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Towards a Working Framework for the Accounting of Environmental Degradation

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TOWARDS A WORKING FRAMEWORK FOR THE ACCOUNTING OF ENVIRONMENTAL DEGRADATION

BACKGROUND PAPER IN SUPPORT OF THE SEEA 2010 REFORM PROCESS

— ACCOUNTING OF ENVIRONMENTAL DEGRADATION —

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§1. Concepts of Sustainability and Consequences for Accounting

A resource or service is defined, in economics, to be scarce if its use implies a significant reduction in other opportunities (that is, an opportunity cost) for members of society, either elsewhere or in the future. When environmental services such as clean air and water were perceived as abundant, they could plausibly be treated as free goods. But increasingly, environmental assets are being perceived as neither non-scarce nor indestructible. Imprudent action by the society can worsen the severity of these resource constraints, so environmental information on exploitation opportunities and the trade-offs imposed by scarcity and renewal rates, becomes crucial for any vision of development.

A key challenge in moving towards a more sustainable future is adequately embedding sustainability principles into organisational decision-making at appropriate scales. And, for this reason, efforts are being made all around the world for the development of data sets and analytical tools to assist in decision-making to support sustainable development initiatives. Greening the national accounts is an important part of this sustainability drive. The diagnosis that (in the past) policies and decisions have failed to take proper account of the impact of human economic activity upon the natural environment. The remedy thus is taking the environment properly into account, and for this it is necessary — though not sufficient — to have good categories of information on the environmental impacts (the damages to be avoided, the benefits to be maintained or gained) and on the society's response options (policy alternatives and their social/economic costs).

Integration into policy of the dimension of ecological sustainability implies a shift in emphasis away from expansion of the vector of produced commodities alone (as measured in aggregate by GDP growth), towards a view of qualitative improvements in life conditions based on the reproduction and resiliency of our biosphere as a collective habitat and life support system. Policies must specifically address the trade-offs between present and future associated with, for example, depletion of minerals and fossil energy sources and of renewable resources such as forests and fisheries, with land degradation, and with the generation and disposal of wastes. The objective of sustainable development thus refers not just to sustaining produced wealth and income flows but also to the maintenance and renewal of human habitats — the living tissues of ecosystems interwoven with social and economic infrastructures. If we think of ecosystems as providing a variety of material flows, services and supports for economic activity, then ecological "goods and services" (natural resources, amenities, waste reception, environmental life support functions) are complementary to economic goods and services as the biophysical basis of human well-being.

This is the context of the current SEEA reform, in which extensions and modifications of the established SNA (systems of national accounts) are sought beyond the domains of economic assets and priced transactions of goods and services, to include environmental assets, environmental damages, and the flows across the economy-environment interface that are concomitant with economic activity but which may alter the quality and quantity of environmental assets and, hence, present and future levels of human well-being. The term ***greened national accounts*** refers thus, in a first definition, to national accounting systems extended to include information on the **state** of the environment and on interactions between economy and environment (e.g., the **environmental services** that assure livelihoods and bring benefits to human society, and the **pressures** on the environment that may modify the flows or potentialities of such services).

However, environmental systems are complex and observations of the state of the environment and of changes to environmental systems can, at best, be only partial. Consequences of current actions on future changes in environmental conditions can often be predicted only imprecisely, and sometimes hardly at all. Depending on the place and scale at which information is to be used, very different levels of aggregation may be pertinent. These features have important consequences for environmental accounting. It is crucial to define clearly the roles of different types of information, and the quality considerations associated with (monetary and non-monetary) information for the different components of the systems under observation, for the many different scales, societal contexts and purposes of observation, measurement and evaluation (see table on following page, with examples of questions and contexts of sustainability assessment requiring, among other things, environmental accounting information).

This paper therefore moves back and forth between two questions: (1) the question what is the "object" of our analysis, viz., what are we describing?, and (2) the question why are we developing this description, viz., the objective(s) of our work.

These two questions are the necessary background to the third, operational question of the SEEA 2010 reform, which is: How do we organise the elements of description, viz., the accounts.

From the standpoint of an accounts user, what matters most, of course, is the objective. But, the roles proposed for different classes of information and, more particularly, for different frameworks of representation and assessment in aiding judgments about 'progress towards sustainability', depend significantly on the way that 'sustainability' itself is characterized. This takes us straight back to the "what?" question.

It would be an interesting but quite complex exercise to review the spectrum of conceptions of economy, environment and sustainability across the published literature since the 1970s, and the precursors before that time. However, in a pragmatic way this review will limit itself to discussions concerning two prevailing 'paradigms' of sustainability. These are:

- Sustainability as non-diminishing aggregate consumption (or societal utility) underpinned by natural capital, as in the neoclassical economics modelling conventions, and
- Sustainability as a complex systems co-evolution engaging four major classes of organizational forms, the economic, biophysical, social and political spheres.

A short (and certainly incomplete) list of Questions on the Sustainability Assessment agend

THEME/ASPECT OF SUSTAINABILITY ASSESSMENT	REMARKS ON THE STATE OF THE ART
The question of the roles for valuation (monetary and otherwise) is inseparable from the concepts of sustainability that are adopted to inform the systems of accounts or the frameworks of sustainability assessment. This has important consequences for the development of norms for scientific and statistical quality assessment and for the types of multi-disciplinary partnerships needing to be built between statisticians, accountants, environmental engineers, systems scientists, economists, social policy experts and political theorists.	See for example Brouwer, Radermacher & O'Connor (1999); O'Connor (2001); O'Connor & Steurer (2006); Lawn (ed., 2006); this question has also been put on the agenda in the background papers framing the UNCEEA (2006) steering of the SEEA reform.
In the business world, corporate social responsibility (CSR) reporting and related activities of indicator development often address sustainability agendas through reference to a "triple bottom line" but, this link is often only implicit, sometimes is made in opportunistic ways and without clear reconciliation with wider societal frames of reference. This emerging profile of Corporate Social Responsibility (CSR) places distinct requirements on company management, notably the need to address a Triple Bottom Line of economic, social and environmental performance. There is also an emphasis on new forms of social dialogue as a contribution to company reporting, strategy definition and decision-making	The decade since the mid-1990s has been marked by a new societal demand for measuring the performance of the business sector relative to a spectrum of sustainable development goals (e.g., De Marchi (1997); GRI (2002); WBCSD (2000); (De Marchi et al. (2001); Faucheux & Nicolaï (2003); Le Dars (2004); Faucheux & Hue (2001); EEC & Fishburn Hedges (2003). Growing recognition of the complex socio-political context that surrounds sustainable development has led to calls for participative and pluralistic approaches to sustainability assessment (e.g. O'Connor 2000; 2002a; Bebbington et al. 2006). Experiments are being made with procedures for developing CSR indicator systems with attention to having methodological robustness, accessibility and legitimacy in the face of diverse stakeholder constituencies (e.g., Faucheux & Nicolai 2004a,b Spangenberg 2006; O'Connor & Spangenberg 2006 in press; Chamaret et al., 2007).
In regional develop and territorial planning, there is increasing emphasis on "integrated" assessment approaches and (inter alia) on the use of batteries of indicators to evaluate policy options and to highlight progress (or lack of it) relative to multiple objectives. This integrative perspective highlights the interfacing of business (and consumer), public administration, civil society and research perspectives on performance and information, and raises the challenge of finding, and using, effective methods for this interfacing.	These questions were at the heart of the *SRDTOOLS* Project and were highlighted in the preceding study DG REGIO (2003), Evaluating the Contribution of the EU Structural Funds to Sustainable Development (Report to DG REGIO). Work in territorial resource management contexts has often been underpinned by complex map preparation and system modelling analyses, without yet there being clear "best practice" for the manner to bring the different aspects of system performance into an "integrated" assessment of cogency to public policymakers, territorial administration, business and civil society stakeholders.
Indicator development work and accounting is carried out at many different scales (e.g., company accounts, CSR reporting, regional planning, national accounts) and there is no ready-made bridge between the "micro" (household, firm) and "macro" levels of sustainability accounting.	This point has been highlighted in relation to economic costs, in the EC funded GREENSTAMP Project (see Brouwer & O'Connor 1997a,b; Brouwer, Radermacher & O'Connor (1999); Radermacher, Riege-Wcislo & Heinze (1999). Concerning environmental services and pressures, some features such as appreciation of landscapes or notions of ecosystem integrity are quite difficult to transpose across scales.
The importance of building stakeholder dialogues for robust evaluations and policy assessments is widely affirmed but, despite interesting experiments and 'case studies' for more than 20 years, there is not yet a set of clear signals on effective ways to integrate formal accounting, modelling, spatial analysis, and evaluation methods with social processes of deliberation.	There is a great deal of interesting literature, both 'grey' and published, emanating from the EC R&D programmes, including the EFIEA (European Forum for Integrated Environmental Assessment) since 1997. DG Research as a Concerted Action largely financed the first three-year period of EFIEA, in the period from early 1998 until early 2001. The second cycle, EFIEA-II was again a Concerted Action financed by DG Research for another three years period, from 2002 to 2005.
Despite more than 30 years of academic (aid wider societal) debates and notwithstanding the wide recognition of "limits to CBA", the question of the relative roles for money and non-money, quantitative and non-quantitative indicators an accounting still remains unresolved, (and, more curiously, there does not seem even to be much common agreement about the reasons for this question remaining unresolved!).	See M. O'Connor (2007), "Paradigms for Sustainability Assessment: Inventory of Costs and Benefits versus Representative Diversity of Indicators", background paper for the London Group meeting Johannesbourg, March 2007

§2. From "Natural Capital" to Models of Sustainability

Economic analysis since the 1970s has, responding first to compartmentalised poverty and environmental concerns and then to the wider agenda, proposed sustainability requirements in terms of the maintenance of multiple "capitals".

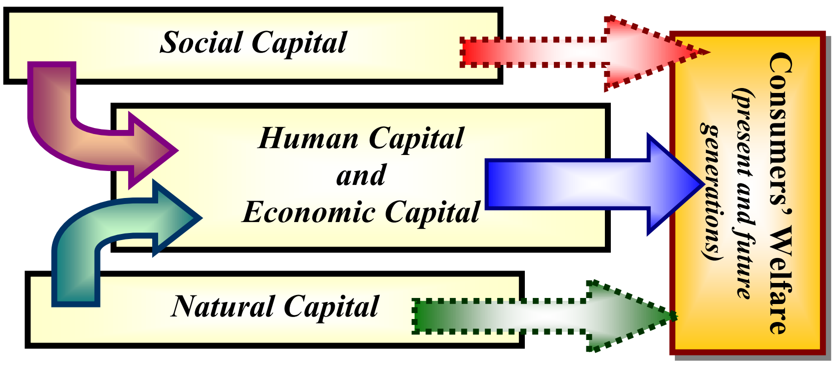
- Environmental assets and infrastructures are portrayed as a *"natural capital"* that is both limited and fragile, and this "natural capital" takes its place as one of the three traditionally identified factors of production (and, hence, sources of wealth and well-being) of classical political economy, viz., (1) land = natural capital, (2) labour = human capital, and (3) built capital.
- In parallel with natural capital has emerged a consideration of political institutions, cultural forms, symbolic bonds and community infrastructures as a *"social capital"* upon which economic performance depends.[1]
- The consideration of the "natural" and "social" pillars of sustainability together leads, thus, to a "four-capitals" model in which the category "social capital" is distinguished from the three factors of production (land, labour and built capital) of classical political economy.

Ekins (2006), reviewing the four capitals model for the *SRDTOOLS* project, highlights a set of attractive features for the four capitals model in SA applications.[2]

- It ensures that all three of the pillars of SD — economic, social and environmental — are explicitly included in the analysis.
- It ensures that the focus of the evaluation is not just on stocks of things, but also on the flows of benefits to which they were intended to give rise.
- It provides a better basis for engaging stakeholders with the concerns of SD than often evoked by the use of the term SD itself.
- It encourages stakeholders to think of environmental and social concerns in the same language as, and by implication on a par with, economic issues, instead of (as is often the case) as subsidiary to them.

In effect, Ekins argues that the four capitals model is a robust approach that permits analysts and decision-makers to arrive at qualitative judgements about whether, and to what extent, all three SD pillars had been taken into account in the programme and project formulation, design, implementation and monitoring; and, where trade-offs between the three pillars were evident, whether these were incurred through conscious choice and deliberation or through oversight or accident.

In a general sense, the evaluation of development policies or programmes is based on appraising changes to each of the four capitals and considering the compatibility (or incompatibility) of these changes with defined sustainability criteria.



However, there are a number of quite different conceptual frameworks for the specification of the sustainability criteria.

[1] Following the characterization given by Ekins (2006) for the *SRDTOOLS* project, "*in essence social capital derives from relationships*", suggesting that indicators of social capital for an SD assessment may usefully be grouped under the following headings: *(a) Values: trust; equity; (b) Social health: social integration and cohesion; social exclusion; (c) Social organisation: networks; horizontal associations; hierarchical associations; (d) Governance: political, legal and financial arrangements.*

[2] These points were also highlighted in the DG REGIO 2003 report preceding *SRDTOOLS*; see: *Evaluating the Contribution of the EU Structural Funds to Sustainable Development*'. The complete report to DG REGIO is available at http://europa.eu.int/comm/regional_policy/sources/docgener/evaluation/rado_en.htm

In the prevailing neoclassical perspective, typically described as utilitarian, the four capitals are presented as the 'means' (via primary and intermediate production) towards the 'end' of consumers' welfare (via 'final consumption' of goods and services). Admitting that both the environment (NATURAL capital) and general societal conditions (SOCIAL capital) can provide direct contributions to welfare as well as through the intermediary of {ECONOMIC plus HUMAN} capital, we have the utilitarian schema as above.

This asymmetric utilitarian schema is well known, and underpins many neoclassical approaches to modelling sustainable development in terms of non-declining time-paths of final consumption or consumers' utility and in the definition of 'genuine savings' and the so-called 'weak sustainability' indicator (see discussions below).

Yet, whatever the scale of analysis and whatever the precise roles or significance attributed to natural capital, some fundamental questions remain about the extent to which is possible to make meaningful measurements of natural capital and, hence, to quantify changes in 'natural capital' and to estimate opportunity costs of its use or degradation. Analysts insisting on the 'complexity' of natural (as well as social) systems tend to emphasise intrinsic limits to measurability and, correspondingly, set out to formulate sustainability in terms such as system viability without seeking to quantify natural (or social) capital stocks in any aggregate way.

There are, thus, quite a few variations of the "four capitals" model in the SA literature. In what follows, we will first of all provide a general overview of the natural capital concept and then, for illustrative purposes, will mention two applications that seem relatively topical, chosen to illustrate 'lower scale' and 'higher scale' accounting contexts. The first (in **Section §4**) is the approach proposed by Bebington and colleagues for site or company level sustainability accounting based on four categories of capital: economic, natural resources, environmental and social (cf., Bebbington, Brown & Frame, 2006). The second (in **Section §5**) is the estimation of natural capital depreciation in the context of "greened" national (or regional) accounting.[3] We will then come back to the underlying questions of measurability of natural capital and its changes (**Section §6**) and move from there to a consideration of the complex systems perspective and its consequences for accounting practices later on (see **Sections §7** and onwards).

§3. Environmental Services and the "Functions" of Natural Capital

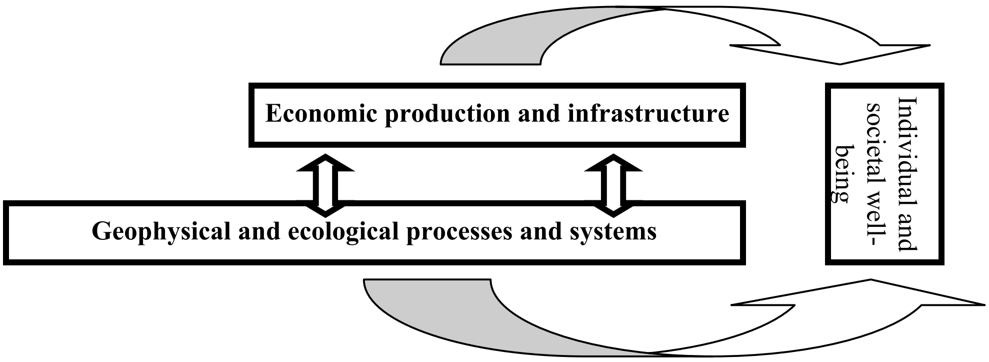
This section presents key concepts and some examples of environmental accounting challenges, organised around the notion of *natural capital*. First we must explain what the concept means. It involves the extension of the well-established economist and accountant's notions of a firm's assets as the stocks and equipment capable of delivering flows of money or physical services through time. As Herman Daly has put it:

> *Natural capital is the stock that yields the flow of natural resource; the population of fish in the ocean that regenerates the flow of caught fish that go to market, the standing forest that regenerates the flow of cut timber; the petroleum deposits in the ground whose liquidation yields the flow of pumped crude oil.*

Natural capital is thus a hybrid concept. On the one hand it is a notion taken from the economic domain; on the other hand it points to the importance of environmental quality, resilience and integrity

[3] There is not any fundamental conceptual inconsistency between these several "four capitals" models, but their emphases do differ significantly. Relative to the Ekins characterisation, the Bebington approach splits off Natural Resources from the rest of Environmental Capital and assimilates Human Capital within Economic and/or Social Capital. Work in green(ed) economy national accounting tends to separate out natural resources that are mobilised as process inputs from environmental functions that provide services *in situ*, but this is more a matter of sub-divisions within the general domain of "natural capital". Work on the "informal economy, employment and poverty since the 1970s, has highlighted the impossibility of separating "human capital" formation and maintenance from wider social networking, infrastructure and collective capacities now assimilated under the heading "social capital". Influential institutions such as the OECD and the World Bank have, since the 1980s, affirmed the importance of collective social capital. But, while certain themes are clear, the frontiers for policy or project appraisal purposes between human, social and economic capitals are not very clearly traced.

as pre-conditions for human well-being and long-term sustainable economic activity. We summarise this in the **Figure** below.



Natural systems and human well-being

Natural capital is represented by the lower box, the geophysical and ecological systems. These are the components of our physical and living world that underpin all economic activity and that provide, directly and indirectly, the environment that keeps us alive. We can straight away remark on some qualitative differences between natural capital and man-made (manufactured) capital.

- Natural capital is a vast category. It covers far more than specific minerals and fuel sources; it refers to the whole surface of the planet Earth as a dynamic life-support system.
- Natural capital is essentially an endowment of nature and not producible by human societies. The endowment can be somewhat modified, but, as in the examples of mineral deposits or genetic components, the "base" is given and is substantially irreplaceable.
- Environmental resources are not simple stocks; they are dynamic systems and infrastructures that have a multiplicity of functions including life-support for human as well as non-human communities.
- In general, it is not possible to substitute completely manufactured capital for natural capital as a basis for human welfare, except at high costs and for limited spheres. This is partly due to the life-support functions and partly due to the complex systemic properties of the relevant natural systems.
- Changes in the natural environment caused by human activities are often irreversible. The irreversibility of energy use has been emphasised, on thermodynamic grounds, by pioneering ecological economists such as Nicholas Georgescu-Roegen, René Passet, Kenneth Boulding, Herman Daly, Juan Martinez-Alier, Malte Faber and Dick Norgaard. Biologist Rachel Carson in her book *Silent Spring*, published in 1960, highlighted the irreversibility of imminent disappearance of bird, insect and other species due to indiscriminate pesticide use. Production of radioactive wastes in nuclear electricity plants is essentially irreversible, as are (to greater or lesser degrees) the wide variety of chemical toxic wastes dispersed in the environment.

In sum, our natural capital systems are complex, essential and fragile. They can be depleted or destroyed. Once degraded, they will not always re-grow — not in the forms that have supported human health and activity up until now, at any rate. A requirement for *sustainable development* is that this life-support base not be degraded beyond repair.

The questions to which we must formulate responses are: how best to conceptualise these environmental limits to and preconditions of societal well-being, and second, how most usefully to assess development prospects and constraints through accounting practices relating to environmental systems, economy-environment

Kinds of Environmental Damage

It is useful to distinguish three main dimensions to the concept of environmental damage:

* It can refer to adverse effects to the physical, chemical and biological systems which are required for the possibility of human life and economic activity being sustained over a long period of time.

* It can refer to the adverse effects of human activity upon the natural world — in the loss of biodiversity, the destruction of habitats and so on.

* It can refer to the detrimental impact of human activity upon aesthetically and culturally significant landscapes and places and the environment as a source of recreation.

The sources of environmental concern are complex, and so these broad categories overlap in various ways.

interactions and changes to these systems and interactions over time?

In effect, through introduction of the notion of natural capital into national accounting and policy, we place new emphasis on ecosystems (and the biosphere more generally) as dynamic processes upon which human economic activity and well-being depends. Information may be sought in utilitarian terms of the *functions provided for* economic activity and human well-being by the natural. But, if we have a concern for robust and reliable knowledge, this leads more or less directly on to a consideration the *functioning of* the environmental systems in themselves.

In the environmental and ecological economics literatures since the 1980s, sustainability requirements have typically been expressed in terms of three sorts of constraints to be imposed on economic growth paths so as to respect ecological limits.[4]

- that the utilisation of renewable resources should not exceed their rate of renewal;
- that waste emissions should be less than the assimilation capacity of the environment; and
- that exhaustible resources should be extracted at such a rate as permits their replacement by renewable sources.

A wide spectrum of hypotheses have been advanced concerning the character, significance and severity of these constraints. In the literature, these have coalesced around what are now known as the 'weak' and 'strong' sustainability perspectives.

The *Weak sustainability* perspective, which relies on the hypothesis of some degree of substitutability between differing types of capital for production or direct welfare purposes, would allow that each of these three constraints might be relaxed by virtue of technological progress. That is, substitution between inputs, and/or productive efficiency improvements can permit a continuous reduction in dependency on natural capital as a production input or as a sink for pollutants.

The *Strong sustainability* perspective, by contrast, treats major categories of natural capital as 'critical' in the sense of being strongly complementary with produced capital for the maintenance of durable economic activity. The presumption is that there are not unbounded possibilities of substitution away from environmental sources and sinks (cf., Ekins & Simon 1999; Faucheux & O'Connor (eds.) 1998). The terms "strong sustainability" and "strong criterion of sustainability" refer, since the 1980s, to the guideline of maintenance (non-negative change) in the "stock" of natural capital as a complement to the categories of economic and human capital treated in post-WW2 development theory.[5]

These two perspectives can be considered complementary rather than exclusive if and inasmuch as they are to be applied in complementary rather than overlapping domains (Faucheux & O'Connor 2001). In effect,

- The 'Weak sustainability' precepts can be regarded as applying to the exploitation of non-renewable, and also some renewable resources, to the extent that these latter are not deemed essential and permanent pre-conditions for durable economic activity.
- The 'Strong sustainability' precepts, by contrast, apply to components of natural capital that, considered as components of functioning natural systems, are deemed necessary supports for viable economic activity. This refers, notably, to the essential roles of ecosystems in life-support services, waste assimilation, renewal of water and biological resources, and so on.

This demarcation between domains where the 'Weak' and 'Strong' sustainability precepts are respectively to be applied, is thus based on a fundamental difference in the role that the natural capital is attributed for achieving sustainability. This shows up directly in the manner in which the question of the value of natural capital is approached in each case:[6]

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4 For example, Barbier and Markandya (1990). For a review of the 1980s and 1990s literature, see Faucheux & O'Connor (eds., 1998, notably chapters 2, 3 and 4).

5 This leads, by generalisation, to the principle of maintenance (or non-negative change) of each the four capitals as "multiple bottom lines" for sustainability (e.g., in the recent European project SRDTOOLS; see Ekins 2006).

6 An analysis by Serôa da Motta (1998) on water resources for Brazil, illustrates the Weak/Strong demarcation through describing a set of distinct ways to obtain monetary value figures on the basis of a range of different propositions about the desirable levels of industrial and domestic effluent reduction, treatment and water purification. First, they suppose that the marginal damage to society of additional water pollution might be reflected in existing expenditures to partially clean the polluted water. They deduce a figure for the

- On the one side, the resources and assets that are valued from the point of view of their potential conversion into commercially priced goods and services (e.g., trees into wood products);
- On the other side, the assets that are valued from the point of view of their roles as *in situ* services as sites, scenery, scientific interest and ecological life-support in complement to human economic activity.

The decision whether or not to make the valuation of an environmental asset (as a component of natural capital) from the point of view of market value, must therefore be addressed on the basis of explicit consideration of **means** and **ends**. Two main considerations are to be noted. Either the features of the environment in question are valued (respected) as being "ends in themselves"; or they are valued in terms of their perceived necessity as systems requirements for sustainability of some other valued entity.

If the Strong Sustainability perspective is adopted, then the valuation of the element, feature or object is expressed first of all in the affirmation of a commitment or duty of respect; and then, in a derivative way, through an enquiry into the *opportunity costs of avoiding depletion or degradation*. This approach is in many ways appealing because it makes explicit the goals of sustainability, and avoids the requirement to make tortuous or artificial assumptions about how input substitutability and preferences on the 'demand side' of the problem might be reflected in market prices. The societal or policy goals are specified in non-monetary terms as respect for and maintenance of the key features of natural systems (see also **Sections §7 & §8** below). [7]

§4. SA at Company Scale: the Bebington SAM

Among the capital theory based SA tools currently emerging that are intended to assist organisations to make sustainable decisions at a company or territorial project level are the Sustainability Assessment Model (SAM) developed by Bebington and colleagues in the UK.[8] The SAM has been put forward as one option to highlight and assess sustainability principles within various project decisions, and has been portrayed as a "Full Cost Accounting tool" designed to graphically display the monetised costs and benefits of externalities arising from the social, environmental, resource and economic implications of a project – where a "project" consists of any economic activity for which a scope can be defined and acceptable boundaries laid (e.g. development of an oil and gas field or waste disposal). However, it has also been asserted that the task of quantification was not as an end in itself; the primary intention of the SAM developers being to provide a tool permitting the engagement of a broad range of stakeholders, so as to generate dialogue around indirect impacts of a given project, in turn facilitating broader consideration of options and in doing so achieve greater sustainability for that project.

'depreciation' of water natural capital for comparison with GNP, closely aligned to 'Weak' sustainability. Second, they estimate the economic costs associated with fully respecting norms of preserving intact the existing capital stock levels and quality. This is close to 'Strong' sustainability, and suggests an 'economic opportunity cost' for water quality maintenance that is substantially higher than the figure for the natural capital 'depreciation' obtained through the pricing system.

[7] So-called 'Weak' sustainability is usually associated with neoclassical economics because many neoclassical theoretical results about optimal resource use make the presumption of substitutability in production and for consumer satisfaction. Nonetheless, there is nothing in the strong sustainability perspective that steps outside of the neoclassical utilitarian conceptual framework. The question between 'strong' and 'weak' in this regard is of the empirical (and systems theoretic) reasons, including 'critical thresholds' (if they exist), irreversibility and uncertainties, for preferring complementarity over substitutability as hypotheses for the capital requirements for future generations' welfare levels. However, there is also a question of the character of consumers' preferences (e.g., whether or in what sense respect for biodiversity, for future generations' well-being and reduction of present-day poverty constitute 'ends' that are to be served by wide management of available capitals). We return to both these questions in **Section §8** below.

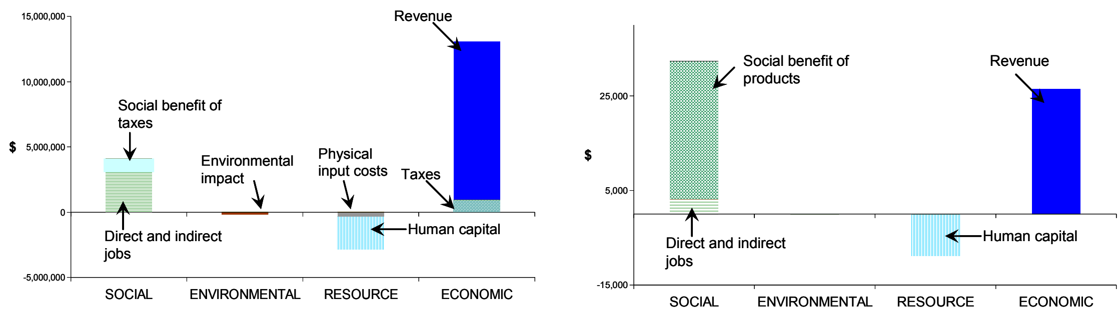
[8] SAM was developed in the UK by British Petroleum (BP) and Genesis Limited (UK division) with the University of Aberdeen in Scotland (Baxter *et al*. 2002; Bebbington & MacGregor 2005). SAM has also been presented to various New Zealand businesses and public sector organisations as a tool potentially useful to assist them in developing more sustainable ways of operating (Bebbington and Frame 2003; Cavanagh et al. 2006).

Formally, the SAM proposes a Full Cost Accounting (FCA) approach to assess a discrete project (where a "project" consists of any economic activity for which a scope can be defined and acceptable boundaries laid) and considers the full life-cycle, including identification and monetisation of the project's operational impacts. The FCA should generate information about "externalities" that are not currently reflected in the open market and that are not likely to be reflected in the market in the near future.[9] (In other words, the external costs identified by FCA are not borne by the project's owners; rather they fall on other components of society as part of the "total" costs and benefits to society of an activity over the defined boundary.) The SAM approach as developed by Bebington, considers the flow of four capitals within a project: economic capital, resource capital, environmental capital and social capital. These capitals are valued over the life-cycle of that project, and changes in capital are shown as annualised amounts.

- Economic capital is the economic benefit that accrues from the project and notionally represents the money going into society, or the project's direct contribution to GDP.
- Resource capital includes the cost of using finite supplies of raw materials and land for the given project.
- Environmental capital includes the cost of environmental damage such as emissions into the atmosphere and impacts of wastes generated by the project. It may also include benefits such as improved biodiversity or improvements in environmental quality.
- Social capital captures the potential social benefits arising from the project such as improving quality of life. Potential social costs associated with the project, such as road accidents and workplace injuries.

When presented visually, the quantification of changes in these categories of capital can provide a sustainability profile for a given project and can be used to compare and discuss the relative sustainability of different options. Several recent papers (e.g., Bebbington et al. 2006) discuss experiences gained through the application of SAM in corporate contexts in the UK and in urban case studies in New Zealand, including assessment of different waste management options, housing and transport projects.

To illustrate the SAM approach, we take a relatively simple example, that of preliminary SAM assessments regarding options for the disposal of organic waste for the Christchurch City Council in New Zealand. The first alternative was the processing of organic waste through conventional means (a combination of disposal to landfill, disposal via in-sink disposal units, green-waste collection and composting). This conventional alternative was compared to the processing of organic waste in community gardens. Details of the assessments are provided in Cavanagh et al. (2006); operational information was obtained from the Christchurch City Council and the best available literature was used to "monetise" the impacts. The profiles developed for the two scenarios are shown in the Figure below.



SAM profile for (a) disposal of organic waste through conventional means and (b) processing through community gardens. Source: Cavanagh et al. (2006)

With these figures, we have a graphical expression of the use of the "four capitals" model for expressing a *multiple bottom line* as the basis for an evaluation "from the point of view of

[9] In this regard, the initial goals of SAM were akin to the ambition of the *EXTERNe* programmes financed by the European Commission since the 1990s.

sustainability". Each of the four capitals is considered individually. In the example just given, the SAM profile developed for organic waste processed via conventional means (left-hand Figure) is dominated by the project revenues (economic bar); this is largely derived from the operational costs associated with the landfill and composting operations. According to the figures obtained; the impact of air emissions associated with collection of solid and green waste is minimal. The social benefit of organic waste management is primarily driven by indirect jobs created as a result of the organic waste industry (e.g. machinery maintenance, support services), with a limited social benefit generated by the product (e.g. taxes arising from the sale of compost). The conventional profile contrasts markedly to that generated by processing organic waste through community gardens (right-hand Figure). This 'community garden' profile is dominated by the social benefit and economic revenue. In this case, social benefit also arises from the therapeutic value associated with working in a garden.[10]

§5. SA at Macroeconomic Scale: Adjusted National Aggregates

One of the most well developed applications of the capital theoretic approach to sustainability assessment is the domain of "green national accounting" and, more particularly, the notion of "adjustment" to national or macro-economic performance indicators as guides to sustainability. National accounting since its inception (e.g., during the 1940s wartime) has a pragmatic utilitarian orientation, setting out to quantify primary and intermediate production activities with a view to estimating capacities for different classes of goods and services. Since these beginnings, the questions have been broadened to perspectives for capital formation and consumption growth more generally (the concern with 'growth and development') and to assessment of the natural resource base for future economic well-being.

As discussed by O'Connor (2001), Lawn (ed., 2006) and many others, there are several roots of the concern for monetary valuation of natural resources and of environmental benefits and damages in an enlargement of national accounting. A lot of these are related to the idea, widespread since the 1960s, that natural resource depletion, environmental damages and pollution caused by economic activity should somehow be registered as a dis-investment (hence an actual or potential welfare loss), and therefore set against the benefits of this economic activity as measured in the GDP. The question of precisely how to set these environmental costs in relation to economic benefits has, however, been a matter of debate throughout the ensuing decades.

These arguments took on particular focus as the notion of 'sustainable development' gained currency, and the two following questions were posed.

- First (for rich countries), "Can the current level of aggregated national consumption be sustained indefinitely?";
- Second (for poor countries), "is there an upper limit to the future income level that, once attained, could indefinitely be maintained?"

These questions, apparently simple, can be given a precise quantitative formulation ***only*** in the framework of a deterministic mathematical model. The role of modelling is to provide a framework for checking the logical consistency for important concepts, hypotheses, results and interpretations, while bearing in mind that real development and environmental change processes are not so deterministic at all. The key question posed for national accounting, and that has underpinned the push for 'adjusted aggregates' since the 1980s, was:

- "Can an estimate be obtained for a nation's sustainable national income, on the basis of appropriate adjustments to the conventional GFP figure?"
- And, if the answer is "yes",
- "What are these adjustments and how can an estimation procedure be implemented in practice?"

[10] We do not go into detailed result discussion. Among the challenges identified in the course of undertaking the SAM project-scale assessments, analysts have noted the requirements for establishing appropriate boundaries for assessment, data limitations, differing levels of engagement achieved with different stakeholders, and the relationship of the SAM to more conventional assessments (including cost-benefit analysis and triple bottom line reporting). These issues are quite typical of those encountered across the whole SA field.

These are the questions to which the neoclassical growth theory claimed to furnish a response when Solow (1986) and others noticed, on the basis of results from Weitzman (1976) and Hartwick (1977), that in a model solution for an economy having constant consumption indefinitely (that is, sustaining its national income), the 'net savings' or change in the value of the capital assets in the economy, is zero. This dovetailed with the Hicksian concept of income (Hicks 1946) which was: *"The maximum amount which can be spent during a period if there is to be an expectation of maintaining intact the capital value of prospective returns."* Under certain assumptions, this 'income' equals consumption plus net savings. So, turning the formula around, the conclusion would be that when net savings are zero, the consumption is at the sustainable level.

Translated into the language of national accounting, this gave the proposition that the sum of national net savings plus national consumption, if net savings are calculated taking natural capital into account, will be an estimate for the level of income that the economy could, in principle, maintain indefinitely — that is, the 'sustainable national income' (SNI) for the country. On the basis of this reasoning (which, as it turned out, is incorrect on a crucial point), it would be sufficient to estimate the 'green NDP' defined as the net national product *taking into account changes in all capital assets including natural capital*, in order to have an estimate for the country's SNI. Therefore, it was concluded, environmental economists and statisticians should go to work to obtain information on the state of natural capital from year to year, and attribute money values to the changes, and the job is done. This was the motivation underlying, for example, the work reported by Pearce & Atkinson (1993) for a cross-section of countries (see Box).

A 'WEAK' INDICATOR OF SUSTAINABILITY?

Pearce & Atkinson (1993) developed estimates for the 'net savings' (ΔS) taking into account not only economic capital savings and depreciation but also depletion of natural resources. Using $SNI = C + \Delta S$, their interpretation was:

■ If the net savings are negative, then current consumption (C) exceeds the sustainable consumption level (SNI).

■ If current consumption (C) is less than the SNI, then there is room for continued consumption growth without nuisance to future generations.

The Pearce & Atkinson (1993) results took into account only a very limited number of categories of natural resources such as petroleum, minerals and forests. In the ensuing debates, criticisms have been made of these results and their interpretation as a sustainability indicator along three lines:

- First, that concerning natural assets and, more generally, environmental services that contribute to human well-being but that are vulnerable to degradation, "far more has been left out than has been included" (see, e.g., Victor, Hanna & Kubursi, 1998);
- Second, that the existing or estimated resource prices employed for the calculations are unlikely to reflect inter-temporal opportunity costs as the underlying theory presupposes (see, e.g., Martinez-Alier & O'Connor, 1996);
- Third, that, even within the confines of the relevant theory, the 'greened NDP' and the 'sustainable national income' are not necessarily the same. On the contrary, depending on the assumptions made about, *inter alia*, technological progress, openness or closure of the economy towards the rest of the world, relative abundance of different sorts of capital, population change, substitutability and income elasticities, efficiency or not of current prices (etc., etc.), the green NDP can be much higher, or much lower, than the SNI — so much different that nothing reliable can be inferred about the SNI relative to current consumption from the sign or magnitude of the estimated net savings (see, e.g., Asheim 1994; Faucheux, Muir & O'Connor 1997; Pezzey & Withagen 1998; Weitzman 1997).

These criticisms cumulatively are compelling, and pure theory justification for using an adjusted aggregate (viz., the green NDP) as a way to estimate the sustainable national income is very weak. This does not, however, mean that there is no relevance in estimates for changes in various categories of natural capital. What it means is that, while the 'silver bullet' approach to getting a 'SNI' indicator in this way is not convincing, there is nonetheless an interesting indicator of the monetary value of changes in value for a specified basket of net national assets, obtainable on a period-by-period accounting basis as in business accounting (O'Connor 2001; O'Connor & Steurer 2006).

Hueting (1980) on the same macroeconomic indicator problem had followed a somewhat different line of reasoning. He started with the argument that sustainability policies mean the maintenance through time of all key 'environmental functions' and that this should be pursued by setting restrictions on the extraction of renewable resources, the emissions of pollutants and other sources of environmental damage, in order to ensure the sustaining of environmental qualities and life support capacity. He further argued that an economy that does not respect the sustainability standards, could be 'adjusted' by adopting measures such as pollution abatement, substitution away from over-used resources, etc., in order to make it meet these standards. These adjustments would cost money (more exactly, they would imply the redeployment of resources within the economy), so they could be considered as imposing a reduction in the value of economic goods and services available for current consumption. This led to the suggestion that the 'sustainable national income', meaning the national consumption level for the economy respecting the standards, could be estimated by subtracting these costs of adjustment from the current income.

The early Hueting formula thus appears, in this respect, to be similar in character to the formula for SNI obtained on the basis of the neo-classical growth theory. Both involve the subtraction of environmental values from GDP. But whereas the Pearce & Aktinson results are based on using estimates for monetary values of natural capital in the existing economy, the Hueting approach is based on calculations associated with adjustments to the existing economy. The methodology and system reference points for the two approaches are not the same.

The Hueting approach also presents distinctive difficulties. One of these is related to the scales of analysis. What level of sectoral aggregation is to be adopted? What is the time-frame over which costs of adjustment should be calculated? An adjustment that may appear as a high cost for a firm, for a sector or for the national economy if measures for (say) water pollution reduction are to be implemented in the short term (say, 2 years), could also appear as a relatively low or even 'negative' net cost if adjustment and investment opportunities are allowed and appraised over a longer time-frame (say 15 years). Since sustainability is the concern and adjustment processes take time, the opportunity costs for forward-looking policy should usually be estimated in an inter-temporal analysis framework.

These scale-related problems were given careful attention during the mid-1990s in a multi-country European study, the **GREENSTAMP** Project.[11] This work suggested that it was useful to introduce the concept of a 'greened economy GDP' as a characterisation of an 'adjusted economy' — that is, an economy that, over time or hypothetically, is altered in structure so as to respect specified environmental performance criteria. In this approach, *the greened-economy GDP, or geGDP, refers to the feasible economic production, for the accounting period(s) in question, subject to the condition that the economy is respecting the specified set of environmental standards.*

Distinct from Hueting's approach, the *GREENSTAMP* 'greened economy GDP' concept is developed directly at a whole-economy level, and would be estimated through comparative static or dynamic scenario modelling approach. The direct recourse to modelling created a link between the SA and green national accounting agendas and an independently existing body of work since the 1970s which has been concerned with developing scenarios for 'soft energy paths' and, more generally, for 'alternative' and 'green' economies. Many examples for a *'geGDP'* are therefore to be found directly in the guise of aggregate output or income indicators of models developed for exploring alternative energy or environmental scenarios in macroeconomic sustainability studies, even if these latter were not conceived for *geGDP* estimations as such.

These brief paragraphs show, through and beyond the historical variations, the coexistence of two fundamentally distinct adjustment concepts: first, an adjusted aggregate for an existing economy, and

[11] The *GREENSTAMP* research project on *Methodological Problems In The Calculation Of Environmentally Adjusted National Income Figures* was carried out during 1994-1996 for the European Commission DG-XII, and involved collaboration between several statistics offices and economics and environmental research institutions. The acronym refers to the methodological perspective on *GREEned National STAtistical and Modelling Procedures* developed in this research project. See Brouwer & O'Connor (eds., 1997a, 1997b), also Brouwer, O'Connor & Radermacher (1999) for full Project documentation. This project investigated the different theoretical options for defining an 'environmentally adjusted national income figure' — a *geGDP* — that could be estimated based on available statistical data and analytical tools and that would be plausible as an indicator about future macro-economic performance potential taking account of environmental performance goals.

second, the adjustment of the economy. According to O'Connor (2001) and O'Connor & Steurer (2006), these two concepts can *both* be the basis of a useful sort of 'environmentally adjusted national income' figure; the **Table** below highlights the four combinations that are logically possible.

		System boundary (capital stocks included in the measure of asset value change)	
		Usual set of produced economic assets	*Enlarged to include all produced assets plus specified environmental and other assets*
Reference economy for estimation	*Statistics for the current really existing economy*	**[A-1] The traditional or 'unadjusted' GDP and NDP (NDP = consumption + net savings)**	**[A-2] An 'environmentally adjusted' Domestic Product for an enlarged portfolio of national assets**
	Shadow aggregates for a model economy respecting environmental performance standards	**[B-1] GDP and NDP 'volume' measures for an 'environmentally adjusted economy'**	**[B-2]** *[Indicator estimation based on a combination of the two adjustment concept; while logically possible this has not (as far as we know) yet been done…]*

- The TOP LEFT box refers to the 'traditional' macro-economic indicators based on the standard national accounting conventions for estimating GDP and NDP.
- In the TOP RIGHT box, there are 'environmentally adjusted' net domestic product figures for an existing economy. These are based on using an enlarged asset boundary when assessing net asset change for the national economy during the current accounting period. O'Connor & Steurer (2006) propose the acronym **AICCAN**, meaning *Aggregate Indicator for the Change in the Current economic Assets of the Nation*. The 'environmentally adjusted national income' or 'green NDP' is then defined as this net asset change (net savings) plus national consumption. Both consumption and asset changes are valued using current prices (or, in the case of environmental assets for which real prices don't exist, using shadow prices obtained by reference to other goods or costs for the current period). This gives an 'environmentally adjusted' or 'green' NDP for an unadjusted economy.
- In the BOTTOM LEFT box, there are the 'unadjusted' GDP and NDP for an 'environmentally adjusted economy'. These are figures obtained for a hypothetical economic structure, using suitable statistical and analytical techniques, responding to the question: What would be a feasible macro-economic performance if the existing economy were modified so as to respect specified environmental performance standards? These are *'greened economy GDP'* figures, henceforth as **geGDP** for short. Such figures may be obtained notably by comparative static and dynamic scenario modelling analyses.

The top right and bottom left boxes each involve only one of the two forms of 'adjustment' to estimation procedures. The bottom right box provides, logically, for indicator measures that combine both types of adjustment together. This combination; which involves hypotheses about changes to economic structure or activity patterns together with a shift of the asset boundary for accounting purposes, is of conceptual and policy interest for forward-looking analyses (Faucheux & O'Connor 2001); but systematic estimations of this concept have not (as far as we know) yet been developed as part of national-scale empirical SA.

§6. General Questions of Measurement and Aggregation

The span of the natural capital concept is vast, and so the diversity of the "components" of environmental or natural capital is very great. Both theoretically and in practice, it is hard to find a convincing way to put the variety of benefits — ranging from fundamental life-support functions of the biosphere to ecosystems as reservoirs of more-or-less unique symbolic (cultural), biological (genetic), and scientific (aesthetic) interest — onto a single evaluation scale.

Since the 1970s, economists and accountants have considered various possibilities of aggregate measures of capital stock. Formally, the main possibilities are:

- the *physical quantity* of natural resource stocks.

- the *total value* (in economic units) of the natural resource stocks, which would permit physically declining levels of a stock if accompanied by a rising unit value (price) in society.
- the *unit value of the resource/service* (as measured by a price or shadow price).
- the *total value of the resource/service flows* obtained through time from the stock.

The last of these expresses the conventional economist's idea of a sustainable development, namely the ensuring a non-declining *benefit stream* of environmental services into the relevant economies. But it has insurmountable difficulties of operationalisation. In standard economic analysis, relative prices are used as an estimator of opportunity costs associated with production or use of different goods and services. But we cannot make a correct monetary valuation of natural capital unless we know the extent to which different natural stocks are substitutable for each other and/or can be substituted by manufactured capital.

If, by contrast, physical units are used, a variety of scientifically valid measures can be obtained — such as tonnes of material or joules of available energy. But then one is then faced with the problem of meaningfulness and policy relevance (or not) of aggregate measures for composite stocks.

- One topical example is furnished by the modelling of climate dynamics using linked atmospheric circulation and ocean models. Models based on extensive data sets, examinations of the historical record and rigorous hypotheses about thermal and physical transport processes in the atmosphere, etc., now give a good insight into the complex dynamics of climate, hence possibilities of anthropogenic climate change. But this is not to say that the models can predict the severity, rapidity, or exact character of this possible climate change at the level of spatial and temporal resolution that would be necessary for making "climate change forecasts" that could be the basis of agricultural and other investment decisions…
- Another example is the cumulative ecosystem, human health and other impacts (which might be judged harmful, degrading or otherwise) of genetically modified organisms introduced into the biosphere. At a social level a variety of cultural, ethical and historical factors will bear on individual and collective evaluations, for example, notions of food integrity and food quality, people's individual and collective senses of the sacred (for humans and for nature), fear of health risks.

The conclusion is that, in general, there is no fully satisfactory indicator for the total quantity or stock of natural capital.

At a disaggregated level, however, it may well be possible to define various measures of stocks and of the quality of goods and services obtainable. This opens the door to approaches that characterise the components of environmental systems in non-monetary terms, for example by focussing on the maintenance of *environmental functions*. This means, in the language of "procedural rationality" (e.g., Herbert Simon), that sustainability policy is constructed in a piecewise and iterative fashion, through the specification of sub-goals and the investigation of the feasibility (or not) of simultaneous respect for the spectrum of sub-goals.

If this approach is accepted, then it can be seen that refusal of aggregate indicators (whether expressed in monetary valuation or any other single numéraire) of changes in natural capital — and, as a subset of this, of damage or degradation of natural capital (and of risks of damage…) is not necessarily due to a lack of 'economic rationality' on the part of policymakers or other members of society. Rather, it can be seen to arise as a coherent and reasonable response given the inherent properties of the situations, notably the *irreducible systems uncertainties* and the *multiplicity of specific ethical convictions* that, together, add spice to the dilemmas and challenges of *societal choices*.

These issues may be classed together as *challenges of complexity*. Environmental decision-making, like all other policy fields, necessarily works to privilege some interests, while others may be penalised or cast aside as counting for nothing. Environmental policies are typically about identifying, managing and — partially — resolving ecological (as well as economic) distribution conflicts. These are often made more difficult because they can involve sharing out "bads"— risk distribution and imposed suffering such as health damage and loss of food production capacity — as well as goods. Side effects on health and ecological systems may, in many cases, fully emerge only

> ***The Challenges of Complexity***
>
> *Assessments of natural capital are caught up by three challenges, which overlap and interfere with each other):*
>
> - Scientific knowledge advising of irreducible uncertainties and/or irreversibilities associated with courses of action;
> - Plurality of value systems, political and moral convictions, and justification criteria within society;

over long periods of time and across large distances. The affected parties may be extremely diffuse or hypothetical in character (future generations and ecosystems that may be affected by climate change or accumulation of carcinogenic contaminants), and different constituencies in society ma hold quite contrasting views on the acceptability, or not, of different classes of risks.

We will return to these complexity and inter-disciplinary considerations at length later on (**Sections §7, §8, §9, §10...**). As an intermediate step, it is useful to develop a "piecewise" approach, looking in a very schematic way at accounting prospects for the 'components' of environmental systems in anticipation of the need for social/political process of "arbitrage" between multiple sub-goals.

A great amount of environmental policy is organised using variations of the *Pressure-State-Response*, or *PSR* framework of analysis (and, more recently, DPSIR = *Driving Force-Pressure-State-Impact-Response*; for a synthetic overview see Maxim, O'Connor & Spangenberg 2007). In this conceptual framework, the *pressures* are human activities of production and consumption affecting the environment (e.g. oil and mineral extraction, fish catch, carbon dioxide emissions, spent nuclear reactor fuel production, fertiliser applications); the *state* refers to [observable changes of] key features of the environment (e.g. global mean temperature rise, background radioactivity level, algae growth in lakes); the *responses* are the measures proposed or implemented by society to deal with the problem. The term *impact* in the DPSIR variant can, for different analysts, refer to either or both of impacts of economic activities on the state of the environment, or impacts of changes in state on the economy or on societal perceptions of management challenges.

The *Ehrlich formula* gives a simple and intuitive approach to the pressure problem. It links ways of life (as parameterised by indices of consumption) and impact on the environment. Ehrlich wrote **I** = **P**x**C**x**T**, where **I** is the total environmental impact, **P** is the relevant (human) population, **C** is the typical consumption per person within the society or region or sector being studied, and **T** is the environmental impact per unit of consumption. So the **I** is a generic pressure indicator.

Of course this abstract accounting is rather too general for most purposes, because it would require some sort of generic aggregation for impacts that, we we have need, is not really available.

For any chosen environmental problem, specific pressure indicators can be developed on a sector by sector, product by product, or process by process basis for different categories of consumption, and, similarly, for different categories of environmental pressure such as energy and natural resource use, space requirements, pollution and waste discharges, and ecosystem impacts. Given the variety of policy problems and stakeholders, many different scales of change are relevant. Moreover, one will always find contrasting perspectives with regard to the effects of changes in the system. Changes judged as improvements for certain social groups, over a certain time horizon, can represent a step back for others, or on a different time-scale.

Another approach to typology of the state of the environment and changes in state, that has become prominent since the 1980S (e.g., Hueting 1980; De Groot 1992; Daily (ed., 1997), is to characterise the environmental pressures with reference to *environmental functions* of direct and indirect significance to humanity. Environmental functions are defined as the capacities and performances of natural processes and components to provide goods and services which satisfy human needs. The physical environment is considered as a complex system, and one may speak of:

- the *functioning of* natural systems — the internal regulation, cycles of renewal, evolution and transformation by which biosphere activity is maintained;
- the specific roles or services provided by natural systems that support economic activity and human welfare — that is, the environment's *functions for the human economy*.

No universally accepted general framework for taxonomy has yet been stabilised, but it is now common to regroup environmental functions under broad categories, such as 'the five **S**'s' (Noël & O'Connor 1998):

- **S**ource of biological resources, food, raw materials and energy in various forms;
- **S**ink, or place of controlled and uncontrolled disposal of 'waste' products and energy of all sorts;
- **S**cenery, covering all forms of scientific, aesthetic, recreational, symbolic and informational interest;
- **S**ite of economic activity (including all forms of land uses and occupation of space for transportation);
- **L**ife–**S**upport for human and non-human living communities.

Examples of the variety of environmental functions and natural capital components

- Primary energy sources: *Thermodynamically available energy is an essential component of all economic production. While substitution between energy forms is generally possible, the complexity of energy infrastructures and related land uses makes it important to distinguish major subcategories: fossil fuels (coal, oil, gas), uranium and other fission fuels, solar energy captured through photosynthesis, hydroelectricity, wind, tidal energy, geothermal heat, and so on.*
- The atmosphere as multifunction life-support system: *The functions are critical in several dimensions: the air that we breathe; acid rain; the protective ozone layer; atmospheric circulation and its implications for climate stability/change.*
- Forest ecosystems: *On a large scale, forest ecosystems are an important component of atmosphere renewal and purification; this includes their role as carbon sinks. On local scales, forest cover may also be important for stabilising soils in groundwater quality, retention and flood control, and nutrient recycling. Forests may also be economically or culturally critical as habitats and as food and energy sources.*
- Freshwater resources: *Water supply for drinking, irrigation and other uses has always been a determining factor in the localisation of human habitats. Water must be available on a daily basis. Since watersheds are demarcated geographically and transportation is costly, water resource depletion or degradation (through pollution and so on) are similarly localised.*
- Wild and agricultural genetic diversity: *The importance of genetic resources in general (wild resources, improved traditional varieties, modern varieties and genetically engineered varieties) can be a matter of possible future economic interest, or based on of ethical and precautionary principles. Agricultural genetic diversity has arisen in the course of farming societies through hundreds of years of husbandry practices, and this 'cultivated natural capital' usually requires, for its perpetuation, to be complemented by wild relatives and ecosystems.*

Operational sustainability guidelines can then be formulated as goals, standards or norms relating to specified environmental functions, these policy reference points being related, one way or another, to society's objectives for nature conservation and for delivery of an environmental as well as economic welfare base to present and future generations. Emphasis is then placed on defining the economic resource opportunity costs associated with the achievement of specified environmental quality goals, that is, cost-effectiveness in achieving policy norms.[12]

As an example of this sort of approach, we mention the recent EU funded **CRiTiNC** project which, during 1998-2001, investigated the applicability of the principle of identification of categories of *critical natural capital (CNC)* whose levels or quality ought to be maintained at or above specified thresholds. *CNC* is here defined as any set of environmental resources which, at a prescribed geographical scale performs important environmental functions and for which no substitute in terms of manufactured, human or other natural capital currently exist. Application of this concept requires making a detailed appraisal of the roles and significance of different natural capital systems or components for supporting economic activity. It also requires identifying the destructive environmental effects of each economic use/user category. On this basis, it is possible to specify spatial and temporal scales for which certain environmental functions and, hence, the natural capital systems may be critical, taking note of social and cultural factors which may contribute to making these of a 'critical' importance.

THE CRITINC DIAGNOSTIC FRAMEWORK FOR SUSTAINABILITY ANALYSES

The multi-country research project **CRiTiNC** funded during 1998–2000 by the European Commission (co-ordinated by Paul Ekins, then at the University of Keele in England), refined and tested a framework for identification of environmental functions and categories of critical natural capital in relation to sustainability requirements. There are four levels of analysis, linked to each other.

[12] Economists will insist that, whatever concepts of ecosystems dynamics are adopted, scarce resources must be committed, directly or indirectly, in order to maintain the desirable level of environmental functions. Policies aimed at safeguarding environmental functions — that is, meaning to commit scarce resources in order to maintain or recover the desirable level of environmental capacity — correspond to a kind of *social demand for the environment*. This 'social demand' may include provision for future generations and demand for protection from environmental harms: many of the interested parties cannot be present or speak, and many of the benefits in question are diffuse in character.

- **Level 1** is the defining of the parameters (characteristics) of the ecosystems being studied, so as to describe the capacities of the ecosystem or natural area to provide certain functions. This aims to illustrate the links between ecosystem functioning in itself (such as food chains and nutrient cycles, physical transport process, heat and water flows…) and the environmental functions or services furnished to human societies.
- **Level 2** describes which economic sectors affect which environmental functions. More exactly, it analyses the environmental pressures caused, directly and indirectly, by different categories of economic activities.
- **Level 3** presents requirements for sustainability in its various dimensions (economic, environmental, ecological, social, and cultural), at the scale of analysis being undertaken. Thresholds, standards and targets are proposed in relation to specific economic activities, ecosystem functioning and the services they provide for societies, and the interfaces between economic and ecological activities.
- **Level 4** makes the comparison between the standards given in Level 3 and the current impacts or state indicators described in Level 2, and allows the identification of sustainability 'gaps' corresponding to the distance between the current situation and what it would be if resources/ecosystems were managed sustainably. Examining the various gaps is the basis for analyses of technological, land use and other response options.

All of these steps, or levels of analysis, have distinctive requirements for environmental and economic accounting. However the scientific challenges do not stop there. A single ecosystem or natural resource might fulfil a range of economic production input, recreational, biological and pollution absorption functions, for example, forest and river systems. Due to the complexity of ecosystem processes and differing perspectives over the extent to which a function is "critical" or not (and to whom), there can be controversy over scientific justifications for the threshold levels or norms that are proposed. In addition, sustainability policy targets will always have social as well as functional (ecological) dimensions.[13]

For these reasons, setting environmental policy targets is usually a conflictual process, where the basis for a good or reasonable societal choice cannot be reduced to a simple rule such as optimising or precaution. Such questions are resolved partly through the exercise of power and partly through complex political procedures (see **Sections §10, §11, §12** below).

If and when threshold standards are set (or, in simulation work, if various different targets taken in turn), it becomes possible to estimate the 'gaps' between the identified sustainability requirements and the current (and perhaps worsening) situation. Resource management analyses for maintenance of essential and desired environmental functions may then be approached in terms of *cost-effectiveness,* where the goal is to find low-cost and effective ways of achieving a defined norm. However, such analyses must be conducted with care as to apprpriate specifications of system scale (e.g., household, economic sector, national or planetary modelling frameworks) and time horizons (e.g. proposing a *transition* lasting years or decades, or even thousands of years in the case of long-lasting stored wastes). Environmental and interface information organised in this sort of outlook can thus be the support for scenario studies and multi-criteria appraisal in which a range of priorities and strategies (based on differing, and potentially conflicting, views) on how to maintain environmental functions, hence environmental sustainability, can be expressed and analysed.

[13] For example, even if the ecological and economic requirements of tropical forest and ocean fish stock maintenance were well-known, questions still arise about stewardship of which forests (or fish), where, for whom? Non-built environments are often cherished for recreational, aesthetic and spiritual reasons. The conservation and enhancement of ecosystems as habitats for non-human life, and for living biological diversity may be motivated by ethical convictions of respect and coexistence. Communities may identify features of their habitats as 'critical' natural capitals in view of their symbolic or functional significance in defining group identity.

§7. Sustainability as Complex System Co-evolution

Appraisal of changes in environmental systems, and of their ecological, economic and social significance, clearly requires observation of the natural processes and ecosystems in question; and this depends, in turn, on concepts not just from economics and ecosystems science and related disciplines, but also from ethics, politics, anthropology and other fields of social sciences and philosophy. This pushes us towards domains of inter-disciplinary work and to questions of appropriate frameworks for 'integrative' analyses.

The complex systems approach to sustainability, as proposed for example by Passet (1979), highlights the interdependence of four "spheres" or classes of system organisation.[14] These are the *ECONOMIC*, *SOCIAL* and *ENVIRONMENTAL* spheres — usually recognised as the "three dimensions of sustainability" — complemented by a fourth category of organisation, the *POLITICAL* sphere of conventions, rules and institutional frameworks for the regulation of the economic and social spheres (and, indirectly and partially, also the environmental sphere). This leads to a systems model of "four spheres", named by O'Connor (2006b) the **Tetrahedral Model of Sustainability**.

In this perspective, analyses for sustainability must focus attention on the interfaces, the interactions and the interdependencies between the ECONOMIC, SOCIAL and ENVIRONMENTAL spheres, on the characterisation of principles of performance and quality in each sphere, and on the principles of rights, respect or responsibility proposed for one sphere in relation to another.

The POLITICAL sphere has the role of the "referee" that arbitrates in relation to the different — and often incompatible — claims made by the actors of the social and economic sphere for themselves and with regard to the other spheres (including the environmental sphere).

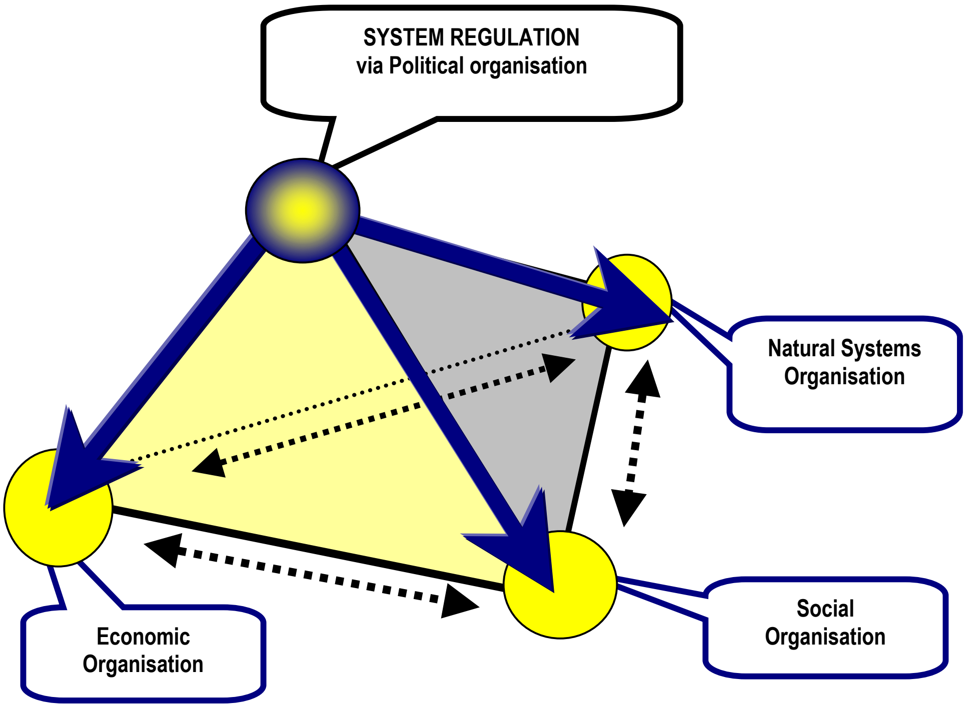
But governance is not determinate control. It is emphasised, in this complex systems view, that natural processes express, at various scales, autonomy and self-regulatory capacities quite other than those that can be applied for economic processes in the industrial model. Achieving sustainability therefore would mean a process of co-evolution respecting a "triple bottom line", that is, the simultaneous respect for (or satisfaction of) quality/performance goals pertaining to each of the three spheres. The vision of the economy here is more of a collective voyage in a boat being navigated intelligently within a powerful river, not the damming and harnessing of the river to provide electricity for the pleasure boat.

> In recent decades, a variety of important concepts of ecosystems dynamics have been developed, around themes of organisational stability and thresholds of instability. Two well-known examples are as Buzz Holling's ecological theory of resilience, and Ilya Prigogine's far-from-equilibrium thermodynamics (linked to concepts such as chaos, multiple equilibrium and bifurcation).
>
> For more than 30 years, ecologists and systems scientists have explored, both theoretically and with empirical observation and experiments, different concepts of ecosystem stability, change, diversity and resilience as a function of internal structuring and external influences. This work has many important insights for human sustainability concerns. These include the emphasis on the webs of interdependency at different organisational scales rather than any simple hierarchy, and the very great complexity of dynamic systems built up of interacting entities organised at very different scales. Analysis may focus on two major sorts of questions: first, the investigation of instability and resilience of natural systems under various sorts of perturbations by human agency, and second, the appraisal of the significance of the possible ecological changes for human interests. But quantitative predictions are not usually possible. Ecosystem (and economic system) resilience, for example, is not a static concept, nor is it a yes/no type property. Through time, economic and ecological systems coevolve and may go major changes in organisation at different scales. These changes may be gradual; or sometimes a system (or sub-system, at a given level of analysis) may 'flip' from one organisational state to another. Different forms of resilience can be expressed — for example (within human communities) within a stable society a family unit may decompose after a certain number of generations; or, the larger society unity may disintegrate while the family network nonetheless remains strong…)

[14] Systems theoretic approaches to sustainability are myriad and the sketch that we give here is highly synthetic without giving credit to all the individual influences in the process.

This "triple bottom line" as a normative reference point proposed by and for a society, is therefore a *complex quality criterion*. Prospects of and policy norms for sustainability cannot be defined for the three spheres separately, nor by reducing the roles of one sphere to the 'needs' of another. On the contrary, assessments with a view to sustainability must propose a characterisation not only of principles of performance and quality in each sphere, but also of the basis for regulating the interactions between the three spheres.

If we consider interfaces between each pair of "spheres" (that is, two different 'types' of organisation), then with the 4 spheres there are 6 pairings. In the **Figure** (below, adapted from O'Connor 2006b), these are portrayed as the "edges" of a tetrahedron. The corners of the tetrahedron evoke the four complementary organisational forms, and the edges signal performance challenges, concepts and criteria arising as "interferences" of two organisational forms. These interface aspects can be characterised through investigation of the "claims" or "demands" made by each sphere relative to the others.



GOVERNANCE FOR SUSTAINABILITY: THE « FOUR SPHERES »

A succinct characterisation of the four spheres and the six interfaces is given in the tabular presentation on the following page.

The Tetrahedral Model for Sustainability Studies

COMPONENT	ELEMENTS OF CHARACTERISATION
THE 3 SPHERES	**THE "THREE SPHERES"…**
↻ ECONOMIC	Economic self-organisation, e.g., markets, performance imperatives such as efficiency, growth (K. Marx: *"accumulate, accumulate, it's the law and the prophets",* etc.) governing production, transport and consumption activities.
↻ SOCIAL	Social self-organisation, notably forms of collective identity and the frameworks of meaning (symbols, culture, etc.) and of relationships (networks, memberships, etc.) through which people situate themselves in human communities and within the biophysical world.
↻ ENVIRONMENTAL	Environmental self-organisation, e.g., the dynamic structures of physical and biological activity including atmosphere and ocean circulation, water and nutrient cycles, living organisms from the virus up to the scale of the Biosphere.
THE 4TH SPHERE	**… AND THE INSTITUTIONAL ARRANGEMENTS FOR THEIR GOVERNANCE…**
↺ POLITICAL	The governance dimension of organisation is constituted through the emergence of conventions and procedures for the regulation of each sphere in relation to the others, in order to assure the simultaneous respect for (or satisfaction of) quality/performance goals pertaining to *all three spheres*. This is the sphere of arbitrage amongst diverse principles and claims of interest, achieved de facto or by design through force and institutional arrangements ranging from town and county councils through national government structures to international agencies of the United Nations.
POLICY DOMAINS	**THE THREE DOMAINS OF GOVERNANCE/REGULATION**
POLITICAL ⇔ ECONOMIC	**POL TO ECON**: Supply of "economic policy" or "governance" of the economic domain. **ECON TO POL**: Demands (with accompanying arguments, reasons, principles) made on government by economic actors concerning "the economy" and with regard to the social and environmental spheres.
POLITICAL ⇒ ENVIRONMENTAL	POL TO ENV: Supply of "environmental policy". Environmental management for sustainability may seek: first, the contribution of "natural capital" to economic welfare as a factor of production of economic goods and services; second, the permanence of the ecological welfare base through maintenance of *environmental functions;* and third, "respect for" environment. [The **ENV-TO-POL** linkage is presumed to be "mute" because non-human nature does not voice demands directly in any political forum.]
POLITICAL ⇔ SOCIAL	**POL TO SOCI:** Supply of "social policy" which may seek, in various ways, to mobilise society for the needs of the economic and/or to promote and ensure respect for specified forms of community (etc.). **SOCI TO POL:** Demands (with accompanying arguments, reasons, principles) made on government concerning civil society, the community (etc.) and with regard to economic and environmental spheres.
SYSTEMS INTERFACES	**CHARACTERISATION OF THE INTERFACES OF THE 3 SPHERES**
ENVIRONMENTAL ⇔ ECONOMIC	The ECONOMIC sphere seeks the "SERVICES" of "natural capital" to economic welfare as a factor of production; this engenders "ENVIRONMENTAL PRESSURES" and "IMPACTS" on environmental functioning and (future) services, including (sometimes disruptive) feedback effects on economy and community.
ECONOMIC ⇔ SOCIAL	The ECONOMIC sphere seeks the "SERVICES" of "human capital" (and also of "social capital") to economic welfare; this signifies, on the one hand, (sought-after) opportunities for wealth, revenues, goods and services but, on the other hand, exploitation and perturbation of existing community forms. For the SOCIAL sphere, the ECONOMIC is a means and not an end, and the question is whether "opportunities" provided by the ECONOMIC are nourishing or perturbing of the affirmed values and FORMS OF COMMUNITY.
SOCIAL ⇔ ENVIRONMENTAL	This is the domain of ENVIRONMENTAL VALUES and the matrix of "culture" that determines the "MEANINGS OF NATURE" or the spectrum of "environmental functions" identified by/for a society, e.g., nature as a cosmology, roles as a "source" of well being or wealth, perceived quality of landscape. This is therefore the material-symbolic space of meanings that (among other things) permits members of society to articulate "risks" and to affirm values: sustainability of what, why and for whom (e.g., productive land uses, biodiversity conservation, reverence for nature; rights and duties of the current generation to consume natural capital relative to rights/duties of respect towards future generations...).

Source: Martin O'Connor (2006b)

This complex systems perspective that proposes analysis in terms of four classes of organisation that inter-penetrate — the four spheres — provides a framework within which to reflect on the problems of measurement and uncertainty, and on questions of the limits to and pertinence of quantitative accounting and (as a subset within this) of monetary valuations of environmental change. From this point of view, the four spheres model helps us to highlight two main features:

- **1. Autonomy, Complexity and Indeterminacy of the natural systems upon which human activity depends.** Ecosystems are not markets, and the biosphere processes do not necessarily unfold "harmoniously" in accordance with coherent governing principles. If the biophysical milieu is treated as "exogenous" and invariant relative to a commodity production system, then under certain conventions a system of prices can be defined for the opportunity costs between different economic commodities. But once environmental changes are admitted as significant, this analytical convenience breaks down. The biosphere evolves, locally and globally, under the influence of forces that are largely independent of human action; it is now also subject to uncontrolled (and increasingly severe) perturbations that are "side-effects" of human economic activity. The complex habitats that furnish life-support functions for human and other species cannot be produced in factories. Restoration of ecosystems that are damaged or altered through economic activity or pollution is often impossible. Ecosystem change and biosphere dynamics are not controllable by human intervention in the same way that commodity production processes are. For all these reasons, the provision of many environmental services and also of harmful effects, is characterized by time-irreversibilities by incommensurabilities.[15]

- **2. Distribution conflicts and the multiplicity of societal values**. The significance of nature, and of built environments, is embodied in a person's or a community's way of life, in their institutions and taboos, in their principles and precepts of right conduct, their habits and forms of cooperation. Very often, explicit value statements about the environment emerge only when these principles are compromised or ways of life are threatened: "value" then is associated with social processes of controversy and conflict. So valuation should be taken broadly to refer to *people's notions of what matters for the future, and why*. These choices for the *"distribution of sustainability*" often cannot be quantified, or can only partly be quantified, often only in non-monetary and somewhat speculative terms. **Nonetheless, these arbitrations and compromises over survival, expansion and disappearance of different forms of life, economies, ethical and aesthetic sensibilities, constitute real resource management decisions.**[16]

In short, over and above scientific uncertainties about economic and ecological evolutions, there are also irreducible social obstacles to specification of opportunity costs in monetary terms. These are linked, for example, to notions of rights to life or property for other people or other species, to people's individual and collective senses of the sacred, or to natural or built features that are paramount matters of local identity. In order to allow SA to be framed incisively we must address the question *which sustainability commitments to uphold, why and for whom?* The simple invocation of abstract considerations such as "balance", "symbiosis" or "sustainability" as reference concepts, does not serve as a decision criterion. It does not, for example, guarantee the conservation of specified productive or reproductive potentialities of any particular society or ecosystem. Nor does it assure the sustaining of all the particular economic interests, communities, or ecologies thus given hope. Once sustainability is the desideratum, we must highlight the realities of human actions (and policy choices more particularly) engaging *decisions about the distribution of sustainability:* which interests and forms of life will be sustained, and which ones left behind, relinquished, destroyed or left to rot?

Once this proposition is accepted, it is not in fact necessary to base policy appraisal speculative and counter-factual propositions about the money value of environmental assets and damages (for example, as inputs to CBA). The approach consistent with the complex systems paradigm is to confine monetary aspects of valuation to questions of the economic resources that must or might be committed in order to avoid specified hazards or categories of damage or to ensure the maintenance of specified dimensions of environmental quality or forms of community. The economic logic of

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[15] For some ecological economics entrées into what has become a very large literature, see Passet (1979), Godard (1984); Peet (1992); Norgaard (1994); O'Connor (1989); there are many more.

[16] Ecological harms include the risks and burdens falling on people as a result of pollution or exploitation — for example disturbed or degraded ecosystems, interruptions to ecological life-support cycles, carcinogenic substances and toxic substances in workplaces and in homes, and loss of food production capacity. The unplanned effects on ecological distribution will, in many cases, fully emerge only over long periods of time and across large distances (Martinez-Alier & O'Connor 1996). The interested parties may be extremely diffuse (for example people suffering from health problems induced by or aggravated by urban pollution or carcinogenic substances), or hypothetical in character (future generations that may be affected by climate change, accumulation of toxic wastes). Moreover, people in their different cultural settings articulate their sense of value about themselves, their communities and nature in multi-layered ways (O'Connor 2000a).

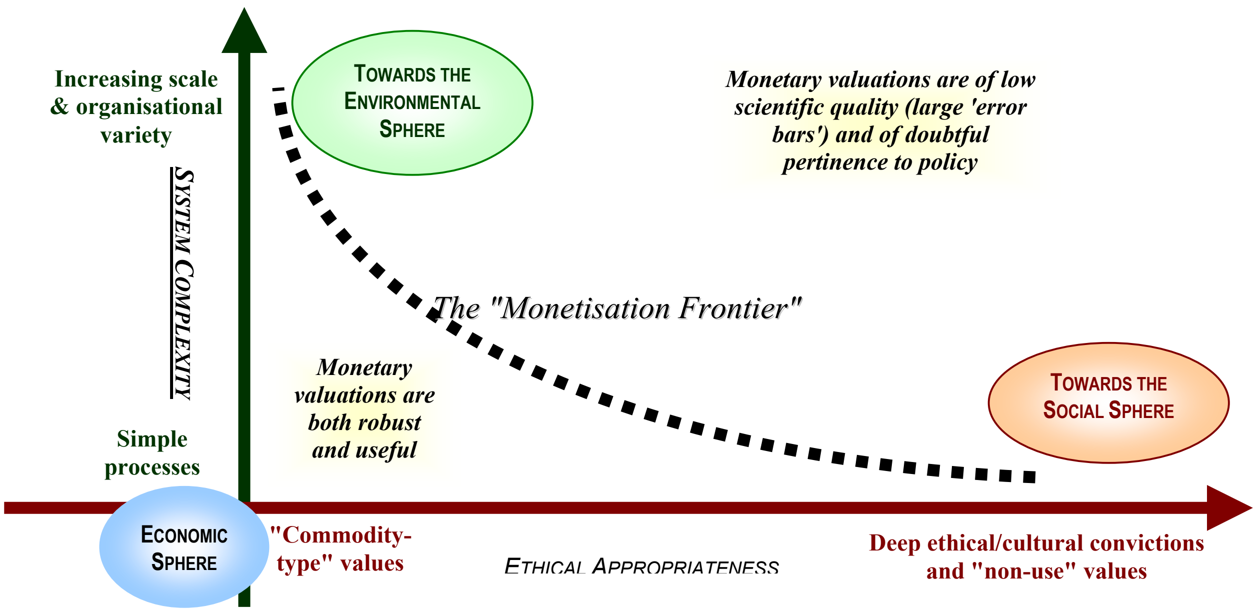
valuation will then be: *first make the proposition to sustain/conserve the forms of community or environmental features in question (e.g., avoid the production of toxic wastes, preserve a designated forest system, or the biological diversity, or other feature of nature), and then investigate what commitments this does or might entail* (O'Connor & Martinez-Alier 1997; Brouwer, O'Connor & Radermacher 1999; Faucheux & O'Connor 2001).

§8. THE FRONTIERS OF (NON) MONETISATION

Whatever the scale at which sustainability policy or appraisal is engaged, reasoning in terms of the four capitals or of governance activity (the political sphere) addressing a "triple bottom line" (of sustainability for the social, environmental and economic spheres) requires us to *specify conventions* for making the distinctions between the "economic" and the "social" spheres, between the "economic" and "environmental" spheres, between the "social" and the "political" spheres, and so on.

Following recent work by O'Connor and Steurer (1999, 2006) in national accounting, we exploit the concept of a Monetisation Frontier (or, more exactly, a set of frontiers) as a didactic mechanism for signalling the demarcation lines separating phenomena attributed to the economic sphere from phenomena attributed to, respectively, the environmental and social spheres (see schema below).[17]

The Monetisation Frontier (schema adapted from that of O'Connor 2006b, following O'Connor & Steurer 1999)



As presented by O'Connor (2000b) following O'Connor & Steurer (1999), the role of the Frontier is to signal thresholds or limits beyond which assessing trade-offs, choices or the consequences of choices on the basis of monetary measures alone is of questionable pertinence. These limits or thresholds may exist for two main reasons: either the estimation is **scientifically very difficult**, or the proposition of a "trade-off" implied by the opportunity cost considerations is deemed **morally inappropriate**. As reformulated by O'Connor (2006b):

- The first frontier relates to physical system complexity and, prima facie with reference to the environmental sphere, concerns matters of scale and aggregation. Physical and ecological systems have an

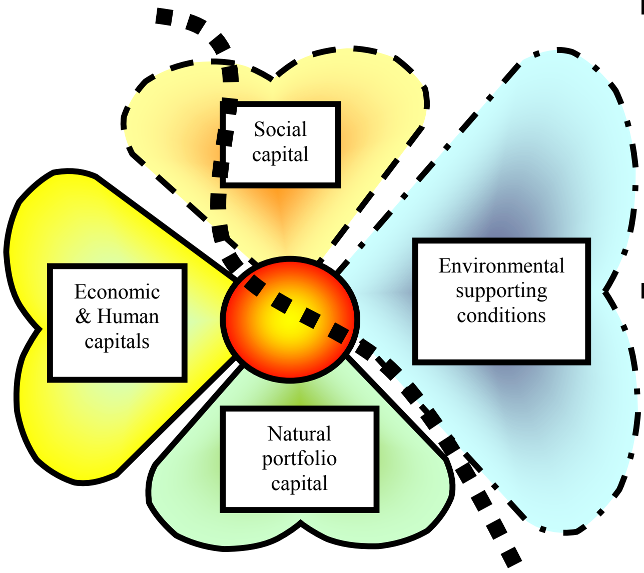
[17] The Monetisation Frontier concept was first elaborated, on the initiative of Martin O'Connor and Anton Steurer during the March 1999 Workshop of the European Union funded Concerted Action 'EVE' (Environmental Valuation in Europe), held in Paris, on the theme of Natural Capital. The concept with its essential motivation was presented in O'Connor & Steurer (1999), and the first published exposition is found in O'Connor (2000b). The exposition here draws on O'Connor (2006b), which re-situates the Frontier concept within the framework of the four spheres.

autonomy and existence in large measure independent of human actions. Although vulnerable to modification under human influence, they are partly exogenous and pre-existing. This has as one corollary, in particular where the physical and temporal scales of the systems under scrutiny are very large (e.g., climate and marine ecosystems, irreversible genetic and toxic chemical transformations), the scientific uncertainties about system dynamics, process interdependencies and (hence) what may come to pass "in the longer term" are inevitably high. The definition of relative opportunity costs, as required for monetary valuation estimates, becomes difficult and sometimes arbitrary.

- The second frontier relates to ethical appropriateness and, with primary reference to the social sphere, concerns the kinds of value involved. All technology choice, land use, infrastructure investment and territorial governance (etc.) decisions have ethical components. These are seen, in some cases, in questions of present-day fairness (as in North-South redistribution) and in the equity issues relating to future generations (the opportunities afforded to them and to the dangers and burdens we have imposed), and also in debates about the moral acceptability and social justifications for intervening in the genetic integrity of organisms, destroying habitats of endangered species (and so on). Where cultural or ethical convictions are fundamental, and where the values of nature in question involve notions of respect (for self and for others), of justice and honour, cultural identity (and so on), then assessment problems take the form more of arbitration between different principles, forms of life, forms of community (etc.) to sustain or respect, than of a comparison of monetary values as in economic optimisation.

This framing gives us some purchase on several points of debate in the fields of greening the national accounts and in the evaluation of trade-offs between environmental and other economic, fiscal and social objectives. If we pose the question of the usefulness of monetary valuations of environmental assets, goods and services, and degradation, then in effect the question being posed is: *Where should the Monetisation Frontier be drawn, and why?*

For example, the two adjustment concepts distinguished in **Section §5** above, which lead respectively, to *AICCAN* and *geGDP* measures, are based on different conventions about (1) where to situate the Monetisation Frontier and (2) how to work at, and across, the boundary. The respective conventions result in quite different quantitative accounting requirements as well as distinctive policy relevance for the indicators obtained. In order to appraise the usefulness of each class of adjusted aggregate, it is important to specify the sorts of economic action or policy objective that they address. In this regard:



- The *AICCAN*-type monetary measures of net asset change involve the assessment of natural resources and assets essentially from the point of view of their contribution (actual or potential) to the production of commercially priced goods and services (e.g., trees into wood products, human health for its impact on worker effectiveness).
- The greened economy GDP, or *geGDP*, by contrast, assesses the significance of natural capital systems in non-monetary terms and gives an indicator of prospects for maintaining economic development while ensuring the maintenance of the environmental functions of natural capital *in situ* — that is, as sites, scenery, scientific interest and ecological life-support.

We may consider again, in this light, the question of the feasibility and pertinence of monetary valuation for different categories of natural capital for inclusion in a *AICCAN*-type macro-economic indicator adjustment process. Classification issues for valuation can be portrayed by a 'shamrock diagram' (above, adapted from O'Connor 2001), which distinguishes the main classes of a society's capital. Three inter-related questions arise:

- What is to be placed in the 'petal' of natural portfolio capital and what is to be left over on the right hand side in the environmental supporting conditions?
- Where, more generally, will the Frontier of Monetisation be drawn (symbolised by the heavy dashed curve) separating societal and environmental assets whose value to society is presented in monetary terms,

from assets whose significance is defined through non-monetary indicators, goals and sustainability standards?

- What methods can be used, in each domain, for obtaining the necessary quantifications?

Evidently, a significant part of produced economic capital can be inventoried, and aggregated, in monetary terms; and indeed, this sort of practice falls within the usual work of traditional national accounts. Evidently also, certain elements constituting 'natural portfolio capital', such as standing forests or proven mineral resources, can pragmatically be inventoried in monetary terms (with some estimation difficulties, however, that mean that the monetary results for these selected assets are not always as useful as one would like). The categories of social capital and the supporting physical environment outside the commercial sphere, might also, in principle be inventoried with an appropriate variety of quantitative and non-quantitative monetary indicators. So where do we draw the lines, and why?

O'Connor & Steurer (2006) have given examples of clusters of environmental assets and their functions which, for accounting purposes (and with a view to decision support and indicator estimation) could be placed, typically, on one side or the other of the Monetisation Frontier. They suggest

- A monetary valuation approach can be highly useful for issues of quantified natural resource depletion such as forests, minerals and petroleum. It can also be used for scorekeeping, e.g., aiding the monitoring of resource rents captured (or not captured) from period to period.
- Some resource depletion and ecosystem protection issues which are associated with high uncertainties, and hence difficulties in quantifying long run environmental and economic consequences, can nonetheless be treated meaningfully with the *geGDP* cost-effectiveness approach. Examples are fisheries (where catch limits can be proposed), freshwater pollution (where concentrations of contaminants can be measured and various emissions thresholds can be applied) and atmospheric pollution (including greenhouse gas emissions and CFCs implicated in ozone-layer destruction, for which emissions and concentration targets can be policy reference points).
- Some environmental issues (biodiversity protection, for example) may pose difficulties for both approaches to indicator specification. Measures for protection of individual ecosystems or population levels of target species can sometimes be put into cost-effectiveness analyses, and thus incorporated within *geGDP* estimates for specific country purposes. But there is little consensus about meaningful indicators of biodiversity change and biodiversity value on a global scale or across a wide diversity of ecosystems. This limits the applicability not only of monetary valuation concepts, but also standards-based analyses.

Of course, many categories of air, water and soil accounting (assets, associated pressures, quality enhancements and degradation) furnish examples of investments and 'dis-investments' in natural capital that could be the object of valuation approaches on *both* sides of the Monetisation Frontier. O'Connor & Steurer (ibid.) have suggested that this can be conceived of as a sort of *tâtonnement* process, not in the sense of finding a 'market equilibrium' between supply and demand, but rather in the sense of the integration of scientific, economic and social dimensions of information in political processes that resolve the 'social demand' for maintenance (or not) of environmental functions. For example,

- on the one side of the Frontier, economic analyses may seek to estimate monetary value of losses to economic production due to health and ecosystem damages from, for example, air pollutants such as acid rain, urban smog, particulates (etc.…) ;
- on the other side of the Frontier, economic costs of meeting emissions targets can be estimated, based on various scales of firm, sectoral and national economy analyses. Less tangible benefits of lower pollution may be layered in as qualitative considerations.

Costs of meeting targets, estimated through model analyses of the economy, can then be presented and considered, in a policy process, in relation to the identified economic production and human welfare benefits of less pollution. In this way an understanding is built up of justifications for lower pollution and of the implications for the economy and for society of achieving lower pollution. The procedure can be repeated for each major category of environmental risk or damage, thus establishing an information base for negotiation of environmental and economic policy targets and priorities. What matters most is the learning about natural systems, technological potential, economic systems, and policy processes that can take place through construction and comparison of the different aggregates, model outputs and scenarios.

§9. Qualitative and Quantitative Performance Principles & Norms

The didactic concept of a Monetisation Frontier allows us to approach questions of policy evaluation and of the "social demand" for sustainability via the distinction between "**ends**" (the social and environmental values to be sustained) and "**means**" (the economic, and also political, considerations for upholding the espoused values). This distinction between ends and means is, of course, not new to economics. But, whereas the neoclassical welfare and capital theoretic approaches tend ideologically to privilege the exercise of choice by 'sovereign consumers' and the role of market mechanisms (or their model analogues) in assuring an efficient mobilisation of the factors of production relative to the 'demands' that the market reveals, the complex systems approach to SA puts the accent on the roles of inter-subjective, cultural and political process for expressing collective values and principles (the society's "**ends**") with reference to which individual stakeholders and communities will construct and resolve their opportunities.[18]

In the pursuit of sustainability goals, a great variety of private and public policy, investment and stewardship decisions are made that respond, in various ways, to demands towards the POLITICAL sphere made by actors from the SOCIAL and the ECONOMIC spheres. These demands are, essentially, claims about *what* should be respected and sustained (in the Economic, Social and Environmental spheres), accompanied by propositions of *reasons why* these things should be respected and sustained. Enlarged national accounting must be responsive to the societal requirements to organise information of the state of the environment, vulnerability and change with reference to high-level notions of collective purpose, identity, value and duty (etc.).

Let us return in this light to the now traditional formulation of strong sustainability referring to natural capital in aggregate terms, separate from manufactured capital, and requiring non-negative change in the "natural capital stock" through time. We have already accepted (as Victor et al., 1998 and many others in ecological economics have affirmed) that there is no meaningful way of aggregating the grand diversity of natural resources, environmental services and ecosystems (etc.) so as to quantify this rule. Does this mean that the Strong Sustainability perspective is also invalidated?

To some extent this difficulty can be overcome through introducing concepts such as **critical natural capital** or **environmental services**, which refer to specific environmental resources or system capacities that perform important welfare support (or other) functions. The terrm 'critical' is introduced to signal the proposition that no substitute is readily available in terms of manufactured, human and social capital. Strong sustainability is then framed in a disaggregated way, in terms of the requirement for maintenance of these environmental capacities or functions. Cumulatively, this translates into a commitment for maintenance of the integrity of the environment (which, in this sense, is considered loosely as a "fund" or a "capital stock" in the economist's sense), without however presuming to make any aggregate valuation of this stock.

Policy applications can then, in principle, proceed by specifying (or asserting) environmental standards or thresholds below which the environmental function is not maintained (or there is a significant risk of it being lost or impaired, etc.); these "critical considerations" are *performance standards that ought to be respected.*

Proposals for environmental protection (or, in the language of capital theory just introduced, for the maintenance of some critical natural capital) will often be justified by systems-type arguments of the need for these environmental functions as pre-conditions for economic (and social) sustainability. But, they will also, very often, be justified in terms of ethical or environmentalist attitudes that affirm a duty or desire for respect of the existence of the environmental features in question, and/or of the forms of community (human and otherwise) supported by these environments (or, again in the capital theory language, for the maintenance of some morally "critical" social capital). In other words, the

[18] There are precedents in political economy at least as far back as Mill (1861); for more recent examples see, for example, Sagoff (1998), Holland (1997); O'Neill (1997), Foster (ed., 1997).

ethical appropriateness considerations relating to moral and cultural determinants of the *pertinence* of monetary valuations are as much pertinent for the ENVIRONMENTAL as for the SOCIAL sphere.

In this regard, the demarcation principle being proposed via the Monetisation Frontier concept, separating the "economic" from the social and environmental spheres, is based on the identification of distinct zones of wealth and communities of interest that are considered, for policy purposes, as "*ends in themselves*" — that is, as "critical" and non-substitutable and whose "respect" is to be considered as a bottom-line in a way complementary to the economic performance bottom line.[19] Retaking the characterisations already sketched above:

- In the case of NATURAL CAPITAL we identify, on one side of the Monetisation Frontier, resources and assets that are valued within the conventional logic of the economic sphere, that is, from the point of view of their potential conversion into commercially priced goods and services (trees into wood products, for example); and, on the other side, assets that are valued from the point of view of their permanent roles in the bio/natural sphere as *in situ* services as sites, scenery, scientific interest and ecological life-support in complement to economic sphere activity.
- In the case of SOCIAL CAPITAL we consider, on one side, the potential of societal assets as factors of production for economic wealth creation; but, on the other side, we designate the contours of the social sphere by specifying the classes of community (spanning (present humanity, future humanity and non human communities) meriting to be sustained.

Once these frontiers are drawn and the performance obligations or targets are set, cost-effectiveness analyses can be elaborated by exploring the least-economic-cost way of achieving the defined norm at an appropriate scale of analysis (cf., Faucheux & O'Connor 2001). This gives an operational meaning to the notions of (1) estimating *"economic costs for respecting the integrity of the environment"* on the interface of the Economic and Environmental spheres and also (2) estimating *"economic costs for respecting the integrity of social capital",* on the interface of the Economic and Social spheres. Such work can be made as inputs into a deliberative process of Sustainability Assessment.[20]

Although our principle concern here is environmental accounting and, hence, natural capital, it is useful to note the importance of these considerations of ends and means when we adopt a generalisation of the strong sustainability criterion to require maintenance of a multiplicity of distinct classes of capital. Consider momentarily in this light the question of social capital. As in the case of natural capital, it rapidly becomes clear that it is hardly meaningful to seek to quantify an absolute value for the "fund" of social capital. More important in practice, is to identify significant changes in the capacities of distinct stakeholder groups, communities and societies, and to explore the costs or constraints on economic activity associated with assuring their integrity through time.

Sustainability assessments therefore need, one way or another, to make reference to two sets of principles: **"systems integrity"** and **"ethical integrity".** The systems integrity concern can be expressed, in general terms, as the principle of maintenance of the "four capitals". However, in order to give this general precept a societal and political meaning, a necessary complement is to be added, by considerations along ethical plane, namely, the application of *a principle of respect for multiple classes of community*.

This is where the question of the "stakeholders in sustainability" (and in SA) takes on its paramount importance. Just as *social choice* decisions about the distribution of income, wealth and exposure to risk are matters of responsibility and justice (etc.) that have to be arbitrated through political processes, the "social dimension" of sustainability performance assessment is irreducibly a matter of social choice. O'Connor (2006b) suggests, in recognition of this proximity with the economist's welfare theoretic distribution problem, that an operational specification of the social dimension should start by *deliberation about the (relative and absolute) status to be given to the various candidate*

[19] For example, the principle of precaution can be considered a normative principle in this sense, complementing or replacing the substantive principle of non-negative change in critical natural capital under conditions of uncertainty.

[20] As pointed out by the *GREENSTAMP* Project in the context of environmental standards, the work of cost estimation and cost-effectiveness appraisal must be carried out differently at different scales (Brouwer et al., 1997, 1999; see also O'Connor & Steurer, 2006). In effect, scenarios can be explored of the economic costs associated with different means of achieving targets, with different levels or targets of performance (perhaps as a function of divergent stakeholder positions), and with different models and methods of estimating costs.

stakeholders in sustainability. This can be formulated as a sort of "ethical appropriateness" test to be applied to each prospect of conversion (or question of potential convertibility) of a societal value into monetary currency (viz., in the marketplace). This "test" is epitomised by expressions such as *"save the whales"* or *"you don't sell your own grandmother"* — declarations that point to something other than a purely economic/utilitarian motive for the respect of systems integrity, whether in the environmental or social domain.

Principles of respect are not panaceas. Just as in most problems of justice, there arise, in every sustainability policy domain, difficult questions of fairness in the distribution of opportunities, benefits, costs and risks within each community of interest. This focus on social capital in terms of communities, their differentiation one from another, and the question of their respect, nonetheless allows the definition of an important class of performance criteria — namely, indicators of individual and collective capacities and, correspondingly, of poverties. We illustrate this (see inset box) with the example of a typology of nine different basic human needs developed by Max-Neef (1991).

- The first two needs in Max-Neef's the list — subsistence and protection — relate to survival and comfort of the biological organism, and can appropriately be attributed to Human Capital.
- The remainder of Max-Neef's categories are strongly relational in character (notably: affection, understanding, participation, identity) and, in this sense, characterise Social Capital.

Inadequacy in relation to any one of these categories constitutes POVERTY. This suggests a two-tiered framework for the articulation of performance goals or criteria with reference to diverse *stakeholder communities*.

> **NINE DIMENSIONS OF WELL-BEING AND POVERTY**
>
> ***Subsistence, Protection, Affection, Understanding, Participation, Idleness, Creation, Identity, Freedom***
>
> *Source*: M.A. Max-Neef (1991), *Human Scale Development*.

- The primary level of analysis would specify obligations of respect for the stakeholder classes or communities given standing — in other words, identification of the classes of community meriting respect and of the forms or norms for expression of that respect. (Given the 'monopoly' presence of the present generation, it is up to today's policymakers and citizens to affirm duties towards — or, by proxy, the 'entitlements' of — future generations, endangered species and ecosystems, vulnerable peoples and so on.)
- The second level of analysis would address fairness or unfairness in access to services, distribution of opportunities, vulnerability, stresses and risks (etc.) within each class.

Indicators at the first level are essentially qualitative, for the identification of the stakeholder classes involved and of the terms in which respect is due. Indicators at the second level can often be quantitative, as a function of the various notions of capacity, vulnerability and poverty (etc.) involved.

> An example of POVERTY ALLEVIATION as a precept for policy choice is the *theory of justice* put forward by John Rawls in *A Theory of Justice* (1971), by which an action is 'just' if it improves the well-being of the worst-off individual or category of society, and 'unjust' if it worsens the well-being of the least well off category in society. The policy goal is one of *reducing life-threatening stress* due to VIOLENCE, to POVERTY of available means of subsistence, or to other LOSS OF CAPACITIES (including communication lines in political processes, etc.). Indicators developed according to this criterion give guidelines as to the sign (plus or minus) to be attributed to systems change indicators as a function of the impacts of the project/policy for each major class of community and its components.

It is obvious that, although environmental accounting may not be concerned specifically with social poverty indices, there are many categories of information about access to environmental assets and services that will be relevant in this sort of social and economic policy domain.

§10. SUSTAINABILITY QUALITY-PERFORMANCE MULTIPLE BOTTOM LINES

In **Sections §7, §8 & §9**, we have characterised the societal project of sustainability as the pursuit of a trajectory of co-evolution of economic, social, biophysical and political systems with a view to simultaneous respect of "**Sustainability Quality-Performance Multiple Bottom Lines**".[21] We have

[21] Probably the most well-known exposition of co-evolutionary perspectives on sustainability is given by Norgaard (1994). However, the decades from the 1970s have seen quite a diversity of such contributions reflecting the 'spirit of the times', including Passet (1979) and Gowdy (1994). There is a continuum between explicitly co-evolutionary perspectives and others of more institutionalist character espousing multiple bottom

also noted that, with this referent of **SQPMBLs**, assessment from the point of view of sustainability presents the same sort of structure and dilemmas as the generic economists' social choice problem, as formulated by Nobel Prize winner Kenneth Arrow in the post-WW2 years.

In general terms, the *social choice* problem is to decide, for a society made up of many constituents having non-identical interests and value systems, what might be desirable within the bounds of the feasible. When articulated in everyday language, this takes on the form of an arbitrage between different principles that might guide or govern the distribution of opportunities across — in our context — sustainability's stakeholders. Following the Brundtland formulation (WCED 1987) we can adopt as one of the specifics of sustainability, the tension between present and future generations. But this tension has also to be situated within the broad pre-existing contexts of cultural diversity (and antagonisms), the power blocs of geopolitical and globalised economic jostling, concerns for poverty within and between societies, and the environmental ethics questions of respect for the natural world and for non-human biodiversity. The present/future line of tension is one aspect of a more general structural opposition — between 'us' and the 'others', between self-interest and interest in the livelihoods of others, between human and non-human communities, between 'our' culture (whichever it is) and other cultures, and so on.

The formal treatment of the social choice problem (see Arrow 1963; also Sen 1970), led to a paradoxical result that, for some, has seemed like an impasse but which opens the doors to a deliberative political model. The apparent impasse consists of the so-called "Impossibility" results, which, briefly and roughly speaking can be formulated as follows:

- On the one hand, if the attempt is made to advise on what is "best" for the society on the basis of a "general" rule (or set of criteria), then the choice comes down to one between Dictatorship or Inconsistency;
- On the other hand, if both Dictatorship and Inconsistency are to be avoided by weakening the rule system, then either the advice may be indecisive or the possibility is opened to dishonourable outcomes.

The impasse is really only formal. There is a simple way of moving forward, through accepting that performance criteria will generally be multiple and not always reconciled.

If we adopt this view, then it follows that no amount of work at construction of indicators or generic choice algorithms can, on its own, solve the problem of reconciling the contradictions between multiple quality criteria or sub-goals. There is a need for social process. For example Commons (1934, p.712) in his *Institutional Economics*, taking the cases of legal tribunals, had offered an elaborate plea for a process view of economic reasons and reasoning:

> *"The Court enters beneath the letter of the law and investigates the economic circumstances out of which the conflict of interest arises. Each dispute is a separate case with its own facts, although these facts may be brought within general principles and reconciled with particular precedents discovered in similar cases. The general weighing of all the facts thus investigated, in view of all these principles and precedents, is the process of deciding what is reasonable under all the circumstances."*

Commons here insists that no general formula could be relied upon to produce "reasonable" outcomes in application to all sets of problems of fairness and justice in resource allocation. Reasoned and reasonable compromises would have to be deliberated and worked out in a permanent social process. Moreover, this permanent working out of our coexistence problems centres on the substance and significance given to redistribution of risk and economic opportunities — that Samuels and Schmid would later call the "distribution of sacrifice" — at any moment in time and projecting into the future. In other words, if a reasoned basis for action is to be established, then forms of deliberative and regulatory procedure must be established that "relativise" the contradictory positions while not seeking entirely to dispose of any of them. The challenge is to work with a permanent argumentation between the several contradictory positions. An analyst in such circumstances needs to be like a "midwife of problems" (Rittel 1982, pp.35-48), helping to raise into visibility, "*questions and issues towards which*

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lines, for example Ignacy Sachs (1980, p.37) who set out notions of *eco-development* as *"...a development of peoples through themselves utilizing to the best the natural resources, adapting to an environment which they transform without destroying it. [....] Development in its entirety has to be impregnated, motivated, underpinned by the research of a dynamic equilibrium between the life process and the collective activities of human groups planted in their particular place and time."*

you can assume different positions, and with the evidence gathered and arguments built for and against these different positions".

§11. Pragmatic Organization of Environmental Accounts

What guidance can we propose, therefore, as to the reference points for environmental accounting that seeks to aid our navigation with a view to sustainability? We have presented the "four capitals" model (with its variants) and the "strong sustainability" injunction for maintenance of each category of capital as a complement to the others; and we have presented the "four spheres" coevolution model. Various other generic concepts come to mind, such as *stewardship, precaution* and *inter-temporal fairness in distribution*. These are all examples of principles that are too abstract in their generic formulations to provide operational policy guidance, but which be given more specific content in any particular context.

Recent work by O'Connor & Spangenberg (2007) has suggested ways that sustainability assessment work can be organised in a multi-layered way, with three main levels moving "upwards" and "downwards" around a discursively derived set of **SQPMBLs** (*Sustainability Quality-Performance Multiple Bottom Lines*). Their schema proposes, as the articulation of the upper and middle levels, a generic versus specific interface — *a sort of theoretical "top-down and bottom-up" dialogue requirement* — relating to the establishment of the **SQPMBLs**. Then it proposes, as the articulation of the middle and bottom levels, the mobilisation of a *representative diversity of indicators* whose role is to signal the preoccupations of the full spectrum of stakeholders across the spectrum of performance issues and to permit an assessment that is transparent and robust for this full spectrum of issues and stakeholders. This multi-layered discursive approach thus considers sustainability goal specification and indicator development as a deeply social decision making process for which a diversity of viewpoints must be brought together in a structured way, in order to furnish a robust and pertinent representation of the sustainability governance challenges.

SA Level	Outcome
Characterising "Sustainability"	Agreement about the vision of "Sustainable Development" or "Governance for Sustainability" as the pursuit or achievement of a coevolution of interdependent systems respecting simultaneously multiple "bottom lines".
Articulating the relevant "Bottom Lines" "Sustaining of What, Why and for Whom?"	Agreement by Stakeholders on the set of Performance/Quality considerations that are affirmed as "Bottom Lines" for the specific policy situation or class of management challenges being addressed.
Proposing and Mobilising Baskets of Indicators for each category or sub-category of CSR Performance	Consensus about baskets of appropriate indicators to be mobilized in each category of SA, as a function of issues, stakeholder diversity and the range of sites, scales and options under discussion.
	Source: O'Connor & Spangenberg 2007

This vision has important consequences for environmental accounting conventions. There will necessarily be a tension between decisions for "high level" organisation of accounts with a relatively small number of key themes, and the need/desire for sensitivity to the great variety of situation specific elements. In other words, given the diversity of sustainability considerations at multiple scales and expressed at different levels of abstraction, the starting point for integrated economic and environmental accounting is always confusion. One way out of this confusion (with its plethora of "weak signals") is to propose the structuring of the accounting terrain with reference to **a relatively small number of "strong SQPMBLs".**

- Sometimes the **SQPMBLs** might be explicitly based on 'generic' sustainability preoccupations, e.g., systems theoretic considerations such as the four capitals or the 'four spheres';
- Sometimes the **SQPMBLs** will be obtained empirically, e.g., identifying the strategic goals or governance issues for a specific business context or territorial authority or national agency (etc.);

Any putatively generic framework has to be given a specific and policy-relevant content and, this depends in part on the 'values' that the society affirms.[22] **Therefore, we conclude that there is an irreducible requirement for the identification of "strong SQPMBLs" based not only on theory, not only on expertise, but also on stakeholder dialogue.** This signals the importance of well-structured procedures for articulating sustainability goals and sub-goals, and assessing the adequacy of accounts in a pragmatic way against these goals. This will need to be an iterative process, and will engage a *bottom-up* social science as well as a *top-down* systems science framing of appropriate conventions for integrated economy-environmental accounting.

Quality Considerations for National Sustainability Indicators

- *scientific adequacy:* do the description and evaluation methods deal well with the important features of the natural world and of the ecological, technological and social change processes in question?
- *social adequacy:* do the methods furnish information in ways that respond to stake-holders' needs and that support social processes of decision making?
- *economic rationality:* do the suggested choices or courses of action that emerge from the valuation, statistical analysis and modelling procedures respect economic efficiency, in the sense of appearing to be reasonably cost-effective ways for moving in the desired directions or for arriving at the envisaged outcomes?
- *statistical adequation* can the methods and measurements proposed be implemented in conformity with established quality standards in statistical work, within the budgets available for this work?

— Source: Brouwer & O'Connor (1997a, 1997b), *Methodological Problems In The Calculation Of Environmentally Adjusted National Income Figures.*

In their summing up of the *GREENSTAMP* project's recommendations about appropriate methods for calculation of environmentally adjusted national income figures, Brouwer & O'Connor (1997a, 1997b) argued for the importance of four broad sets of quality considerations (see inset box on the left): *scientific adequacy, social adequacy, economic rationality and statistical adequation*. No one of these four criteria on its own, it was argued, is enough to judge the adequacy of an approach to development of macro-economic indicators for sustainability:

"Our work has consisted of a process of 'tuning' theory, statistical concepts, actual measurement and the corresponding interpretation and use of results. When it has turned out that a theoretical concept is not applicable to the situation being analysed, or that it cannot be measured in a reliable way, then we have abandoned it as inadequate for offering policy guidelines."

The set of ***methodological*** **QPMBLs** relate, in sum, to the challenge of the question of *mobilisation of knowledge* and of *working effectively with different forms and sources of knowledge* under conditions of complexity.

[22] It would be a very big task to make a survey of examples of discursively established sets of "strong **SQPMBLs**" in ecological economics, integrated assessment, project and policy evaluation, CSR assessment, SEEA and other SA fields. In a separate **APPENDIX** we give a range of examples of discursively established sets of "strong SQPMBLs". Some of these are quite close to the "four capitals" and "four spheres" conceptual frameworks; others are quite differently conceived or only loosely coupled