Precautionary Governance and the Limits of Scientific Knowledge: A Democratic Framework for Regulating Nanotechnology

Oren Perez *

* LL.B. Tel Aviv University, Faculty of Law; LL.M, Ph.D. London School of Economics; Professor, Bar Ilan University Faculty of Law, Ramat Gan, Israel. I would like to thank the participants of the UCLA 2009 Working Conference on Nanotech Regulatory Policy (April 17, 2009) and the participants of the colloquium of the Science, Technology and Society program at Bar Ilan University for helpful comments on an earlier version of this paper. I would also like to thank the editorial team of JELP for their excellent work on this article.

I.
INTRODUCTION

Nanotechnology presents regulators with a difficult challenge. Nanomaterials and nanoprocesses involve deep uncertainties regarding their potential benefits and health and environmental risks, reflecting the embryonic state of the underlying science. These uncertainties are exacerbated by the fact that nanotechnology is not a uniform domain, but encompasses a broad range of technologies and products, including bionanotechnology, supramolecular chemistry, nanostructured materials, and self-assembly nanoprocesses.[1]

Given these uncertainties, there have been various calls to use the precautionary principle (PP) as a governing principle in the regulation of nanotechnology. Thus, for example, the Intergovernmental Forum on Chemical Safety (IFCS) recommended in September 2008 that the precautionary principle be used "as one of the general principles of risk management throughout the life

1. *See* Thomas Theis et al., *Nan'o·tech·nol'o·gy* n., 1 NATURE NANOTECHNOLOGY 8, 8-10 (2006), *available at* http://www.nature.com/nnano/journal/v1/n1/index.html; K. Böhringer, *Engineered Self-assembly from Nano to Milli Scales*, *in* MULTI-MATERIAL MICRO MANUFACTURE (S. Dimov & W. Menz eds., 2008).

cycle of manufactured nanomaterials."[2] A recent joint statement by several environmental NGOs notes similarly that "[t]he Precautionary Principle must be applied to nanotechnologies because scientific research to-date suggests that exposure to at least some nanomaterials, nanodevices, or the products of nanobiotechnology is likely to result in serious harm to human health and the environment."[3] Drawing on the PP, many environmental groups have called for a moratorium on the sale (and even research) of products containing nanomaterials, arguing that the research to date is insufficient to guarantee the safety of nanoproducts, and that whatever safety research has been conducted has not been properly disseminated to the public.[4]

The need to apply a precautionary strategy in the regulation of nanotechnology has also been recognized by legal scholars,[5] advisory bodies[6] and regulators.[7] These calls rest on several assumptions:

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2. INTERGOVERNMENTAL FORUM ON CHEMICAL SAFETY, SIXTH SESSION OF THE INTERGOVERNMENTAL FORUM ON CHEMICAL SAFETY (2008) [hereinafter CHEMICAL SAFETY], *available at* http://www.who.int/ifcs/documents/forums/forum6/f6_execsumm_en.pdf.

3. INTERNATIONAL CENTER FOR TECHNOLOGY ASSESSMENT, PRINCIPLES FOR THE OVERSIGHT OF NANOTECHNOLOGIES AND NANOMATERIALS 2-3 (2008) [hereinafter PRINCIPLES], *available at* http://www.icta.org/doc/Principles%20for%20the%20Oversight%20of%20Nanotechnologies%20and%20Nanomaterials_final.pdf.

4. *See generally* JULIAN LEE & RWANDA KIGALI, CENTRE FOR APPLIED STUDIES IN INTERNATIONAL NEGOTIATIONS, GLOBAL NANOTECHNOLOGY ADVOCACY BY NGOS (2006), *available at* http://www.casin.ch/web/pdf/nanotechnologyreport.pdf. Friends of the Earth has called in a recent report for a moratorium on the further commercial release of nanofoods until nanotechnology-specific safety laws are established and the public is involved in decision making. GEORGE MILLER & DR. RYE SENJEN, FRIENDS OF THE EARTH, OUT OF THE LABORATORY AND ON TO OUR PLATES: NANOTECHNOLOGY IN FOOD AND AGRICULTURE 4 (2008). *See also* NanoAction, Introduction to Nanoaction, http://www.nanoaction.org/nanoaction/index.cfm (last visited Nov. 13, 2009).

5. *See, e.g.*, Ortwin Renn & Mihail Roco, *Nanotechnology and the Need for Risk Governance*, 8 J. NANOPARTICLE RES. 153 (2006) [hereinafter Renn & Roco], *available at* http://www.springerlink.com/content/y80541n7740785gm/fulltext.pdf (offering a sophisticated framework for risk governance, informed by the PP).

6. THE U.K. ROYAL COMMISSION ON ENVIRONMENTAL POLLUTION, NOVEL MATERIALS IN THE ENVIRONMENT: THE CASE OF NANOTECHNOLOGY 65-71 (2008) [hereinafter RCEP/NM], *available at* http://www.rcep.org.uk/reports/27-novel%20materials/documents/NovelMaterialsreport_rcep.pdf.

7. *See, e.g.*, HM GOVERNMENT, RESPONSE TO THE ROYAL SOCIETY AND ROYAL ACADEMY OF ENGINEERING REPORT: NANOSCIENCE AND NANOTECHNOLOGIES: OPPORTUNITIES AND UNCERTAINTIES (2005), *available at* http://www.berr.gov.uk/files/file14873.pdf.

- There is plausible support for the claim that nanotechnology is possibly risky, and is risky in novel and non-uniform ways.[8]
- There is an expanding gap between the pace at which new products containing nanomaterials are being developed and the generation of relevant environmental, health and safety data. This gap also reflects the fact that current methods of risk assessment are not necessarily appropriate for the evaluation of nanomaterials.[9]
- There are various gaps in the regulatory framework that apply to nanoproducts (in particular, within the field of chemical regulation).[10]

Another important theme which underlies the various interventions of civic groups concerns the need for stronger public participation in the regulatory process concerning nanotechnologies. Thus, for example, the Dakar statement emphasizes the need for continued dialogue between governments and stakeholders on the benefits and risks of manufactured nanomaterials and on strengthening the capacity of civil society so that it may effectively take part in decisionmaking related to manufactured nanomaterials. The Principles for the Oversight of Nanotechnologies and Nanomaterials state similarly that the "potential of nanotechnologies to transform the global social, economic, and political landscape makes it essential that the public fully participate in the deliberative and decision-making processes."[11] Both documents also highlight the need for transparency.[12] The need to develop participatory mechanisms was also recognized by various government agencies.[13] Despite these

8. *See, e.g.*, RCEP/NM, *supra* note 6, at 27-54; Craig A.Poland et al., *Carbon Nanotubes Introduced into the Abdominal Cavity of Mice Show Asbestos-like Pathogenicity in a Pilot Study*, 3 NATURE NANOTECHNOLOGY 423 (2008); Dietram A. Scheufele et al., *Scientists Worry About Some Risks More than the Public*, 2 NATURE NANOTECHNOLOGY 732, 733 (2007); Directorate-General on Health & Consumers, Scientific Committee on Emerging and Newly Identified Health Risks, *Risk Assessment of Products of Nanotechnologies* (Jan. 2009) [hereinafter SCENIHR], *available at* http://ec.europa.eu/health/ph_risk/committees/04_scenihr/docs/scenihr_o_023.pdf.

9. *See* RCEP/NM, *supra* note 6, at 30.

10. *Id.* at 60; BRYAN WARD & SARAH HARLEY, REACH AND THE REGULATION OF NANOTECHNOLOGY 1 (2008), *available at* http://www.safenano.org/Uploads/NanoREACH.pdf; Renn & Roco, *supra* note 5, §2; Reut Snir, *Regulating Risks of Nanotechnologies for Water Treatment*, 38 ENVTL. L. REP. NEWS & ANALYSIS 10233 (2008).

11. PRINCIPLES, *supra* note 3, at 6.

12. *Id.* at 5-6; CHEMICAL SAFETY, *supra* note 2.

13. *See* RCEP/NM, *supra* note 6, at 72.

calls, the contemporary regulatory landscape is governed by expert-led decisionmaking bodies. While there has been some effort to incorporate the public into the decisionmaking process, primarily in Europe, most commentators agree that the impact of civic voice on the actual decisionmaking process was generally negligible.[14]

This Article seeks to highlight the intrinsic link between the calls to apply the PP to the domain of nanoregulation and calls to subject the regulation of nanotechnologies to deeper public scrutiny. Reinterpreting the PP as a political framework for regulating risks provides a way, I argue, to respond to these concurrent demands. This political understanding of the PP is motivated by the principle's deep vagueness and the normative impasse generated by this vagueness. After presenting my general argument, I conclude the Article by exploring some of the key challenges underlying this political reframing of the PP, placing it in the context of the governance of nanotechnology.

II.
A PRINCIPLE IN SEARCH OF MEANING: THE NORMATIVE FLUIDITY OF THE PRECAUTIONARY PRINCIPLE

A. *Introduction: On the Pragmatic Nature of the Precautionary Principle*

The PP reflects an attempt to arbitrate between two competing social concerns: an increased anxiety about the possible adverse environmental and health effects of novel technologies and the scientific-economic drive for technological innovation. On the one hand, the PP provides a response to the broadening demand for a more proactive risk regulation. This demand was boosted by several highly publicized ecological disasters and public-health scandals at the 1980s and 1990s (such as the 1984 disaster at Bhopal, and the outburst of the mad-cow disease in England).[15] On the other hand, the PP also seeks to respond to the concerns of industry by rejecting demands for the introduction of

14. *Id.* at 75; Georgia Miller, *Nanotechnology and the Public Interest: Repeating the Mistakes of GM Foods?*, 7 INT'L J. TECH. TRANSFER & COMMERCIALISATION 274, 277 (2008).

15. For a discussion of the Bhopal disaster, see Sheila Jasanoff, *Bhopal's Trials of Knowledge and Ignorance*, 98 ISIS 344 (2007). For a discussion of mad-cow disease, see Peter Washer, *Representations of Mad Cow Disease*, 62 SOC. SCI. & MED. 457 (2005); Jacqueline Janka & Frank Maldarelli, *Prion Diseases: Update on Mad Cow*

a complete ban on potentially risky technological innovation. This is achieved by setting bounds on the ability of regulators to intervene in the development of new technologies. Since the 1980s, the PP was endorsed and incorporated by numerous legal instruments, both international and national,[16] and has dominated the discussion of risk in the regulatory domain. However, despite its widespread adoption, the PP remains deeply contested.[17] One way in which the ambiguities underlying the PP can be resolved, I argue, is by developing a political understanding of precautionary governance. This interpretation does not constitute the only possible solution to the interpretative puzzle underlying the PP. Indeed, various other interpretations have been offered by scholars, regulators and courts.[18] However, the political understanding of the PP responds, I believe, to wide-ranging social expectations regarding the way in which the governance of risk should be carried out in a democratic society.

To set the stage for the discussion, consider the language of the two most dominant formulations of the PP. Principle 15 of the Rio Declaration on Environment and Development states:

> 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 damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.[19]

Disease, Variant Creutzfeldt-Jakob Disease, and Transmissible Spongiform Encephalopathies, 6 CURRENT INFECTIOUS DISEASE REPORTS 305 (2004).

16. For a survey, see Arie Trouwborst, *The Precautionary Principle in General International Law: Combating the Babylonian Confusion*, 16 REV. EURO. COMM. INT'L ENVTL. L. 185 (2007).

17. The ambiguity of the precautionary principle was discussed by other writers. *See, e.g.*, P. Sandin et al., *Five Charges against the Precautionary Principle*, 5 J. RISK RES. 287 (2002); Christian Gollier & Nicolas Treich, *Decision-Making Under Scientific Uncertainty: The Economics of the Precautionary Principle*, 27 J. RISK & UNCERTAINTY 77, 77 (2003).

18. *See, e.g.*, M. Peterson, *Should the Precautionary Principle Guide our Actions or our Beliefs?*, 33 J. MED. ETHICS 5 (2007); Per Sandin, *A Paradox Out of Context: Harris and Holm on the Precautionary Principle*, 15 CAMBRIDGE Q. HEALTHCARE ETHICS 175 (2006); Cass R. Sunstein, *Irreversible and Catastrophic*, 91 CORNELL L. REV. 841 (2006); Gollier & Treich, *supra id.*; Robert S. Pindyck, *Uncertainty in Environmental Economics*, 1 REV. ENVTL. ECON. & POL'Y 45 (2007); *Communication from the Commission on the Precautionary Principle*, 1 COM (Feb. 2, 2000), *available at* http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2000:0001:FIN:EN:PDF.

19. Rio Declaration on Environment and Development, June 14, 1992, 31 I.L.M. 874, 879 (1992). Another prominent example is Art 3(3) of the U.N. Climate Change Convention (1992), which provides:

The 1998 Wingspread Statement on the PP states:

> Where an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public bears the burden of proof.[20]

Before moving to discuss the ambiguity of the PP, I want to consider the nature of the PP. In particular, should the PP be understood as an epistemic principle, setting universal criteria for the justification of beliefs in situations involving environmental and health risks?[21] Or should it be interpreted as a decisionmaking principle, setting guidelines for action?[22] Given the institutional context in which the PP is primarily invoked—legal and regulatory discourse—I argue that the PP is only intelligible as a prescriptive principle. Legal norms belong to the realm of practical reasoning; their main concern lies in actions, not beliefs.[23] Law makes no claim to provide universal epistemic criteria.[24] By focusing on actions rather than beliefs, law enables people to accept behavioral generalizations, despite profound disagreements regarding the fundamental justification of these practices.[25] Fur-

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> The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. . .

United Nations Framework Convention on Climate Change, May 9, 1992, 31 I.L.M. 849, 854 (1992).

20. Wingspread Statement on the Precautionary Principle, Wingspread Conference Center, Racine, Wisconsin (Jan. 23-25, 1998) [hereinafter Wingspread Statement], *available at* http://www.gdrc.org/u-gov/precaution-3.html.

21. For this interpretation, see Peterson, *supra* note 18.

22. For this interpretation, see Sandin, *supra* note 18. The prescriptive interpretation also characterizes the discussion of the PP in the legal, economic and public health literature. *See, e.g.*, Sunstein, *supra* note 18; Pindyck, *supra* note 18; Gollier & Treich, *supra* note 17; Douglas L. Weed, *Precaution, Prevention, and Public Health Ethics*, 29 J. Med. Philos. 313, 314 (2004); Bernard D. Goldstein, *The Precautionary Principle Also Applies to Public Health Actions*, 91 AM. J. PUB. HEALTH 1358 (2001).

23. To be intelligible as a legal principle the PP needs, therefore, to be viewed as a *deontic schema*. For an explanation of this concept, see Paul McNamara, *Deontic Logic*, THE STANFORD ENCYCLOPEDIA OF PHILOSOPHY (Edward N. Zalta ed., Spring 2009), *available at* http://plato.stanford.edu/archives/spr2009/entries/logic-deontic/.

24. On the role of norms in practical reasoning (the idea of norms exclusionary reasons for action), see JOSEPH RAZ, THE MORALITY OF FREEDOM 57-8 (1986).

25. RAZ, *supra id.*, at 58 (referring not just to epistemic beliefs, but to others—for example, religious and moral beliefs—as well).

thermore, legal prescriptions maintain their validity even in the face of contradictory experiences.[26] It is, of course, true that law also contains rules regarding the treatment of evidence, pertaining both to the ways in which they can be introduced (admissibility) and the inferences that can be drawn from them (weight, causality).[27] However, these are not epistemic rules, but rather secondary norms, which are needed in order to allow the generation (whether by court or a regulatory agency) of action-guiding prescriptions.

Douglas Weed has suggested, for example, that the PP could alter public health methodology by reducing the number of criteria used in making causal judgements.[28] However, these alternative criteria are not meant to serve as epistemic principles: they make no claim to provide universal criteria for the production of knowledge. Rather, they constitute secondary rules driven by the need to enable practical decisions in the domain of risk governance; their validity is limited to the legal, regulatory domain.[29]

Of course, even if it is agreed that the PP should be interpreted as an action-guiding principle, we are still left with the question of how to interpret it. But at least the challenge is clear.

B. *The Normative Fluidity of the Precautionary Principle: A Close Look*

Taken as an action-guiding principle, the PP can be interpreted as consisting of the following three elements; if there is (1) a (sufficiently) serious threat, which is (2) uncertain, then (3) some kind of regulatory action should be taken.[30]

The difficulty with the foregoing formulation is that the law has failed to develop universally accepted criteria for interpreting and applying it. This fluidity undermines the capacity of the PP to serve as a prescriptive principle. Further, this normative vagueness is *endemic*: it is not limited to law but is also shared by

26. NIKLAS LUHMANN, LAW AS A SOCIAL SYSTEM 148 (Fatima Kastner ed., K. A. Ziegert trans., 2004).

27. Susan Haack, *Inquiry and Advocacy, Fallibilism and Finality: Culture and Inference in Science and the Law*, 2 L., PROBABILITY & RISK 205 (2003) (discussing the different rules of inference in science and law).

28. Weed, *supra* note 22, at 320-24 (referring to the "Hill's Criteria").

29. It is of course true that there is a social interest to prevent a gap between reality and its 'legal/regulatory' reflection. It is less clear whether we have the right mechanisms to assess (or eliminate) this gap.

30. This interpretation draws on the writings of Per Sandin and the Appellate Body ruling in the Hormones case; *see* Sandin, *supra* note 18.

other disciplines. The law cannot, therefore, resolve its internal normative perplexity by drawing on the intellectual resources of other discursive realms, be it science, economics or philosophy. It is this deep normative perplexity that calls for a political interpretation of the PP. Let me now turn to a more detailed elaboration of this argument, exploring each of the different components of the PP.

1. The Hazard Condition

What kind of hazard could justify the invocation of the PP? Is it possible to identify a clear hazard threshold that would trigger the application of the PP? The Rio Declaration uses the phrase "serious or irreversible" to designate those risks that fall within the ambit of the PP. A similar emphasis on the notions of seriousness and irreversibility can be found in the jurisprudence of the Appellate Body, the supreme judicial tribunal of the World Trade Organization (WTO). The Appellate Body considered the PP in the context of the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). It notes, in its important *EC-Hormones* ruling, that a panel charged with determining whether "sufficient scientific evidence" exists to warrant a particular SPS measure "may. . . and should, bear in mind that responsible, representative governments commonly act from perspectives of prudence and precaution where risks of *irreversible*, e.g. *life-terminating*, damage to human health are concerned."[31] A similar focus on irreversibility can be found in other legal instruments, such as the 2006 *Equator Principles*.[32]

The foregoing discussion suggests that the PP should be invoked in the face of environmental or health hazards that are (1) of significant scope; and (2) potentially irreversible. While this formulation seems intuitively compelling, closer examination

31. Appellate Body Report, *ECMesuares Concerning Meat and Meat Products (Hormones)*, ¶124, WT/DS26/AB/R (Jan. 16, 1998). *See also The Value of Nature and the Nature of Value*, 289 SCI. 395, 396 (2000); PAUL HARREMOES ET AL., THE PRECAUTIONARY PRINCIPLE IN THE 20TH CENTURY: LATE LESSONS FROM EARLY WARNINGS 171 (2002).

32. The *Equator Principles* set out environmental impact procedures for banks involved in the funding of international projects. They distinguish between three types of projects according to their risk-profile. Category A projects which are subject to the strictest assessment requirements are those "with potential significant adverse social or environmental impacts that are diverse, irreversible or unprecedented." *See* EQUATOR PRINCIPLES FINANCIAL INSTITUTIONS, THE EQUATOR PRINCIPLES 6 (2006), *available at* http://www.equator-principles.com/documents/Equator_Principles.pdf.

raises doubts about its capacity to generate the normative surety we seek. Consider first the notion of irreversibility. In a groundbreaking article from 1974, K.J. Arrow and Anthony Fisher define irreversibility as a development that would be "infinitely costly to reverse."[33] Arrow and Fisher give two examples of environmentally damaging investment to illustrate their point: the construction of a major dam or development associated with the emission of persistent (stock) pollutants (e.g., non-degradable pesticides or CO_2).

While Arrow and Fisher's definition seems appealing, it raises two key difficulties. First, this definition seems too wide. Any environmental risk with adverse public health effects is intrinsically irreversible, since human injury or death cannot be undone (either physically or through monetary compensation).[34] Second, Arrow and Fisher focus solely on the irreversibilities associated with development-triggered environmental damage. However, policies aimed at reducing environmental or health risk can lead to other forms of irreversibility because they impose sunk costs on society (e.g., power stations might be forced to decommission their coal-fired turbines in order to enable the installation of gas turbines). Environmental policies may lead society to commit resources in a non-reversible way to the prevention of uncertain risks. These sunk costs may ultimately prove to be unjustified and wasteful, if the future shows that the targeted risks were exaggerated or illusory. The dual meaning of irreversibility means that the PP can be understood as supporting both a policy of "act, then learn" and "learn, then act."[35]

The idea of irreversibility thus involves two types of ambiguities. First, it pulls together too many risks, without giving any guidelines with respect to the way in which different irreversible risks should be ranked (thus requiring the decisionmaker to apply additional, unspecified criteria, in order to limit the risk domain in which the PP applies). Second, it provides no guidance

33. K. J. Arrow & Anthony C. Fisher, *Environmental Preservation, Uncertainty, and Irreversibility*, 88 Q. J. ECON. 312, 315 (1974).

34. This argument can be extended to pure environmental risks under certain moral views such as deep ecology.

35. The latter problem is also highlighted by Sunstein. Sunstein, *supra* note 18, at 860. *See also* Pindyck, *supra* note 18, at 47. It should be noted that irreversibility creates a problem only under conditions of deep uncertainty. If it is possible to assign exact probabilities to the environmental/health risks associated with irreversible investment, then both of the types of irreversibility become less problematic.

as to how to balance between the competing irreversibilities associated with the PP.

Consider next the notion of seriousness. Can this idea be used—instead of the notion of irreversibility—as a guideline for ranking risks? Unfortunately, the notion of seriousness is no less vague. The risk literature has developed multiple approaches for ranking risks in terms of their "seriousness." Among the possible ranking criteria are *welfare based criteria* (focusing on scale and probability), *moral criteria* (focusing on the equitability of the risk as measured by the distributive profile of its impacts and its relative voluntariness) and *psychological criteria* (e.g., "dread" effect).[36] None of these methods enjoys a privileged social status; indeed, they represent totally different worldviews.[37]

The law does not provide a way out of this semantic conundrum. The law has not developed clear criteria for ranking risks that could resolve the ambiguities underlying these two concepts. Attempts to resolve these ambiguities by adopting more precise definitions generate a different type of problem. One possible approach is to flatten the differences between varied risks by interpreting the PP as embodying a general form of risk aversion. But, as Cass Sunstein notes, this interpretation will turn the PP useless as a policy guide because "[i]t is possible to take precautions against particular risks, but it is not possible to take precautions against all of them. . . [i]t is possible to display aversion to particular hazards, but it is not possible to display aversion to all of them."[38] Another potential approach would be to limit the PP to catastrophic risks.[39] This interpretation is inconsistent, how-

36. Welfare-based ranking of risks commonly draws on the methodology of cost-benefit analysis. This technique allows the regulator to rank hazards according to the marginal benefit (in terms of improvement to human health) of investing one US$ in regulatory/precautionary action directed at that hazard. Such a comparison should lead to a ranking of hazards and regulatory options according to the relative seriousness of the hazards and the relative efficiency of possible regulatory actions (in reducing health risks), all measured in monetary terms. Theoretically, such ranking should allow the regulator to equalize, at the margin, the resources devoted to avoiding one fatality from each hazard. M.W. Jones-Lee, *Safety and the Saving of Life: The Economics of Safety and Physical Risk*, *in* COST-BENEFIT ANALYSIS 296 (Richard Layard & Stephen Glaister eds., 2d ed. 2003). This type of examination requires, of course, deep understanding of the potential damage of each hazard, and a capacity to translate this knowledge into monetary values.

37. For a general discussion of the complexity of ranking risks, see *id.*; P. Slovic, *Perception of Risk*, 236 SCI. 280 (1987).

38. Sunstein, *supra* note 18, at 853.

39. *See* Fritz Allhoff, *Risk, Precaution, and Emerging Technologies*, 3 STUD. ETHICS L., & TECH. 1, 12-13 (2009).

ever, with the current usages of the PP, since the PP is invoked both in the context of potentially catastrophic risks (climate change) and in the context of relatively minor public health risks (PVC in toys; the use of pesticides in schools).[40]

2. The Knowledge Condition

The second element of the PP that requires elaboration is uncertainty. The Rio Declaration and the Wingspread Statement articulate this notion by distinguishing between full and partial scientific certainty.[41] According to this distinction, only risks that possess a certain degree of uncertainty fall within the boundaries of the PP. Certain risks belong in a different "drawer" in the regulatory toolbox. Yet, the PP jurisprudence does not provide clear guidance with respect to the proper interpretation of this distinction. In an attempt to cast the full/partial scientific certainty schema in more exact terms, Cass Sunstein has suggested to interpret it along the lines of Frank Knight's classic risk/uncertainty distinction. *Risk situations* are those in which "outcomes can be identified and probabilities assigned to various outcomes"; in contrast, situations of *uncertainty* are those in which "outcomes can be identified but no probabilities can be assigned."[42] The problem with using Knight's schema as a platform for interpreting the PP is that it is inconsistent with current regulatory practice. Almost all of the decisions made by environmental and health and safety regulators fall under the category of "uncertainty."[43] Knight's distinction between risk and uncer-

40. Anthony C. Fisher, Uncertainty, Irreversibility, and the Timing of Climate Policy (Oct. 2001) (paper presented at the conference on the "Timing of Climate Change Policies" Pew Center on Global Climate Change); D. Kriebel et al., *The Precautionary Principle in Environmental Science*, 109 ENVTL. HEALTH PERSPECTIVES 871, 872 (2001). *See further* Greenpeace International, *PVC-Free Future: A Review of Restrictions and PVC free Policies Worldwide* (June 30, 2003), *available at* http://www.greenpeace.org/raw/content/international/press/reports/pvc-free-future-a-review-of-r.pdf; LOS ANGELES UNIFIED SCHOOL DISTRICT, INTEGRATED PEST MANAGEMENT POLICY (rev. May 23, 2002), *available at* http://www.laschools.org/employee/mo/ipm/docs/ipmpolicyretype.pdf.

41. The Rio Declaration and the Wingspread Statement use in this context the phrases "lack of full scientific certainty" and "even if some cause and effect relationships are not fully established scientifically." Rio Declaration, *supra* note 19; Wingspread Statement, *supra* note 20.

42. Sunstein, *supra* note 18, at 876. For further discussion of these concepts, see Jochen Runde, *Clarifying Frank Knight's Discussion of the Meaning of Risk and Uncertainty*, 22 CAMBRIDGE J. ECON. 539, 540 (1998); Martin Shubik, *Information, Risk, Ignorance, and Indeterminacy*, 68 Q. J. ECON. 629 (1954).

43. Weed, *supra* note 22; Kriebel et al, *supra* note 40, at 872; Pindyck, *supra* note 18, at 62. I disagree in this context with Sunstein, who argues that "[e]nvironmental

tainty fails, therefore, to provide a reasonable basis for interpreting the PP, because it implies that the PP should govern all the regulatory decisions made in the health or environment domain.

Other attempts to develop a binary understanding of the full/partial scientific certainty distinction have proven to be equally problematic. One alternative interpretation was offered by the Appellate Body in the context of a food safety dispute. According to the Appellate Body, the precautionary principle, as it appears in the SPS Agreement, applies only in those situations in which "the body of available scientific evidence does not allow, in quantitative or qualitative terms, the performance of an adequate assessment of risks" as required under standard regulatory procedures.[44] This seems like an ingenious attempt to resolve the puzzle of interpreting uncertainty by moving it from the realm of epistemology to the realm of regulatory praxis. It seeks to define the universe of PP risks as a residual category—as a complement to the set of risks to which standard regulatory procedures apply. The problem is that this solution presupposes a clear distinction between normal and abnormal regulatory procedures. This, of course, is far from true: there is little agreement regarding the nature of these 'standard' risks and the regulatory procedures which should be applied to them.[45] Absent a clear definition of the baseline set, the boundaries of its complement cannot be determined. The distinction between normal and abnormal regulatory procedures is itself vague, and usually the product of contextual regulatory discretion or political deliberation. There are no *a priori* rules that determine this question. Another important attempt to develop legal criteria, which could distinguish between situations of scientific knowledge and scien-

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problems usually involve risk, in the sense that a range of probabilities can be assigned, or at least in the sense that probabilities can be assigned to probabilities." Sunstein, *supra* note 18, at 897.

44. *See* WORLD TRADE ORGANIZATION APPELLATE BODY, UNITED STATES – CONTINUED SUSPENSION OF OBLIGATIONS IN THE EUROPEAN COMMUNITIES – HORMONES DISPUTE ¶ 674 (2008), http://www.wto.org/english/tratop_e/dispu_e/cases_e/ds320_e.htm; WORLD TRADE ORGANIZATION DISPUTE SETTLEMENT, EUROPEAN COMMUNITIES – MEASURES AFFECTING THE APPROVAL AND MARKETING OF BIOTECH PRODUCTS ¶ 7.2990 (2006) (complaints by United States, Canada, and Argentina respectively). This statement refers to Articles 5.7 (the SPS version of the PP) and article 5.1 (which together with Annex A of the SPS Agreement defines the 'standard' risk assessment procedures).

45. It is tempting to argue that 'normal' risks are those to which one can apply standard cost-benefit tools, attributing exact probabilities and scales to potential risks and benefits. But this ideal image is rarely applied in practice, and hence cannot serve as a useful basis for interpreting this notion.

tific ignorance, can be found in the U.S. Supreme Court trilogy on expert testimony (the rulings in *Daubert*, *Joiner* and *Kumho*).[46] However, these important rulings, and the intricate jurisprudence that followed in their aftermath, have failed to articulate an unambiguous definition of scientific certainty.[47]

The way in which the notion of scientific justification has been articulated in the fields of philosophy of science and public health also points to the need to develop a more nuanced understanding of knowledge, which will replace the binary distinction between full and partial knowledge with a non-binary continuum. Within philosophy of science, the question of the truth-status of scientific propositions continues to be overshadowed by Hume's challenge to the method of induction. Hume argued that any attempt to justify the extension of our conclusions from past observations to the future must ultimately fail. Such extension cannot be justified through demonstrative reasoning since we can always conceive of a change in the course of nature (which cannot be ruled out *a priori*). Neither can we rely on probable reasoning, since any inference from experience is based on the supposition that nature is uniform—that the future will be like the past. This supposition cannot be proved by appeal to experience, because such appeal will be question-begging.[48] Induction, as Bas Van Fraassen notes, "cannot tell us which applications of induction will succeed."[49] Hume's critique, which despite being more than 200 years old has not been refuted, means that the scientific endeavor is by its very nature incomplete.[50] It implies

46. Daubert v. Merrell Dow Pharm., Inc., 509 U.S. 579 (1999); Gen. Elec. Co. v. Joiner, 522 U.S. 136 (1997); Kumho Tire Co. Ltd. v. Carmichael, 526 U.S. 137 (1999). While these cases focused primarily on the question of admissibility, their logic and arguments are applicable to the question of weight as well.

47. *See* Margaret A. Berger, *What Has a Decade of* Daubert *Wrought?*, 95 AM. J. PUB. HEALTH S59, S61 (Supplement 1, 2005); Michael J. Saks & David L. Faigman, *Expert Evidence After* Daubert, 1 ANN. REV. L. & SOC. SCI. 105, 123 (2005).

48. DAVID HUME, ENQUIRIES CONCERNING HUMAN UNDERSTANDING, AND CONCERNING THE PRINCIPLES OF MORALS (L.A. Selby-Bigge ed., P.H. Nidditch rev., Oxford University Press 1985) (1748). *See also* William Edward Morris, *David Hume*, *in* STANFORD ENCYCLOPEDIA OF PHILOSOPHY § 6 (Edward N. Zalta ed., Spring 2001), *available at* http://plato.stanford.edu/archives/spr2001/entries/hume/; COLIN HOWSON, HUME'S PROBLEM: INDUCTION AND THE JUSTIFICATION OF BELIEF 6-21 (2000).

49. Bas C. Van Fraassen, *The False Hopes of Traditional Epistemology*, 60 PHIL. & PHENOMENOLOGICAL RES. 253 (2000).

50. Ken Binmore, *De-Bayesing Game Theory*, *in* FRONTIERS OF GAME THEORY 321, 328 (K. Binmore, A. Kirman & P. Tani eds., 1993); NICHOLAS RESCHER, NATURE AND UNDERSTANDING: THE METAPHYSICS AND METHOD OF SCIENCE 31-34

that the content of our objective factual claims about such things as fullerenes, carbon nanotubes or the Higgs particle will always outrun the evidence for making them. The endorsement of any such claim, as Nicholas Rescher notes, always involves "some element of evidence-transcending conjecture."[51] The cognitive incompleteness of the scientific project means that our theories of the world are inherently fallible—there is always the risk that the discovery new data or some conceptual innovation will bring us to revise our view of the world.[52] The scientific propositions that are invoked in the context of nanotechnology are thus by their very nature—by being scientific—insufficient.[53]

Similar scepticism regarding the possibility of certain knowledge animates the discourse of public health. Thus, for example, Weed, one of the prominent public health scholars in the United States, notes:[54]

> Perhaps the general public or industry executives think in terms of full scientific certainty (1992 Rio Conference version), 100% evidence about everything (Horton's 1998 Lancet version), or proof that cause-and-effect relationships are not fully established (1998 Wingspread Conference version), but public health professionals and philosophers typically do not. Public health decision-making always has involved acting on evidence below the level of 'proof' or 'certainty'. Public health decisions, in other words, are similar to other real life endeavors where practical needs require decisions based on imperfect and uncertain evidence.[55]

Ultimately, neither philosophy nor science has developed universally agreed theoretical or pragmatic criteria for distinguishing between knowledge that is epistemologically "sound."[56]

(2000); Susan Haack, *Inquiry and Advocacy, Fallibilism and Finality: Culture and Inference in Science and the Law*, 2 L., PROBABILITY AND RISK 205, 208 (2003).

51. RESCHER, *supra id.*, at 33.

52. *See id.* at 35-36; Binmore, *supra* note 50, at 325.

53. No matter how sophisticated knowledge is, it will always be subject to some degree of ignorance. HARREMOES ET AL., *supra* note 31, at 169. *See also* RESCHER, *supra* note 50, at 35.

54. Douglas Weed is the Chief of the Office of Preventive Oncology, and Dean of Education and Training in the Division of Cancer Prevention at the National Cancer Institute (NIH).

55. Weed, *supra* note 22, at 317, 324-25; David B. Resnik, *The Precautionary Principle and Medical Decision Making*, 29 J. MED. PHIL. 281, 285 (2004).

56. Weed, *supra* note 22, at 324-325; Paul R. Thagard, *The Best Explanation: Criteria for Theory Choice*, 75 J. PHIL. 76 (1978); W. A. Brock & S. N. Durlauf, *A Formal Model of Theory Choice in Science*, 14 ECON. THEORY 113 (1999); Thomas S. Kuhn, *Rationality and Theory Choice*, 80 J. PHIL. 563 (1983); Harriet Zuckerman, *Theory Choice and Problem Choice in Science*, 48 SOC. INQUIRY 65 (1978).

The tension between the binary language of the PP and our regulatory experience points, therefore, to the need to develop a more nuanced understanding of knowledge.[57] What is at stake in the application of the PP therefore is the articulation of a hierarchy of insufficient knowledge. The objective of articulating such hierarchy is, however, pragmatic and not epistemological. It should facilitate the development of pragmatic understanding of the PP, by allowing decisionmakers to place the domain of precautionary action on some interval on this epistemological ranking. It is therefore a means for facilitating regulatory action, not an attempt to define degrees of knowledge. The failure of the law to articulate a clear response to this challenge points again to politics as the proper arena in which this question should be settled.

3. The Prescriptive Dimension

The third challenge in applying the PP concerns the decision about the kind of regulatory action that should be taken in response to the projected risk. There is a wide spectrum of possible actions that could be considered at this point: from changing the allocation of research funds, to imposing registration requirements on nanomaterials, to imposing stricter requirements on laboratory safety rules, to imposing a complete ban on a suspected technology. Ideally, given the range of values that could be taken by the hazard and knowledge conditions, the PP should have provided decisionmakers with an algorithm that could take as input the scale and nature of the hazard and the degree of knowledge (or uncertainty) associated with it, and provide as output the proper regulatory response.[58] This would have responded to the need to adjust the regulatory action to the range of possible values these conditions admit.[59] Unfortunately, despite more than three decades of jurisprudence, the law has failed to develop a clear doctrinal response to this puzzle (leading to inconsistent regulatory decisions).

The law cannot refer in this context to other discursive domains, since they are animated by similar confusion. Consider morality. Moral theory deals with similar pragmatic dilemmas

57. *See further* Resnik, *supra* note 55, at 285; G. Weiler, *Degrees of Knowledge*, 15 PHIL. Q. 317 (1965).

58. Or, possibly, even a more basic answer: should there be regulatory intervention at all?

59. *See* Allhoff, *supra* note 39, at 15-16.

(risk choices), but it does not offer a complete answer to the prescriptive puzzle. First, morality is animated by deep controversies about the things that matter and the way in which these interests should be balanced. Consider, for example, the question of how the interests of future generations should be factored into current regulatory decisions.[60] While there is wide agreement about the moral value of future generations, there is little agreement with respect to the way in which their interests should be represented today (e.g., in terms of discount rate). Further, morality also offers no clear guidelines regarding the application of the concern for future generations in cases involving deep uncertainties.[61]

Economic theory exhibits similar ambivalence. The PP applies exactly in those situations in which the conditions of the problem do not allow for the use of conventional cost-benefit methodology. The economic theory of uncertainty does not offer clear advice as to how to balance between the sunk costs imposed on society by precautionary action and the uncertain environmental benefits that may accrue in the future (whose magnitude and probability are highly uncertain).[62] Economists can only provide us with pragmatic guesses, whose theoretical status remains doubtful.[63] There is also no point of turning to science for an answer. The scientific project is not aimed toward providing guidelines for action. Its interest lies in producing truth—not in social prescriptions.[64] While scientific knowledge can assist deci-

60. *See* Sunstein, *supra* note 18, at 854-55; Sudhir Anand & Amartya Sen, *Human Development and Economic Sustainability*, 28 WORLD DEV. 2029 (2000).

61. *See* Sunstein, *supra* note 18, at 854-55 (comparing the distributional aspects of varied precautionary actions—from climate change to DDT ban and GMOs); Pindyck, *supra* note 18, at 61-62 (discussing the influence of uncertainty on discount rates).

62. For this dilemma, see Sunstein, *supra* note 18, at 862-867; Pindyck, *supra* note 18, at 47. Sunstein makes the point succintly:

> In many settings, it makes sense to pay for an option to avoid a risk of irreversible losses. The amount of the payment depends on the magnitude of the loss if it is irreversible. . . But because environmental expenditures are typically sunk costs, an emphasis on irreversibility will sometimes argue in favor of delaying, rather than accelerating, environmental protection. Whether it does so depends on the magnitude and likelihood of the relevant effects.

Sunstein, *supra* note 18, at 866.

63. *See* Resnik, *supra note* 55, at 283-85.

64. Science is commonly understood as an endeavour seeking to acquire "the best possible understanding of the workings of nature, man, and human society." Sven Ove Hansson, *Science and Pseudo-Science*, *in* THE STANFORD ENCYCLOPAEDIA OF PHILOSOPHY (Edward N. Zalta ed., Fall 2008), *available at* http://plato.stanford.edu/archives/fall2008/entries/pseudo-science/.

sionmakers in understanding the potential environmental and health implications of various risks, it does not offer criteria which may assist decisionmakers in prioritizing risks in a regulatory environment characterized by deep uncertainty. Similarly, while scientific knowledge is certainly relevant to assessing potential counter measures to risks, the natural sciences do not offer advice as to how to construct an optimal program of social intervention.

Ultimately, the decision whether "to jump to conclusions" or "to think twice"[65]—whether in the general level or in a concrete case—is a political decision, having no algorithmic solution.

III.
FROM AMBIVALENCE TO POLITICS: THE PRECAUTIONARY PRINCIPLE AS A POLITICAL FRAMEWORK FOR REGULATING RISKS

A. *Why Politics: Legitimacy, Reflexivity and Creativity*

As noted above, there is little agreement with respect to the criteria which should regulate the application of the PP in actual cases. It is this profound ambiguity which stands at the basis of the political vision of the PP. The PP should be interpreted as a semi-constitutional principle, calling for the establishment of an alternative framework for risk governance. This framework should provide the deliberative conditions necessary for a democratic resolution of the varied choices left open by the PP schema. Politics comes into play in this context because there is no universally accepted meta-principle that resolves all the ambiguities underlying the PP. The PP is incomplete in this context, since it sets out the challenge for politics—it does not specify the political framework itself.

The choice in politics is not, however, a necessary product of the normative perplexity underlying the PP; the case for democratizing the PP requires further justification (which is elaborated below). It is also possible to resolve the normative impasse underlying the PP by choosing some hierarchical rule, allocating responsibility to a particular agency or some body of expertise. But if we choose hierarchy rather than democracy, we should at least not delude ourselves about the capacity of either experts

65. Kent Bach, *Default Reasoning: Jumping to Conclusions and Knowing When to Think Twice*, 65 PAC. PHIL. Q. 37 (1984).

(scientists, economists, and lawyers) or public officials to resolve the ambiguities of the PP through a rational, nontranscendental deployment of their respective intellectual domains.

Before elaborating the case for democracy, I want to clarify what is entailed by a democratic reconfiguration of the PP. It requires the establishment of mechanisms that will provide meaningful opportunities for citizens and NGOs to contribute to the regulatory process associated with the governance of novel technologies (such as nanotechnologies). Participatory mechanisms must be structured in a way which will allow those who stand outside the regulatory circle to inform policy development.[66] The value of civic participation was recognized by the Royal Commission on Environmental Pollution in its recent report. The Commission notes that it is desirable "to move beyond one-off public engagement 'projects' to recognize the importance of continual 'social intelligence' gathering and the provision of ongoing opportunities for public and expert reflection and debate. We see these functions as crucial if, as a society, we are to proceed to develop new technologies in the face of many unknowns."[67]

This view rejects the attempt to conceptualize risk-democracy as an educational or knowledge dissemination exercise seeking to secure acquiescence to new technologies.[68] This thin conception of democracy is driven by deep scepticism of the capacity of civic society to contribute to the regulation of nanotechnology, and an overstated belief in the capacity of experts to lead this project.

In justifying the democratization of risk governance, I want to highlight three distinct themes: *legitimacy*, *reflexivity* and *creativity*. Subjecting the law-making process to wide-ranging public scrutiny is seen, first, as a means to confer legitimacy on the regulatory regime. From a normative perspective, the legitimacy of regulatory structures lies in their capacity to obtain the assent of all affected citizens in a discursive process of norm-making.[69] The normative conception of legitimacy presupposes the possibility of rational political will-formation. This argument, whose main proponent is Jurgen Habermas, is far-reaching in that it as-

66. *See* PRINCIPLES, *supra* note 3, at 6; RCEP/NM, *supra* note 6, at 73.

67. RCEP/NM, *supra* note 6, at 73.

68. *See* Douglas J. Sylvester et al., *Not Again! Public Perception, Regulation, and Nanotechnology*, 3 REG. & GOVERNANCE 165-185 (2009); Gary E. Marchant et al., *Risk Management Principles for Nanotechnology*, 2 NANOETHICS 43 (2008).

69. JURGEN HABERMAS, BETWEEN FACTS AND NORMS: CONTRIBUTIONS TO A DISCOURSE THEORY OF LAW AND DEMOCRACY 110 (William Rehg trans., 1998).

sumes the existence of "right" answers to complex political questions. It is possible, Habermas argues, to reach consensual decisions through collective, rational deliberation in each of the various discursive domains that are involved in political dialogue.[70]

But can we make sense of the notion of legitimacy if we reject Habermas' claims regarding the viability of collective consensus?[71] Such skepticism calls, I believe, for the adoption of a more nuanced understanding of legitimacy. This alternative notion of legitimacy is based on the idea that having an institutional infrastructure, which encourages free discussion across all the thematic horizons involved in democratic deliberation, has an intrinsic moral value irrespective of the possibility of reaching collective agreement. The legitimacy of a political arrangement rests, under this account, on its capacity to facilitate a communicatively complex (and nonexclusionary) deliberative process, in which each valid claim has an equal opportunity to be heard. Thus, one of the key features of a legitimate democratic regime lies upon its capacity to create a discursive environment that is rich in terms of the categories of arguments and reasons it includes. This interpretation of legitimacy emphasizes then, the quality and diversity of the deliberative process, rather than its overall inclusiveness or its capacity to produce consensus.

Is the principle of deliberative complexity, which is critical to the legitimacy of regulatory decisions, also instrumentally valuable, in the sense of facilitating the acceptance of welfare enhancing regulatory schemes? I believe that deliberative complexity is also instrumentally constructive in the sense that it works against dogmatic thinking. Forcing the experts to deal with external cri-

70. *See* JÜRGEN HABERMAS, THE THEORY OF COMMUNICATIVE ACTION, REASON AND THE RATIONALIZATION OF SOCIETY 1, 8-23 (Thomas McCarthy trans., 1984); Thomas Risse, *"Let's Argue!": Communicative Action in World Politics*, 54 INT'L ORG. 1, 9–11 (2000). Habermas argues that there are different types of discursive tests that could be employed in public deliberation to resolve disputes involving different thematic horizons. Habermas distinguishes in this context between questions of empirical truth, moral rightness, ethical goodness, aesthetic value and personal sincerity. Habermas, *supra* note 69, at 108, 110. *See further* James Bohman & William Rehg, *Jürgen Habermas*, *in* THE STANFORD ENCYCLOPEDIA OF PHILOSOPHY (Edward N. Zalta ed., Spring 2008), *available at* http://plato.stanford.edu/archives/spr2008/entries/habermas/#HabDisThe.

71. Gunther Teubner, *De Collisione Discursuum: Communicative Rationalities and the Law*, 17 CARDOZO L. REV. 901 (1996). This critique points, among other things, to the lack of a meta-discourse which can guide us in the resolution of political dilemmas involving multiple thematic domains.

tique, to explain their decisions, and to do so in diverse institutional and conversational contexts could provide some guarantee against dogmatic reasoning or regulatory capture. It provides the necessary conditions for continuous self-critique. Further, by extending the cognitive horizon and social scope of the regulatory process, civic participation can also improve the creativity of the regulatory framework, providing new perspectives and ideas.[72] Finally, public participation can also positively influence perceptions of legitimacy. This may be crucial for the success of the regulatory program, a claim already explored in the psychological literature, primarily by Tom Tyler. In a series of studies, this literature has demonstrated that giving people a voice in the decisionmaking process increases the extent to which people conceive the process as fair and legitimate.[73] It should be noted, though, that this instrumental justification is 'weak' in the sense that it does not claim that the democratization of risk governance can guarantee an optimal solution (in a moral or economic sense) to the PP puzzle. As I argued above, there is no reason to expect such an outcome from politics given that neither morality nor economics provide an algorithm that guarantees such result.

Before exploring the ways in which this vision of democratic risk-governance can be realized, I want to examine two possible objections. The first objection argues that the lack of public understanding of the science underlying nanotechnology severely undermines its capacity to contribute to the discussion surrounding the regulation of nanotechnology. This is an important question because the argument for democratization presupposes that the participants' contributions will be informed and reasoned. We expect people to base their comments and reflections on a deep understanding of the regulatory dilemma under discussion. These expectations also underlie the demand for transparency, which can only make sense if we take the principle of informed

72. *See, e.g.*, Brian Wynne, *May the Sheep Safely Graze? A Reflexive View of the Expert-Lay Knowledge Divide*, *in* RISK, ENVIRONMENT AND MODERNITY: TOWARDS A NEW ECOLOGY, 44, 45-46 (Lash, Szerszynski & Wynne eds., 1996); Kriebel et al., *supra* note 40, at 873.

73. *See* Jason Sunshine & Tom R. Tyler, *The Role of Procedural Justice and Legitimacy in Shaping Public Support for Policing*, 37 LAW & SOC'Y REV. 555 (2003); Tom R. Tyler, *Psychological Perspectives on Legitimacy and Legitimation*, 57 ANN. REV. PSYCHOL. 375, 382-383 (2006); TOM R. TYLER, WHY PEOPLE OBEY THE LAW: PROCEDURAL JUSTICE, LEGITIMACY, AND COMPLIANCE 148 (2006). However, these perceptions are not necessarily linked to the discursive quality of the process.

citizenship to be part of our concept of democracy.[74] The argument that people lacking a PhD in Chemistry, Physics, Electrical Engineering or Molecular Biology cannot understand any of the problems associated with the regulation of nanotechnology could be a fatal rebuttal to the argument for democratization. According to this argument, uninformed comments constitute noise, and therefore make no contribution to the legitimacy or complexity (in the above sense) of the deliberation process. While I agree that this argument is potentially fatal to the democratization thesis, I disagree with the empirical claim regarding the capacity of lay citizens (including nonscientific experts such as philosophers, economists and lawyers) to take part in an epistemologically responsible debate regarding the regulation of nanotechnolgies. Nonetheless, this argument highlights two important challenges for the project of designing participatory mechanisms in the nano-domain: first, the need to create an accessible informational environment; second, the need to delineate those questions which are most suitable for public deliberation. The PP, in the way I have interpreted it, leaves many open questions that can be decided through public deliberation.[75]

The second objection focuses on the issue of cognitive biases. The claim in this context is that the capacity of lay citizens to contribute to the debate about nano-risks is severely undermined by various cognitive biases.[76] I find this argument unconvincing. First, because the nano-domain is so distant from our daily experiences, people do not have ready intuitions or pre-dispositions regarding the risks (or benefits) of nanotechnologies. While social cues—such as media reports or views of environmental NGOs— have significant influence on people's judgments, I do not think that at this point it is possible to extract a clear anti-nano message from the media or the environmental movement

74. For the important role of transparency in modern administrative law, see, e.g., THE RIGHT TO KNOW: TRANSPARENCY FOR AN OPEN WORLD (Ann Florini ed., 2007); David C. Vladeck, *Information Access–Surveying the Current Legal Landscape of Federal Right-to-Know Laws*, 86 TEX. L. REV. 1787 (2008).

75. For an interesting observation regarding the possibility of communication between scientists and non-scientists in the nano-domain, see Kim Allen, *"Facts" from the Net* (1997), http://kimallen.sheepdogdesign.net/Fuller/policy.html.

76. *See, e.g.*, Marchant et al., *supra* note 68; Dan M. Kahan et al., *Cultural Cognition of the Risks and Benefits of Nanotechnology*, 4 NATURE NANOTECHNOLOGY 87 (2008). *See also* Cass R. Sunstein, *Misfearing: A Reply*, 119 HARV. L. REV. 1110 (2006).

(the nano case differs in that sense from the GMO case).[77] I do not argue that the discussion of nano regulation is free from cognitive biases—only that it is less affected by them at this point relative to some similar risks.

Second, cognitive biases affect everyone, including experts.[78] Such biases could contaminate the supposedly 'clean' expert decisionmaking process. This effect is prominently a product of two psychological heuristics: affect bias and confirmation/disconfirmation bias. I will say more about these biases below.[79] At this point, I simply want to highlight the significant problems stemming from the occurrence of such biases in experts. First, experts are more skilful than lay people in presenting arguments. This fact gives their opinions a rhetorical advantage and conceals the existence of biases. Second, experts enjoy epistemological authority that makes it more difficult to challenge their opinion.[80] Countering the risk of expert bias provides further justification for opening the decisionmaking process to public scrutiny.

B. *The Politics of Precaution: Generic Building Blocks*

I argued above that it is the deep normative perplexity of the PP as an action-guiding principle that calls for a political interpretation of the PP. This Part considers the generic challenges associated with this thesis, drawing on my suggested interpreta-

77. *See, e.g.*, Scheufele et al., *supra* note 8, at 733. The argument made by Marchant et al. in this context is unconvincing. *See* Marchant et al., *supra* note 68. Marchant et al. highlight the possibility that people's reaction to nanotechnology may be influenced by affect bias. They support this argument with the claim that there is "overwhelming negative publicity" regarding nanotechnology in the media. Such argument, while theoretically plausible, requires a detailed study of the treatment of nanotechnology in the media as well as the attitudes of other political intermediaries, such as environmental groups, and political leaders. However, Marchant et al. support their argument by referring to a single paper. *See* T. Sheetz et al., *Nanotechnology: Awareness and Societal Concerns*, 27 TECHNOL. SOC. 329–45 (2005). This paper does not provide a thorough analysis of the media treatment of nanotechnology and as such does not provide the necessary empirical basis for their argument. Without the necessary empirical work, I believe that the basic intuition—that people do not have clear dispositions regarding this technology because of its distance from daily experiences—holds.

78. *See, e.g.*, Eliezer Yudkowsky, *Cognitive Biases Potentially Affecting Judgments as Global Risks*, *in* GLOBAL CATASTROPHIC RISKS 91 (Nick Bostrom & Milan M. Cirkovic eds., 2008); Nickerson's discussion is particularly enlightening in that respect. *See* Raymond S. Nickerson, *Confirmation Bias: A Ubiquitous Phenomenon in Many Guises*, 2 REV. GEN. PSYCHOL. 175, 191-197 (1998).

79. Research has shown that experts are also prone to other biases such as *hindsight bias* and *overconfidence bias*. Yudkowsky, *supra id.*

80. *Id.*

tion of the PP ("If there is (1) a (sufficiently) serious threat, which is (2) uncertain *then* (3) some kind of regulatory action should be taken"). Before reflecting on the interpretation of a politically reconfigured PP, I want to stress again the objectives of such political framework. First, this framework should serve the pragmatic function of the PP. It should operate both as a means for reaching a determinative interpretation of the PP (whether universal or contextual) and as a means for applying it in the context of concrete regulatory dilemmas. Second, the construction of a democratic framework for precautionary governance should also be guided by the understanding that properly designed participatory structures can enhance the legitimacy, reflexivity and creativity of the political process. Public participation is not merely a mechanism for securing acquiescence to new technologies, but rather a means of facilitating a communicatively complex (and nonexclusionary) deliberative environment.

In thinking about the realization of the political vision of the PP, we therefore need to distinguish between two different types of political decisions: the development of a general interpretation of the PP (noting its different components) and the application of this general schema in a particular regulatory context (e.g., nanotechnology).

1. The Hazard Condition

The PP jurisprudence suggests that it should be invoked in the face of environmental or health hazards that are of significant scope and are potentially irreversible.[81] While this formulation seems to capture an important facet of the PP, it leaves, as I argued above, many open questions. The first challenge underlying the hazard condition is the development of more refined ranking taxonomies, which could bring some order into the semantic perplexity underlying the notions of "seriousness" and "irreversibility." I am doubtful though about the possibility of reaching a wide consensus about the ranking criteria which should determine the spectrum of hazards falling under the ambit of the PP. Nonetheless, this exercise is critical in order to facilitate a meaningful dialogue in concrete contexts, making sure that the discussion is not hindered by terminological misunderstandings.

The main challenge for the democratization project seems to lie, therefore, in the applicatory phase. This phase will have to

81. See the discussion above.

involve both a discussion of the ranking criteria and a characterization and evaluation of the hazards in question in view of these criteria. In the context of nanotechnology, this dual analysis involves several components. First, the analysis requires the development of various risk-scenarios associated with nanotechnology, taking into account different categories and generations of nanotechnology products and processes, as well as different contexts of evaluation (e.g., distinguishing between environmental and health impacts).[82] Second, the public dialogue should also include a discussion of the evaluative criteria that should guide the ranking process (by addressing, for instance, the definition of adversity and the relative weight afforded to different adverse effects).[83]

An interesting example of how this process of scenario construction could be pursued in a collaborative fashion is the Center for Responsible Technology (CRN) Scenario Project. CRN Scenario Project Task Force, which consisted of more than fifty people from six continents, took upon itself to produce a series of professional-quality scenarios of a near-future world in which exponential general purpose molecular manufacturing becomes a reality. The purpose was to offer plausible, logical, understandable stories that illustrate the challenge of contending with the implications of advanced nanotechnology. The project task force was driven by the following question: "What can we learn from picturing it now that might help us avoid the worst pitfalls and generate the greatest benefits?"[84]

82. Renn and Roco distinguish between four generations of nano products and processes: passive nanostructures, active nanostructures, systems of nanosystems and molecular nanosystems. *See* Renn & Roco, *supra* note 5; RCEP/NM, *supra* note 6, at 20.

83. On the question of ranking risks, see, e.g., Kara M. Morgan et al., *A Deliberative Method for Ranking Risks (II): Evaluation of Validity and Agreement among Risk Managers*, 21 RISK ANALYSIS 923 (2001); Jan Abel Olsen et al., *Implicit Versus Explicit Ranking: On Inferring Ordinal Preferences for Health Care Programmes Based on Differences in Willingness-to-pay*, 24 J. HEALTH ECON. 990 (2005), *available at* http://ms.cc.sunysb.edu/~dsdwyer/wtp.jhe.pdf.

84. CRN Scenario Project is located at http://www.crnano.org/CTF-Scenarios.htm (last visited Aug. 6, 2009). This web-page also includes a detailed description of eight scenarios that were developed by the Task Force. *See also* M. Anissimov et al., *The Center for Responsible Nanotechnology Scenario Project*, 4 NANOTECHNOLOGY PERCEPTIONS 51 (2008); Morgan et al., *supra id.*

2. The Knowledge Condition

As I argued above, applying the knowledge condition requires, as a first step, the development of a general hierarchy of insufficient knowledge. The objective of articulating such hierarchy is pragmatic and not epistemological. It is a necessary step in the attempt to determine an epistemic space for precautionary action. In delineating the boundaries of this epistemic space participants in a democratic dialogue are facing two challenges. First, they need to distinguish between those risks which are deemed sufficiently probable to justify precautionary action and those which fail to provide sufficient justification. In particular, participants will have to determine whether the PP applies also in situations of complete ignorance, i.e., where nothing can be said about the possible likelihood of an adverse event.[85] Second, participants also need to determine what knowledge conditions take the risk from the realm of precautionary regulation to the realm of standard regulatory practice, allowing the application of more rigorous analysis. Neither science nor law provides an answer to the question of determining this space.

As with the hazard condition, I think that the elaboration of this epistemic space would tend to be contextual rather that universal. Nonetheless it may be useful to discuss one possible approach to the challenge of developing a hierarchy of insufficient knowledge. Charles Weiss has developed an interesting model in this context, drawing on the insights of sociology of science. Weiss distinguishes between eleven categories of (subjective) levels of scientific uncertainty: fundamental, rigorously proven, very probable, probable, more likely than not, attractive but unproven, plausible, possible, unlikely, and impossible.[86] Underlying this hierarchy is an anthropological vision of scientific knowledge. Arguably this scale reflects the discourse scientists are using when "gauging the likelihood that a given scientific proposition will 'turn out to be true.'"[87] The precautionary prin-

85. Douglas Weed has suggested in that spirit that "[t]he intriguing question that precaution brings to the table is this: what counts as the *least* amount—the minimum level—of evidence that we would accept as a warrant for preventive action?" Weed, *supra* note 22, at 317.

86. Charles Weiss, *Expressing Scientific Uncertainty*, 2 L., PROBABILITY & RISK 25, 36-38 (2003).

87. *Id.* at 26. This hierarchy is richer than more common classifications, which distinguish between three possible forms of scientific knowledge. Peterson, for example, distinguishes between decision-making under *ignorance*, in which nothing is known about the likelihood of the outcomes, but the desirability of the outcomes

ciple should be invoked at some interval on this schedule where scientific confidence is considered sufficiently high to justify the invocation of the PP (making the causal nexus regulatory plausible) but not sufficiently high to enable the application of more rigorous analysis (e.g., in terms of probabilities of various events, and our understanding of the scale of associated risk and benefits).[88]

The second step in applying the knowledge condition involves its application in actual regulatory contexts. This process should involve two deliberative phases. First, the determination of the epistemic interval in which the PP is applicable—in context. Second, the elicitation of probability measures or confidence reports from experts,[89] fitting them into the epistemic framework developed in the first phase. How to integrate the public into these deliberative processes is a question that requires further work.

3. The Prescriptive Dimension

Let me make two general observations regarding the challenges involved in making the ultimate decision about regulatory action. First, there is nothing in the PP which requires those invoking it to choose a certain regulatory path, such as a ban of the suspected technology. The deliberative framework in which the PP is invoked should therefore facilitate an open discussion, which will encompass a wide spectrum of possible actions, includ-

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can be ranked on an ordinal (i.e., qualitative) scale, decision-making based on *qualitative information*, in which both the likelihood and desirability of each outcome can be ranked on ordinal scales, and decision making based on *quantitative information*, in which both the probability (a quantitative measure of likelihood) and the utility (a quantitative measure of desirability) can be ranked on cardinal scales. M. Peterson, *The Precautionary Principle is Incoherent*, 26 RISK ANALYSIS 595, 596 (2006).

88. Weiss's proposal is attractive as a platform for public discussion because it uses non-technical jargon. It makes no sense to use in this context the jargon of 'statistical rules of significance'. *Compare* Weiss, *supra* note 86, *with* Weed, *supra* note 22, at 323.

89. The elicitation process should reflect, of course, the epistemic scale and language developed in the first phase. The elicitation process is far from simple. *See* John Reilly et al., *Climate Change: Uncertainty and Climate Change Assessments*, 293 SCI. 430 (2001); Robert R. Hoffman, *Eliciting Knowledge from Experts: A Methodological Analysis*, 62 ORG. BEHAV. & HUM. DECISION PROCESSES 129 (1995); Anthony O'Hagan & Jeremy E. Oakley, *Probability is Perfect, but We Can't Elicit it Perfectly*, 85 RELIABILITY ENGINEERING & SYS. SAFETY 239 (2004). Further, if, as is argued by some philosophers, the natural sciences do not have a privileged role in generating factual descriptions, the views of other disciplines (e.g., economics, sociology, anthropology, esthetics, etc.) should be taken into account in this process. *See* RESCHER, *supra* note 50, at 30; Humberto R. Maturana, *Reality: The Search for Objectivity or the Quest for a Compelling Argument*, 9 IRISH J. PSYCHOL. 25, 33 (1988).

ing research funding priorities, the imposition of registration requirements on nanomaterials, and various data-gathering obligations. In considering these multiple options, the discussion should be sensitive to the scale and nature of the hazard, the ranking criteria according to which the risks were evaluated, and the degree of knowledge associated with it (again, noting the underlying conception of knowledge hierarchy). Second, while one of the background conditions of applying the PP is the unfeasibility of a full-scale cost-benefit analysis, it is important, nonetheless to try to gauge the potential costs to society, of any regulatory measure, also in terms of *benefits foregone.* This reflects the fact that precautionary measures are risky in the sense that we may find out in the future that the sacrifices we have made for safety (in terms of direct costs and foregone benefits) were actually unnecessary. There is a price for being careful—and this price should be explicitly acknowledged in the political conversation.[90]

IV.
RE-POLITICIZING THE GOVERNANCE OF RISK: FIVE CHALLENGES IN THE DEMOCRATIZATION OF RISK REGULATION IN THE CONTEXT OF NANOTECHNOLOGY

One of the key challenges facing the democratization project in the context of nanotechnology is the wide gap between, on the one hand, the principled acceptance by public authorities of the value of public participation, reflected in the development of experimental participatory processes, and on the other hand, the negligible impact of these emerging mechanisms of public engagement on the ultimate regulatory output.[91] This gap points out the need for innovative thinking, which could further advance the democratization project.[92] In the following Parts I want to outline several key challenges in the democratization of risk governance—areas where there is also great potential for in-

90. This is what economists call the opportunity costs of precaution. Douglas A. Kysar, *It Might Have Been: Risk, Precaution, and Opportunity Costs* (Cornell Legal Studies Research Paper No. 06-023, 2006), *available at* http://ssrn.com/abstract=927995.

91. *See* RCEP/NM, *supra* note 6, at 73; KARIN GAVELIN, RICHARD WILSON, & ROBERT DOUBLEDAY, DEMOCRATIC TECHNOLOGIES? THE FINAL REPORT OF THE NANOTECHNOLOGY ENGAGEMENT GROUP (NEG) X-XII (2007); Maria C. Powell & Mathilde Colin, *Meaningful Citizen Engagement in Science and Technology: What Would it Really Take?*, 30 SCI. COMM. 126 (2008); Miller, *supra* note 14, at 278-79.

92. *See also* GAVELIN ET AL., *supra id.*, at XII; RCEP/NM, *supra* note 6, at 73.

novation. Responding to these challenges require long-term commitment and continuous experimentation. These challenges link in various ways to the generic political framework explicated above. It is important to emphasize that my approach in delineating these challenges is non-utopian. It takes as its premise the understanding that political decisions take place in a messy and untidy world. It is not driven by an implicit vision of ideal politics. Neither should we expect political deliberation to generate an "optimal" decision: there is no reason to expect that given the lack of universal meta-criteria. Rather, the following discussion is motivated by a "second-best" reasoning, recognizing that by continuously reinventing politics, and acknowledging the multiplicity of ways through which politics can be performed, we are already reaching the best we can achieve.

A. *Extending the Horizon of Civic Participation: From the Regulation of Risks to the Governance of Innovation and Scientific Policy*

In order for civic participation to make a meaningful contribution, it must be implemented in all the key decisionmaking junctions. A particularly important junction is the point in which research priorities concerning nanotechnologies are being decided. It is precisely at this meta-regulatory junction that civic participation can be most valuable. Public engagement can generate insights regarding key policy questions, such as whether nanotechnology's development should be targeted towards objectives that are more socially useful,[93] how much funding should be allocated to research on risk assessment methodologies (including a risk-focused study of future generations of nanotechnologies), and whether funds should also be allocated to the exploration of models of civic participation pertaining to risk-governance.[94] So far however, there has been little enthusiasm among governments to incorporate the public at this decision-making junction.[95] This may explain the current pattern of the budget allocation, which seems to give relatively little weight to environmental and health assessment of nanotechnology and the

93. Miller, *supra* note 14, at 277.

94. In this context, see also GAVELIN ET AL., *supra* note 91, at XII; RCEP/NM, *supra* note 6, at 73-74; Powell & Colin, *supra* note 91, at 135.

95. RCEP/NM, *supra* note 6, at 71-75; Richard E. Sclove, *Town Meetings on Technology: Consensus Conferences as Democratic Participation*, *in* SCIENCE, TECHNOLOGY AND DEMOCRACY 33 (Daniel Lee Kleinman ed., 1998).

question of risk-democracy.[96] There is no single institutional solution to this challenge. The recent report of the Royal Commission on Environmental Pollution on Novel Materials proposes, for example, to create a standing deliberative forum, which will be given the task of informing policy on nanotechnology development, regulation and research.[97] The United Kingdom Department of Environment, Food, and Rural Affairs (UK-DEFRA) Nanotechnologies Stakeholder Forum and Nanotechnology Engagement Group, which were established in order to provide ongoing public feedback on all policy activities related to nanotechnologies, constitute an interesting attempt to realize this vision.[98]

B. *Changing the Institutional Framework of Doing Nanoscience: Science Shops as Mediating Agents*

A recurring theme in the literature on the democratization of risk-governance is the need to develop mechanisms that will connect civic society and scientific institutions.[99] The establishment of such mechanisms is viewed as a prerequisite to any attempt to extend civic involvement in the governance of risks. Such mechanisms could serve several goals. They could reflect a public recognition of the social importance of nano-research (facilitating socially responsible nano-research), contribute to the dissemination of knowledge to the public, and encourage research on the democratization of risk governance. The potential contribution of such engagement mechanisms is therefore wide-ranging, even if they will not be part of the regulatory decisionmaking process.

The model of science shop, which was initiated in the Netherlands in the 1970s and has gained influence in Europe during the

96. There are differences between the U.S. and EU approaches in this context. For the U.S., see U.S. Nanotechnology Risk Research Funding—Separating Fact from Fiction (Apr. 18, 2008), http://community.safenano.org/blogs/andrew_maynard/archive/2008/04/18/u-s-nanotechnology-risk-research-funding-separating-fact-from-fiction.aspx; but see Sally S. Tinkle, *Maximizing safe design of engineered nanomaterials: the NIH and NIEHS research perspective*, 2 WILEY INTERDISCIPLINARY REVIEWS: NANOMEDICINE AND NANOBIOTECHNOLOGY 88 (2009). For the EU, see ANGELA HULLMANN, EUROPEAN COMMISSION, DG RESEARCH, EUROPEAN ACTIVITIES IN THE FIELD OF ETHICAL, LEGAL AND SOCIAL ASPECTS (ELSA) AND GOVERNANCE OF NANOTECHNOLOGY (2008), *available at* ftp://ftp.cordis.europa.eu/pub/nanotechnology/docs/elsa_governance_nano.pdf.

97. RCEP/NM, *supra* note 6, at 74.

98. *See* UK-DEFRA, Nanotechnologies—Policy Activities Website, http://www.defra.gov.uk/environment/quality/nanotech/index.htm (last visited Feb. 2, 2009).

99. *See, e.g.*, GAVELIN ET AL., *supra* note 91, at XII; Powell & Colin, *supra* note 91, at 134.

last two decades, could provide an interesting platform for achieving these goals. The science shop model involves "a working relationship between knowledge-producing institutions, such as universities, and citizen groups that need answers to relevant questions."[100] In the case of nanotechnology such cooperation should allow a pluralistic, interdisciplinary deliberation on the social repercussions of nanotechnology, and the implications of these repercussions on the direction and nature of nano-research. Science shops can act in this context as mediating agents between science and society. The science shop model was inspired, from the outset, by a strong democratic ethos, seeking to provide broader access to the scientific knowledge base within universities.[101] But this early motif was later supplemented by the understanding that such collaboration could lead to the creation of a novel institutional setting, with unique reflexive potential, generating new communicative themes—topics, research questions, answers—at both the civic and scientific side of the collaboration.[102] Within the United States, the concept of legal clinics and environmental law clinics in particular, seem to reflect a similar vision.[103]

The institutional structure of science shops is quite flexible and can encompass a multitude of formats and working practices. It can be tailored to local contexts, reflecting national and institutional idiosyncrasies.[104] Some science shops within Europe have operated outside the university structure, with a strong grassroots orientation. Such structure, despite its anarchistic appeal, is problematic, both in its capacity to foster long-standing collaborative ties with the scientific community within the university and in its ability to raise necessary funding. I believe that science shops should operate from within the university, setting the

100. LOET LEYDESDORFF & JANELLE WARD, SCIENCE SHOPS: A KALEIDOSCOPE OF SCIENCE-SOCIETY COLLABORATIONS IN EUROPE 3 (2005).

101. *Id.* at 8.

102. *Id.* at 14-15.

103. For a review of the evolution of clinical legal education in the U.S., see Suzanne Valdez Carey, *An Essay on the Evolution of Clinical Legal Education and Its Impact on Student Trial Practice*, 51 U. KAN. L. REV. 509 (2003). For a review of the work of environmental law clinics, see Michael J. Robinson-Dorn, *Teaching Environmental Law in the Era of Climate Change: A Few Whats, Whys, and Hows*, 82 WASH. L. REV. 619, 639-643 (2007).

104. *See* LEYDESDORFF & WARD, *supra* note 100; *see, e.g.*, Joseph Wechelder, *Democratizing Science: Various Routes and Visions of Dutch Science Shops*, 28 SCI. TECH. HUM. VALUES 244, 244-73 (2003); Fischer Corinna, Leydesdorff Loet & Schophaus Malte, *Science Shops in Europe: The Public as Stakeholder*, 31 SCI. & PUB. POL'Y 199, 199-211 (2004).

ground for a cross-disciplinary cooperation between nanoscientists, scholars from law, humanities and the social sciences, and civic activists. The funding and support for these nano-specific science shops should come directly from government funding for nano-research. Since science shops do not require substantial budgets, their funding should not constitute a substantial burden on national research budgets. Requiring that all nano-related grants partially be used to fund nanoscience shops and also requiring applicants to also describe how they will contribute to its operation, could transform the dynamic of scientific work in universities. A good example for such structure is the Nanoscale Science and Engineering Center at the University of Wisconsin-Madison. The center is built around five research thrusts. Three focus on the "traditional" scientific questions. The other two focus on "Environmental Health and Safety Implications of Nanotechnology" and "Citizen Engagement and Societal Dialogues about Emerging Nanotechnologies." The center has produced substantive research on questions pertaining to citizen engagement and has also been involved in several practical projects of nano-engagement.[105]

The evolution of nanoscience shops depends, crucially, on top-down support. Scientists have little institutional incentives to be involved in such projects. They do not necessarily lead to publications (and hence do not add to their promotion or status), do not normally represent opportunities for grants (from either government or business), and require them to engage in issues and discourses they have not been trained to engage in. The EU Commission has made some effort in this direction in its Science in Society research program.[106]

C. *E-deliberation*

Arguing for the value of civic engagement is not enough. Such argument has to be complemented by institutional proposals, focusing on the ways in which this ideal could be realized in the context of risk-governance. There is a need to move beyond cur-

105. This includes a "Citizens Coalition on Nanotechnology" and "Nano-Cafes." *See* University of Wisconsin—Madison Nanoscale Science and Engineering Center, http://www.nsec.wisc.edu/NS—Publications.php (last visited Mar. 10, 2010).

106. For details on this program, see European Commission, Research: Science in Society, http://ec.europa.eu/research/fp7/index_en.cfm?pg=society (last visited Nov. 13, 2009); European Commission, Capacities: Science in Society, http://ec.europa.eu/research/science-society (last visited Nov. 13, 2009).

rent models of civic-participation such as citizens' juries, focus groups and consensus conferences.[107] This need reflects the limitations of the current participatory toolkit in terms of costs, limited accessibility and the unimpressive record in influencing the regulatory decisionmaking process.[108] Indeed, there seems to be a general frustration in the literature from the continuing failure of participatory processes to influence the regulatory output,[109] leading to a call for the creation of "Systemic institutional mechanisms for ongoing long-term citizen involvement" that will be "incorporated into academic and government institutional decision-making processes."[110]

The idea of e-democracy holds, I believe, great potential for reinvigorating democratic practice in the context of risk-governance. To realize the potential of the web, however, we have to abandon the naïve conception that e-democracy means simply posting an invitation for comments on the web. The experience that was gained with e-consultation thus far suggests that this simple utilization of the Internet does not generate sufficient civic reaction (in terms of both quality and reach).[111] Realizing the potential of the Internet requires more sophisticated thinking

107. For a general survey of participatory mechanisms, see Nikki Slocum, *Participatory Methods Toolkit: A Practitioner's Methodological Manual* (2003), http://www.viwta.be/files/30890_ToolkitENGdef.pdf. For examples in the nano context, see TA-Swiss Publifocus Nanotechnology, http://www.ta-swiss.ch/e/arch_nano_pfna.html; UK Nanojury, http://www.nanojury.org.uk/; University of Wisconsin—Madison NanoCafes Project, http://www.nanocafes.org/; PATRICK HAMLETT ET AL., NATIONAL CITIZENS' TECHNOLOGY FORUM: NANOTECHNOLOGIES AND HUMAN ENHANCEMENT 3 (2008). For discussion, see Jasber Singh, *The UK Nanojury as "Upstream" Public Engagement*, 58 PARTICIPATORY LEARNING & ACTION 27 (2008); REGULA VALERIE BURRI, DELIBERATING RISKS UNDER UNCERTAINTY: EXPERIENCE, TRUST, AND ATTITUDES IN A SWISS NANOTECHNOLOGY STAKEHOLDER DISCUSSION GROUP (2007), *available at* http://www.springerlink.com/content/9753275h6q742642/fulltext.pdf (last visited Sept. 16, 2009). For further discussion, see Maria C. Powell & Mathilde Colin, *Participatory Paradoxes: Facilitating Citizen Engagement in Nanotechnologies From the Top-Down?*, 29 BULL. SCI. TECH & SOC. 329 (2009); M. Powell, *Café Scientifiques*, ENCYCLOPEDIA OF SCIENCE AND TECHNOLOGY COMMUNICATION (forthcoming 2009).

108. *See, e.g.*, RCEP/NM, *supra* note 6, at 75.

109. *See, e.g.*, GAVELIN ET AL., *supra* note 91, at X; RCEP/NM, *supra* note 6, at 75; Powell & Colin, *supra* note 91, at 127.

110. *See* Powell & Colin, *supra* note 91, at 135.

111. *See* Cary Coglianese, *The Internet and Citizen Participation in Rulemaking*, 1 I/S: J. L. POL'Y FOR INFO. SOC'Y 33 (2005); Cary Coglianese, *Citizen Participation in Rulemaking: Past, Present, and Future*, 55 DUKE L.J. 943 (2006); Raimo P. Hämäläinen et al., We Have the Tools—How to Attract the People? Creating a Culture of Web-based Participation in Environmental Decision-Making 17 (June 2, 2006), http://www.sal.hut.fi/Publications/pdf-files/mmus06.pdf.

and tools. In the following I want to highlight two key challenges in this context.[112]

1. Multi-layered Participation—Confronting the Attraction Problem

Attracting people to the web constitutes one of the key problems facing e-democracy. One way to approach this problem is through the notion of multi-layered participation. Multi-layered participation constitutes a balanced compromise between the demands of inclusiveness and discursive depth and complexity. It allows the organizers of the e-process to distinguish between classes of participants according to their willingness to invest time and intellectual resources in the process (learning the issues and considering other voices) and recognizes that people's opinions may be given different weight according to their investment in the process. Such multi-layered participation is already utilized by some regulatory agencies.[113]

The success of such schemes also depends on creating motivational anchors. Establishing multi-layered participatory schemes can increase motivational levels if it is accompanied by stronger institutional commitment to take into account civic input. Another option could focus on offering some compensation to citizens who are willing to invest more time in the deliberative process, reflecting the fact that they perform an important civic duty.[114] Such compensation is commonly used by companies offering web-based surveys using on-line panels. The compensation does not necessarily need to be high. The experience of

112. It should be noted in this context that e-tools do not need to stand alone. In fact one of the key lessons of past experimentation with e-democracy is that combining e-deliberation with off-line meetings can increase the reach and scope of the engagement process. *See* Hämäläinen et al., *supra id.* For a practical example of such combination, see European Citizens' Consultations: The Economic and Social Future of Europe, http://www.european-citizens-consultations.eu/uk/content/about-project (last visited Mar. 9, 2010). *See also* HAMLETT ET AL., *supra* note 107, at 4.

113. *See, e.g.*, On-Line Advisory Panel of TransLink, the South Coast British Columbia Transportation Authority, https://www.translinklistens.ca (last visited Sept. 16, 2009); Consumer Attitudes Survey 2007, http://www.foodstandards.gov.au/_srcfiles/Consumer%20Attitudes%20Survey.pdf (last visited Sept. 16, 2009).

114. Such compensation is offered to citizens serving in juries in the U.S. although it is considered by many as inadequate. *See, e.g.*, Massachusetts Jury System, http://www.mass.gov/courts/sjc/jury-system-b.html#compensation%20for%20jury%20service (last visited Sept. 16, 2009); Paul W. Rebein & Cary Silverman, *Full Participation of Citizens in the Jury System*, FOR THE DEFENSE, July 2003, at 12; ROBERT G. BOATRIGHT, IMPROVING CITIZEN RESPONSE TO JURY SUMMONSES: A REPORT WITH RECOMMENDATIONS 123 (1998).

these firms show that it is possible to attract people to participate in surveys even with small remuneration, drawing on their (non-instrumental) motivation to voice their opinions. The monetary reward operates only as a complementary incentive, serving more as a symbolic gesture.[115]

2. Using Computer Supported Argumentation and Collaborative Decisionmaking Systems

Another challenge associated with e-deliberation concerns the discursive depth and complexity of the process. E-consultation processes are highly susceptible to mass email campaigns. While such campaigns can play a useful role in reflecting public sentiments, they can undermine the reflexive capacity of the deliberative process by crowding out individual and original contributions.[116] Further, by focusing attention to volume—rather than substance—mass email campaigns undermine the general political impact of e-deliberation by reducing the chances that civic contributions, with low public salience, will receive government attention. There is a need, therefore, for tools that could increase the intelligence, transparency and deliberative power of web-based deliberative exercises.

Deliberation support systems can support the realization of these goals by imposing various conditions on deliberative contri-

115. The remuneration paid to participants in online surveys is usually quite small. *See* Terry Daugherty, Wei-Na Lee, Harsha Gangadharbatla, Kihan Kim, & Sounthaly Outhavong, *Organizational Virtual Communities: Exploring Motivations Behind Online Panel Participation*, 10 J. COMPUTER-MEDIATED COMM. (2005), *available at* http://jcmc.indiana.edu/vol10/issue4/daugherty.html. *See further* G. Van Rysin, *Validity of the On-Line Panel Approach to Citizen Surveys*, 32 PUB. PERFORMANCE MGMT. REV. 236 (2008); RENEE SMITH & HOLLAND HOFMA BROWN, ASSESSING THE QUALITY OF DATA FROM ONLINE PANELS: MOVING FORWARD WITH CONFIDENCE 3 (2005), *available at* http://www.hisbonline.com/pubs/HI_Quality_of_Data_White_Paper.pdf. For practical examples of online panels, see Knowledge Networks, KnowledgePanel, http://www.knowledgenetworks.com/knpanel/index.html (last visited Mar. 10, 2010); Consumer-Opinion.com, http://www.consumer-opinion.com/ (last visited Mar. 10, 2010); and Consumer Fieldwork; Panel and Quality Management, http://www.consumerfieldwork.com/quality.htm (last visited Mar. 10, 2010). For general discussion of the online survey methodology, see T. Buchanan, *The Efficacy of a World-Wide Web Mediated Formative Assessment*, 16 J. COMPUTER ASSISTED LEARNING 193 (2002); U.D. Reips, *Internet-based Psychological Experimenting: Five Dos and Don'ts*, 20 SOC. SCI. COMPUTER REV. 241 (2002).

116. For this discussion of the problem, see Stuart Schulman, Perverse Incentives: The Case Against Mass E-Mail Campaigns (paper presented at the annual meeting of the American Political Science Association, Aug 30, 2007), *available at* http://www.allacademic.com//meta/p_mla_apa_research_citation/2/0/9/4/2/pages209426/p209426-1.php.

butions. By creating formal protocols in which any discursive contribution needs to be made, the system provides a structured space in which participants can interact. Deliberation support systems can make sure that the discursive contributions satisfy certain argumentation rules, pertaining, for example, to their justificatory form. These systems can further contribute to the discursive richness of the process by helping participants monitor the deliberation by sorting different issues into distinct threads and keeping track of the exchange of arguments (noting the reasons offered for each argument and the conclusions drawn). In keeping track of the argumentation process, these systems also play a record-keeping role, providing a complete description of the decisionmaking process. Finally, these systems can also fulfill a more problematic function of evaluating the justification status of the statements made during the deliberation process.

The most popular and widely used deliberation support system is the Wiki platform, which allows users to create and edit content in a collaborative manner. The Wiki platform could be particularly useful as a mechanism for a collaborative discussion of a policy document or a standard, such as DuPont/EDF Nano Risk Framework.[117] An interesting and recent example of the use of a deliberation-support system in a political context is the deliberative process initiated by AccountAbility in 2008, using a Wiki platform, with respect to the revision of the AA1000 Assurance Standard.[118]

Another interesting set of deliberation support tools that could be very useful in the governance of risk are web-oriented multicriteria analysis tools.[119] The Multi-Criteria Decision Analysis

117. *See* ENVIRONMENTAL DEFENSE—DUPONT NANO PARTNERSHIP, NANO RISK FRAMEWORK (June 2007), http://www.edf.org/documents/6496_Nano%20Risk%20Framework.pdf.

118. The deliberation platform created by AccountAbility was not, however, completely bottom-up. The final authority to approve the standard remained within the hands of the AccountAbility Standards Technical Committee (ASTC). However, AccountAbility has committed to publish any interventions of the ASTC on the Wiki. *See* AccountAbility, http://www.accountability21.net/default2.aspx?id=4186 (last visited Sept. 16, 2009).

119. *See, e.g.*, Jyri Mustajoki, Raimo P.Hämäläinen, & Mika Marttunen, *Participatory Multicriteria Decision Support with Web-HIPRE: A Case of Lake Regulation Policy*, 19 ENVTL. MODELING & SOFTWARE 537 (2004). *See also* Decisionarium: Tools for Multi-Criteria Evaluation and Participation, http://www.decisionarium.net/ (last visited Mar. 10, 2010); Alexander V. Lotov, *Internet Tools for Supporting of Lay Stakeholders in the Framework of the Democratic Paradigm of Environmental Decision Making*, 12 J. MULTI-CRITERIA DECISION ANALYSIS 145 (2003); Raimo P. Hämäläinen, *Negotiating and Collecting Opinions on the Web*, 12 J. MULTI-CRITE-

(MCDA) framework provides a mechanism to link heterogeneous information on risks with decision criteria and weightings elicited from varied stakeholders. It also allows for the visualization and quantification of the trade-offs involved in the decision-making process, enabling decisionmakers to consider how different decision criteria and values affect the decision. Given the lack of meta-criteria which could be used to interpret the PP—both in general and in the context of nanotechnology—the capacity of MCDA tools to incorporate multiple points is highly attractive. MCDA tools can be used at different regulatory junctions, whether to prioritize research and information-gathering tasks or to make decision on particular nanosubstances.[120] A good example of a web-based, participatory oriented MCDA tool with a proven record of civic application is the Web-Hipre platform.[121]

While there has been substantial progress over the last decade in developing decision support systems and experimenting with them, substantial challenges remain. In particular, more effort needs to be made in developing user-friendly interfaces and in educating people to take part in complex e-consultation projects.[122] To a large extent, motivating people to make the necessary effort also requires a real commitment to take what they say seriously. But using these tools may also have a price in terms of the reach of the deliberative process.

RIA DECISION ANALYSIS 101 (2003); Raimo P. Hämäläinen, Jyri Mustajoki, and Mika Marttunen, *We Have the Tools—How to Attract the People? Creating a Culture of Web-Based Participation in Environmental Decision Making* (Oct. 26, 2006), *available at* http://www.sal.hut.fi/Publications/pdf-files/cham06b.pdf; Mats Danielson, Love Ekenberg, Anders Ekengren, Torsten Hökby, and Jan Lidén, *Decision Process Support for Participatory Democracy,* 15 J. MULTI-CRITERIA DECISION ANALYSIS 15 (2008); Hemant K. Bhargava, Daniel J. Power & Daewon Sun, *Progress in Web-Based Decision Support Technologies*, 43 DECISION SUPPORT SYS. 1083 (2007); Richard Shepherd, *Involving the Public and Stakeholders in the Evaluation of Food Risks*, 19 TRENDS IN FOOD SCI. & TECH.234; Jutta Geldermann & Jens Ludwig, *Some Thoughts on Weighting in Participatory Decision Making and E-Democracy*, 7 INT'L J. TECH., POL'Y & MGMT. 178 (2007).

120. For more details, see Igor Linkov et al., *Multi-criteria Decision Analysis and Environmental Risk Assessment for Nanomaterials*, 9 J. NANOPARTICLE RES., 543 (2007).

121. *See* Decisionarium Home Page, http://www.decisionarium.tkk.fi/ (last visited Mar. 10, 2010); Raimo P. Hämäläinen, *Decisionarium—Aiding Decisions, Negotiating and Collecting Opinions on the Web*, 12 J. MULTI-CRITERIA DECISION ANALYSIS 101 (2003).

122. Hämäläinen et al., *supra* note 111, at 15-19.

D. *Risk Visualization*

Visual presentation is an important mechanism for reducing complexity.[123] Visualization can facilitate understanding by offering nontextual forms for representing the risk-data using visual means such as charts, graphs, drawings, pictures and maps. The claim that visual aids can enhance understanding received support in numerous studies,[124] although the extent of this impact depends upon context[125] and user personality.[126] Politically oriented websites are already using various visual technologies.[127] The regulatory process in the fields of resource management and planning draws heavily on Geographic Information Systems (GIS), which offer advanced visualization tools.[128]

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123. For the argument that visualization can enhance understanding risks, see Isaac M. Lipkus & J.G. Hollands, *The Visual Communication of Risk*, 25 J. NAT'L CANCER INST. MONOGRAPHS 149 (1999); Martin Eppler & Markus Aeschimann, *Envisioning Risk: A Systematic Framework for Risk Visualization in Risk Management and Communication* (University of Lugano, Working Paper #5/2008, 2008).

124. Lipkus & Hollands, *supra id.*; Gary W. Dickson, DeSanctis Gerardine & D. J. McBride, *Understanding the Effectiveness of Computer Graphics for Decision Support: A Cumulative Experimental Approach*, 29 COMMUN. ACM 40 (1986); Cheri Speier, *The Influence of Information Presentation Formats on Complex Task Decision-Making Performance*, 64 INT. J. HUM.COMPUTER STUD. 1115 (2006).

125. Graphical representation may be superior to other forms of representation when there is a cognitive fit between the information emphasized in the representation format and that required by the task. Thus, for example, while tables emphasize symbolic data and lead to better performance for the task of reading individual data values, graphs emphasize spatial information and lead to better performance (relative to numerical presentation) for most elementary spatial tasks, including summarizing data, conveying trends, comparing points and patterns of different variables, forecasting, and showing deviations. S. L. Jarvenpaa, & G. W. Dickson, *Graphics and Managerial Decision Making: Research-Based Guidelines*, 31 COMMUN. ACM 764 (1988). Graphs may also affect attentional processes through a vividness effect, attracting and holding people's attention because of their concrete and visual form of displaying information. Lipkus & Hollands, *supra* note 123, at 149-50.

126. J. J. Jahng et al., *Personality Traits and Effectiveness of Presentation of Product Information in E-Business Systems*, 11 EURO. J. INFO SYS. 181 (2002).

127. For examples of using visual aids in consultation regarding local planning projects, see Veterans' Glass City Skyway, http://www.veteransglasscityskyway.org/4_public.htm (dealing with the construction of a new, massive bridge over the Maumee River, Toledo, Ohio: The Veterans' Glass City Skyway).

128. GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. *See* Geographic Information Systems, What is GIS?, http://www.gis.com/content/what-gis (last visited Mar. 9, 2010). *See also* Mapping for Change: International Conference on Participatory Spatial Information Management and Communication, http://pgis2005.cta.int/ (last visited Mar. 9, 2010). For a good example of a website using GIS technology to disseminate information to the public, see SafeRoadMaps, http://www.saferoadmaps.org/home/index.htm (last vis-

By promoting better understanding of the risks associated with nanotechnologies, visual tools can assist in the deliberation process in each of the domains identified above: the specification of the hazard spectrum, the determination of the (epistemic) confidence interval, and the specification of the appropriate regulatory response. An interesting framework for thinking about the use of visualization techniques in the context of risk-governance was proposed by Martin Eppler in a series of articles.[129] Eppler and his colleagues explore various *representation formats* to visualize risks in risk management, risk governance and risk communication. Eppler's framework seeks to provide answers to the questions of *why*, *what, for whom*, *when,* and *how* which risks and risk-related information (the *what*) should be visualized.[130] Eppler's framework assumes that visualization can play an important role in facilitating mutual understanding in the deliberation process.

Thus, for example, the following image demonstrates how visualization can assist decisionmakers by explicating some of the risks associated with airborne nanoparticles.[131]

The following qualitative risk diagram provides another example of the potential usefulness of visualization. In this context, visualization can assist decisionmakers in the classification of risks and consideration of proper responses. It can support decisionmakers in reasoning about the PP, and its place within the broader universe of risks.[132]

While it is generally agreed that visualization can enhance understanding, the use of visual aids has been widely criticized.[133] The critiques point out that despite the objective look of visual

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ited Mar. 9, 2010) (providing visual representation of traffic safety across the United States).

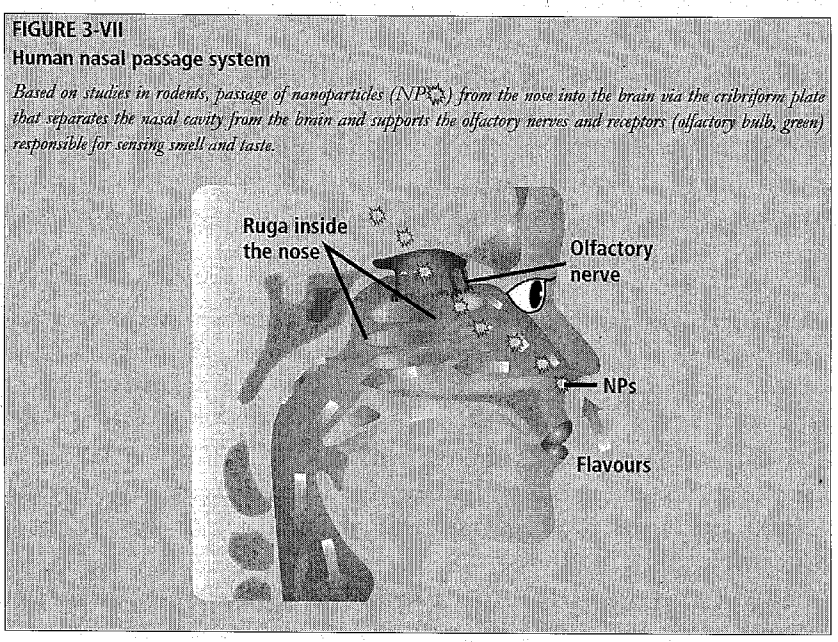
129. *See* Eppler & Aeschimann, *supra* note 123; Martin Eppler et al., *Seven Types of Visual Ambiguity: On the Merits and Risks of Multiple Interpretations of Collaborative Visualizations*, *in* PROCEEDINGS OF THE 12TH INTERNATIONAL CONFERENCE ON INFORMATION VISUALIZATION 391 (2008).

130. Eppler & Aeschimann, *supra* note 123, at 6.

131. RCEP N/M, *supra* note 6, at 44. For technical discussion, see Andrew D. Maynard & Robert J. Aitken, *Assessing Exposure to Airborne Nanomaterials: Current Capabilities and Future Requirements*, 1 NANOTOXICOLOGY 26 (2007).

132. MARTIN EPPLER, Risk Visualization for effective Risk Communication, Coordination and Governance: Relevance, Conceptual Framework, Examples 66 (2008), http://www.risk-visualization.org/RiskViz%20Sample%20Images.pdf.

133. *See, e.g.*, Renee Sieber, *Public Participation Geographic Information Systems: A Literature Review and Framework*, 96 ANNALS ASS'N AM. GEOGRAPHERS 491 (2006); Kevin S. Ramsey & Matthew W. Wilson, *Rethinking the 'Informed' Participant: Precautions and Recommendations for the Design of Online Deliberation*, *in*



representations such as maps and photos, they are in fact the product of unstated selections undertaken by anonymous technical intermediaries. The impression that GIS maps or photos

Impact	Risk Management Actions		
Significant	Considerable management required	Must manage and monitor risks	Extensive management essential
Moderate	Risks may be worth accepting with monitoring	Management effort worthwhile	Management effort required
Minor	Accept risks	Accept, but monitor risks	Manage and monitor risks
	Low	Medium	High
	Likelihood		

ONLINE DELIBERATION: DESIGN, RESEARCH, AND PRACTICE 259 (T. Davies ed., 2009).

open a window to reality uninfluenced by ideology is thus ungrounded.[134] The hidden selections underlying these representational mechanisms may pre-determine the consultation process, undermining the whole purpose of the deliberative process.

The challenge in using visual tools to support risk-deliberation processes is therefore dual. First, we need better understanding of how visual techniques can enhance deliberation, and how different visual techniques can be tailored to different deliberative tasks.[135] Second, using visual tools also requires us to develop new normative sensitivities, highlighting the way in which undemocratic technical intermediation can influence the deliberation process.

E. *De-Biasing the Decisionmaking Process*

Risk perception and risk judgment are fraught with cognitive biases. There is a wide-ranging literature that explores these biases in various contexts.[136] The risk-biases literature has developed a rich catalogue of generic biases which were examined in various technological contexts. However, this rich body of literature has failed so far to develop a deep theoretical understanding of the ways in which these multiple biases could be countered in a decisionmaking context. The key challenge facing the risk-biases research community—and with them, the regulatory community—is the development of regulatory-oriented de-biasing mechanisms. This challenge is both theoretical and pragmatic. It is complex because the development of these mechanisms requires engagement at both the individual and group levels and an appreciation that these biases should not be understood as isolated individualistic phenomena, but as both a cause and a construct of social processes and structures.

Let me start by exploring in more detail some of the biases affecting risk perception and risk judgment. In a series of articles exploring the decisionmaking process of citizens, Milton Lodge and Charles Taber have questioned the capacity of traditional ra-

134. Ramsey & Wilson, *supra id.*

135. Another important and under-explored question concerns the interaction between visualization tools and the various cognitive biases discussed below.

136. For an overview, see Dan M. Kahan, *Nanotechnology and Society: The Evolution of Risk Perceptions*, 4 NATURE NANOTECHNOLOGY 705 (2009); Dan M. Kahan et al, *Fear of Democracy: A Cultural Evaluation of Sunstein on Risk*, 119 HARV. L. REV. 1071 (2006); Sunstein, *supra* note 76.

tional decisionmaking models to explain political behaviour.[137] Citizens, they argue, are motivated or biased reasoners "who find it near impossible to evaluate new, attitude-relevant information in an evenhanded way." The deliberative process associated with political discussion—the search, selection and evaluation—of supportive or contrary evidence and arguments, Lodge and Taber argue, is highly biased and strongly influenced by an initial and uncontrolled affective response.[138]

The primary cause for this "deliberative" failure is the "affect bias." The affect bias refers to the way in which "subjective impressions of 'goodness' or 'badness' can act as a heuristic, capable of producing fast perceptual judgments, and also systematic biases."[139] The affect bias (or prior attitude bias) is a general term describing how people's prior attitudes regarding an issue will influence how they select and evaluate evidence and arguments concerning that issue. This effect captures several different phenomena associated with the selection and evaluation of evidence and arguments. The selective exposure bias refers to people's tendency to seek out supportive arguments. The confirmation bias refers to the tendency of subjects to treat attitudinally congruent evidence as inherently stronger than attitudinally incongruent evidence. The disconfirmation bias describes people's inclination to accept supportive evidence uncritically but actively argue against challenging evidence.[140] The deliberation of risks involves several other biases, which may distort people's perceptions of risks, such as the availability or vividness biases.[141]

Kahan and colleagues explored in a series of studies the scope of the affect bias in the context of nanotechnology. They demonstrated that public attitudes toward the risks and benefits of nanotechnology are likely to be shaped by psychological dynamics

137. Milton Lodge & Charles S. Taber, *The Rationalizing Voter: Unconscious Thought in Political Information Processing* 17-18 (Dec. 21, 2007), *available at* http://ssrn.com/abstract=1077972. Lodge and Taber are drawing in this context on a rich background of research in political psychology. *See* Doris Graber, *Mediated Politics and Citizenship in the Twenty-First Century*, 55 ANN. REV. PSYCHOL. 545 (2004).

138. Lodge & Taber, *supra id.*, at 32.

139. Yudkowsky, *supra* note 78.

140. *Id.*; Charles S. Taber & Milton Lodge, *Motivated Skepticism in the Evaluation of Political Beliefs*, 50 AM. J. POL. SCI. 755 (2006); Lodge & Taber, *supra* note 137, at 33.

141. Slovic, *supra* note 37; P. Slovic et al., *Risk As Analysis and Risk As Feelings: Some Thoughts About Affect, Reason, Risk, and Rationality*, 24 RISK ANALYSIS 1, 1-12 (2002).

associated with cultural cognition. Cultural cognition refers to the tendency of people to base their factual beliefs about the risks and benefits of a putatively dangerous activity on their cultural appraisals of these activities, drawing on their pre-determined cultural worldviews.[142] This argument rejects the familiarity hypothesis, which holds that support for nanotechnology will likely grow as awareness of it expands. Furthermore, as a result of this motivated reasoning, attitudes are also prone to become more extreme in the face of conflicting conversational environments.[143] All together, these varied biases can lead to what Sunstein describes as "misfearing": people may fear things that are not dangerous and fail to fear things that impose serious risks.[144]

This description of the risk-deliberative process is quite distant from the rational and open minded process imagined by Habermas in his communicative model of political deliberation. The societal deliberation of risks seems to be torn between two systems of analysis: an analytic, highly conscious system, which uses algorithms and normative rules, such as probability calculus, formal logic, and risk assessment; and an experiential system, which is intuitive and mostly automatic, and draws on images and associations, linked by experience to emotion and affect.[145]

One of the critical challenges of the regulatory system involves the recognition that experts—who are supposed to represent the analytic system of analysis in the regulatory process—are not immune to these cognitive biases. In an insightful article about the confirmation bias Raymond Nickerson describes how this bias affects the reasoning and judgments of various experts, from public officials to physicians and scientists.[146] The capacity of science,

142. *See* Kahan et al., *supra* note 76.

143. Lodge & Taber, *supra* note 137, at 35. Lodge and Taber argue further that these biases are particularly pronounced for citizens with more knowledge and stronger political attitudes, those 'informed citizens' on whom Habermasian democratic theories rely most. *Id.* On the issue of group polarization, see Cass R. Sunstein, *Deliberative Trouble? Why Groups Go To Extremes*, 110 YALE L.J. 71 (2000).

144. Cass R. Sunstein, *Misfearing: A Reply*, 119 HARV. L. REV. 1110 (2006).

145. Slovic et al., *supra* note 141.

146. Nickerson, *supra* note 78. For further discussion of how cognitive biases affect the decisions of experts, see James H. Barnes Jr., *Cognitive Biases and Their Impact on Strategic Planning*, 5 STRATEGIC MGMT. J. 129 (1984); Pat Croskerry, *The Cognitive Imperative Thinking About How We Think*, 7 ACAD. EMERGENCY MED. (2000); Itiel E. Dror, David Charlton & Ailsa E. Péron, *Contextual Information Renders Experts Vulnerable to Making Erroneous Identifications*, 156 FORENSIC SCI. INT. 74 (2006); Kenneth L. Fisher & Meir Statman, *Cognitive Biases in Market Forecasts*,

as an institution, to overcome the psychological biases of its practitioners lies, Nickerson argues, in the institutional attributes of science—not in the ability of scientists to overcome these challenges as individuals. Thus, Nickerson observes:

> It is not so much the critical attitude that individual scientists have taken with respect to their own ideas that has given science the success it has enjoyed as a method for making new discoveries, but more the fact that individual scientists have been highly motivated to demonstrate that hypotheses that are held by some other scientist(s) are false. The insistence of science, as an institution, on the objective testability of hypotheses by publicly scrutable methods has ensured its relative independence from the biases of its practitioners.[147]

Unfortunately, the institutional mechanisms that guard science against the cognitive pitfalls of its practitioners—for instance, peer review, aggressive competition to publish in top journals, and the professional credit received by new discoveries or the refutation of dominant models—do not exist in the regulatory domain in which experts function not as scientists, but as regulatory figures who give advice on policies and actions. In this domain there is no peer review, no public platform for argumentation, and no clear mechanisms for discovering a wrong argument.

The cognitive-bias literature suggests, however, that it is possible to control these biases.[148] Thus, for example, Lodge and Taber note that "of course, under the right circumstances and given enough motivation to be prudent we can confront challenging evidence and correct for biases, but correction processes are very effortful and no guarantee of success."[149] Meta-cognition and cognitive forcing strategies can possibly counter the effect of these biases.[150] But is it possible to specify the institutional conditions which can lead to a deliberative environment that is less prone to biases—that can somehow correct for our inevitable

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27 J. PORTFOLIO MGMT. 1 (2000); E. Pronin, *Perception and Misperception of Bias in Human Judgment*, 11 TRENDS COGNITIVE SCI. 37 (2006); Yudkowsky, *supra* note 78.

147. Nickerson, *supra* note 78, at 194.

148. Pronin, *supra* note 146 (educating people about the shortcomings of introspection reduces their denial of personal bias); E. Pronin, *How We See Ourselves and How We See Others*, 320 SCI. 1177 (2008); Croskerry, *supra* note 146, at 1227-28 (explaining the possibility of countering cognitive errors in emergency medicine practice); Yudowsky, *supra* note 78, at 21 (arguing everyone should study the cognitive-bias literature in addition to their domain-specific knowledge).

149. Lodge & Taber, *supra* note 137.

150. Croskerry, *supra* note 146, at 1227-1228.

cognitive limitations? Are there any decisionmaking protocols that can be invoked?

Indeed, Lodge and Taber highlight this question as a key puzzle for future research:

> . . . [O]nce triggered, once the preconditions come into play, thoughts are linked to feelings to goals to choices outside of conscious awareness without necessarily triggering conscious or deliberative guidance. Where, when, how, and for whom deliberative processing will successfully override the automatic response is the critical, heretofore unanswered question that goes to the heart of all discussions of human rationality and the meaning of a responsible electorate.[151]

Practitioners of participatory democracy are certainly aware of the need to counter possible biases in designing participatory processes. Thus, for example, Regula Burri, who studied a participatory project regarding public reactions to nanotechnology in Switzerland initiated by the Centre for Technology Assessment (TA-Swiss) notes that the organizers sought to offer the participants well-balanced information about nanotechnology. The information brochure that was circulated to the participants sought to provide a balanced picture of the debate, and has "neither privileged potential positive nor potential negative consequences of nanotechnologies."[152] Further, the guidelines developed by TA-Swiss to structure the discussion were "well-balanced raising hopes, fears, visions, and risks of nanotechnologies and did thus not impose a specific perspective on participants."[153] This approach seems to be based on reasonable intuitions, but it lacks any foundation in basic research regarding the best way with which cognitive biases could be overcome.[154]

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151. Lodge & Taber, *supra* note 137, at 42.

152. Know Your Nano! Information Brochure, *available at* http://www.ta-swiss.ch/a/nano_pfna/2006_TAP8_IB_Nanotechnologien_e.pdf (last visited Sept. 17, 2009).

153. *See* BURRI, *supra* note 107, at 146-47. For a description of the methodology, see Centre for Technology Assessment, Public Reactions to Nanotechnology in Switzerland 14-20 (2006), *available at* http://www.ta-swiss.ch/a/nano_pfna/2006_TAP8_Nanotechnologien_e.pdf. For a similar approach in the Nano context, see Nick Pidgeon et al., *Deliberating the Risks of Nanotechnologies for Energy and Health Applications in the United States and United Kingdom*, 4 NATURE NANOTECHNOLOGY 95, 97 (2009).

154. For a similarly intuitive approach to de-biasing (in the context of medical decision-making), see JEROME GROOPMAN, HOW DOCTORS THINK 41-58 (2007). *See also* Overcoming Bias, http://www.overcomingbias.com/ (last visited Mar. 9, 2010).

There have been some attempts to develop meta-cognition strategies or counter-biasing protocols. Thus, for example, Wikipedia's neutral point of view policy (NPOV)[155] offers guidelines for dealing with conflicting perspectives on a topic. It requires that where multiple or conflicting perspectives exist within a topic each should be presented fairly and offers detailed guidelines seeking to ensure the realization of the goal of fair presentation.[156] The NPOV policy is not directly relevant to our question, however, because it is not decision-oriented. Nonetheless, some of the issues discussed in this policy, such as bias in attribution, one-sided selection of information, and comparative credibility of the experts are also relevant to decision-oriented deliberative processes. This is not to say that NPOV provides the best response to the bias-dilemma in the context of risk-governance structures, but it gives a good idea of what is at stake. The legal literature has also developed some insights in this direction, focusing on areas such as the litigation process and the work of forensic experts.[157]

It is clear that more work needs to be done in order to apply the foregoing insights to the risk-governance context, exploring it at both the individual and collective perspectives. Further, we should also be conscious about the objective of the de-biasing project. I do not see it as an attempt to establish some ideal institutional conditions facilitating a sterile, objective conversation, in the style of Thomas Nagel's "view from nowhere." Rather, this project has a more modest goal of enabling an open conversation, in which the other voices in the conversation are not automatically discounted. One practical lesson that can be extracted from the foregoing discussion concerns the value of making the issue of cognitive biases more salient. Drawing on the literature

155. Wikipedia Neutral Point of View, http://en.wikipedia.org/wiki/Wikipedia:Neutral_point_of_view (last visited Mar. 9, 2010).

156. Wikipedia NPOV Tutorial, http://en.wikipedia.org/wiki/Wikipedia:NPOV_tutorial (last visited Sept. 17, 2009).

157. *See, e.g.*, Christine Jolls & Cass R. Sunstein, *Debiasing Through Law*, 35 J. LEGAL STUD. 199 (2006); Babcock, Linda, George Loewenstein & Samuel Issacharoff, *Creating Convergence: Debiasing Biased Litigants*, 22 L. & SOC. INQUIRY 913–25 (1997); Neil D. Weinstein & William M. Klein, *Resistance of Personal Risk Perceptions to Debiasing Interventions*, *in* HEURISTICS AND BIASES: THE PSYCHOLOGY OF INTUITIVE JUDGMENT 312, 312-23 (Thomas Gilovich, Dale Griffin & Daniel Kahneman eds., 2002); Roger G. Koppl, *How to Improve Forensic Science*, 20 EUR. J. L. & ECON. 255 (2005); Roger G. Koppl, *Democratic Epistemics: An Experiment on How to Improve Forensic Science* (2006), *available at* https://papers.econ.mpg.de/evo/discussionpapers/2006-09.pdf (discussing designing error-minimizing mechanisms in forensic science).

on contextualism in epistemology, we can distinguish in this context between two conversational environments that vary based on the degree to which the issue of cognitive bias receives salience.[158] Making the possibility of bias salient could facilitate self-reflection on the part of the participants and avoid some of the collective pitfalls of cognitive biases, such as attitude polarization and the tendency of conflicts to follow a downward spiral.[159] According to this view, de-biasing operates as an institutionalized series of red-flags, alerting us to our cognitive failings.[160]

V.
BRINGING DEMOCRACY INTO THE PRECAUTIONARY PRINCIPLE: CONCLUDING REMARKS

I highlighted above some of the key challenges that underlie the project of democratizing the regulation of nanotechnology. This project draws on a political understanding of the precautionary principle. But how should the law accommodate the pressures to develop new precautionary politics? What kind of legal structures could emerge in response to this new reading of the PP? Three possible responses can be distinguished in this context: codification, interpretation and experimentation. Codification requires the consolidation of the intricate details that constitute the PP as a democratic framework for governing risks into a detailed legal instrument. However, such a move seems premature, given the state of our knowledge regarding, for example, the ways in which cognitive biases can be overcome in deliberative contexts or how visual tools can be used to promote reasoned dialogue. Codification is also inconsistent with the ethos of pluralism and non-dogmatism, which underlie the new vision of precautionary politics. It seems therefore that the law would have to cope with the challenge of democratizing risk-governance through interpretation and experimentation. These processes can take place at various domains—from courts to public legislation to private norm-making initiatives (e.g., EDF/DuPont joint project). To a large extent, these processes can take place parallel to scientific progress in the study of nano-processes and substances.

158. Stewart Cohen, *Knowledge, Speaker and Subject*, 219 PHIL. Q. 199, 200 (2005).

159. *See, e.g.*, Pronin, *supra* note 146, at 1180.

160. GROOPMAN, *supra* note 154, at 45.

The forgoing discussion offers a broad theoretical platform for thinking about risk-governance in conditions of extreme uncertainty. But does it offer more concrete and immediate lessons for our thinking about nanotechnology regulation? For me the critical lesson lies in extending the horizon of civic participation to the junction in which research priorities concerning nanotechnologies are being determined. This is probably the junction in which public engagement can be most valuable. Thus, for example, public deliberation could focus on the question of whether the allocation of research funds should be influenced by the social value of the proposed research path; whether more money should go into the study of risk assessment methodologies; and whether the scientific study of nanotechnology should also include a social science component, focusing, for example, on the exploration of models of civic participation pertaining to risk-governance. However, governments have so far shown little enthusiasm to incorporate the public at this decisionmaking junction. Probably the most far-reaching attempt in this direction is the British model: the Nanotechnologies Stakeholder Forum and Nanotechnology Engagement Group, which were established by UK-DEFRA in order to provide ongoing public feedback on all policy activities related to nanotechnologies.[161]

161. *See supra* note 107.