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APPLICATION OF NON-MONETARY PROCEDURES OF ECONOMIC VALUATION FOR MANAGING A SUSTAINABLE DEVELOPMENT

SUMMARY FINAL REPORT

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I. OBJECTIVES.

This project researched the production and application of non-monetary information on economic and environmental change that can be used as a support for sustainable development management. Concern with economic and ecological sustainability involves imaginative extrapolation a considerable distance into the future, often several decades and in some instances longer. In studies of the prospects and requirements for sustainability, it is necessary to extrapolate from information about past and present economic and ecological activity, in order to construct model trajectories or scenarios into the future. Underlying this research project was the presumption that, for gauging the pressures of an economic system on its biophysical milieu, measures and information filtered through monetary measurement (prices, valuation of services and assets, macroeconomic aggregates) can be opaque and incomplete. The research had three sets of interwoven scientific objectives:

To explain the importance of non-monetary information and measures as “indicators for sustainability” -- that is, allowing evaluation of economic, environmental, and social dimensions of a society’s development path, according to a variety of concepts and criteria reflecting different aspects of a complex problem.
To make some methodological advances in this domain, in particular through clarification of conceptual and measurement issues in the construction of energy-based indicators, and through defining procedures for the effective utilisation of non-monetary indicators in decision making and public policy.
To implement the ECCO physically-based dynamic input-output model for scenario construction, with the goal of comparative analyses of the French and United Kingdom economies.

The ECCO model may be used to define a range of physical measures associated with sectoral capital formation (including the energy supply sectors), aggregate consumption, primary energy flows, and requirements for natural resource use, and pollution emissions associated with both production and consumption. The measures and time-trends (under defined scenario assumptions) of these system variables may then serve as “indicators” of sustainable and non-sustainable characteristics of the modelled economy. Use of the model, subject to the limitations of measurement inherent in all empirical work, thus allows for the quantification of requirements and prospects for economic sustainability (capital formation and consumption levels), under a variety of possible development scenarios including consideration of technological choices, available of primary energy sources, population change, consumption choices, and public policy options.

II. METHODOLOGY:

It is possible to consider concerns for “sustainability” under the three broad headings of economic, social, and ecological. This distinction refers to : (1) the nature of the system or feature being “sustained;” and (2) the sort of units used in the measure or evaluation. The economic category can be deemed part of the social; and the social category can be considered to include features of the natural world that have distinctive social or cultural meanings. So for example, one might be concerned with:
economic system performance, as measured by total commodity output per unit time (money or physical quantity) or by statistical measures of an average level of consumption or “standard of living;” etc.

sustaining of particular features of the so-called natural environment such as levels of specified natural resources, landscapes, species population numbers or diversity (ecological sustainability, as indicated by energy, material, spatial, or biological categories of measure).

particular characteristics of a society (such as the number of small-scale bakers in Paris) or features of the natural world or patrimony particularly valued by a society as part of their cultural heritage or specificity (such as types of agricultural production, wildlife, scenic features).

Since sustainable development is an objective, or more precisely evokes a set of objectives more or less easily reconciled to each other, it becomes natural to search for measures and indicators of sustainability. Indicators of “sustainability” -- and, correspondingly, indicators of “non-sustainability” -- refer, by definition, to the question of changes over time of key variables, features, or levels of economic and ecological activity. So the emphasis is on the temporal patterns rather than performance or level at a single moment in time. In order to give the concept some precise meaning, the research introduced a number of conceptual and methodological distinctions. First of all, the distinction was drawn between:

a definition of sustainability as a “sustainable” pattern of activity (characterised qualitatively and perhaps measured quantitatively); and

the idea of a transition or approach towards a “sustained” or “sustainable” time path of activity from an initial state or pattern of activity which is judged as being not sustainable; or conversely a movement away from a sustainable activity.

In these terms, indicators of sustainability might have any of the following roles :

indicators of the feasibility or infeasibility of achieving a “sustained” or “sustainable” path from some given starting point and conditions of resources, technology, etc.;

norms or measures stating key features of, or requirements for, a “sustainable” pattern of activity, e.g., using a national resource within limits of its renewability, maintaining a specified species population or habitat; etc.;

measures of the distance between the existing situation or reference projected time path and a sustainable state of affairs considered as a reference point or goal, and the requirements for achieving a feasible sustainability path, these “distances” and costs/requirements being measured in terms of physical changes, monetary costs, or changes in key variables.

A major purpose of the project has been a critical examination of the usefulness and shortfalls of information and measures using a money *numéraire* (e.g., monetary measures of depreciation of a nation’s stocks of natural capital) as guides to the sustainability or non-sustainability of current patterns of economic activity. Two main reasons exist for the inability of monetary measures to fully serve this purpose:

inherent difficulties of giving any sort of non-arbitrary monetary valuation for the diversity of life-support functions, biodiversity, aesthetic and ethical dimensions of the biophysical world.

the difficulty of having real prices that reliably reflect the opportunity costs of resource allocation choices whose impacts are distributed far into the future, are largely irreversible, and more or less uncertain in their exact consequences.

These limitations justify the search for non-monetary indicators of sustainability. In recent years, economic modelling and evaluation techniques have, increasingly, been extended to include environmental domains (natural capital) as a finite source of raw materials and services, including biodiversity, amenities and life-support, and waste-assimilation capacity. But in making this extension to the natural world, careful attention must be given to the plausibility of the implicit presumptions about biophysical reality “behind” the model parameters. Model specifications ought to fit the “stylised facts” that we think we know about, for instance: (i) conservation of matter and energy and entropic irreversibility; (ii) the limits to substitutability between natural and produced capitals; (iii) the irreversibilities of natural resource depletion, of land degradation, of species extinction; and so on.

There are, by now, a wide range of conceptual frameworks available for representation of economy-environment interdependencies and prospects for sustainability. The concept of “natural capital” is increasingly employed in describing the dependence of human economic activity on the habitat in which it is embedded—on the environment as a source of energy and materials, as the space and site of production, consumption and recreational activities, and as receiver of the waste flows and by-products of human activities. In effect, the biophysical milieu is seen as a reservoir of “natural capital” from which desired materials and services are obtainable or may flow. The limited, and uncertain, possibilities of substitution for the variety of services furnished by different categories of natural capital have led scientists as well as ecological economists to insist on the critical and non-substitutable roles of our collective natural capital in furnishing habitat and life support, stocks and flows of energy, and waste-reception services. This leads to what is called the “strong” criterion for sustainability, which can be expressed either as non-negative change in total natural capital stock (posing problems of aggregation), or as maintenance of specified “critical natural capitals” at or above thresholds needed to maintain vital services and functions. This sustainability criterion signals the importance of maintaining, and “investing” in, natural systems and their renewal.

This is the perspective in which this research project developed its approach to the construction of non-monetary indicators for sustainability. The tasks of scientific and ecological economic analysis thus are threefold:

to define quantitatively and qualitatively the valuable stocks, services and amenities provided by the environment as the biophysical milieu, and hence the benefits associated with investments in conservation and renewal of natural capital;

to furnish information useful for defining these maintenance requirements, including the thresholds to be respected and the economic costs and trade-offs involved in pursuing the identified benefits;

to provide information useful to resolve, with a commitment to justice, the distributional conflicts over access to environmental resources and services and to the economic benefits these can provide.

III. MAIN RESULTS.

The results come under the following four headings :

Justifications for non-monetary indicators for sustainability: Explanation, with reference to the "weak" and "strong" criterion of economic and ecological sustainability, the crucial importance of non-monetary analyses and gauges of economy/ecosystem time-path possibilities. This work has proceeded through, first, a clarification of the rationales of, and insights obtainable from, the traditional economic modelling approaches for gauging sustainability prospects of a resource- or ecologically- constrained economy (that is, an economy dependent on "scarce natural capitals"); and, second, appraisal of the theoretical limitations of these approaches and hence the limits to reliability of any empirical estimations obtained within these frameworks .

Theoretical definition of energy-based indicators for sustainability: Theoretical definition and discussion of the insights that can be obtained from energy-based measures of economic activity and economy-environment interdependencies.

Dynamic economic modelling: Demonstration of dynamic simulation modelling techniques, in particular the ECCO modelling methodology, for investigation of constraints and opportunities for economic development relating to primary energy sources and environmental pollution assimilation capacities considered as "critical natural capitals".

Decision processes for sustainability: Presentation of effective ways for the use of scientific information and simulation modelling results as "indicators for sustainability in social decision making in environmental and economic policy domains.

This summary discussed mainly the last two categories. The modelling methodology developed, as well as the suggestions about scientific inputs in decision-making, are of course, partly products of the theoretical insights reported in the first two categories.

Scientific work has focused on primary energy resources and environmental pollution assimilation capacity. These are considered as two important categories of "critical natural capital".

Within this general perspective, the research has involved work with energy-based measures on two different levels :

Conceptual insights, and theoretical principles for construction and use of "generic" measures characterising economic and ecological systems, and their interactions, obtained on the basis of energy stock and flux accounting with defined thermodynamic potentials (enthalpy, entropy, free energy, essergy, etc.).

Analytic and quantitative modelling work using an energetic *numeraire*, as a method of natural capital accounting. The laws of thermodynamics furnish the basis for "energy accounting" for exchanges between economic and ecological processes, and for quantitative analysis of the transformations (energy storages, conversions, dissipations) taking place within these processes.

Thermodynamics permits measures of physical transformations taking place within any chosen system. Any sector of commodity production, or household consumption, or a national economy as a whole, can be considered as a transformation process in this sense. One of the most valuable methodological functions of thermodynamic analysis is that it introduces into economy-ecosystem modelling a method for "holding on to reality," through incorporation of the physical conservation principles in description of transformation process and system constraints. Broadly speaking:

Energy resources, that is, the sources of energy in forms useful for economic purposes, are limited in total availability to the quantities furnished exogenously on a flow basis as self-renewing fluxes (solar radiation, tides, geothermal heat, etc.), and the accessible stocks of fossil fuels and fission materials. Biomass may be considered as a dynamically renewable storage of solar energy. Energy analysis techniques allow us to define opportunity costs, in energetic units, of exploitation of these stock and flux energy resources.

Energy and mass conservation, together with the second law of thermodynamics (entropic irreversibility), implies the inevitability of unwanted by-products or waste energy in the course of economic production and consumption. The capacity of surrounding ecosystems to absorb these waste emissions without impairment of stability and vitality, is limited. Energy-based measures can provide indicators of the severity of waste emissions as a source of stress on the biophysical systems. The significance of different types of wastes as pollutants with nuisance or ecologically disruptive effects cannot be deduced from energy accounting alone. However, the physical conservation laws mean that energy measures (and, similarly, mass measures) can always be used, in principle, for a systematic accounting of waste flows. This can be an important first step in defining technological options and economic change policies for a reduction in the quantity and toxicity of waste emissions.

Various reports produced in the course of this project explain in detail the theoretical basis for construction of such measures and their uses. The indicators fall into one or other of the following categories:

norms or measures stating features of a "sustainable" pattern of activity, e.g. for the economy itself, non-negative change in aggregate capital stock, or in aggregate consumption levels; or with regard to the environment, respect of defined emissions levels thresholds, or constraints on energy or material resource availability determined by rates of renewability.

measures of the "distance from sustainability", meaning the investment requirements and the opportunity costs (the trade-offs through time in terms of energy requirements, capital requirements, consumption levels, and pollutants emissions, etc.) for achieving sustainability goals—if indeed these are feasible -- compared with a non-sustainable "business as usual" or other model reference path.

Building on this theoretical work, dynamic modelling has been undertaken of national economies as a demonstration of the construction and use of such indicators. This showed how energy analysis and simulation modelling may be used to obtain estimates of limits and opportunity costs for economic development over time relating to : (1) availability of primary energy sources; (2) requirements for meeting waste emission goals; and (3) possibilities of technological change.

The ECCO modelling methodology, developed from a pilot world model (PIE-em) by Slesser and Hounam in 1977, was aimed at determining the potential rate of expansion of an economy in the context of user-imposed policies, user-selected technologies, and user-determined environmental objectives. The economic system was modelled in terms of the rate of wealth production, expressed as the rate of production of human-made capital, and the rate of consumption of human-made capital resulting from the structure of the system, its state, and the demands placed upon it. The net surplus determines the system's potential for growth. The model generates outputs as time series on energy demand, waste, water demand, rates of capital creation by sector (50 in all) and much other macro-economic information. It is presumed that labour is not a binding constraint except as to quality.

In this project, versions of the ECCO model for the United Kingdom and France economies have been developed for the definition and estimation of "indicators of sustainability" based on energy unit based measures of primary energy use, capital accumulation, consumption, and pollutant emissions in a national economy.

The ECCO modelling exhibited the two complementary features of energy-*numéraire* analysis mentioned above. For example with regard to waste generation, the energy accounting inherent in the model "maps" (in units of enthalpy of a stated quality, usually that of natural gas/hard coal/oil) the main fluxes between the economy and its environment. Emissions levels can be related back, through model coefficients, to inputs and outputs of capital production, energy supply, and consumption sectors. This draws attention to the reality of waste outflows, and yields a physical measurement of the main emissions. Then, for specific pollution policy purposes, ECCO may be used to estimate opportunity costs in terms of economic capital, consumption foregone, and direct and indirect energy requirements of achieving targets for waste treatment and reduction (such as through partial recycling, or processing before disposal).

The final task of the project has been to present methodological perspectives and practical-suggestions for the effective use of non-monetary information as inputs to social decision making for sustainability. The usefulness of physical measures as “sustainability indicators” depends in large part on the extent to which the measures being provided by the analysis (through direct empirical observation and/or modelling) are felt to “capture” the real sustainability concerns in the minds of the society or policymaker. This in turn depends on demonstration of how the scientific and economic systems analysis results can be employed in policy decisions.

IV. SCIENTIFIC INTEREST AND POLICY RELEVANCE.

The purpose of the project has been to clarify theoretical foundations for the construction of non-monetary indicators for sustainable development, and to demonstrate the usefulness of these indicators in policy evaluation and decision support. The theoretical contributions are reported in a variety of academic articles and conference papers The theoretical contributions related mainly to:
methodology for scientific practice and decision-making in relation to ecosystem management and economic sustainability;
economic theory of natural capital;
theory and applications of energy analysis for constructing indicators for economic and ecological sustainability.

The project, in conjunction with several related research projects has also generated an important body of empirical data and simulation study results for the United Kingdom and French economies. The main interest of these scientific and economic analysis results lies with their applications in policy domains.

For simulation work, a distinct version of the ECCO model must be developed specifically for each national economy, taking account of distinctive features of the economy, especially relating to types of energy use. This is done through specification of the relevant parameters, policy variables, and coefficients describing the technologies and linkages of energy and non-energy sectors, and the linkages to the external environment, and then calibrating the model based on historical data and detailed sectoral technology investigations.

The dynamic simulation analysis proceeded through deciding the particular scenarios to be constructed. These choices were based on several considerations, most importantly:

the study objectives of obtaining indicators relating to energy input, technology choice, and emission measures, which cast some light on the long-term sustainability or not of conceivable development paths for the selected economies.

the particular propositions explored about the sorts of policy options, technological change possibilities, resource substitution possibilities, environmental constraints, and also political/strategic constraints on availability of energy or key natural resources.

the technical possibilities and limitations of the model, including variants dealing with specific aspects of economic activity.

In this research, scenario analyses have been carried out of alternative technological choices in energy supply and pollution control for the U.K. and French economies. This involved examining energy sector investment requirements, economic growth prospects, and possible transitions between fossil fuels, nuclear energy and renewables.

This work has also furnished the tools for further model refinements and applications, undertaken in other research projects (for example, links between energy use and pollutant emissions from the industrial, household, and transportation sectors; and implementation of pollution abatement policies for selected emissions such as CO2 and sulphur oxides, with reference to EU environmental policy options).

The project has also addressed the questions of how most effectively to integrate the information provided by such indicators, through either empirical or simulation studies, within social decision-making procedures. In general, policymakers are concerned not just with problems of environmental sustainability, but also with a wide range of other social, political, and economic problems. Four overall conclusions have emerged from the research:

The value of non-monetary indicators as baseline information in the process of defining, in physical resource or in monetary terms, the investment requirements or the opportunity costs (in terms of consumption foregone) for achieving economic, ecological, and social "sustainability" goals starting from a given state of the economy.
The appropriateness of multiple indicators, each of which can be defined in a relatively unambiguous way, and each of which signals some feature or features deemed significant of economic or environmental change, but which cannot meaningfully be reduced to a single "aggregate" indicator (problems of non-reducability and incommensurability).
The necessity to define procedures for the organisation of information obtainable from multiple indicators, so that the insights obtained from each one may be set fruitfully in relation to onsights from the others (without false reductionism).

The importance of social conflict resolution in policy and decisionmaking for sustainability.

These procedural and conflict resolution requirements have been approached in terms of :

Demonstration of application of "multiple-criteria decision analysis" and decision support methods to assist in the evaluation of options for pursuing social, economic, and ecological sustainability objectives.
Concepts of "procedural rationality" for working with both monetary and non-monetary (energetic) indicators for sustainability, permitting appraisal of policies and development directions against a spectrum of sustainability indicators considered as complementary rather than exclusive.
The notion of "post-normal science" which provides a way for thinking about the way scientific considerations and ethical and political judgements necessarily bear on each other in the evaluation of possible policies and courses of action.
A number of formal schema for multi-criteria evaluation have been developed, which are complementary to the simulation modelling and methodological discussions. These are decision support tools helping with the identification and prioritising of social, economic, and environmental objectives.

In a static decisionmaking perspective, the assessment of sustainability prospects is based on the simultaneous consideration of the various sub-goals. A nation's or region's development trajectory is deemed "sustainable" if the system analysed satisfies all the designated criteria for sustainable development. Two important qualifications, however, must be made for any such assessment. First, satisfaction of designated criteria at a given moment, based on empirical analyses and model extrapolations, does not guarantee real sustainability into the future. Second, for a given nation, sustainability constraints may be relaxed through advantageous import-export relations, but this sort of advantage cannot be obtained by all nations simultaneously.

In order to consider progress towards sustainability, one must consider the historical time dimension of actions and decisions. Here we adopt a dynamic perspective on prospects for a sustainable development in terms of possibilities for moving towards identified sub-goals. For example, there may be possibilities of technological progress, and of changes in production methods and comsumption patterns that would relieve specified pressures on natural resources and the environment.

When introducing these temporal considerations, we get a sequential and iterative decision-making process which suggests possible trajectories for implementing a sustainable development. In effect, we first consider the global objective (sustainable development) in terms of the three classes of subgoals, ecological, economic and social. Then, supposing that some of these indicators are unsatisfactory, we identify policies to pursue a transition from the unsustainable towards a long-term sustainable pattern of economic activity. Such a transition is not immediate, and the implementation of pro-sustainability policies thus implies an iterative procedure with economic, technological, and ecological change over time.

This project developed the "dynamic sustainability tree" as a way to portray schematically this iterative process of decisionmaking and evaluation. The sustainability tree portrays the application of two key characteristics of procedural rationality: the identification and appraisal of sub-goals, and the satisfycing principle, worked with iteratively through time. The framework does not give a method to solve a policy design of a chosen problem in an optimising manner. Rather, it is a conceptual tool to help the decision-making, through allowing information of a wide variety of types to be brought together in an orderly and structured way.

This decision/evaluation tree can be operationalised, along selected axes, by appropriate simulation modelling techniques. In a simulation modelling framework, the decision maker can test different model trajectories exploring sustainable development policies and their effects under alternative assumptions about natural resource availability, population growth, technological change possibilities and consumer patterns, and environmental sensitivity to pollution and other stresses. The ECCO modelling methodology applied in the project is one example of such a technique. The model user can explore scenarios for a national economy in interactive and iterative ways, based on alternative assumptions about technological change feasibility, international trade conditions, and domestic social, economic, and political choices.

This interactive modelling methodology is consistent with the emphasis on the importance of explicit decision-making procedures for appraisal of policy priorities. In terms of the sorts of indicators for sustainability discussed and applied, the patterns of economic activity of most countries today is far from sustainable. This will be reflected in non-satisfaction of several subgoals. Which goals should most urgently be addressed?

The work presented decision support concepts and methods, allowing scientific and economic information, and policy alternatives, to be appraised in an orderly and structured way. In the perspective adopted of Post-Normal Science, decisionmaking and evaluation takes place through an iterative process of identifying trade-offs and compromises with multiple criteria, with the aim of ending up with a solution that is satisfactory in terms of economic, social, and ecological imperatives. Decisionmaking can be understood as a collective argumentative process, with different questions and possible priorities put forward, and evidence gathered and arguments built for and against these different positions.

Finally, it is possible to give a mathematical representation of some aspects of this prioritisation process. For example the research explained how “fuzzy set” multi-criteria decision analysis can be used as a complementary tool to the dynamic sustainability tree. By incorporating veto criteria (minimum standards) as well as satisfycing standards, it is possible to give a characterisation of scenario outcomes as “near” or “far” from sustainability. Fuzzy set MCDA can also be used as a type of sensitivity analysis for policy prioritisation depending on the levels decided for veto and satisfaction standards, and on the relative weightings given to different subgoals. In this way, there is clear and explicit recognition of the necessity of making choices as to the particular “interests” - economic, communal and ecological - that are going to be sustained. Effective sustainability policy depends on putting in place political and communal processes for deciding on the “mix” of economic, community, and environmental purposes to be pursued.