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Review

Before and beyond the precautionary principle: Epistemology of uncertainty in science and law

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Abstract

The precautionary principle has become, in European regulation of science and technology, a general principle for the protection of the health of human beings, animals, plants, and the environment. It requires that "[w]here there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation".

By focusing on situations of scientific uncertainty where data are lacking, insufficient, or inconclusive, the principle introduced a shift from a neutral legal attitude towards science to a bias in favor of safety, and a shift from the paradigm of science certain and objective to the awareness that the legal regulation of science involves decisions about values and interests. Implementation of the precautionary principle is highly variable. A crucial question still needs to be answered regarding the assumption that scientific certainty is a 'normal' characteristic of scientific knowledge. The relationship between technoscience and society has moved into a situation where uncertain knowledge is the rule. From this perspective, a more general framework for a democratic governance of science is needed. In democratic society, science may still have a special authoritative voice, but it cannot be the ultimate word on decisions that only the broader society may make. Therefore, the precautionary model of scientific regulation needs to be informed by an 'extended participatory model' of the relationship between science and society.

Keywords: Science policy; Precaution; Science and democracy

Contents

Legalizing science

In recent decades, national governments' and international organizations' interest in science and technology (Bush, 1990), not only has increased greatly, but it has changed qualitatively by turning into direct participation and

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involvement. The leading role that science is playing regarding economic and social development has caused politics and the law on the one hand to pay particular attention to the regulation of technoscience (the inextricable connection between science and technology) and to its applications and on the other hand, they have been pervaded and colonized by scientific knowledge which is widespread in the very life of legal and political institutions (Schwartzenberg, 2000).

Many decisions concerning public policy strongly depend on scientific knowledge. Thus, the powers of the State – the organs of government, legislative power, and the judiciary – have been directly involved in scientific-and-legal choices and they have equipped themselves with experts (committees and boards of experts, expert witnesses, risk assessors) in order to acquire the necessary cognitive competencies. Furthermore, in connection with the increasing impact of science on society, legal systems initiated a broad regulatory activity towards scientific products and procedures. The interplay between science and society – between science and political and legal institutions – has become so strong that it deeply affects the structures and institutional dynamics, the roles of the groups that represent various interests, and the positions of individual citizens. In this situation, the obsolescence or the inadequacy of some legal concepts has to be recognized (Jasanoff, 1990, 1995).

When science has to deal directly with public policy, this so-called 'policy-related science' (Shepherd, 2000) must be conceptually separated and its aims must be different from either pure science or from applied science. Pure science is mainly guided by the researcher's curiosity, applied science is guided by a project and its goal to achieve particular outcomes. In contrast, policy-related science must help to define the problems which, as they have to find a social application, are linked to broad judgments that eventually demand a political choice even where they appear to be purely scientific or technical problems (Shepherd, 2000).

The complexity resulting from the mixing of science and the rules that govern civil life give rise to concern about the most adequate ways of governing science in democratic societies and lead to rethinking the idea of the State under the rule of law, the State that governs within the framework provided by legal norms and guarantees (Schmandt and Katz, 1986; Tallacchini, 2002a). The revision of the contract between science and society has been recently widely discussed and different models of relationship have been proposed (Nowotny et al., 2001; Liberatore and Funtowicz, 2003).

Science policy models

The most traditional analysis has pointed out two different aspects of the relationship between science and policy (Brooks, 1968). One aspect may be defined as 'science in policy' and concerns the strong presence of scientific knowledge in legal matters. The second aspect, called 'policy for science', refers to the open and uncertain character of much scientific knowledge, an uncertainty that poses the problem in which specific normative choices have to fill the gaps left by science. 'Science in policy' refers to the increasing number of science-based fields ruled by the law and to the normative qualification based on scientific data. Therefore, it refers to the technoscientific component that forms the cognitive content of the set of rules. 'Policy for science' indicates the situation in which normative evaluations fill the cognitive gaps when scientific data are insufficient, inadequate or inconclusive.

Actually, the two components are linked in the regulation of scientific activity. On one hand, the political and legal decision-makers are asked to be better informed about science. On the other hand, the position or role of scientists and experts involved in the production and implementation of the law – advisors, members of technical boards, expert witnesses in trials – seems to be deeply modified. In matters still in discussion among scientists, but which have to be quickly determined because of their social importance, the experts are no longer the mere spokesmen of neutral or certain knowledge which is unanimously shared by the scientific community, but they form an integral part of the political–scientific decision making process (Jasanoff, 1993).

The interactions among scientific and normative elements may inform several models, where different nuances exist in how science and the law merge together: scientific knowledge may prevail on legal and political evaluations, or scientific validity may be subordinated to the axiological and normative statements. But between these extreme points, many versions are possible. In the following analysis, I will concentrate my attention on three models, namely the models of the 'republic of science' (Polanyi, 1962), of the 'precautionary principle' (Jonas, 1985) and of 'extended participation' (Liberatore and Funtowicz, 2003). Through these three models, which represent the chronological evolution of science and policy, it is possible to perceive the increasing complexity of this relationship. This exposes the reason for the transition from one to the other, even if they actually coexist and confront each other in different contexts. It also highlights their interactions in the increasing presence of technoscience in individual and social life. Finally, it points out the need for specific warranties for science connected to public goals.

The republic of science: the idealization of scientific community and the myth of 'science speaking truth to power'

Since the origins of modern thought, political and legal philosophy has emphasized the neutrality and objectivity of scientific method, which seem irremediably lacking in political and legal thought. The unique opportunity and example that science has offered to social disciplines in

order to make them free from values and subjective opinions have been widely explored by legal scholars and political scientists as ways both to shaping legal systems according to the rules of logic and to founding the social contract on scientific bases.

This attempt has been accompanied by a substantial a-historicity and abstraction in the way it looks at both science and law. From this perspective, science is considered both as the ultimate methodological referent and as a separate entity within society. Hence, any parallel between the scientific system and the legal system may be seen only as a remote exchange between forms of 'knowledge' with substantially incommensurable and non-communicating methodologies and goals.

However, the criticisms raised against this vision of science as a methodological paradigm for political and legal theories have failed to address the assumption of the separateness of science, which, even within such perspectives, continues to appear as a self-contained form of knowledge with no links to social practices.

By and large, this approach has also influenced the legal regulation of scientific activities and products. Since science is considered an independent social institution which uses objective criteria to determine which knowledge may be deemed valid in a given situation, the law that interacts with science to regulate it is conceived of essentially as a 'technical norm' bound acritically to acknowledge knowledge ascertained and evaluated elsewhere.

The image that the scientific community has transmitted about itself and that still exists, is the ideal of the 'republic of science' immortalized by Michael Polanyi and Robert Merton (Polanyi, 1962; Merton, 1968). According to it, scientists form a perfect community of peers, self-governed through shared and freely discussed knowledge, without any coercive mechanisms and forms of authority other than knowledge itself.

Science is considered a community that naturally imposes itself on civil society because of the authority of its knowledge. Actually, as Polanyi observes: "The authority of scientific opinion remains essentially mutual; it is established between scientists, not above them. Scientists exercise their authority over each other. Admittedly, the body of scientists, as a whole, does uphold the authority of science over the public" (Polanyi, 1962: 60).

The structure of such a community is strongly linked to the nature of knowledge circulating in it. Such knowledge is expert knowledge, non-available to non-scientists and non-experts. That has for a long time justified the decision-making processes of scientific boards, where the decisions are not based on pluralistic procedures aimed at creating consensus and trust (Jasanoff, 1993), but are considered legitimate simply on the basis of the assumed validity of science. Furthermore, in the idealized image of science that Polanyi and Merton suggested – in order to reassert its value when the public confidence in the scientific community was beginning to decline – validity and ethicality of scientific knowledge were identified as an indissoluble combination. Validity is part of that ethos that, according to Merton, while expressing the reliability of scientific method, also shapes scientists' moral integrity.

"The virtual absence of fraud in the annals of science, which appears exceptional when compared with the record of other spheres of activity, has at times been attributed to personal qualities of scientists (...); a more plausible explanation may be found in certain distinctive characteristics of science itself. Involving as it does the verifiability of results, scientific research is under the exacting scrutiny of fellow-experts" (Merton, 1968: 613).

The intrinsic ethicality of the scientific community has represented one of the most important reasons to exempt science from legal and political guarantees constructed against other powers (Bush, 1990). In this vision, "science speaks truth to power" (Wildavsky, 1979), namely legal rules or political decisions simply represent the normative framework for scientific content autonomously established by scientists.

The hypothesis of the separation of science from the other social systems, incorporated in the model of the 'republic of science', fails at least to consider that such a concept is implausible when analyzed in the context of the institutional procedures and social practices, where science, policy and the law merge in co-producing their respective forms of knowledge (Jasanoff, 1995). If we analyze how science used for regulatory purposes is produced, we see not only that the methods applied are different from the theorized ones, but also that the boundaries between scientific and legal epistemology, between the 'facts' of science and the 'values' of law, become blurred.

Scientific uncertainty and the precautionary model

Contemporary scientific knowledge is characterized increasingly by uncertainty (O'Riordan and Cameron, 1994). This is due not only because both the risks and the unpredictability linked to it are increasing, but above all because of the intrinsic incompleteness and indeterminacy of scientific knowledge compared with the needs to make social choices, public policy, and legal decisions. Such uncertainty is the daily condition where science works, and it shapes the social issues, where complex collective and individual trends must be reformulated through methodological decisions and through the reductionist analytical character of scientific procedures. The expression 'scientific uncertainty' has been used to refer to different forms of lack of information in science: the complexity of knowledge, the lack of data, the unpredictability of results, and the stochastic character of predictions. This means that more and more often, the experts involved in regulatory science are unable to adopt an unequivocal position, and, therefore,

that science produces different or partially diverging theses. The unending work that characterizes scientific research has already shifted to radical forms of indecisiveness.

Beginning with the eighties, uncertainty in science has been widely explored after philosopher of science Ian Hacking remarked that the centrality of ignorance in contemporary science has not received attention enough as to its epistemological statute (Hacking, 1986).

According to Smith and Wynne, lack of knowledge may lead to different situations: risk, uncertainty, ignorance and indeterminacy (Smith and Wynne, 1989). In decisions under conditions of risk, the main variables of a problem are known and the respective probability of different outcomes is quantified. In contrast, in decisions under conditions of uncertainty, even if we know the main variables of a system, we do not know the quantitative incidence of the relevant factors, and so we ignore the probability of an event. A different definition qualifies uncertainty as 'a probability of the second order' (Bodansky, 1994). This means that, while in cases of risk we can quantify the probability of the event, in cases of uncertainty we can only quantify the probabilities relating to alternative risk assessments. Ignorance is the situation defined as that of 'unknown unknowns' (European Environmental Agency, 2001), when, since the basic elements of a problem are unknown, the possible negative outcomes are also unknown, they are unpredictable unless new cognitive elements emerge. Finally indeterminacy is the concept that summarizes the basically open and conditional characteristic of all knowledge, particularly its contextual meaning and its socio-cultural determination.

Scientific uncertainty seems to challenge the reliability of decision-making process. The last few years have seen the radical subversion of the conditions that made the theoretically neutral and separate relationship between science and law tenable. Scientific activities and products subjected to the scrutiny of law have increased exponentially, and contexts have appeared in which science has at once created risks and proved largely incapable of controlling them (Raffensperger and Tickner, 1999). The technoscientific component has increasingly constituted the cognitive content of norms, but the number of situations is increasing in which law has to fill cognitive gaps, since scientific data prove uncertain, insufficient or susceptible to sharply diverging interpretations.

On the one hand, the strong presence of scientific learning in subjects of normative competence means that it is necessary to explore relationships between science and law as an intersection between scientific and legal concepts and qualifications. On the other, the indeterminate or uncertain character of much scientific knowledge poses the problem of selecting specific norms to overcome the gaps left by science.

The problem of the legal treatment of uncertainty is at the root of the precautionary principle. The precautionary principle (PP) was introduced internationally in 1992 – as precautionary approach – by Principle 15 of the Rio Declaration on Environment and Development: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damages, lack of full scientific certainty shall nor be used as a reason for postponing cost-effective measures to prevent environment degradations".

The Maastricht Treaty (Art.130 R, par.2, art.174 of Amsterdam EC Treaty, now European Convention, Sec. 5, Environment, Article III-129) presented the PP for the first time as distinct and autonomous from the principle of prevention. Some overlaps exist between precaution and prevention. The preventative element is certainly present in the PP, even if it is a question of the prevention of a damage only potentially hypothesized. It is more correct to speak of anticipatory aspect: i.e. the anticipation of the (political) judgment of the presence of 'signs of causality' in absence of ascertained causal links.

The most interesting interpretation of precaution has developed according to this vision: the awareness that the law must intervene "even before a casual link has been established", where the anticipation does not hint at a general preventive intervention, but it hints at the critical awareness that causal and scientific evidence may be achieved too late or may be unattainable (Bodansky, 1994). Thus, law and science appear to complement each other in decision-making process under conditions of uncertainty.

With PP, law frees itself from submission to science and it works out a critical position that acknowledges a positive role to ignorance. As Bodansky has outlined, "Risk assessment, unlike the precautionary principle, generally assumes that we can quantify and compare risks. It is information intensive and rational. Moreover, it can and often does take a neutral attitude towards uncertainty. (..) In contrast, the precautionary principle is not neutral towards uncertainty—it is biased in favor of safety" (Bodansky, 1994: 209). The passage from a two-value science to a three-value science is fulfilled: from an idea of scientific quality which confines itself to evaluating the truth/falsity (verification/not verification) of the scientific hypothesis, to a science which expressly considers and recognizes the hypothesis of uncertainty and of indecision. The need for this three-value science, as Shrader-Frechette has pointed out, depends on an essential difference between theoretical science and science applied to risks. Actually, while the former moves in the abstract perspective of true/false, the latter is connected to the real and complex question of risk acceptability or unacceptability (Shrader-Frechette, 1996). In risk analysis, two different kinds of errors may happen in decisions under uncertainty: errors of type-I occur when one rejects a true null hypothesis (a claim of no effect); errors of type-II occur when one fails to reject a false null hypothesis. In assessing environmental impacts, in a situation of uncertainty where both types of error cannot be avoided, when we minimize type-I error, we minimize

the error of rejecting a harmless development; when we minimize type-II error, we minimize the error of accepting a harmful development. The former depends on an excessive scientific optimism, the latter on an excessive prudence. The prospect inherent in the precautionary principle tends to reduce as much as possible the mistakes that produce risks for people, considering that it is better to make a mistake harmful to the economy – a mistake that limits development not risky in itself – but not harmful to people.

In 2000, the Communication of the European Commission on the PP qualified it as a general principle of the European Union for human, animal, vegetable, and environmental health (Commission of the European Communities, 2000). The PP – the Commission says – must be considered inside a unitary process of risk analysis (communication and management) and may be used when scientific information is inadequate, inconclusive and uncertain. Once evoked, the PP may be applied by adopting different measures of information and protection, as well as deciding not to adopt any particular measure. But what the Commission makes very clear is that the PP is a political principle, namely the principle that considers certain risks as "inconsistent with the high level of protection chosen for the Community", and "an eminently political responsibility".

The PP is the object of great criticism by the scientific world which judges it to be a kind of obscurantism and an instrumental support of the people's irrational fears. The philosophical and moral reflection which, at the roots of its theoretical foundation, has had a great impact on this interpretation is Hans Jonas' perspective of the 'heuristics of fear' (Jonas, 1985): according to the Author, when confronted with scientific uncertainty and in order to protect what is possibly at stake and what we must beware of, it is wiser and more responsible to accept the priority of the prophecy of doom on the predictions of hope.

It is interesting to observe that Jonas has provided the PP with a 'psychological' foundation – the feeling of fear – instead of an epistemic one. In Jonas' philosophical vision, there is no room for a cognitive dimension outside the objectivity and certainty of science. Lack of full knowledge is also lacking an epistemic statute and ignorance is more a psychological position than a cognitive one. Accordingly, fear appears as a substitute for cognitive dimensions towards the unknown, and an adequate mechanism for a prudent behavior. But uncertainty is not just a synonym for non-rationality or irrationality. According to Hacking, we should reflect on the 'statute of lack of knowledge' in its cognitive aspect and determine our actions accordingly. This means a behavior of active scientific wisdom combined with the awareness of the value-laden dimensions of science, and strengthened by the use of procedures aimed at making choices more legitimate, objective and shared. But this position does not reflect the reality of the PP.

Although the PP is considered the most characteristic feature of an emerging European epistemological identity in science policy (Tallacchini, 2002b), it is hard to see it as an innovative principle in the political decision-making process. Even though some legally binding European documents, such as the Directive 2001/18/EU on the deliberate release of Genetically Modified Organisms (GMOs) or the Directive 2004/40/EC of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from electromagnetic fields, make the consultation with the public mandatory, these procedures do not unequivocally reflect a more democratic attitude towards science-based policy, but may be aimed mainly at obtaining consensus. In fact, according with the Communication on the PP, the principle can be institutionally evoked only by the European Commission and no legal power is granted to citizens about it.

It is important here to observe that both the positivist view of science – denying the existence of uncertainty – and the 'psychological' foundation of the PP (Jonas, 1985) – denying the cognitive side of ignorance – are similar in their easily leading to authoritarian political results. The former is associated with a technocratic perspective where the scientific community informs the content of legal and political decisions. The latter, even when linked to public consultation, can in any case have authoritarian results, relying exclusively on a political will, divorced from a cognitive rationale and supported by public fear. Actually, both the perspectives agree on a 'certainty-or-irrationality' alternative, the model according to which, outside scientific certainty, only opinions or merely felt preferences exist.

But theoretical reflections on the relations among science, policy and the law have gone beyond this alternative, which actually is an absence of alternatives.

Beyond the precautionary principle: democratizing science and expertizing democracy

Jerry Ravetz (Ravetz, 1999) and Silvio Funtowicz (Funtowicz, 2001), referring to the normative challenges set by life sciences, have coined the expression 'post-normal science' to indicate the situations where "typically facts are uncertain, values in dispute, stakes high, and decisions urgent".

But the present situation concerning the social impact of technoscience nearly always represents post-normal science: in other words, post-normal science usually represents the 'normal' situation in most of scientific social choices.

From this point of view, the PP, so as it has been defined by Principle 15 of the Rio Declaration on Environment and Development, seems to be conceptually superseded. Principle 15 actually describes a 'lack of full scientific certainty' thus implicitly assuming that the normal condition of science is certainty, and that uncertainty is always circumstantial and temporally limited. Again, it concerns an incremental model of science where sooner or later the truth is reached. According to Jean-Pierre Dupuy, in the PP,

the very notion of uncertainty is missed: "The key notion here is that of informational incompressibility, which is a form of essential unpredictability. In keeping with von Neumann's intuitions on complexity, a complex process is defined today as one for which the simplest model is the process itself. The only way to determine the future of the system is to run it: there are no shortcuts. This is a radical uncertainty" (Dupuy, 2004: 80).

In Dupuy's view, the introduction of subjective probabilities in statistics has allowed the reduction of uncertainty to the concept of quantifiable risk, because subjective probabilities no longer correspond to any sort of regularity found in nature, but simply to the coherence displayed by a given agent's choices. "A risk can in principle be quantified in terms of objective probabilities based on observable frequencies; when such quantification is not possible, one enters the realm of uncertainty. It is easy to see that the introduction of subjective probabilities erases the distinction between uncertainty and risk, between risk and the risk of risk, between precaution and prevention. No difference remains compared to the case where objective probabilities are available from the outset. Uncertainty owing to lack of knowledge is brought down to the same plane as intrinsic uncertainty due to the random nature of the event under consideration. [...] In truth, one observes that applications of the 'precautionary principle' generally boil down to little more than a glorified version of 'cost-benefit' analysis" (Dupuy, 2004: 78–79).

More advanced perspectives on science policy are overcoming the PP. They are beyond the idea of an emergency principle about science, and they are supporting a more general democratization of scientific expertise and public participation in scientific decisions for public policy. The appearance of risks and uncertainties linked to the social implementation of science has revealed a double need: in the first place, the need to widen consultation with scientists where the divisions of opinions arise about the possible occurrence of potentially harmful events; in the second place, the opportunity to involve citizens more in science-based decisions that directly concern the civil society (Irwin and Wynne, 1996; Nowotny, 2003).

The European Commission White Paper on Governance (Commission of the European Communities, 2001, 2004) goes in this direction. It expresses the need for deepening democracy in Europe, and it includes the topic of science governance. The European context has been shaken by emergencies linked to inadequate and inefficient regulating measures in scientific fields. But the European reflection about science governance is not only a pragmatic answer to the political need to re-establish citizens' trust in the institutions facing scientific challenges. It also reflects a theoretical effort to work out a European way to regulate policy-related science.

The changes in the relation between science and society are deeply modifying the institutional structures and all the rights that are linked to the notion of a social contract and particularly to the idea of a constitutional state (Fuller, 2000). The political rights granted to citizens in the *lato sensu* liberal democratic governments have been mostly the ones that help people to determine their political orientation using their vote. The need to make more visible and transparent the decisional procedures inside the institutions has more recently formed a new kind of participation in government action (at least potentially) through what is more and more recognized to be the citizens' right to know.

The store of warranties which define the very idea of a constitutional state has not adequately affected the relationship among science, individuals and institutions. The appointment of experts, the setting up and running of scientific and technical boards, and the same scientific knowledge considered the expression of an objective and certain method, have not been considered a problematic topic from the point of view of the protection that the state offers to its citizens (De Schutter et al., 2001). The need to introduce specific warranties and rights as well as to promote greater democratic participation of the civil society today specifically concerns science regulation, a field where up to now citizens' absence has been nearly complete.

This vision of the relationship between science and society does not refuse to acknowledge the privileged character of scientific language. Science may speak particularly reliable words, but it does not have the power to utter the exclusive or final word about social choices. We must establish the conditions of public acceptance of the different kinds of knowledge; we must determine the forms of public control of such knowledge, the different methodological and axiological assumptions, that suggest their operation; no form of knowledge may be asserted only on the basis of a predefined validity or truth.

In this sense, the governance of science is a problem of democracy: here, the word democracy does not refer to the predominance of a majority, but to the open and unauthoritative characteristic of any language (including scientific ones). Every social decision must be screened in different places and through a plurality of knowledge, comparisons and transactions. Moreover, law becomes the place where different knowledge and languages are discussed and guaranteed through the participation of different subjects. It would be reductionist to interpret such a position as an antiscientific one. It does not consist of a limitation on science and scientists' freedom—if such freedom is ethically qualified and it is not seen as a merely arbitrary explication. On the contrary, it is a question of favoring a deeper comprehension of the complex links between science and society, determining more adequate ways and procedures in scientific and technological choices, at the root of social and civil transformations. In a recent publication devoted to democratizing scientific expertise and to expertizing democratic procedures, Angela Libera-

tore and Silvio Funtowicz clarify their use of such challenging terms:

"If democracy is only seen as majority voting, and expertise as a self-referential system in which only peers can recognize and judge each other, then clearly democratizing expertise, is a contradiction in terms. When such premises are challenged however, the contradiction disappears, while different issues still need to be addressed" (Liberatore and Funtowicz, 2003: 147).

This is the wider context of science policy where the PP has to be placed, having had the pioneering merit to indicate that the times were ripe to reflect on our criteria for democracy and rationality. "Science (seen as that activity performed by technicians and experts) is considered as a part of 'the relevant knowledge' and it is included only as a part of the probative evidence of a process. The ideal of rigorous scientific demonstration is thus replaced by an ideal of open public dialogue. Inside the knowledge production process, citizens become both critics and creators. Their contribution has not to be identified as 'local', 'practical', 'ethical', or 'spiritual' knowledge, but it has to be considered and accepted as a plurality of rightful and coordinated perspectives with their own meanings and value structures. The strength and the importance of scientific evidence may be then the object of the citizens' analysis, every scientific aspect may be the object of a dialogue in order to be enriched in its content. Otherwise, it may turn out to be fictitious and imperfect. Through this co-production of knowledge, the existence of a wide community of experts and revisers may be the source of a kind of 'experience democracy' " (Liberatore and Funtowicz, 2003: 147).

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