lowering the interest rate for damages beyond that time horizon. In consequence, Rabl recommends to split STP in an

[11] Relative high (market) discount rates of 6 or more percent normally represent the concept of opportunity costs of capital.

$$STP = ITP + W \times U \quad \text{for short term effects} \quad (< 30 \text{ to } 40 \text{ years}) \quad (3)$$

and an

$$STP = W \times U \quad \text{for long term effects} \quad (> 30 \text{ to } 40 \text{ years}) \quad (4)$$

At first glance, the splitting concept and the time horizon for market transactions chosen by Rabl seem to be very arbitrary. At second glance, a special treatment of long term effects seems to be reasonable, because otherwise damages occuring a hundred or more years in the future will be totally ignored in monetary valuation studies. Understood as a first rule of thumb, Rabl's concept of time-variant discount rates helps to improve the treatment of long term effects in external cost studies.

Following the idea of the Chichilniskys criterion (see section 2.2.1), Heal (1996, pp. 6 - 7) has introduced the concept of logarithmic discounting with a similar consequence, namely a decreasing discount rate in time. In his approach, the discount rate is inversely proportional to distance into the future. This formalisation has been derived from the Weber-Fechner law stating that „human response to a change in a stimulus is inversely proportional to the pre-existing stimulus" (Heal, 1996, p. 6). Heal argues that a decreasing discount rate is a natural phenomenon: „postponement by one year from the next year to the year after, is clearly quite a different phenomenon from postponement from fifty to fifty one years hence. The former represents a major change: the latter a small one". Compared with the approach of Rabl, the concept of logarithmic discounting is more elaborated and sophisticated. The main advantage is that discontinious damage functions can be avoided.

It can be summarized that the introduction of time-variant discount rates is reasonable with regard to long-term environmental damages. To express it in the words of Sterner and Azar (1996, p. 174), „a constant discount rate should only be seen as a special case of the more general case where the discount rate is allowed to vary".

Markandya's estimate for ITP is around 1 or 2 percent. Added with W, the result is a STP of 2 to 4 percent (CEC/US Joint study, 1993, p. 2-20). Rabls estimates of W are quite similar to Markandya's values (Rabl, 1993, p. 2 - 4).

3.3.2.2 Zero discount rate

A more radical position is to set the discount rate equal to zero (Pearce, 1993, pp. 57 - 61). A zero discount rate follows the rule that consumption at one point of time does not count more than welfare at another point of time. However, it is feared that a zero discount rate would imply infinite social costs and total current sacrifice (Pearce, 1993, p. 58).

Nevertheless, there is some reason to use zero discount rates for certain natural resources (W_{NR}) whose market value are expected to rise proportionally to the Gross Global Product (GGP). One important example is the demand for safety, expressed in terms of an statistical value of life (VSL). It can be assumed that the growth rate of the WTP for reducing health risks will be at least as high as the growth rate of GGP. All things considered, 0 percent seems to be an appropriate discount rate only if

$$W = 0 \tag{5}$$

or if

$$W > 0, \text{ and } W_{NR} \approx W \tag{6}$$

A prerequisite for (6) is that W_{NR} is not already included in calculations of the underlying cost and benefit streams. Studies expressing the cost of global warming as a percentage of GGP (Mayerhofer, 1994, pp. 2 - 5) already include W_{NR}, whereas WTP for reducing health risks can be assumed to be at least proportional to GGP but is commonly calculated with a constant statistical value of life (Rabl, 1994, pp. 1 - 2).

3.3.2.3 Discounting, equity and distribution

The main controversial issue among the different discounting concepts is the question of compensation among generations. While the use of market interest rates assumes compensation from one generation to another for losses of natural capital, the use of lower discount rates assumes more or less that environmental protection is the only way to make these transfers (Arrow/Cline/Mäler et al. 1996, p. 133). Following this argument, intergenerational fairness can be characterized as a matter of distribution across generations. It seems to be reasonable to separate these issues of distribution from issues of efficiency.

According to Daly, "the policy instrument for bringing about a more just distribution is transfers - taxes and welfare payments" (Daly, 1992, p. 186). Norgaard and Howarth argue in the same direction by pointing out that "if we are concerned about the distribution of welfare across generations, then we should transfer wealth, not engage in inefficient investments. Transfer mechanisms might include setting aside natural resources, and protecting environments, educating the young, and developing technologies for the sustainable management of renewable resources. Some of these might be viewed as worthwhile investments on the part of this generation, but if their intent is to function as transfers, then they should not be evaluated as investments. The benefits from transfers, in short, should not be discounted" (Norgaard/Howarth 1991, p. 98).

From this point of view, the discount rate should only function as a mechanism of efficient allocation of resources. Distributional aspects are separated from allocation, although they are not independent. It is plausible that transfers to future generations change relative prices. As Norgaard and Howarth remark: "With different distributions and efficient allocations, new prices arise. One can no more speak of 'the' rate of interest when societies are giving major consideration to the sustainability of development than one can speak of 'the' price of timber when deciding whether to conserve forests. Redistributions change equilibrium prices" (Norgaard/Howarth, 1991, p. 97).

3.4 Conclusions

It can be summarized that the approach of deriving weak sustainability indicators of global warming by estimating damage costs requires strong normative choices about inter- and intragenerational fairness and the handling of uncertainty. This normative choices are made in most cases implicitly, i.e. they are hidden unter a veil of aggregation and discounting rules. These problems have been especially emphasized by the Second IPCC Assessement Report. However, important responses to the IPCC criticism have now been made. While the long term dynamic effects of global warming and the resulting social and economic impacts are still not well understood, at least some important contributions have been made with regard to an improved handling of intra- and intergenerational equity issues. As far as allocation is concerned, an appropriate range of discount rates should integrate

- 0 percent as a rate for long term effects which are expected to rise with GDP,

- 1 percent as rate for STP ignoring ITP,

- 3 percent as a rate for STP including ITP and

- higher discount rates representing market interest rates (concept of opportunity costs of capital).

The concept of time-variant discount rates seems to be consistent within the principles of welfare theory. While 3 percent can be used as a standard discount rate, lower rates can be applied for the long-term global warming effects.

It is obvious that equity weighting and time-variant discounting will have a substantial influence on the fact which amount of investments for stabilizing the global temparature can be justified by mere economic reasons. In the IPCC report with a cited range of 5 - 125 $ marginal per ton of carbon, the lower bound of the range is derived from the Nordhaus study. Using mainly the Nordhaus parameters and a model considering the retention of carbon in the atmosphere, Azar and Sterner (1996, p. 182) introduce time-variant discount rates and equity weighting as described above. Doing this, they calculate marginal damages in the range of 260 - 590 $ per ton of carbon. This is roughly 50 to 100 times higher than the Nordhaus value.

Nevertheless, large uncertainties concerning future climate scenarios and damage paths remain. A reasonable solution may be to link monetary indicators with more ecologically oriented approaches which will be presented in the next chapter.

4 Assessment of strong sustainability indicators of climate change

4.1 Indicators of environmental space

Important early contributions to the discussion of acceptable levels of greenhouse gas emissions have been made by the Dutch Advisory Council for Research on Nature and Environment (RMNO) (Weterings/Opschoor 1994) and by the German Enquete Commission „Preventive Measures to Protect the Earth's Atmosphere". The Enquete-Commission has derived specific national reduction targets and general targets for developed and developing countries (German Bundestag 1991, Vol. 1; pp. 70-75) from the recommendations of the World Conference on Atmospheric Change in Toronto 1988. The recommendation of the conference had been (German Bundestag, 1991,Vol 2, 796 -840):

- to reduce global emissions of CO2 and other trace gases by over 50 percent by the year 2050 and

- to reduce global CO2 emissions by about 20 percent by the year 2005, relative to 1988 emission levels.

Furthermore, the recommendations of the RMNO and the Enquete Commission are based on a study of Krause, Bach and Koomey (1990) estimating tolerable CO_2-emissions. The authors calculate a tolerable relative deviation of 0,1°C per decade (data on the ability of trees to migrate suggest this as a maximum rate of temperature-rise) and an absolute warming limit of 2,0-2,5°C above pre-industrial level for the next 100 years (which would lead to a maximum acceptable sea level rise of 1 meter in the forthcoming centuries). Within this temperature change the most important ecological functions are supposed to be sustained. These thresholds have been transferred into critical concentrations and critical emission paths.

In a report to the RMNO, Weterings and Opschoor have used the concept of environmental space to share the global budget for CO_2-emissions among nations. They describe the concept of environmental space as follows:

> „Environmental utilisation space (or: environmental space) is a concept which reflects that at any given point in time, there are limits to the amount of environmental pressures that the earth's ecosystem can handle without irreversible damage to these systems or to the life support processes that they enable. This suggests to search for the threshold levels beyond which actual environmental systems might become damaged in the sense indicated above, and to regard this set of deductively determined critical values as the operational boundaries of the environmental space“ (Weterings/Opschoor 1994, p. 3).

Five different criteria have been used for the distribution of the carbon-budget over regions and nations:

- GNP,
- land area,
- current energy consumption (status quo criterion),
- current population (equity current criterion; equal emission per capita),
- current and future population (equity cumulative criterion; equal emssion per capita).

Following each of the five criteria, the global carbon-budget was distributed among nations and regions. The different sustainability indicators (according to different distribution criteria) were compared to the actual and forecasted performance of the OECD countries (see table 1). The report comes to the conclusion that „the OECD does not meet the various sustainability criteria currently and is not forecasted to do so in the forthcoming decades. Nor any of the individual member-states does. Even if we forget about a more equal distribution in respect of the developing countries, the OECD emission exceeds sustainability (status quo) by more than a factor 2. From the equity perspective the OECD performance is unsustainable by a factor of 7 to 10“ (van der Loo 1993, p. 65).

Obviously, the definition of strong sustainability standards requires some normative choices. Compared with „weak“ optimisation concepts, the advantage is that these choices are made explicitly and are not hidden unter a veil of aggregation and discounting rules.

Table 1: Sustainability Criteria for OECD-carbon release
(Assumption: Sustainable world carbon budget 300 GtC as estimated by Krause et al. 1990; OECD current annual release 2.8 GtC)

Criterion	OECD Budget 1985- 2100 (% global budget)	(GtC)	OECD Annual average (GtC)	% current emission
GNP	63 %	189	1.64	57 %
Land area	24 %	72	0.63	22 %
Status Quo	47 %	140	1.17	42 %
Equity current	16 %	48	0.42	15 %
Equity cumulative	11 %	33	0.29	10 %

Source: van der Loo (1993), p. 65.

4.2 The „Invers Scenario“ or „Tolerable Window Approach“

Another example of making such choices explicitly and describe them transparently is the „invers scenario“ of the German Advisory Council on Global Change (WBGU). Based on the scenario asumptions, the WBGU draws the conclusion that the acceptable absolute positive deviation from the present mean temerature on earth is 1.3 °C and a temperature change of 0.2 °C per decade is the tolerable upper limit.

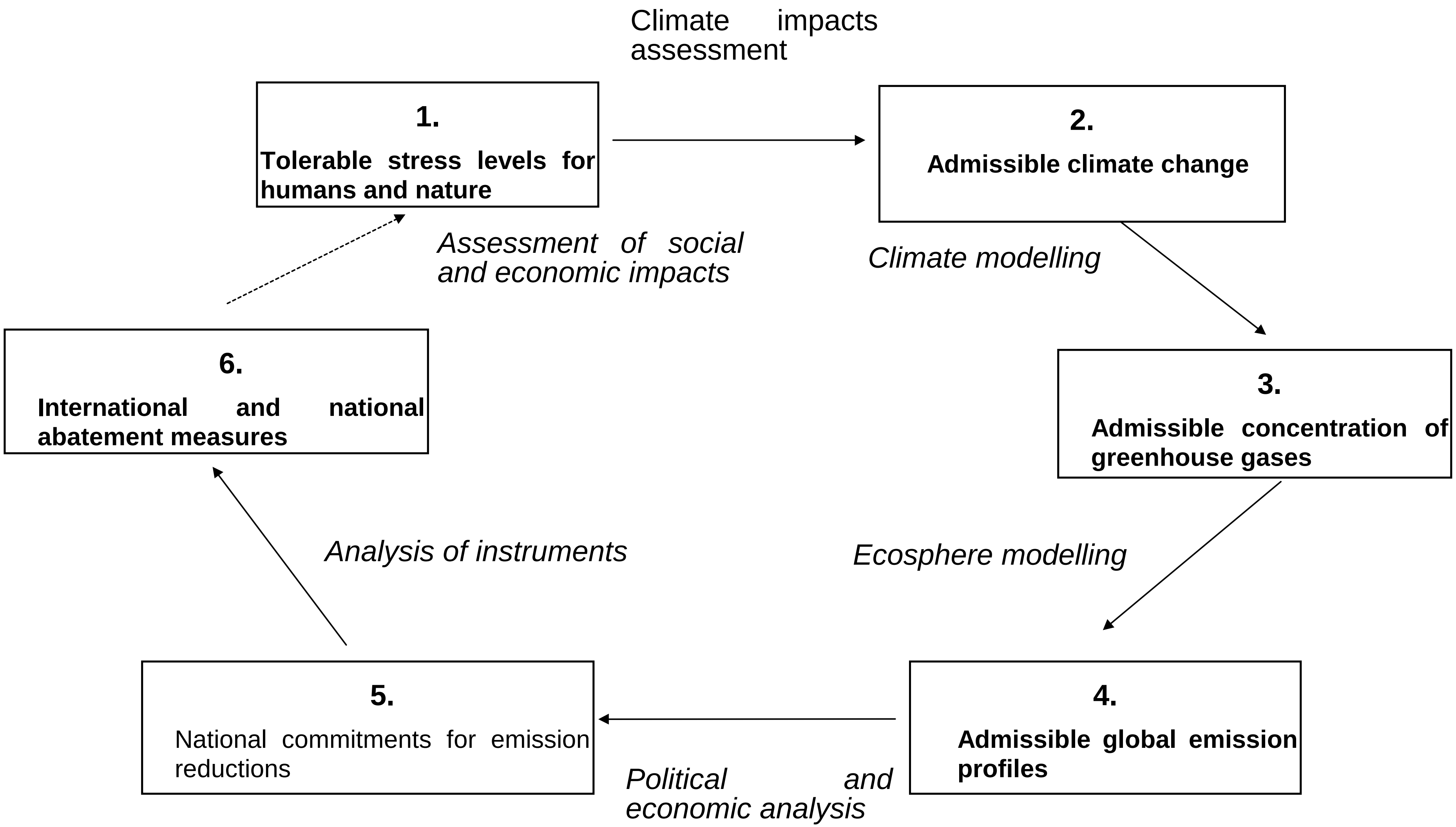
The new „scenario for the derivation of global CO_2-reduction targets and implementation strategies“ was published on the occasion of the Climate Conference in Berlin (WBGU, 1995a, pp. 111-128). The scenario specifies firstly tolerable stresses for humans and nature, „and then, by proceeding backwards, the long-term global reduction target is derived which would ensure that these maximum stress levels are complied with“ (WBGU, 1995b, pp. 3 - 4). Thus, the „backwards mode“ of the scenario follows a strong sustainability approach being based on acceptable impacts or minimum standards of climate stability. Standard scenarios are carried out in a „forwards mode“ estimating future, possibly non-sustainable emission and damage paths.[12]

The „backwards scenario“ or „inverse scenario“ contains six steps (see figure 1):

[12] For example, the impact pathway methodolody of the ExternE-project belongs obviously to these „forwards mode“ scenarios (EC 1995, pp. 7 - 30).

1. In step one, a range of tolerable stresses caused by climate change is defined. Identifying tolerable impacts and damages, the „inverse scenario" starts explicitly with a *normative judgement*.
2. In step two, temperature changes are derived which assure that the tolerable stresses are not exceeded.
3. In step three and four, admissible concentrations and
4. emissions of greenhouse gases (here: only CO_2) are quantified by using models of climate dynamics and the carbon cycle.
5. In step five, the total emission reduction has to be broken down to indiviual states or groups of countries.
6. In a final step, a mix of efficient instruments for mitigating climate change has to be derived.

The Council's „inverse scenario"



The basic normative principles of the council are the preservation of Creation and the prevention of excessive costs. The principle of preservation of Creation is formalised in the form of a tolerable „temperature window“ (WBGU 1995b, p. 7) being derived from the natural temperature fluctuation during the geological period having shaped our present environment (late Quarternary period). The minimum and maximum values of this temperature window are the last ice age (10.4 °C) and the last interglacial period (16.01 °C). With an extension of this temperature range by 0.5 °C at either end, the window extends from 9.9 °C to 16.6 °C. Using these thresholds, the acceptable absolute positive deviation from the present mean temerature on earth (15.3 °C) is only 1.3 °C.

The principle of the prevention of excessive costs is defined very crudely in losses of GGP. On the assumption that a disruption of economic systems will take place if losses of GGP exceed 5 percent, this value is taken as a threshold for economic impacts. The possible unequal spatial distribution of damages across nations (e.g. for island states) and non-monetary burdens are not yet considered in this minimum-standard. Most monetary estimates of doubling CO_2-concentrations until 2100 (mean temperature increase of roughly 0.2 °C per decade) have calculated GGP-losses of around 1-2 percent. Considering that these calculations did not include several damage categories (e.g. extreme events) and may have underestimated the total costs, the WBGU sees „good reason to assume that with a temperature change of 0.2 °C per decade the upper limit for adaptation costs of 5 percent of GGP would be reached“ (WBGU 1995b, p. 8).

The thresholds of the temperature window have been formulated as minimum standards for political reasons because the results should not be assessed too pessimistically. With the help of these operational criteria, a two-dimensional climate window is defined that should not be exceeded.

It is important to mention that the missing link of „backwards“ and „forwards“ scenarios is the assessment of social and economic impacts. This assessment is located here between step 6 and 1. Pursuing a closed circle of integrated assessment, an economic analysis of different abatement and adaptation strategies would be desirable, including a valuation of remaining damages with monetary or non-monetary values.

5 Discussion and Conclusions

It has been shown that the outcomes of studies estimating economic and social impacts in monetary units are very uncertain. However, as the alternative approaches of strong sustainability have illustrated, uncertainties do not disappear when norms are used instead. Schellnhuber (1995, p. 58), one of the developers of the „invers scenario“, states that norms can only induce maximums or minimums (e.g. a safe minimum standard) and not optimums. If the identification of optimal emission paths among minimum and maximum standards would be pursued, the strong sustainability approach should be supplemented by an economic impact assessment of damages, adaptation and abatement strategies. This would close the circle of integrated assessment of climate change.

Given perfect information about damage paths and present as well as future preferences, impact assessment would be able to replace the normative judgements in step 1 of the „inverse scenario“. However, in the light of the discussion about decision-making under uncertainty, it becomes clear that a complete substitution of normative judgement by cost-benefit-analysis or integrated assessment models will hardly be possible. Damage cost valuation techniques themselves contain central normative assumptions.

On the other hand, even normative target approaches often depend on monetary values for defining tolerable stress levels. The „invers scenario“ documents this close link between acceptable emission paths and economic damages. Thus, it becomes evident that further information about the global distribution of costs and benefits of climate change is desirable for the political negotiation process. For example, what is to do when global average damages do not exceed 5 percent of GGP, but reach 100 percent of the national income for certain island states and coastal zones? And how to handle high disparities of damages between economic sectors, social groups or species? Which damages can be compensated, which can not?

Many of these questions can only be answered by following a broader approach of strong sustainability including damage figures as far as valid estimates are available. Within the negotiation process, tolerable stress levels depend on specific burdens and economic costs of world regions and losses of certain economic sectors or societal groups. Thus, the relevance of imperatives like preservation of creation and prevention of excessive costs for political negotiations can be improved by more disaggregated sectoral and regional information about climate change impacts.

So, it seems reasonable to improve economic impact assessment and to include it into integrated models for assessing climate change policy (WBGU1995b, p. 7). Weak and strong sustainability indicators can be used complementarily in the assessment of climate change. Both can be understood as parts of broader approaches of integrated assessment models.

The critical IPCC review of social cost studies seems to have influence on research and has enhanced methodological progress, especially the handling of intra- and intergenerational equity issues. Further progress may lead towards more dynamic models and a multidimensional valuation of impacts. It should be noted that damage cost valuation is only one aspect in a modern interpretation of cost benefit analysis as it has been described in the IPCC report (Munasinghe et al., 1996, p. 170). According to the IPCC report, cost benefit analysis encompasses a family of decision-analysis techniques like multicriteria analysis or decision analysis. Using such a broad interpretation, social and economic impacts do not necessarily have to be described in monetary units. A main disadvantage of cost benefit analysis is that in complex decision situations relevant multiple criteria (e.g. efficiency, equity, uniqueness of resources or health and safety) are mixed and reduced to one single criterion. Multicriteria analysis may be a better way to show trade offs between these different policy goals (Munasinghe et al., 1996, p. 168).

It can be summarized that monetary indicators within a weak sustainability approach dominate the economic literature because cost benefit analysis has commonly been interpreted in a narrow sense. Broadly speaking, the narrow approach can be charaterized by assuming perfect markets (e.g. rationality and flexibility) with the exception that the existence of external costs is admitted. Global environmental problems and especially global warming require a broader approach considering inter alia uncertainty, bounded rationality, equity and scale effects. Obvious deficits of economic approaches with regard to these issues have promoted the search of more adequate alternatives. Ecological economics, one of the relevant scientific streams for searching new ideas, is driven by the underlying paradigm of strong sustainability. It is concluded here that, even within a strong sustainability paradigm, estimates of costs and benefits of climate protection remain to be a valuable and important tool for decision making. The prerequesite for an appropriate use of cost benefit analysis is a move towards a more frequent use of multiple, monetary and non-monetary valuation schemes.

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