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Post-Normal Science

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1. Introduction

Post-Normal Science (PNS) is a new conception of the management of complex science-related issues. It focuses on aspects of problem solving that tend to be neglected in traditional accounts of scientific practice: uncertainty, value loading, and a plurality of legitimate perspectives. PNS considers these elements as integral to science. By their inclusion in the framing of complex issues, PNS is able to provide a coherent framework for an extended participation in decision-making, based on the new tasks of quality assurance. The shift to a post-normal mode is a critical change. The approach used by normal science to manage complex social and biophysical systems as if they were simple scientific exercises has brought us to our present mixture of intellectual triumph and socio-ecological peril. The ideas and concepts belonging to the umbrella of PNS witness the emergence of new problem-solving strategies in which the role of science is appreciated in its full context of the complexity and uncertainty of natural systems and the relevance of human commitments and values

Ecological Economics provided the initial intellectual and personal setting in which PNS evolved. The first conference in Ecological Economics was the first major appearance of the new problem-solving framework (Funtowicz and Ravetz 1991). The original ambition of Ecological Economics was to develop a scientifically-informed movement to face the epistemological and governance challenges presented by sustainability (see Joan Martinez-Alier 2002, Martin O'Connor 2000, and Mario Giampietro 2000 & 2001**).** It should be noted, however, that very often the work done under the mantle of Ecological Economics is reduced to being a minor branch of mainstream economics, with all its pathologies of reductionism and pseudo-quantification.

It is significant that some leading economists are now calling for the inclusion of the political and social contexts into their analyses and models (Laffont 2002, Stiglitz 2002). This would amount to a return to the great social science of Political Economy, which flourished until economists became seduced by the example of Victorian physics, with its promise of perfect accuracy and perfect predictability.

2. New tools for new problems

In the sorts of issue-driven science relating to the protection of health and the environment, typically facts are uncertain, values in dispute, stakes high, and decisions urgent. The traditional distinction between 'hard', objective scientific facts and ‘soft’, subjective value-judgements is now inverted. All too often, we must make hard policy decisions where our only scientific inputs are irremediably soft. The requirement for the “sound science” that is frequently invoked as necessary for rational policy decisions may affectively conceal value-loadings that determine research conclusions and policy recommendations. In these new circumstances, invoking ‘truth’ as the goal of science is a distraction, or even a diversion from real tasks. A more relevant and robust guiding principle is quality, understood as a contextual property of scientific information (Funtowicz and Ravetz 1990, Ravetz 1996).

A picture of reality that reduces complex phenomena to their simple, atomic elements can make effective use of a scientific methodology designed for controlled experimentation, abstract theory building and full quantification. But that is not best suited for the tasks of science-related policy today. The traditional ‘normal’ scientific mind-set fosters expectations of regularity, simplicity and certainty in the phenomena and in our interventions. But these can inhibit the growth of our understanding of the new problems and of appropriate methods for their solution.

This situation is a novel one for policy makers. In one sense issues of environment and sustainability are in the domain of science: the phenomena of concern are located in the world of nature. Yet the tasks are totally different from those traditionally conceived for Western science. For that, it was a matter of conquest and control of Nature; now we must manage, accommodate and adjust. We know that we are no longer, and never really were, the “masters and possessors of Nature” that Descartes imagined for our role in the world (Descartes 1638).

These new problems are characteristic of ‘complex systems’. These are not necessarily complicated; they involve interrelated subsystems at a variety of scale levels and of a variety of kinds (Gallopin *et al* 2001). Thus we now know that every technology is embedded in its societal and natural contexts, and that ‘nature’ itself is shaped by its interactions with humanity. In such complex systems, there can be no single privileged point of view for measurement, analysis and evaluation. Moreover, in such contexts there is generally no ‘hidden hand’ whereby selfish individual actions automatically benefit the wider societal and natural communities. Hence there is no substitute for morality in the good conduct of our affairs. The phenomena of life, society, and now the environment, cannot be captured, nor their problems managed, by sciences assuming that the relevant systems are simple. In terms of such paradigms, they will always present anomalies and surprises. PNS has been developed as the appropriate methodology for integrating with complex natural and social systems.

The difference between old and new conditions can be shown by the present difficulties of the classical economics approach to environmental policy. Traditionally, economics attempted to show how social goals could be best achieved by means of mechanisms operating automatically, in an essentially simple system. The “hidden hand” metaphor of Adam Smith conveyed the idea that conscious interference in the workings of the economic system would do no good and much harm; and this view has persisted from then to now. But for the achievement of sustainability, automatic mechanisms are clearly insufficient. Even when pricing rather than control is used for implementation of economic policies, the prices must be set, consciously, by some agency; and this is then a highly visible controlling hand. When externalities are uncertain and irreversible, then it is impossible to set “ecologically correct prices” (through contingent valuation or other economic techniques) to be utilised in actual or fictitious markets. There might at best be “ecologically corrected prices”, set by a decision-making system. The hypotheses, theories, visions and prejudices of the policy-setting agents are then in play, sometimes quite publicly so. And the public also sees contrasting and conflicting visions among those in the policy arena, all of which are plausible and none of which admits of refutation by any other. This is a social system that, in the terms discussed above, is truly complex, indeed reflexively complex (Funtowicz and Ravetz 1994).

The issue is not whether it is only the market place that can determine economic value, for economists have long debated other means of valuation. The post-normal perspective challenges the assumption that in any dialogue, all valuations or ‘numeraires’ should be reduced to a single, one-dimensional standard. And when this is done by one side in a debate, we need to query whose special interests are served by the elimination of some particular dimensions of the uncertainties and the values from the universe of discourse (Funtowicz and Ravetz 1994, Funtowicz *et al* 1999).

In such novel contexts, there is a new role for science, both natural and social. The facts that are taught from the textbooks used in training institutions are still necessary, but they are no longer sufficient. Contrary to the impression that the textbooks convey, in practice most problems have more than one plausible answer, and many have no well-defined scientific answer at all. There are other lessons to be learned as well. In the artificial world studied in academic science courses, it is strictly inconceivable that science-related problems could be tackled and solved except by deploying the accredited expertise. Practical techniques that cannot be explained in principle by accepted science are commonly dismissed as the products of dogmatic tradition or blind chance. And when persons with no formal qualifications attempt to participate in the processes of innovation, evaluation or decision-making, their efforts have tended to be viewed with suspicion or scorn. PNS provides a means for correcting this sort of mindset, which has now become quite counterproductive, both for the legitimacy and for the quality of science-related policy processes.

3. Science for the Post-Normal Age

As a theory, PNS links epistemology and governance, for its origins lie in the relations between those two domains. Its authors were concerned that the sciences devoted to solving health and environmental problems (such as ecological economics and toxicology) are radically different from those that are instrumental in creating them (such as the applications of physics and molecular biology). In comparison to those traditional sciences, the policy-relevant sciences have enjoyed less prestige and funding, are less matured scientifically, and are more subject to external influences and constraints. By the criteria of the traditional philosophy of science, their results frequently fail to attain the status of ‘sound science’. It has been argued that they should therefore be rejected as evidence in policy debates; but a more appropriate conclusion would be that the philosophy of science needs recasting. PNS provides a response to these crises of science and philosophy, by bringing ‘facts’ and ‘values’ into a unified conception of problem solving in these areas, and by replacing ‘truth’ by ‘quality’ as its core evaluative concept. Its principle of the plurality of legitimate perspectives on any problem leads to a focus on dialogue, and on mutual respect and learning, wherever possible.

PNS comprises those inquiries that occur at the interfaces of science and policy where uncertainties and value-loadings are critical. It can be analysed as a ‘policy cycle’ including: policies, priorities, persons, procedures, products, and post-normal assessment; it also extends to the ‘downstream’ phases of implementation and monitoring (Funtowicz *et al,* 2000). Depending on the particular context, the task may be more like policy-related research, or science-related decision making, or creative technical-social innovation. The distinctions are never absolute, as the whole policy process is a complex system with interrelated natural, technical and societal elements.

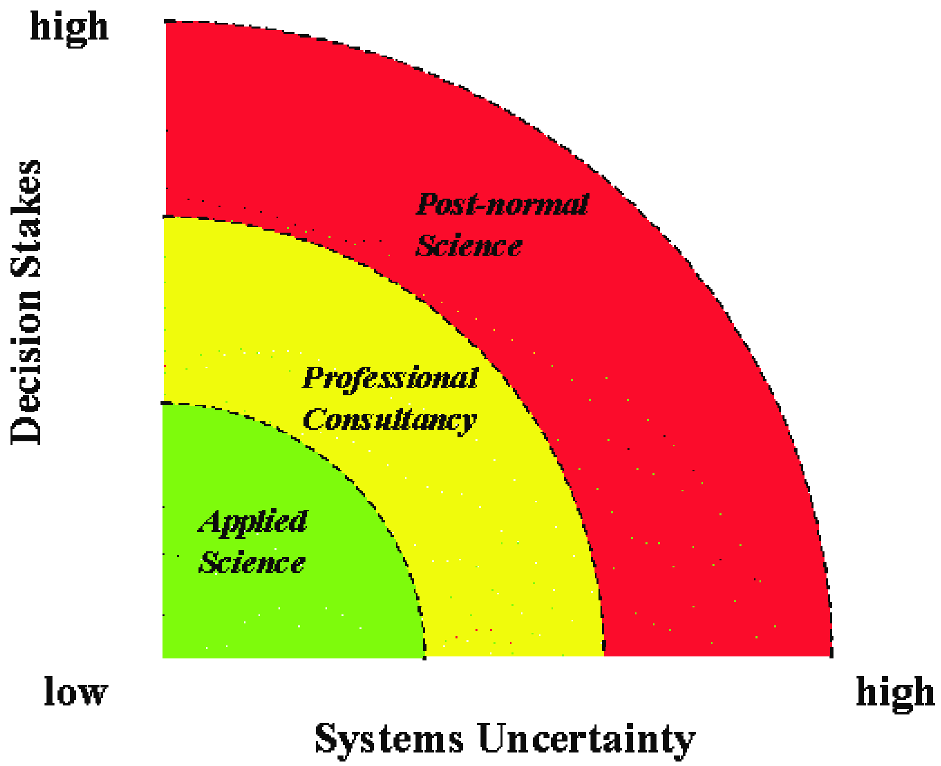

Figure 1: PNS diagram

PNS can be located in relation to the more traditional problem-solving strategies by means of a diagram (see Figure 1). On it, we see two axes, ‘systems uncertainties’ and ‘decision stakes’. When both aspects are small, we are in the realm of ‘normal’, safe Applied Science, where expertise is fully effective. When either is medium, then the application of routine techniques is not enough; skill, judgement, sometimes even courage are required. This is

Professional Consultancy, with the examples of the surgeon or the senior engineer in mind. In such cases, the creative element is more an exercise in design than the discovery of facts. Our modern society depends on armies of ‘applied scientists’ pushing forward the frontiers of knowledge and technique, with the professionals performing leading roles in technical and policy matters. In recent years we have learned that even the skills of professionals are not always adequate for the solution of science-related policy issues. When risks cannot be quantified, or when possible damage is irreversible, then we are out of the range of competence of traditional sorts of expertise and traditional problem-solving methodologies. This situation is represented on the diagram as the outer band, that of PNS. We notice that the band extends through the whole quadrant, right up to the region where ‘systems uncertainties’ vanish. This feature reflects the fact that if in some policy process the decision stakes are very high (as when an institution is seriously threatened by a proposed policy) then a defensive strategy will involve challenging every step of a scientific argument, even if the systems uncertainties are actually quite small.

The term ‘post-normal’ provides a contrast to two sorts of ‘normality’. One is the picture of research science as ‘normally’ consisting of puzzle solving within the framework of an unquestioned and unquestionable ‘paradigm’, in the theory of Kuhn (1962). Another is the assumption that the policy context is still ‘normal’, in that such routine puzzle solving by experts provides an adequate knowledge base for decision-making. The great lesson of recent years is that this assumption no longer holds. We may call it a ‘post-modern’ ‘rejection of grand narratives’, or a green, NIMBY (‘Not In My Back Yard’) or Luddite politics. Whatever its causes, we can no longer assume the presence of this sort of ‘normality’ of the policy processes of the environment and sustainability.

The management of systems uncertainties through the involvement of decision stakes occurs even in routine science. Whatever the statistical test, there will always be errors: no test can completely avoid being either too selective (rejecting genuine correlations) or too sensitive (accepting spurious ones). A balance must therefore be struck between the error-costs of excess selectivity and those of excess sensitivity, and that balance depends on the policy framework of the test. For example, if the main concern is to guard against spurious correlations in a lab experiment (correlations of the sort the researcher might want to see) a prudent policy is to increase the selectivity of the test. But if the task is to detect possible harm from contaminants, it is better to err on the side of precaution and make the test more sensitive. A very selective test designed around avoiding ‘false positives’ could exclude potentially important information, which could then remain permanently unknown. The well-known ‘confidence level’ expresses this value-driven choice. It is ‘normally’ not assigned by researchers; rather they automatically apply the level that is standard for their field.

All these considerations have been articulated in statistical theory, in terms of the ‘nul hypothesis’ around which tests are designed, and the errors of its rejection when true (Type I), or acceptance when false (Type II). These correspond to errors of excess sensitivity, and of excess selectivity, respectively. These are the stuff of routine work in ‘normal science’. Statistical theory tends to undervalue another sort of error, ironically called Type III, when the whole artificial exercise has no relation to the real issue at stake. Type III errors are a characteristic pitfall when the 'normal science' approach is deployed in post-normal situations. Modelling exercises are particularly prone to this sort of error, as when the gap between the available data and a manageable model on the one hand, and the real policy situation on the other, cannot be bridged.

All conventional economics outside of the most narrowly empirical sort is particularly prone to the Type III error. The combination of quantitative data with mathematical arguments or computer processing seems guaranteed, by traditional scientific methodology, to produce valid results. Then the role of economics in policy is to demonstrate the 'optimal' solution to all problems. With the post-normal perspective, we can see how uncertain data and inconclusive arguments can easily yield vacuous results. But with awareness and management of uncertainties and value-loadings, economic analysis can be a strong and indispensable tool in policy dialogues. This is the path of genuine ecological economics.

When a problem is recognised as post-normal, even the routine research exercises take on a new character. For the value-loadings and uncertainties are no longer managed automatically or unselfconsciously. As they may be critical to the quality of the product in the policy context, they are the object of critical scrutiny by researchers themselves as well as by the peers, ordinary and extended. Thus 'normal science' itself becomes 'post-normal', and is thereby liberated from the fetters of its traditional unreflective, dogmatic style.

For example, passenger transport had traditionally been seen as an essentially straightforward engineering problem of maximising mobility, subject to the constraints of optimising costs and safety. Now transport technologies and policies are strongly influenced by environmental considerations of many sorts, including concerns about sustainability. Moreover, consumer demand for passenger transport depends directly on lifestyles. Just now, Americans want large, gas-guzzling vehicles, and Europeans want cheap air travel to the sun. In terms of post-normal theory, passenger transport presents the severe systematic uncertainties of climate change, combined with the crucial decision stakes in conceptions of the good life, along with considerations of equity between peoples and generations. The entire population of passenger transport users has effectively become an extended peer community. The success of sustainable transport technologies will depend on the effectiveness of the public's commitment to the values of the global environment.

4. Extensions of the peer communities

There are now many initiatives, increasing in number and significance all the time, for involving wider circles of people in decision-making and implementation on health and environmental issues. The contribution of all the stakeholders in cases of PNS is not merely a matter of broader democratic participation. For these new problems are in many ways different from those of research science, professional practice, or industrial development. Each of those has established its own means for quality-assurance (peer review, professional associations, or the market) for the products of the work (Funtowicz 2001). But for these new problems, the maintenance of quality depends on open dialogue between all those affected.

This we call an ‘extended peer community’, consisting not merely of persons with some form or other of institutional accreditation, but rather of all those with a desire to participate in the resolution of the issue. Since this context of science is one involving policy, we might see this extension of peer communities as analogous to earlier extensions of the franchise in other fields, such as women’s suffrage and trade union rights. This is not merely a matter of extensions of liberty of individuals. With PNS we can guide the extension of the accountability of governments (the foundation of modern democratic society) to include the institutions involved in the governance of science and technology (Funtowicz and Ravetz 1992, 1993).

Extended peer communities are already being created, in increasing numbers, either when the authorities cannot see a way forward, or when they know that without a broad base of consensus, no policy can succeed. They are called ‘citizens’ juries’, ‘focus groups’, ‘consensus conferences’, or any one of a great variety of other names. Their forms and powers are correspondingly varied. But they all have one important element in common: they assess the quality of policy proposals, including a scientific element. They have proved their competence using the science they master during the exercise combined with their knowledge of their own situation in all its dimensions. And their verdicts all have some degree of moral force and hence political influence (De Marchi and Ravetz 2001).

These extended peer communities will not necessarily be passive recipients of the materials provided by experts. They will also possess, or create, their own ‘extended facts’. These may include craft wisdom and community knowledge of places and their histories, as well as anecdotal evidence, neighbourhood surveys, investigative journalism and leaked documents. Such extended peer communities have achieved enormous new scope and power through the Internet. Activists scattered among large cities or rainforests can engage in mutual education and coordinated activity, providing themselves with the means of engagement with global vested interests on less unequal terms than previously. This activity is most important in the phases of policy-formation, and also in the implementation and monitoring of policies. Thus in addition to extending the traditional processes of quality assessment, participants can enhance the quality of the problem solving processes themselves.

Along with the regulatory, evaluative function of extended peer communities, another, even more intimately involved in the policy process, is springing up. Particularly at the local level, the discovery is being made, again and again, that people not only care about their own environment, but can also become quite ingenious and creative in finding practical means for its improvement, integrating the social and technological aspects. For local people can imagine solutions and reformulate problems in ways that the accredited experts, with the best will in the world, do not find ‘normal’. In locations where relevant traditional knowledge survives, as in agriculture and healing, PNS provides a rationale whereby this traditional knowledge is utilised, harmonised, enhanced and validated anew. This provides the communities with both the means and the confidence, in their struggle to build a better life.

Under these new conditions, the appropriate style will no longer be rigid demonstration, but inclusive dialogue. Rather than proofs that one side is right and the other wrong, there will be tools displaying to each and to all the legitimate presuppositions and commitments of the parties. The practical implementation of the post-normal approach is indicated by this passage by Munda (2003): "In evaluating public policies there is a clear need to integrate scientific and technical expertise with local knowledge and legitimate interests, values and desires of the extended peer communities. A possible bridge between post normal science and practical evaluation tools may be the concept of social multi-criteria evaluation. Social multi-criteria evaluation puts its emphasis on the transparency issue; the main idea being that results of an evaluation exercise depends on the way a given policy problem is structured and thus the assumptions used, the ethical positions taken, and the interests and values considered have to be made clear. In this framework, mathematical models still play an important but less ambitious role than traditional optimisation, that is the one of guaranteeing consistency between assumptions used and results obtained."

What we call 'science' has undergone many changes over the centuries in its objects, methods and social functions. In the nineteenth century, mathematical science matured and became the unquestioned model for all other sciences, regardless of how appropriate it might be to their special circumstances. With PNS we are characterising the changes in science which will be necessary in this new century for our civilisation to become sustainable, and thereby worthy of survival.

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