SCIENCE, GOVERNANCE, COMPLEXITY, AND KNOWLEDGE ASSESSMENT

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Summary

Scientific progress and the human condition have always been tightly coupled, but the pace of change and a growing awareness of the complex and fragile nature of biological and ecological systems, means that increasing attention is being paid to the relationship between science and governance. For instance, the European Union is obliged to integrate environmental policy into all policies. In doing so it recognizes firstly that the scientific basis on which decisions are based does not allow environmental degradation to be measured on any undisputed basis and secondly that the outcomes of actions or inactions usually cannot be predicted. Therefore it takes a precautionary approach to regulation and is exploring how a scientific support to policies can be developed that recognizes and takes into account uncertainties and allows stakeholders to participate in the scientific process. This means an increasing emphasis on the management of scientific knowledge and its assessment-explaining the uncertainties and clarifying the affiliations of the scientists who produced the work.

1. Introduction

The strengthening of scientific capability worldwide has been established as one of the cornerstones for the process of sustainable development. For example, *Agenda 21*, Chapter 35 emphasizes the necessity of "strengthening the scientific basis for sustainable management." The challenges to science that are posed by the search for sustainability are not only technical ones. There are also fundamental empirical and science methodology challenges for achieving better understanding of our environment and the planet's complex life-support systems. Finally there are moral and procedural challenges for defining the roles of science-based knowledge and innovations for governance of technological and environmental risks, for sustainable ecosystems management, and for effective communication of scientific information to achieve these goals.

Advances in science are opening up new domains of potential technological innovation, with potentially vast consequences for human health, energy supply, food production and environmental engineering. These fields of advancing knowledge carry many hopes for humanity. Yet science and technology also bring new hazards to society and new challenges for quality assurance.

A feature of many new domains of science-based innovation is their intervention in complex biological and ecosystem processes where quality assurance in terms of outcomes is almost impossible to conduct. This difficulty warrants some reflection. It has long been recognized that industrial production activities, mass consumption and intensive agriculture can have unwanted negative effects on ecosystems and environmental quality. What has more recently been emphasized is that some of the adverse consequences can be very long-term, irreversible and also very difficult to manage. We must now incorporate the awareness that science-based interventions in complex natural processes can constitute a self-renewing source of problems that may jeopardize not only the environment, but also community livelihoods, health and future economic prospects. This is highly publicized concerning risks in the nuclear industry and in biotechnology applications based on genetic engineering. It is also true for the complicated yet fragile systems of food production and communication upon which modern societies depend. For example, many of the achievements of increased productivity within the agro-food industry depend on a permanent utilization of pest-control chemicals, fertilizers, hybrid or genetically modified stock, and other capital inputs. These technological developments can heighten the vulnerability of the food production systems in the face of technological, economic or natural disruptions. The intensive production is also, in many regions, having serious negative consequences for soil and water quality, which will undermine productivity in the long-term.

A lesson that may be drawn from these is that the relationship between advances in science and in science-based technologies on the one hand, and sustainable development on the other hand, is complex, multi-faceted and ambiguous. Just as the recognition of ecological constraints on the scale and forms of sustainable economic production and consumption means that "more output" is not the same as "good output," so it has to be noted that more scientific knowledge expressed in technological innovations does not necessarily lead to a more sustainable society.
Therefore important changes in the relation between the problem identification and the prospects of science-based solutions are necessary.

> *The changed relation between the problems being addressed by science and the prospects of science-based solutions:*
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> Science is no longer mainly offering the "benefit" of new discoveries and applications, as a sort of added-value from investment.
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> Rather it is placed in the reactive role of trying to fill a "knowledge deficit" as awareness grows of problems such as hazardous wastes, water contamination, renewable resource depletion, climate change, other atmospheric pollutions and disruption to aquatic and terrestrial habitats.
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> Analyses are, increasingly, being sought that can contribute to technological and policy responses. In this respect we can speak of a scientific activity that is designed around serving the goals of sustainable development.
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> However this "science for sustainability" will be issue-driven, as well as curiosity-generated or mission-oriented. It will address problems that are salient for sustainability, regardless of their capability for a traditional "solution." These will include complex and difficult issues, even those where our knowledge is swamped by uncertainty, ignorance and value-conflict.

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One of the implications is that the priorities for science must evolve if science is to contribute effectively as a force for sustainable development. This is a message that has to be communicated to the scientific community itself. Scientific practice is not fundamentally "value-free" but it has to find its justifications by reference to prevailing social concerns. The object of the scientific endeavor in this new context may well be to enhance the process of the social resolution of the problem, including the participation and mutual learning among stakeholders, rather than definitive "solutions" or technological implementations.

The normative orientations of sustainable development must, in this regard, guide scientific work towards technological innovations that respect fundamental sustainability values such as local ecosystem resilience, mitigation of global climate change impacts, energy efficiency, food security, and enhanced problem-solving capacities of local populations. An important part of this guidance and justification, we suggest, is the design and implementation of agreed social processes for quality assurance in science knowledge and technological implementations. This will entail the emergence of new social institutions to perform the quality assurance function. In this style of science, place-specific knowledge and resources of local communities will need to be integrated as complementary to the universal knowledge of traditional scientific practice.

Although the world is probably no more complex than it was ten, a hundred or even two thousand years ago there are a number of factors that make individuals more aware of its complexity. This awareness is fuelled by a greater flow of information to nearly all individuals through the new media-television, Internet.

But, although we are now information-rich we are knowledge-poor. It is difficult for individuals to assess the validity of conflicting opinions based on the same information.

The whole subject of managing this knowledge and assessing its quality is too vast to include within one paper so we shall focus on one aspect of it-the provision of scientific advice to the policy process. Focusing still further, we shall concentrate on matters concerning the European Union whose emergence on the world stage is a new factor that could be considered as adding to the world's complexity. Managing knowledge to provide better scientific advice to European institutions is a challenge that is currently under discussion by scientists, policy makers and the general public.

2. Science and Governance

There are a number of reasons why there is an ongoing discussion on the subject of science and governance within the EU.

First, there is the progress in science itself. Developments in life sciences, triggered by an increased understanding of genetic structures within biological processes and rapid developments in technology, are producing new products and services for the market. These products are bringing undoubted benefits to society. In-vitro fertilization is now applied routinely to solving miseries of infertility, and some plants genetically engineered for resistance to pests can reduce the requirements for chemical pesticides. Similarly the explosion in information and communication technology has revolutionized the factory and the office and enabled many people (those with electricity and website connections) to access a substantial proportion of the world's knowledge from their homes. The promises for the near future are glamorous but the impact of these changes needs to be understood and regulated. We must learn how to cope with innovations, which could have effects that are long-term, unpredictable, and possibly irreversible, and highly inequitable.

Second, the attention devoted to science by governments is increasing. This is partly due to an increased need for scientific input to regulations and partly due to the increasing efficiency and sophistication of lobby groups. An analysis by Padilla and Gibson showed that the proportion of questions, motions and debates in the British Parliament with a scientific content has risen six fold over the past decade. Questions with a scientific and technical content went from 1% in 1988–1999 to 6% in 1998–1999. Biological (medicine and food) and environmental sciences (including energy) accounted for most of the growth. Reports by Sir Robert May from the UK Office of Science and Technology on "The Use of Scientific Advice in Policy Making" and by the Council of Science and Technology Advisors Secretariat of Canada assess the urgent need for developing appropriate advice mechanisms and suggest guidelines for producing sound advice.

Third, there has been an evolution in European institutions. The development of an Internal Market with common European standards and regulations, together with the emergence of the European Union as a representative of the Member States in trade discussions, such as those at Seattle, or environmental negotiations such as those at Kyoto, means that deliberation and debate at a European level will certainly augment. The particular responsibilities of Member States, Council, Commission, Parliament, Agencies, Scientific Committees, and courts are unique to Europe and the mechanisms for scientific advice to policy are not, in general, the same as elsewhere.

Fourth, this evolution is continuing at an increasing pace. The enlargement of the Union to include countries from the former Soviet-bloc is imminent and sure to bring new challenges to European governance. The Commission has recently opened a debate on the subject. According to Romano Prodi, current President of the Commission, European integration until the 1990s was a largely economic process establishing the single market and introducing the single currency. But events have moved on. New frontiers of integration include Justice and Home Affairs, the Common Foreign and Security Policy, defense cooperation and the crucial question of fundamental political values. These issues go to the heart of national sovereignty and will require an even greater level of political consensus than those which dominated the 1980s and 1990s.

Fifth, an increased understanding of the complexity of the natural world has led to a realization that scientific certainty in a number of important areas will not be achieved in the near future. Examples include the impact of soil physics and biochemistry and of particular greenhouse gases (including water vapor itself) on global climate change, the impact of pollution on human health, or the possible hazards of the release into the environment of new bio-chemical species, such as Xeno-oestrogens or genetically modified organisms. Where such risks are involved, some sort of "precautionary principle" needs to be explicitly invoked rather than implicitly assumed in the practice of research or regulation. Assessment of risks in a quantitative, technical style needs to be complemented by attention to the contextual aspects of the complex systems in which hazards arise.

A deep and widespread lack of trust has characterized recent debates on policy issues. Trust is essential for the proper functioning of science and governance alike, and is paradoxically more vulnerable in a literate, sophisticated society where citizens are able to assess the quality of performance of their institutions. The strength and acceptability of a decision-making system depends to a large extent on its ability to show that it can be fair and transparent and takes into account all the legitimate interests and opinions. There is a general agreement that the failed trade preparatory meeting of the WTO in Seattle highlighted a growing influence of citizens' groups on global policies. If science can be located within an interactive, reflexive and recursive process of governance, then public trust in science and confidence in the policy-making process can be restored and maintained.

3. Scientific Challenges

Although fundamental curiosity-driven research is at the core of the total research enterprise, any society establishes overarching goals for research. These can be expressed in various ways but in this report we will consider four as dominant preoccupations of the world's powers-that-be:

developing a sound economy;
protecting health;
maintaining integrity of an increasingly vulnerable natural environment
providing security against external threats;

These correspond approximately to the objectives stated by the United States House Committee in 1998. But it is worth noting that the same themes could probably be retained, with very different meanings, for subsistence societies in (say) South Asia or Madagascar. Interestingly, the importance given to the environment is relatively recent. The study by V. Bush that shaped United States post-war science policy had only three goals-economy, health and defense.

In this paper we will consider only issues relating to health and the environment.

3.1 Health

Developments in science, particularly genetics, are likely to have a huge influence on health policy. A report by the Public Health Genetics Unit of the UK Cabinet Office, says that the Government must consider urgently "all possible options for the future funding of health services" in the light of new technology. Dr Ron Zimmern, head of the unit, predicts that gene science will become an "inseparable component" of health care with wide-ranging financial, social and ethical implications. Screening programs to identify people susceptible to diseases such as breast cancer, Alzheimer's and schizophrenia, through DNA tests, and pre-emptive treatment targeting 'vulnerable' groups are among the sweeping changes, which could become reality.

The Treaty establishing the European Community (the consolidated one as amended by the Treaty of Amsterdam) stipulates that a high level of human health protection must be assured in the definition and implementation of all Community policies and activities. The Treaty also deals with Consumer Protection: "To promote the interests of consumers and to ensure a high level of consumer protection, the Community shall contribute to protecting the health, safety and economic interests of consumers, as well as to promoting their right to information, education and to organize themselves in order to safeguard their interests."

This is a logical consequence of the Internal Market. Once free transit of goods across borders within the European Union was established it became inevitable that these matters would have to be considered at a Community level. Thus human health has to be taken account of in issues such as vehicle emission limits, contamination in food or drinking water quality regulation of GMOs, and medicines.

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Biographical Sketches

Silvio Funtowicz taught mathematics, logic, and research methodology at Buenos Aires, Argentina. During the 1980s he was a Research Fellow at the University of Leeds, England. He is now a Scientific Officer at the European Commission Joint Research Center in Ispra, Italy, where he is in charge of the program of Knowledge Assessment at the Institute of Systems, Informatics, and Safety. He is the author of *Uncertainty and Quality in Science for Policy* (1990, Kluwer, Dordrecht) in collaboration with Jerry Ravetz, and numerous papers in the field of environmental and technological risks and policy-related research. He is a member of the editorial board of several publications and of the scientific committee of many international conferences, and has lectured extensively.

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Iain Shepherd, a physics graduate, has worked at the European Commission's Joint Research Center (JRC) for 20 years. During this period he has contributed to scientific aspects of a number of policy issues including nuclear reactor safety, habitat protection, the elimination of anti-personnel landmines, and fisheries monitoring. He has been a member of the JRC's Scientific Committee for the past 10 years.