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ANALYSIS

Broad sustainability contra sustainability: the proper construction of sustainability indicators

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Abstract

Sustainability indicators covering economic, social and environmental aspects of human activities have emerged, including one by a state research institute advocating the construction of sustainability indicators on the basis of different world views. The proposed indicators have essentially an additive character, that is, the composing elements are added up, with or without weighing. Economic and social elements so far suggested for inclusion in such indicators have no demonstrated or plausible causal relation to sustainability defined as a production level that does not threaten the living conditions of future generations. Such a sustainable level is dependent on the lasting availability of the vital functions of our nonhuman-made physical surroundings (the environment) because loss of one or more vital functions leads to a collapse of production. Both the construction on the basis of different world views and the essentially additive character of indicators conceal conflicts and consequently difficult choices. Therefore, economic and social elements should be presented as separate indicators. Physical indicators for sustainability for renewable resources should focus on the processes that form part of life support systems. One attempt at sustainability indicators, the so-called 'genuine savings' (GS), is only a proper indicator of sustainability when a number of conditions are met; this is currently not yet the case.

Keywords: Sustainability; Sustainable national income; Environmental functions; Fishing

1. Introduction

"The World Conservation Strategy" of 1980 (IUCN et al., 1980), subtitled "Living Resource Conservation for Sustainable Development", introduced the concept of sustainability in the international discussion. This concept was used in a way that was in line with longstanding approaches to safeguard the long-term productivity of forestry and fisheries (Becker, 1997) and with a tradition of advocacy for a steady state economy (Daly, 1973), conceived as an equilibrium relation between human activities and the physical

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environment. This comes down to safeguarding the vital functions (possible uses) of the nonhuman-made biotic and abiotic physical surroundings that include humanity's life support systems,[1] of which ecosystems form part and on which humans are completely dependent (Hueting, 1969, 1974, 1992). Safeguarding these environmental functions yields a production level that can be sustained 'forever' without threatening the living conditions of future generations: the sustainable national income (SNI), an ex-post indicator just like the standard national income (NI; Hueting and de Boer, 2001; Verbruggen et al., 2001).

With the publication "Our Common Future" (World commission on environment and development, 1987), sustainability became the focus of a major worldwide discussion. Taking a cue from "Our Common Future", there has been the tendency to broaden the concept of sustainability. The 2001 Ministerial Declaration of the World Trade Organisation Meeting in Doha stated for instance its commitment to sustainable development, stressing that an open and nondiscriminatory multilateral trading system that contributes significantly to economic growth and the promotion of sustainable development can and must be mutually supportive. In the run up to the Johannesburg World Summit on sustainable development, the UN secretary general wrote: "Sustainable development rests on three pillars: economic growth, social progress and protection of the environment and natural resources" (Annan, 2002).

A similar broadening may be noted at a country level. In the German context, the 'three-pillar' approach to sustainability has been advocated, focusing equally on the environmental, social and economic dimensions (Jänicke et al., 2001). In the United Kingdom, the government has defined sustainable development by including the themes: social progress which recognises the needs of everyone, effective protection of the environment, prudent use of resources and maintenance of high and stable levels of economic growth and employment (Turner and Fairbrass, 2001). In its national sustainability strategy, the Dutch government includes economic, sociocultural and ecological aspects (De Jongh, 2001).

A corresponding trend may be noted at the local level. The Charter of European Cities and Towns Toward Sustainability, a follow-up activity of the 1992 Rio de Janeiro's Earth Summit, states that sustainable development helps cities and towns to base living patterns on the carrying capacity of nature, while seeking to achieve social justice, sustainable economies and environmental sustainability (Capello and Nijkamp, 2002). In countries as wide apart as Australia and Germany, local communities are defining sustainability in a 'triple bottom line' manner, that is, in environmental, social and economic terms (Valentin and Spangenberg, 2000; Rogers and Ryan, 2001). Finally, also in the context of companies, one notices the increasing popularity of an approach that encompasses 'profit, people and planet' (Wheeler and Elkington, 2001).

Against the background of definitions of sustainability that cover economic, social and environmental aspects of human activities, Agenda 21, a document agreed upon at the 1992 Earth Summit, stated: "Indicators of sustainable development need to be developed to provide solid basis for decision making at all levels" (Capello and Nijkamp, 2002). Since 1992, many proposals as to the construction of indicators covering environmental, social and economic aspects of human activities have emerged. In this paper, we will restrict ourselves to indicators regarding countries.

Some of such indicators have already been ruled out in a convincing way. Becker (1997) did show that economic trend assessment regarding Total Factor Productivity and Total Social Factor Productivity run into the objection that no system with finite material resources can grow limitlessly without eventually collapsing.

O'Connor (1995) has suggested to use indicators based on elements, such as stocks of ecological

[1] Life support systems are understood to mean the processes that maintain the conditions necessary for life on earth. This comes down to maintaining equilibria within narrow margins. The processes may be of a biological or physicochemical nature (or a combination thereof). Examples of biological processes include parts the carbon and nutrient cycles, involving the extraction of substances as carbon dioxide, water and minerals from the abiotic environment during creation of biomass and the return of these substances to the abiotic environment during decomposition of the biomass. Examples of physicochemical processes include the hydrological cycle and regulation of the (thickness of the stratospheric) ozone layer. Examples show that there is an interaction between the processes, whereby equilibrium may be disturbed. The water cycle, for example, may be disturbed by large-scale deforestation.

capital, human-made economic capital and human and social capital, as indicators for sustainability. Since then, further indicators for sustainability including both natural and social capital have been developed at the World Bank (Becker, 1997; Spangenberg and Bonniot, 1998). De Kruijf and Van Vuuren (1998) have elaborated a sustainability indicator on the basis of the capital stocks proposed by O'Connor (1995). In doing so, Kruijf and Van Vuuren defined natural capital in terms of ecosystem health, while economic capital was specified in terms of industrial capital, household capital, service capital, consumer goods and public infrastructure. Zoeteman (2004) has suggested a sustainability indicator covering aspects of environmental resources, pollution, social security and economic activity (Table 1). Regarding each element mentioned in this table, a score can be attained ranging from 1 to 5. Zoeteman (2004) and O'Connor (1995) propose sustainability indicators that are to be calculated in an additive way, that is, composing elements are added up. De Kruijf and Van Vuuren favour calculation in a way 'that balances and integrates'. We interpret this as being also essentially additive, while including the attribution of relative weights.

Also, several authors have expressed the need to construct community sustainability indicators in a way involving public and/or societal actors, thus reflecting societal views (Bouni, 1998; Valentin and Spangenberg, 2000; Morse et al., 2001).

Recently, the first proposal by a state research institute, the Dutch National Institute for Public Health and Environment (RIVM), for constructing a sustainability indicator covering environmental, social and economic aspects on a country basis has emerged (RIVM, 2002). RIVM's proposal considers these aspects to be interdependent. Sustainability in terms of a sustainable production level as estimated in the SNI is called 'narrow sustainability', whereas the 'three-pillar approach' is described as 'broad sustainability'. It is stressed by RIVM that different indicators will be constructed in line with different world views. Within the framework of specific world views, computing the indicator will apparently be a matter of adding up composing elements. In the context of the social and economic aspects of human activity, the Human Development Index, the Human Poverty Index, weighted growth of Gross National Product and the worldwide distribution of income are suggested by RIVM as components of the sustainability index. Substance flows are to be included for the environmental aspects. Carrying capacity and stocks are mentioned by RIVM as potential contributors to the sustainability index.

2. Discussion of sustainability indicators

We agree that social progress, production and consumption are important for human well-being. It has been pointed out by Becker (1997) however that scoring systems including social, economic and environmental components have the problem that the choice of components and the assignment of weight are subjective and that the aggregation of different dimensions is often not meaningful. We agree with this observation. We also think that more criticism may be levelled against the construction of sustainability indicators for countries that cover both environmental, social and economic aspects of human

Table 1
Environmental, social and economic elements to be included in a sustainability index according to Zoeteman (2004)

Environmental elements	Social elements	Economic elements
Natural capital	Life expectancy at birth	% Labour force in services
Annual withdrawal of water resources	Urban population connected to sewer	Number of cars per 1000 population
Forest in % of original forest	Murders in urban environment per 10,000 population	Number of telephone lines per 100 population
CO_2 emissions/capita	Social security benefits expenditure in % GDP	Produced assets in US dollars
CO_2 emissions/dollar of GDP	Combined first, second and third education level enrolment ratio	
Maximum concentration of lead in gasoline		

activities, as proposed by O'Connor (1995), De Kruijf and Van Vuuren (1998), RIVM (2002) and Zoeteman (2004). Our criticism concerns three problematic aspects of these indicators.

2.1. Relation production and environmental sustainability

The first problem of the indicators proposed above regards the requirement of a positive relation between proposed constitutive elements of the indicator and environmental sustainability, understood as a sustainable production level. We restrict ourselves in this subsection to the assumed positive relationship between environmental sustainability (a sustainable production level) and the actual production level, as measured in standard national income (NI). That is, environmental sustainability would come closer when the actual production level increases and the other way around: the distance to environmental sustainability would become greater if the production decreases. Simultaneously, we consider the relationship between environmental sustainability and indicators closely related with the actual production level such as industrial capital, household capital, service capital, consumer goods and public infrastructure.

Looking at *historical* long-term causal relationships, relatively high production levels often have been unsustainable. Thus, the relatively rich farmers of the Fertile Crescent in western Asia replaced relatively poor hunter-gatherers, but their culture collapsed because of overexploitation of resources (salinization, soil erosion and deforestation; Diamond, 2002). Diamond (2002) also describes other cases of causal links between overexploitation and collapse of high cultures. Wolff (2000) established the causal link between habitat destruction, overexploitation and pollution by a relatively rich country (The Netherlands) and the *un*sustainability of fisheries. On the other hand, several hunter-gatherer cultures have been able to maintain an equilibrium relation with the physical environment over tens of thousands of years in spite of extremely low levels of man-made capital and a subsequent low production and consumption level.

If we look at the *present situation* and *the future*, the plausibility of whether the gap between (a) the actual production level as measured in standard NI (and closely related elements such as industrial capital and consumption) and (b) environmental sustainability (the safeguarding of vital environmental functions leading to a sustainable production level) becomes smaller when the actual production level increases can be examined. On the grounds of the following six reasons, a development that links increasing production with a closer approach to sustainability is unlikely.

(1) Theoretically, the possibility that growth of production and consumption can be combined with restoration and maintenance of environmental quality cannot be excluded. However, such combination is highly uncertain and scarcely plausible. It would require technologies that are
   (i) sufficiently clean,
   (ii) do not deplete renewable natural resources,
   (iii) find substitutes for nonrenewable resources,
   (iv) leave the soil intact,
   (v) leave sufficient space for the survival of plant and animal species and
   (vi) are cheaper in real terms than current available technologies, because if they are more expensive in real terms, growth will be checked.

   Meeting all these six conditions is scarcely conceivable for the whole spectrum of human activities. Especially, simultaneously realising both (i) through (v) and (vi), which is a prerequisite for combining production growth and conservation of the environment, is difficult. To give one example: as a rule, renewable energy is currently much more expensive than energy generated using fossil fuels. In the case of photovoltaic power, the ultimate price may even be far higher than for electricity from a current coal-fired plant (Johansson et al., 1993). The costs of implementing renewable energy throughout society are very high, and this checks production growth substantially. Anyhow, technologies necessary for the combination of production growth and full conservation of the functions of the environment are not yet available. Anticipating on their future availability is in conflict with the precautionary principle and consequently with sustainability. If the anticipated technological progress is not realised, future generations are confronted with the detrimental consequences. *Not* *anticipating is, of course, not the same as not assuming future technological progress*.

(2) An analysis of the basic source material of the Dutch national accounts shows that roughly one third of the activities (measured as labour volume) making up standard NI does not contribute to its growth. These activities include governing, the administration of justice and most cultural activities. One third contributes moderately to the growth of NI, while the remaining one third contributes by far the largest part to the growth of production. Unfortunately, this latter part consists of activities that cause the greatest damage to the environment in terms of loss of nature (by use of space), pollution and depletion of resources, associated with production and consumption. These activities include the oil and petrochemical industries, agriculture, public utilities, road construction and mining. These results are almost certainly valid for other industrialised countries and probably for developing countries (Hueting, 1981; Hueting et al., 1992).

(3) The burden on the environment as represented in standard NI equals the product of the number of people and the volume of the activities per person. From this and from point 2 above, it follows that environmentally beneficial measures such as decrease in population by family planning and shifts in production and consumption patterns into environmentally benign directions check growth or lead to a lower production level.

(4) According to the rules of the System of National Accounts, a price rise resulting from internalising the costs of the measures which restore the environment means, like any price rise in real terms, a check on production growth. Depending on the situation, this decreases the production level. For a given technology, product costs will rise progressively as the yield (or effect) of environmental measures is increased. Of course, technological progress leads to higher yields. As production increases further, however, so must the yield of the measures in order to maintain the same state of the environment, while the fact of progressively rising costs with rising yields remains unaltered.

(5) An unknown part of the costs of restoration of physical environmental damage caused by production and consumption is entered in standard NI as value added, so as a contribution to its volume (Hueting, 1974).

(6) A sustainable production level with available technology is about 50% lower than the current level, both for the world (Tinbergen and Hueting, 1991) and for The Netherlands (Verbruggen et al., 2001).

In view of the facts presented above, a negative relation between production and environmental sustainability seems more likely. A positive link between elements to be included in sustainability indicators and a sustainable production level should either be demonstrated or at least be plausible. So far, this requirement has not been met for the NI nor for economic elements proposed for inclusion in sustainability indicators by O'Connor (1995), De Kruijf and Van Vuuren (1998), RIVM (2002) and Zoeteman (2004).

2.2. World view

A second problematic aspect specifically concerns the proposal of RIVM and its construction of sustainability indicators on the basis of world views. This is a way of involving social actors in the construction of what sustainability is (cf. Bouni, 1998; Drummond and Marsden, 1999; Valentin and Spangenberg, 2000). We think that such a way of constructing indicators is incorrect. We take fisheries as an example, because arguments about sustainability have a longstanding importance in shaping fishery policies (Hoffmann, 1996; Becker, 1997). It is well known that the fishery business has another world view than do population biologists studying the fate of fish stocks, if only as to their time horizons. Also, small and large entrepreneurs in the fishing industry may have different perceptions of their natural resource (Drummond and Marsden, 1999). Drummond and Marsden (1999) have argued, in discussing the European Union Common Fisheries Policy, that the determination of physical limits is not very meaningful outside the context of such different perceptions of fish stocks. However, the long-term survival of fish stocks is not a matter of world views but of its actual fate. In Section 3, we will show that compromises between different social perceptions have led to strongly reduced and extinct fish stocks by their actual neglect of physical limits.

2.3. Conflicting goals

The RIVM (2002) proposal suggests that within the framework of a specific world view, elements to be included in sustainability indicators will be subject to addition. An additive character is also present in the proposals of O'Connor (1995) and Zoeteman (2004) and is implied in the proposal of De Kruijf and Van Vuuren (1998). An additive character is furthermore present in the use of social, environmental and economic sustainability indicators for assessments at a regional level (Nijkamp and Vreeker, 2000; Morse et al., 2001). Such a character is problematic because there may be tensions between different human goals.

A case in point is the tension between the wishes regarding production (as measured in standard NI) in the short run and the wishes for safeguarding vital environmental functions in the long run in order to attain a sustainable production level that does not jeopardise the living conditions of future generations. Discussions about production levels are concerned with its changes from year to year. Increase of the level is the aim. Maintaining the level is labelled as highly undesirable stagnation of progress. Decrease is labelled as disastrous.

The basis of our existence, our physical environment, has been formed over a period of hundreds of millions of years. Sustainability, defined as passing vital environmental functions undamaged from generation to generation, is also a long-term matter. There is undeniably a serious conflict between the wishes regarding production in the short term and the wishes not to jeopardise the living conditions of future generations. By adding elements reflecting these conflicting goals together in a sustainability indicator, the danger arises that inevitable choices are concealed. This hampers an open decision-making process in the course of which the inevitable sacrifice of either less sustainability or—more likely—less production in the short run is not hidden.

3. Consequences of environmentally unsustainable development

There are several regions in developing countries today where wishes for production in the short term over production that can be sustained in the long term have already led to production levels that are most probably much lower than sustainable levels. Thus, deforestation has contributed to flooding, causing loss of harvests, houses and infrastructure and to erosion leading to loss of soil (UNEP, 2002). Restoration of the damage constitutes costs and consequently a decrease in production. Deforestation has also caused reductions in local rainfall, thus contributing to drought (Silveira and Sternberg, 2001). Overgrazing and salination have led to decreases in the yield of agriculture (UNEP, 2002). Excessive fishing and destruction of the coral reefs by using dynamite have led to lower catches (UNEP, 2002). These developments have partly been caused by companies from rich countries.

However, the consequences of evading difficult choices are also exemplified by fishery policies in Western Europe aimed at conserving fish stocks that in fact go back to the thirteenth century for national waters (Hoffmann, 1996) and to the nineteenth century for international waters (Symes, 1997). Fisheries have been important in creating man-made capital. Some of the important cities in the area such as Amsterdam have even been said 'to be built on fish'. Fishery policies have, however, always been uneasy compromises between what is profitable and socially attractive in the short term and what is preferable on ecological grounds in the long term (Hoffmann, 1996; Symes, 1997). The effects of such compromises, which essentially neglect physical limits, on fish stocks have been dramatic. For instance, in Dutch coastal and inland waters during the last 2000 years, the following fish species have become extinct: dogfish, smooth hound, common skate, thorn back ray, sting ray, sturgeon, allis shad, houting, salmon, 15-spined stickleback and deep-mouthed pipefish (Wolff, 2000). Consequently, their price is far above the price that would have resulted from timely transition to sustainable catches.

To the extent that members of fish species are still present, catches are often well below the levels that would have been realised had fishing activities remained on a sustainable footing. The North Sea cod fishery is currently on the brink of collapse, and the current catch of cod is less than 20% of what would have been possible had fishing remained sustainable (Nakken et al., 1996; Parsons and Lear, 2001). This exemplifies a more general problem.

There is now convincing evidence that the current stock in the seas of large predatory fishes is about 10% of the preindustrial level (Myers and Worm, 2003), a phenomenon that has a strong upward effect on prices.

Thus, considerations aimed at the short-term improvement of living conditions and income in fishing communities, which would have contributed positively to sustainability according to the indicators criticised above, have led in the long term to a collapse of most of the Dutch fishing industry. Similar results may be noted elsewhere. The 40,000 people who lost their jobs in the early 1990s due to the collapse of the once great Newfoundland and Labrador cod fisheries are a case in point (Longhurst, 1998). Consumer prices for quite a few fish species are today well above a level linked to sustainable fishing.

4. A proper way to construct sustainability indicators; comparison with SEEA indicators

This paper is arguing in favour of using as an environmental sustainability indicator a production level that does not threaten the living conditions of future generations. Such a sustainable level is dependent on the lasting availability of the vital functions of our physical surroundings (the environment) because loss of one or more vital functions leads to a collapse of production as can be observed in some regions of developing countries and at the course of events in the fishing industries (Wolff, 2000; Myers and Worm, 2003). So, to be perfectly clear, production is not considered irrelevant for sustainability. On the contrary, safeguarding the maximum attainable production level without putting at risk future production possibilities is precisely the definition of environmental sustainability and the SNI. *Mutatis mutandis*, the same holds for social problems. Alongside an environmental sustainability indicator, separate economic and social indicators should be presented. Combining these items in one indicator is undesirable because they often are in conflict with one another.

Economic theory provides us with a more orderly way for dealing with sustainability than lumping together elements of a country's performance in the economic, social and environmental fields in a sustainability indicator (see Hennipman, 1943).

According to this theory, sustainability would boil down to sustaining levels of supply of all scarce goods in the long run that are in line with existing preferences. These goods include essential aspects of the (interdependent) societal, environmental and production systems that are in competition with one another. If it would be possible to measure and compare everyone's preferences concerning the supplies of all (categories of) scarce goods, an overall welfare function expressing these preferences could be constructed. As this is clearly impossible, one might think of an approximate welfare function, being part of a comprehensive (model) theory of society, describing the supply mechanisms as well. Preferences for sustaining the supplies of scarce goods in the long run should be imbedded in the welfare function. If these preferences are strong, the theory should show a development towards a sustainable development path, this path being characterised by a non-declining welfare level. The comparison of the welfare levels on the actual path and the sustainable path would then provide an economically sound overall indication for all aspects of sustainability. As already indicated, important parts of this procedure are infeasible, the most important being the assessment of the intensity of the weights of the preferences in cases of conflicting goals, and the second important one being the variation of these weights with the demand (or supply) levels. It is possible, however, to follow a less ambitious and still economically sound approach for the construction of separate sustainability indicators (De Boer and Hueting, 2004).

In part, this procedure is a matter of a proper division of labour between the sciences. Determining what is necessary for safeguarding environmental functions for future generations is a matter for the natural sciences. Economic theory that occupies itself with phenomena such as subjective preferences and opportunity costs, with analysis of the economic reality and modelling of alternatives, can contribute nothing worthwhile to determine the physical requirements for restoring and maintaining the environmental functions on which the living conditions of the current and future generations depend. *Long-term sustainability of society can, as far as the physical environment is concerned, only be based on physical standards* (*Hueting and Reijnders, 1998*). These sustainability standards should indicate first which level of the burden inherent in our activities can be maintained without disturbing life support systems and exceeding the carrying capacity of renewable resources, and second at which pace, nonrenewable resources have to be replaced by substitutes. For global burdens, the standards for a country are derived from global sustainability standards in the way described by Hueting et al. (1992) and Hueting and de Boer (2001): the costs of eliminating the burden are attributed to a country in proportion to the contribution of this country to the burden. Respecting these standards guarantees the availability of vital functions of our physical surroundings as defined in Section 1 (first paragraph) for future generations (Hueting and Reijnders, 1998; Hueting and de Boer, 2001).

For constructing an economic sustainability indicator, the measures to attain these standards must be formulated and their opportunity costs must be estimated. These costs can always be calculated, except in cases of irreparable losses. The costs are inputs in a general equilibrium model with the aid of which the distance between the current and a sustainable situation is to be estimated. Because, in contrast to the opportunity costs, preferences for environmental functions can be measured only very partially, making an assumption about preferences is inevitable; *revealed and assumed preferences for the functions of our physical surroundings take the form of physical standards*. Based on the costs to attain these standards, the model generates the shadow prices of environmental functions and produced goods and the resulting reallocation in the environmentally more benign situation. The methodology of the SNI is based on this procedure (Hueting and de Boer, 2001; Verbruggen et al., 2001). Of course, other preferences than sustainability preferences can be assumed, leading to other green national incomes than the SNI. Doing so provides policymakers an instrument for weighing which way to go and at what pace. We are concerned here with a comparative, static approach in which the—probably long—period of time necessary for the (dynamic) development towards the sustainable situation is neglected (see Hueting and de Boer, 2001).

The Integrated Environmental and Economic Accounting (SEEA) (United Nations et al., 2003) deals with a number of methods to adapt standard national income (NI) to environmental losses. Paragraph 199 of Section 10 reads: "Much of the initiative to look for an alternative path for the economy rather than a different measure of the existing economy came from the work of Hueting in the late 1960's and early 1970's. He introduced the concept of environmental function referred to throughout this manual, explaining how pressure on functions leads to scarcity or competition for these functions. As with any economic good or service, this scarcity gives rise to an economic value due to the opportunity costs involved in their use or appropriation. The concern is then to define aggregate indicators to characterise a sustainable economy which ensures the maintenance of key environmental functions in perpetuity. Such an economy may be described as a 'greened' version of the existing economy where typically an increase in national income is secured at the expense of worsening environmental degradation. Interest then focuses not on the new aggregates themselves but in the gap between the existing economy and the greened version."

The SEEA describes quite a few ways to adapt NI for environmental losses. These welfare indicators have the same theoretical foundation and the same structure. They can be distinguished as combinations of the following categories.

- 'Damage-adjusted', 'depletion-adjusted' and 'environmentally adjusted' national incomes on the one hand versus 'greened economy' national incomes on the other indicate welfare in the actual and environmentally more benign development, respectively.
- Ex-post and ex-ante indicators focus on years in the past and the future, respectively.

SNIs are ex-post 'greened economy' estimates that show, in combination with NIs, whether or not the gap with environmental sustainability becomes smaller. Ex-ante 'greened economy' estimates focus on prognoses for the transition path to environmental sustainability (see Fig. 10.2 of the report). Both types of 'greened economy' national incomes are promoted by the GREENSTAMP project (Brouwer and O'Connor, 1997). Maintenance costing and net pricing yield ex-post environmentally adjusted national income estimates.

Despite their common base, most indicators have little similarity with SNI. For instance, a damage adjusted NDP cannot be compared with SNI because attaining environmental sustainability eventually yields negligible damage costs but requires all kinds of elimination measures. Calculating SNI involves the calculation of the costs of these measures. Damage costs are by no means the same as elimination costs as can easily be seen in Fig. 10.1 of the report, in which the benefits equal the avoided damage costs. More or less comparable with SNI are the depletion and the environmentally adjusted Net Domestic Product (dpNDP c.q. eaNDP).

DpNDP is not an environmental sustainability indicator for two reasons. First, it does not take environmental degradation into account. Second, it does not use physical sustainability standards, as it does not intend to describe national income at sustainable resource use. The latter is a prerequisite for determining environmental sustainability, as explained above.

EaNDP too does not use physical standards. As for environmental degradation, eaNDP uses maintenance or avoidance costs (M) for adaptation of NI, as far as these costs are not already accounted for in the NI. There are two versions for M. (a) M consists of the costs necessary to bring about the situation in the beginning of the accounting period. If at this date the situation is not sustainable (which is very likely), eaNDP is also for this reason not an environmental sustainability indicator. (b) M consists of the costs to attain some desired situation, e.g., sustainability. In that case, M "suffers a major conceptual weakness in that it assumes that a new set of prices or production changes can be introduced without consequences for the rest of the economy", as the SEEA report rightly states in paragraph 239 of Section 10.

Popp et al. (2001) have raised the question—what should be sustained in order to arrive at sustainability? O'Connor (1995) and De Kruijf and Van Vuuren (1998) concentrate on stocks. Zoeteman (2004) includes both stock-type and flow-type elements in his indicator (see Table 1). Flows, stocks and carrying capacity have been mentioned by RIVM. All national incomes adjusted for environmental losses basically contain flow-type elements, among which the rates of change of relevant stocks, such as carrying capacities. What is a proper choice? We think that an answer to this question may come from considering more closely an experience from the fishery industry.

The cod fishery off Newfoundland and Labrador generated 1.4 million tons of cod in 1973. Today, the production is practically nil. North Atlantic cod fisheries were based on the assumption that about 20% of the cod population could be caught yearly. Both catches and stock were well monitored. Unfortunately, it remained unnoticed that in the 20% catch, large fertile adults (over 10 years old) were over-represented. Thus, in the 1980s, nearly all fertile cod had been caught and reproduction was reduced dramatically (Longhurst, 1998). Moreover, individual fish mortality tends to decrease with size. And as cod is a predator, an additional complication emerged: small cod do not catch the customary prey, large capelins (De Roos and Persson, 2002). A changing local climate also damaged the stock of cod (Parsons and Lear, 2001). The result was that the once great Newfoundland and Labrador fisheries collapsed in the early 1990s, with as yet no sign of recovery (Longhurst, 1998; Parsons and Lear, 2001; De Roos and Persson, 2002).

This example suggests that in maintaining the functions of a renewable resource such as fish, the focus should be on the processes that underlie the persistence of life support systems. We think that this can be generalized; what sustainability is should be defined in physical terms (as argued by Hueting and Reijnders, 1998) and physical indicators of sustainability should focus on the underlying processes. In the case of fish, not only sizes of stocks and flows (catches) but also age and size structures, the relation to prey (and predators) and climate should be considered important elements determining future availability. This focus on processes is not common in physical indicators that have been proposed to measure sustainability. As pointed out by Becker (1997), indicators based on a multicriteria model do not properly consider the interaction between different system components. The ecological footprint proposed by Wackernagel and Rees (1997) does not focus on processes but rather converts a variety of processes reflected in a variety of impacts into spatial requirements. Indicators reflecting materials and energy flows consider flows in terms of kilograms and joules but are not linked to specific resources and sinks. The absence of a focus on processes suggests that such indicators for measuring sustainability are not appropriate.

5. Genuine savings as an economic indicator for sustainability

Another proposed economic indicator for sustainability is genuine savings (GS), which we discuss below. The GS approach is actively promoted by officials of the World Bank.

Pearce et al. (2001) have defined genuine savings S_g as the savings term of a version of environmentally adjusted net national income as described in Section 4 (eaNNP) which includes adjustments for damages, compensation and depletion. eaNNP=$C+S_g$, analogous to gross savings S in the definition equation of gross national product (GNP=$C+S$) and analogous to net savings S_n (=$S-dK$) in net national product (NNP=$C+S_n$). In these expressions, C=consumption, S=gross saving and dK=depreciation of produced assets. Consequently, $S_g=S-dK-r(R-G)-p(E-A)$, where r=unit resource rent (defined as the difference between the price obtained for a unit of extracted or harvested resource and its marginal costs of extraction or harvesting); R=resource extraction or harvest; G=natural growth rate of the resource (zero for nonrenewables); p=marginal social damages from pollution; E=emissions; A=natural assimilation (i.e., dissipation) of pollutants; $r(R-G)$ and $p(E-A)$ are the value of depreciation on natural resources and the value of net pollution damage, respectively.

We agree with Pearce et al. that the genuine savings approach can provide some kind of (weak) signal vis-à-vis sustainability. The SNI and the GS approach can supplement one another, but only under additional conditions.

As Pearce et al. rightly assert, welfare depends on total stocks of produced, natural and human assets. Produced capital, however, is a combination of labour (technology) and elements from our physical surroundings (the environment). In the final count, we are dependent on only two factors: human and environmental assets (Hueting and de Boer, 2001). The sine qua non of *environmentally* sustainable development is a production level that guarantees preservation of vital environmental functions with available technology (Hueting and de Boer, 2001). From this, there follow already three conditions for the calculation of the 'genuine savings' indicator and for versions of the related eaNNP for that matter.

(1) Any increase in human assets must be used exclusively for environmental protection and/or for growth of production that does not (further) damage the environment. This condition is hard to satisfy because
  (a) expenditures on environmental protection check production growth (Hueting, 1974; Hueting and de Boer, 2001) and
  (b) it is precisely the most environmentally damaging sectors of the economy that account for the bulk of production growth.

  See for the latter point Hueting (1981) and Hueting et al. (1992) and do pay, in implementing condition (1), due heed to the essential difference explained there between (i) an increase in the size of a sector (expansion) in terms of deflated value added and (ii) that sector's contribution to an increase in production volume resulting from increase in labour productivity, as measured in standard NI (more explanation in: Hueting, 1974, p. 170, footnote 2, English edition; Hueting et al., 1992, Appendix 3).

(2) Likewise, increases in stocks of produced assets must be exclusively for the purpose of environmental protection or 'clean' growth. Again, it is a condition that is not easy to satisfy, for the reasons just given under 1(a) and 1(b).

  According to Pearce et al. (2001), investments in infrastructure contribute positively to genuine savings. From the perspective of environmental sustainability, however, their contribution is negative. The fragmentation of the landscape caused by roads and other infrastructure and the consequent loss of habitat and isolation of gene pools are substantially accelerating the rate at which plant and animal species are becoming extinct, which in turn negatively affects life support systems (Hueting and de Boer, 2001). Certainly in the industrialised countries and in tropical rainforests, infrastructure should be demolished rather than constructed if the goal of environmental sustainability is to be realised.

(3) Resource revenues must be invested in environmental protection or 'clean' growth; see (1) and (2). Furthermore,

(4) Consumption C in the genuine savings formula is taken from standard NI statistics. So, C contains expenditures on elimination of and

compensation for loss of environmental functions, financed by government and private households (Hueting, 1974; Hueting and de Boer, 2001). These so-called asymmetric entries must be deducted from *C* in conformity with the welfare theory underlying the national income indicators adjusted for environmental losses, presented by the authors and many others.

(5) The condition $S_g \geq 0$ must hold for all t to warrant (weak) sustainability, that is, for a long time series, not just for a single year or single accounting period, as in the formula presented by Pearce et al.

(6) Only in the case of nonrenewable resources may technology be substituted for nature, as argued in Hueting and Reijnders (1998) and Hueting and de Boer (2001).

As long as these six conditions remain unsatisfied, the genuine savings method certainly cannot serve as an indicator for environmentally sustainable development.

6. Conclusion

In view of the arguments mentioned in the previous sections, the designation ‘narrow’ should be dropped when sustainability refers to an equilibrium relation between human activities and the environment. The indicators for sustainability which also include economic and social elements proposed so far by O’Connor (1995), De Kruijf and Van Vuuren (1998), RIVM (2002) and Zoeteman (2004) are flawed because they rather generate fog than shed light on the road to a sustainable production level. Physical sustainability indicators for renewable resources should focus on the processes that underlie the persistence of life support systems. Genuine savings may be a proper indicator of sustainability when a number of conditions are met, which is currently not yet the case.

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