ECOSYSTEM AND ENVIRONMENT DEVELOPMENT INFORMATION AND KNOWLEDGE

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Contents

Summary

This contribution reviews some of the frameworks that have emerged in systems science, ecological economics and environmental accounting for organizing information about the physical environment and ecosystems as a support for sustainable development policies. Environmental information in the context of sustainability policy, centres on the coevolution between a system and its environment. Where emphasis is placed on ecosystems (and the biosphere more generally) as dynamic processes, information may be developed in terms of the 'functioning of' these systems and their roles or 'functions for' the support of economic activity and human well-being. For those preferring the language of 'opportunity costs', the making of inventories of environmental pressures and changes is a crucial step towards comprehensive

environmental cost-benefit analysis. Work on both sides of the 'Monetization Frontier' can be a basis for defining sustainability standards, critical thresholds and performance goals. At the national economy scale, the various information perspectives may be applied for estimation of environmentally-adjusted macro-economic sustainability indicators, the so-called green(ed) GDP measures. Information systems as supports for governance processes illustrate a recursive relation between learning about natural systems and their potentials and deliberation within society about the justifications for and against different policies. Effective use of information must confront distinctive challenges of knowledge quality assessment, including differences in underlying values, working with uncertainty and indeterminacy (and the tension between foresight and adaptation), and the multiple spatial scales and time horizons.

1. Introduction

Human knowledge and appreciation of the natural world has an indefinite variety. This chapter reviews some of the main frameworks that have emerged in systems science, ecological economics and environmental accounting for organizing information about the physical environment and ecosystems as a support for sustainable development policies. If, by a few examples, the feeling is conveyed of the great richness of the appreciations we may have for nature, then the purpose is served.

Environmental information in the context of sustainability policy is not merely cognition for the sake of cognition. Rather it is intended to be in the service of a particular '*projet de société*', the permanent viability of the relation of coevolution between a system and its environment. This will be our point of departure in **Section 2**.

Since sustainability itself can be framed in a variety of ways, so also the frameworks for information and policy guidance can vary. In **Section 3** we introduce the notion of the Monetization Frontier, a methodological boundary dividing environmental information cast in monetary terms, from information in a variety of non-monetized forms. For those preferring the monetization side of the frontier, the making of inventories of environmental pressures and changes is a crucial step towards comprehensive environmental cost-benefit analysis. For those on the other side of the frontier, where 'monetization' is eschewed, multi-dimensional information sets on the state of the environment and on the various 'pressures' imposed by human societies on their environments, can be a basis for defining sustainability standards, critical thresholds, management and performance goals.

Section 4 looks at ways of organizing ecosystem information - environmental resources, values, assets, landscape features and so on - from the point of view of joint economic and environmental sustainability. Where emphasis is placed on ecosystems (and the biosphere more generally) as dynamic processes, information may be developed in terms of, first, the functioning of these systems in themselves and, second, the services or functions provided by natural systems for economic activity and human well-being.

Section 5 discusses briefly the application of approaches on both sides of the Monetization Frontier, at a national economy or macro-economic scale. Here, the various information perspectives may be applied for estimation of environmentally-adjusted macro-economic sustainability indicators, the so-called green(ed) GDP measures.

Section 6 highlights the complementary and recursive relation between, on the one hand, learning about natural systems and their potentials and, on the other hand, deliberation within society about the justifications for and against different policies.

2. Being and Knowing about Nature

Human societies have formulated a fantastic range of forms of knowledge about the natural world. What we know, first, is our being-in-the-world. In the language of two contemporary biologists, Umberto Maturana and Francisco Varela, the life process is essentially a process of cognition. For the study of living organisms, we can represent the living 'system' in relation to its environment; and then we can apply various concepts, measurements and tools of open systems theory in order to discuss the relationship and co-evolution of this system and its environment. By extension and analogy, it is possible to consider built economic structures, and ecosystems, as processes or 'systems' that are autonomous on the one hand (with their characteristic internal functioning) and inter-dependent with the rest of the world on the other hand. We realize that a system that is 'open' in this way, can evolve, change or die. An organism aware of its own being, is also aware of becoming: it may change or die. This accounts for why, most often, environmental knowledge (or lack of it) is taken for granted until there is a threat of some sort.

The sources of environmental concern in our contemporary societies are complex. It is useful to distinguish three main facets which, overlapping in various ways, are the object of our learning, information and ignorance. These are: (1) economic livelihood interests, such as food security, energy, clean water and air; (2) natural richness of living communities and ecosystems; (3) cultural and symbolic significance including history and landscapes. Appreciation of nature thus takes many different forms. A forest can be a place to walk in with a lover, a favoured area for hunting, a child's delight, a domain of botanical fascination, a place of death and burial or tribal elders, a source of essential food and firewood, a tourist destination, or a jumble of rocks and weeds that is merely a piece of Brahma's dreaming. The catalogue of environmental 'information' must echo this diversity of human ethics, meaning and perception.

3. Natural Capital and the Monetization Frontier

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.

3.1 The Concept of Natural Capital

It has, by now, become commonplace to refer to ecological goods and services as deriving from existing stocks of 'natural capital'. This involves the simple extension of the well-established economist's 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.*

Environmental systems and natural resource stocks provide benefit streams to society. The sustaining over time of these benefit streams is one of the preconditions of sustainable development. This requires in turn, the maintenance of adequate levels of the key 'natural capital' stocks themselves. So natural capital covers far more than specific minerals and fuel sources, it refers to the earth as a life-support system. In this regard, one must straight away remark on some qualitative differences between natural capital and man-made (or manufactured) capital, related closely to issues of irreversibility and uncertainty.

- First, natural capital is essentially an endowment of nature and not producible by human societies. The endowment can be somewhat modified, but, as in the example of the atmosphere, mineral deposits or genetic components, the "base" is given and is substantially irreplaceable.
- Second, environmental resources are not just stocks, they are dynamic systems and infrastructures that have a multiplicity of functions including life-support for human as well as non-human communities. It is not wholly possible to substitute manufactured capital for natural capital as a basis for human life-support.
- Third, changes in the natural environment caused by human activities are often irreversible. The irreversibility of energy use for production has been emphasized, on thermodynamic grounds, by Nicholas Georgescu-Roegen and energy analysts during the 1970s. Biologist Rachel Carson in the 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 is the production of a variety of chemical toxic wastes. When Amazonian jungle is cleared on a large scale for timber or farmland, it is impossible to recreate a comparable ecosystem.

3.2 Sustainability through the Maintenance of Natural Capital

One approach to framing policies for sustainability, is the requirement that present generations' economic activity not prejudice the welfare of generations to come by running down irreversibly the stocks of environmental assets. Economists in this context have proposed a rule of 'non-negative change' to natural capital - that is, maintenance of the stocks of natural resources such as soil and soil quality, ground and surface water and their quality, land biomass, water biomass, and the waste assimilation capacity of receiving environments.

Giving an operational meaning to this rule requires a procedure for measurement and evaluation of the natural capital stocks. The diversity of the environmental capitals is very great, and it is hard 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. Economists have considered possibilities of aggregate measures of capital stock. 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 also has insurmountable difficulties of operationalization. In standard economic analysis, relative prices are used as an estimator of opportunity costs associated with production or use of different goods and services. Yet 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, and such estimates are highly speculative. If physical units are used, a variety of scientifically valid measures can be obtained such as tonnes of material or joules of available energy. One is then faced with the question of meaningfulness of aggregate measures for composite stocks. In general, there is no satisfactory indicator for the total quantity or stock of natural capital. At a disaggregated level, however, it may well be possible to define physical measures of stocks and of the quality of goods and services obtainable.

3.3 The Monetization Frontier

The difficulties with attempts at monetary evaluation of environmental assets, goods and services, are directly related to the attempt to transpose traditional economic valuation methodologies into domains for which they was not originally devised, namely: (1) extension spatially and materially to the non-produced and largely non-commodified natural environment; and (2) extension temporally to the long term of ecological change and sustainability concerns.

For many categories of environmental change, estimations of the impacts (harmful or otherwise) in monetary terms can only be incomplete and extremely speculative. One example is be the cumulative ecosystem, human health and other impacts (harmful or otherwise?) of genetically modified organisms (including humanish ones) introduced into the biosphere. At a social level a variety of cultural, ethical and historical factors may bear strongly on individual and collective evaluations, for example, notions of rights to life or property for other people or other species; people's individual and collective senses of the sacred; natural or built features that are paramount matters of local identity. Moreover, environmental decision-making necessarily works to privilege some interests and criteria, while others may be cast aside as counting for nothing. Debates over fairness arise whenever those who reap the benefits and those who bear the costs are different constituencies. This is plainly the case with inter-temporal distribution issues related to irreversible ecosystem damage (species loss, deforestation, aquifer water and soil contamination, etc.), genetic modifications and disposal of durable toxic wastes.

Reflection around these questions has led to the development of a simple heuristic concept, the *Frontier of Monetization*. This concept addresses (a) the extent to which monetary valuation can be scientifically meaningful, and (b) the policy relevance, or not, of the monetary figures. According to Martin O'Connor and Anton Steurer, the originators of the concept, there are two main dimensions along which debates are aligned. The first concerns matters of scale and aggregation, the second concerns the "kinds" of value involved. The considerations can be portrayed schematically in a graphical representation, as below (Figure 1). The idea is to highlight zones where monetary valuation is relatively more, or less, meaningful and policy-relevant.

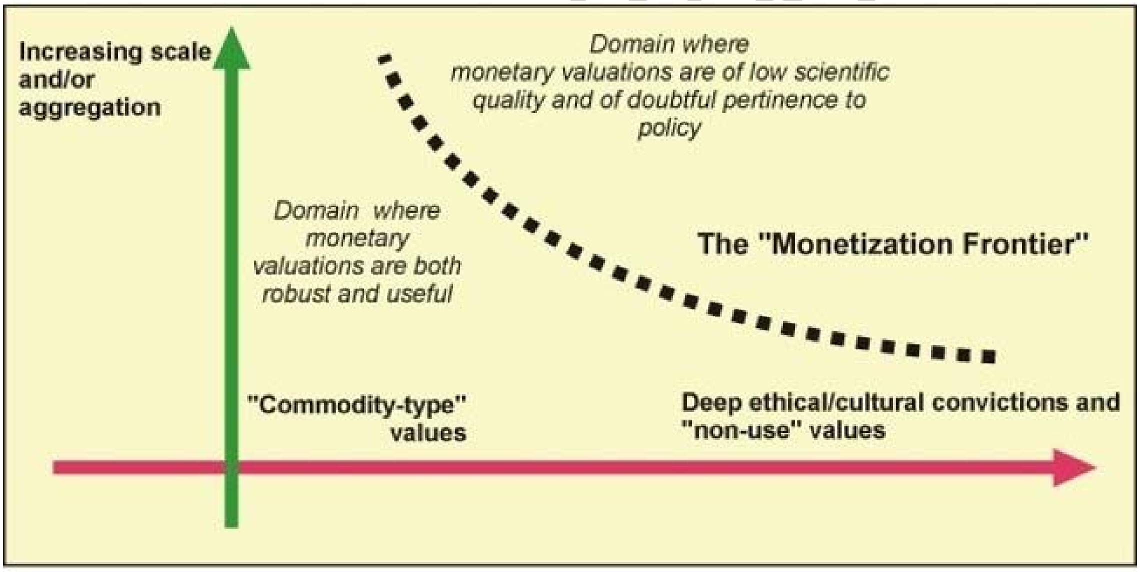

Figure 1. Representation of the Monetization Frontier.

The "scale" consideration, along the vertical axis, has direct consequences for procedures of monetary aggregation. Any attempt to establish a monetary figure for changes in natural capital stocks or in the value of environmental services at a comprehensive national or global scale, will encounter systems uncertainty and time-scale related complications. Where systems complexity is high and relevant time-scales of environmental effects (or their economic feedback consequences) are long, such as with climate changes or biodiversity reduction through ecosystem modification, the resulting aggregate numbers will be of low quality from a scientific point of view. Putting low-quality numbers - which may have parametric uncertainties of one or two orders of magnitude (or more) - in quantitative relation to other statistics of more smallscale economic phenomena (such as current sectoral output measured on a firm by firm, sector by sector basis) will degrade the statistical quality of the aggregates. This loss in quality can, in turn, interfere with policy-relevance.

The "value type" consideration, along the horizontal axis, has important consequences for measurability in principle, not just for aggregation. An example would be to seek willingness-to-accept or willingness-to-pay figures, from peoples whose ecological base of subsistence such as forest or coastal waters, is menaced by a development project such as oil or mineral exploitation, or deforestation and cattle ranching. Where cultural or ethical convictions are fundamental, and where the values of nature in question are not oriented uniquely towards commodity production and consumption but involve notions of self, of justice and honour, cultural identity, cosmic harmony, then conflict resolution problems do not take the form of an economic optimization.

Most sustainability policy choices include ethical components. In part these are seen in questions of present fairness, as in North-South redistribution, and also in the equity issues relating to future generations, to the opportunities afforded to them and to the dangers and burdens we have imposed. In part they are seen, also, in the debates about the moral acceptability or social justifications for (e.g.) intervening in the genetic integrity of organisms, destroying habitats of endangered species. Some quantification of the opportunity costs of respecting this or that value commitment may be pertinent, but this is more in the context of assessing the re-distribution of economic opportunities and the sustaining, or not, of different types of human community.

4. A Structural Ecological Economics Perspective

Kenneth Boulding introduced, in 1966, the notion of the 'economics of Spaceship Earth'. The concept of a limited habitat, hence a limited planetary carrying capacity, was modelled in the early 1970s by the Club of Rome; the 'limits to growth' theme was taken up through the 1970's by the energy analysis discipline, and was popularized by Herman Daly in favour of a steady state economy.

For Daly, thermodynamic first principles impose the ultimate necessity of a steady state, and society should conform to these constraints through (a) choosing a feasible level of population and material wealth, and (b) exploring how the non-physical variables of wants (including the ethical want for 'better wants') and technology can be sensibly adjusted to the physical parameters. During the 1980s and 1990s these concerns have been translated into more diffuse, and sometimes ambiguous, formulations of objectives and criteria of sustainable development.

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Biographical Sketch

Prof. Martin Paul O'Connor - Born in 1958 in Christchurch, New Zealand, on volcanic hills overlooking the Pacific ocean, Martin O'Connor studied physics and humanities in his native country and in Paris. After completing his PhD in economics (titled Time and Environment) at the University of Auckland in New Zealand, he was for several years a Lecturer in Economics at the University of Auckland before taking up a professorial position at the University of Versailles St-Quentin-en-Yvelines (UVSQ, in the western suburbs of Paris) in 1995. He has research degrees in physics, sociology and economics, and specialises in interdisciplinary work in ecological economics theory, development theory, environmental policy and social sciences epistemology. In New Zealand during the 1980s he was active in a range of critical and consulting studies including public policy, environmental and social impact assessments, energy and banking sector studies, in parallel to academic teaching and writing. Since 1995, as Project Manager at the C3ED research centre, he has participated on numerous French and European studies in the environmental valuation, green accounting, scenario studies, integrated assessment, risk and water governance fields. He is a member of the editorial advisory boards for the journals Capitalism Nature Socialism (CNS) and Environmental Values, and currently edits the interdisciplinary International Journal of Water (IJW, published by Inderscience). With colleagues he is active in the development of international teaching networks, notably through the 3^{E}-SDP (European Ecological Economics and Sustainable Development Policy) programme including North-South co-operation.