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Irreversible and Catastrophic

Cass R. Sunstein

IRREVERSIBLE AND CATASTROPHIC

Cass R. Sunstein†

As many treaties and statutes emphasize, some risks are distinctive in the sense that they are potentially irreversible or catastrophic; for such risks, it is sensible to take extra precautions. When a harm is irreversible, and when regulators lack information about its magnitude and likelihood, they should purchase an "option" to prevent the harm at a later date—the Irreversible Harm Precautionary Principle. This principle brings standard option theory to bear on environmental law and risk regulation. And when catastrophic outcomes are possible, it makes sense to take special precautions against the worst-case scenarios—the Catastrophic Harm Precautionary Principle. This principle is based on three foundations: an emphasis on people's occasional failure to appreciate the expected value of truly catastrophic losses; a recognition that political actors may engage in unjustifiable delay when the costs of precautions would be incurred immediately and when the benefits would not be enjoyed until the distant future; and an understanding of the distinction between risk and uncertainty. This Article illustrates the normative arguments in favor of these principles throughout with reference to the problem of global warming; other applications include injunctions in environmental cases, genetic modification of food, protection of endangered species, and terrorism.

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† Karl N. Llewellyn Distinguished Service Professor of Jurisprudence, University of Chicago, Law School and Department of Political Science. I am extremely grateful to Robert Goodin, Robert Hahn, Eric Posner, Richard Posner, Adrian Vermeule, David Weisbach, and the participants in a workshop at Columbia Law School for their valuable comments. Special thanks to Professors Vermeule and Weisbach for many helpful discussions.

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Introduction

Many losses are irreversible. Once a species is gone, it is gone forever. Transgenic crops can impose irreversible costs by increasing pest resistance.[1] Because some greenhouse gases stay in the atmosphere for up to a century, the problem of global warming may be irreversible, at least for all practical purposes.[2] Global warming could be catastrophic as well, potentially endangering many millions of people.[3] Irreversible or catastrophic risks pose distinctive problems for regulators; they require significant adjustments in the standard forms

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1 *See generally* Benoît Morel et al., *Pesticide Resistance, the Precautionary Principle, and the Regulation of* Bt *Corn: Real Option and Rational Option Approaches to Decisionmaking, in* Battling Resistance to Antibiotics and Pesticides 184 (Ramanan Laxminarayan ed., 2003) [hereinafter Battling Resistance] (proposing option theory as an analytical framework for the Precautionary Principle and applying that framework to the issue of commercializing *Bt* corn); Justus Wesseler, *Resistance Economics of Transgenic Crops Under Uncertainty: A Real Option Approach, in* Battling Resistance, *supra*, at 214 (discussing pest resistance as an irreversible cost of transgenic crops).

2 *See* W. David Montgomery & Anne E. Smith, *Global Climate Change and the Precautionary Principle*, 6 Hum. & Ecological Risk Assessment 399, 400 (2000).

3 *See* Richard A. Posner, Catastrophe: Risk and Response 43–58 (2004).

of cost-benefit analysis.[4] In any case, specialists in risk perception have long emphasized the fact that under some circumstances, people are especially averse to risks that are irreversible, potentially catastrophic, or both.[5]

The Precautionary Principle, used in many international documents,[6] is often said to have a special place in the context of irreversibility and catastrophe.[7] Consider a few examples:

- The closing Ministerial Declaration from a United Nations Economic Conference for Europe in 1990 asserts, "In order to achieve sustainable development, policies must be based on the precautionary principle. . . . Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation."[8]
- The 1992 Rio Declaration states, "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."[9]
- The United Nations Framework Convention on Climate Change states,

  Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing [regulatory] measures, taking into account that policies and measures to deal with climate change should be

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4 *See* Montgomery & Smith, *supra* note 2, at 406–10. *See generally* Kenneth J. Arrow & Anthony C. Fisher, *Environmental Preservation, Uncertainty, and Irreversibility*, 88 Q.J. ECON. 312 (1974) (discussing how consideration of an economic activity's irreversibility should inform the cost-benefit calculus).

5 *See* Paul Slovic et al., *Rating the Risks*, *in* THE PERCEPTION OF RISK 104, 117–20 (Paul Slovic ed., 2000).

6 *See generally* ARIE TROUWBORST, EVOLUTION AND STATUS OF THE PRECAUTIONARY PRINCIPLE IN INTERNATIONAL LAW (2002) (discussing the Precautionary Principle as a foundational principle of international law).

7 For a valuable and somewhat technical discussion of this issue, see generally Christian Gollier & Nicolas Treich, *Decision-Making Under Scientific Uncertainty: The Economics of the Precautionary Principle*, 27 J. RISK & UNCERTAINTY 77 (2003). The Precautionary Principle itself is explored *infra* Part I.

8 U.N. Econ. Comm'n for Europe, Bergen, Nor., May 8–16, 1990, *Bergen Ministerial Declaration on Sustainable Development in the ECE Region*, art. I(7), U.N. Doc. A/CONF.151/PC/10 (Aug. 6, 1990), *reprinted in* 1 Y.B. INT'L ENVTL. LAW 429 (1990), *quoted in* Julian Morris, *Defining the Precautionary Principle*, *in* RETHINKING RISK AND THE PRECAUTIONARY PRINCIPLE 1, 5 (Julian Morris ed., 2000).

9 United Nations Conference on Environment and Development, June 3–14, 1992, *Rio Declaration on Environment and Development*, princ. 15, U.N. Doc. A/CONF.151/26/Rev.1 (Vol. I) (Jan. 1, 1993), *quoted in* BJØRN LOMBORG, THE SKEPTICAL ENVIRONMENTALIST: MEASURING THE REAL STATE OF THE WORLD 348 (2001).

cost-effective so as to ensure global benefits at the lowest possible cost.[10]

- The Final Declaration of the First European "Seas At Risk" Conference states, "If the 'worst-case scenario' for a certain activity is serious enough, then even a small amount of doubt as to the safety of that activity is sufficient to stop it taking place."[11]

In American law, similar ideas are at work. A special precautionary principle underlies the analysis of preliminary injunctions in cases involving a risk of irreparable environmental harm.[12] San Francisco has adopted its own precautionary principle, with an emphasis on seriousness and irreversibility:

> Where threats of serious or irreversible damage to people or nature exist, lack of full scientific certainty about cause and effect shall not be viewed as sufficient reason for the City to postpone cost effective measures to prevent the degradation of the environment or protect the health of its citizens.[13]

At the national level, the National Environmental Policy Act (NEPA) requires agencies to discuss "any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented."[14] Courts have been careful to insist that environmental impact statements should be prepared at a time that permits consideration of environmental effects before irretrievable commitments have been made.[15] A number of federal statutes, especially in the environmental context, specifically refer to irreversible losses and make their prevention a high priority.[16]

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10 United Nations Framework Convention on Climate Change art. 3(3), May 9, 1992, S. TREATY DOC. NO. 102-38, 1771 U.N.T.S. 107, *quoted in* INDUR M. GOKLANY, THE PRECAUTIONARY PRINCIPLE: A CRITICAL APPRAISAL OF ENVIRONMENTAL RISK ASSESSMENT 6 (2001).

11 Richard B. Stewart, *Environmental Regulatory Decision Making Under Uncertainty*, *in* INTRODUCTION TO THE LAW AND ECONOMICS OF ENVIRONMENTAL POLICY 71, 78 (Research in Law and Economics vol. 20, Timothy Swanson ed., 2002) (quoting Seas at Risk, *The Final Declaration of the First European "Seas At Risk" Conference*, Annex 1 (1994)).

12 *See* Sierra Club v. Marsh, 872 F.2d 497 (1st Cir. 1989). For the complexities of this analysis, see *infra* Part II.E.

13 S.F., CAL., ENVIRONMENT CODE ch. 1, § 101 (2003), *available at* http://www.sfenvironment.com/aboutus/innovative/pp/sfpp.htm.

14 National Environmental Policy Act of 1969 § 102(C)(v), 42 U.S.C. § 4332(C)(v) (2000).

15 *See, e.g.*, Sierra Club v. U.S. Dep't of Energy, 287 F.3d 1256, 1261–62 (10th Cir. 2002).

16 *See, e.g.*, 22 U.S.C. § 2151p-1(c)(2)(A) (2000) (requiring the President to assist developing countries in a way that responds to "the irreversible losses associated with forest destruction"); 33 U.S.C. § 2712(j) (2000) (making a special exception to the planning requirement for use of federal resources in situations "requiring action to avoid irreversible loss of natural resources"); 42 U.S.C. § 9611(i) (2000) (same exception for Superfund cleanups).

For a long period, both courts and the executive branch also required agencies to engage in "worst-case analysis," focusing on potential catastrophes.[17] That requirement has been eliminated by the Council on Environmental Quality,[18] but agencies continue to be directed to explore "impacts which have catastrophic consequences, even if their probability of occurrence is low."[19] Under the Clean Air Act, the Environmental Protection Agency is asked to build an "adequate margin of safety" into health-based national ambient air quality standards.[20] This explicitly precautionary requirement is not limited to irreversible or catastrophic harms, but it might well be understood as an effort to ensure against them.

The central notions here—irreversibility and catastrophe—play a critical role in many domains, and they lie at the heart of countless discussions of how to deal with risks to safety, health, and the environment. The problem is that both notions are exceedingly ambiguous, and it is by no means clear how regulators should understand them. The central purpose of this Article is to unpack the ambiguities and to identify the proper role of both concepts in law and policy. I shall show that standard option theory, emphasizing the importance of irreversibility,[21] has important implications for environmental law, and indeed that some statutes and doctrines display an implicit appreciation of this point. I shall also show that regulators should sometimes attempt to eliminate the worst-case scenario, even—or perhaps, especially—if they cannot assign a probability to its occurrence. When no such probability can be assigned, the best approach is to assess what is gained, and what is lost, by eliminating the most catastrophic outcomes through regulation—a point that helps discipline the inquiry into many risk-related problems, including global warming, terrorism, and injunctions in environmental cases.

These general points lead to two refined versions of the Precautionary Principle. The first involves irreversibility: *When regulators lack information about the likelihood and magnitude of a risk, it makes sense to spend extra resources to buy an "option" to protect against irreversible harm until future knowledge emerges.* The value of the option is that of delaying the decision until better information is available. An emphasis on

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17 *See* Save Our Ecosystems v. Clark, 747 F.2d 1240, 1243–44 (9th Cir. 1984); Sierra Club v. Sigler, 695 F.2d 957, 971 (5th Cir. 1983).

18 *See* Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 355–56 (1989).

19 40 C.F.R. § 1502.22 (2005).

20 Clean Air Amendments of 1970 § 109(b)(1), 42 U.S.C. § 7409(b)(1) (2000). Similarly, 42 U.S.C. § 7412(d)(4) uses the term "ample margin of safety" in connection with standards for emissions of pollutants.

21 For an influential discussion of irreversibility in the environmental law context, see Arrow & Fisher, *supra* note 4.

options and irreversibility leads to a distinctive principle, which I shall call the Irreversible Harm Precautionary Principle.

The second principle involves catastrophe: *When risks have extremely bad worst-case scenarios, it makes sense to pay special attention to those risks, even if they are unlikely to come to fruition, and even if existing information does not enable regulators to make a reliable judgment about the probability that they will occur.* An emphasis on the need to attend to potentially catastrophic risks also yields a distinctive principle, which I shall call the Catastrophic Harm Precautionary Principle.

At first glance, these two principles seem to justify aggressive action to combat many environmental risks, including those posed by global warming, threats to endangered species, and genetic modification of food. Perhaps societies should invest substantial resources in the reduction of greenhouse gases, first to prevent what might turn out to be an irreversible loss, and second to stop the worst-case scenarios.[22] Outside of the environmental domain, the two principles bear on appropriate steps to reduce the risks associated with terrorist attacks, epidemics, asteroid collisions, earthquakes, hurricanes, and more. An emphasis on the two principles also has the advantage of suggesting the possibility of a rapprochement between the risk judgments of experts and the risk judgments of ordinary people.[23] As risk analysts have long emphasized, ordinary people sometimes pay a great deal of attention to whether risks are irreversible or potentially catastrophic.[24] If the refined precautionary principles are defensible, then ordinary intuitions turn out to be plausible, and experts should accept them. Indeed, the two principles might be combined, in certain cases, into a single Irreversible and Catastrophic Harm Precautionary Principle,[25] which provides the strongest basis for aggressive regulation of greenhouse gases.

At the same time, I shall show that both principles are subject to important qualifications. The unifying claim is that the refined precautionary principles should be implemented with wide rather than narrow viewscreens. They must be attentive to the full range of conse-

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22 *See* POSNER, *supra* note 3, at 162, 184–86, 197. In particular Posner emphasizes "the practically irreversible effect of greenhouse-gas emissions on the atmospheric concentration of those gases. . . . Making shallower cuts now can be thought of as purchasing an option to enable global warming to be stopped or slowed at some future time at a lower cost." *Id.* at 161–62.

23 *See* Paul Slovic et al., *Facts and Fears: Understanding Perceived Risk*, *in* THE PERCEPTION OF RISK, *supra* note 5, at 137, 148–51.

24 *See id.* These psychometric studies coexist, however, with evidence that people dismiss many low-probability risks of catastrophe, as discussed *infra* Part III.A. A simple example is that people do not pay much attention to the risk of asteroid collisions, even though there is a good argument that they should do so. *See* POSNER, *supra* note 3, at 24–29.

25 For an early treatment of similar issues, see generally Talbot Page, *A Generic View of Toxic Chemicals and Similar Risks*, 7 ECOLOGY L.Q. 207 (1978).

quences, not simply to a subset. A focus on irreversibility and catastrophic harm threatens to violate this principle through a kind of selective perception. More particularly, the idea of irreversibility is exceedingly ambiguous; because time is linear, every step is in a literal sense irreversible. In the technical literature, the problem of ambiguity is solved through a particular definition of irreversibility.[26] But under that definition, irreversibilities are usually on all sides of environmental problems. If significant steps are taken to reduce greenhouse gases, those very steps will inflict irreversible losses, environmental or economic—making it necessary to explore the likelihood and magnitude of such losses in order to decide what to do. An Irreversible Harm Precautionary Principle is both coherent and sensible, but it calls for precautions against the irreversible harms associated with environmental protection as well as environmental neglect.

In addition, it can be costly, and even environmentally harmful, to avoid worst-case scenarios. If those scenarios are exceedingly unlikely, then there are clear limits on how much regulators should do to eliminate them. If it would cost a great deal to avoid those scenarios, or if doing so would subject people to high probabilities of very-bad-case scenarios, then avoiding the worst case may not be sensible. It is both necessary and possible, in short, to explore what is gained and what is lost by eliminating worst-case scenarios. As we shall see, an understanding of the uses and limits of the refined versions of the Precautionary Principle, focusing on irreversibility and catastrophe, casts new light on the foundations of environmental law, and indeed on all aspects of law that deal with the reduction of serious risks to safety and health.[27]

This Article comes in four parts. Part I briefly explores the conventional Precautionary Principle, emphasizing that precautionary steps often produce risks of their own. Part II discusses the question of irreversibility. The key point here is that because environmental harms are often irreversible, it is appropriate to spend resources to maintain flexibility for the future; the theory of real options has important implications for the theory and practice of environmental law, and indeed for regulation in general. An understanding of the problem of irreversibility also helps to explain debates over the issuance of preliminary injunctions in environmental cases. Armed with that understanding, we can discipline the analysis of injunctions in those cases.

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26 *See, e.g., infra* notes 109–112 and accompanying text.

27 On related issues in tort law, see ARIEL PORAT & ALEX STEIN, TORT LIABILITY UNDER UNCERTAINTY (2001), which investigates the risk-of-damage notion together with the forms of tort liability for externalized risks of damage.

Part III turns to the risk of catastrophic harm. A particular focus is the difference between risk, for which probabilities can be assigned to various outcomes, and uncertainty, for which no such probabilities can be assigned. With respect to catastrophe, risk aversion is perfectly sensible, but it is hard to defend the idea that regulators should generally seek to eliminate the worst-case scenario, whatever the environmental and other costs of doing so.

Part III also offers some experimental evidence that people do not focus on the worst-case scenario under circumstances of either risk or uncertainty. The most important point here is that a form of cost-benefit balancing, perhaps with distributional weights, can inform the decision of whether to eliminate the most catastrophic outcomes. Part IV offers some brief remarks on the question of whether experts and ordinary people display "rival rationalities," and on the relationship of irreversibility and catastrophe to that question.

I
THE PRECAUTIONARY PRINCIPLE

In the face of risks of environmental harm, it has become common to invoke the Precautionary Principle, an increasingly influential idea for environmental protection.[28] My principal concerns here are irreversibility and catastrophe, but in order to understand those problems, it is necessary to explore the Precautionary Principle more generally.

Unfortunately, there are twenty or more definitions of the Precautionary Principle, and they are not all compatible with one another.[29] The most cautious and weakest versions suggest, quite sensibly, that a lack of decisive evidence of harm should not be a ground for refusing to regulate an activity. Controls might be justified even if it is impossible to establish a definite connection between, for example, low-level exposures to certain carcinogens and adverse effects on human health. Thus, the Ministerial Declaration of the Second International Conference on the Protection of the North Sea, held in London in 1987, sensibly suggests: "Accepting that, in order to protect the North Sea from possibly damaging effects of the most dangerous substances, a precautionary approach is necessary which may require action to control inputs of such substances even before a

28 *See, e.g.*, PRECAUTION, ENVIRONMENTAL SCIENCE, AND PREVENTIVE PUBLIC POLICY (Joel A. Tickner ed., 2003). This section draws extensively from Cass R. Sunstein, *Beyond the Precautionary Principle*, 151 U. PA. L. REV. 1003 (2003).

29 *See* Morris, *supra* note 8, at 1–19.

causal link has been established by absolutely clear scientific evidence."[30]

The widely publicized Wingspread Statement, produced during a meeting of environmentalists in 1998, goes much further: "When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not established scientifically. In this context the proponent of the activity, rather than the public, should bear the burden of proof."[31]

In Europe, the Precautionary Principle is sometimes understood in a still stronger way, suggesting that it is important to build "a margin of safety into all decision making."[32] Another strong version suggests that the principle means "that action should be taken to correct a problem as soon as there is evidence that harm may occur, not after the harm has already occurred."[33] The word "may" is the crucial one here, because it signals the need for corrective action even in the face of merely speculative evidence that the risk is serious.[34]

In a comparably strong version, it is said that

> the precautionary principle mandates that when there is a risk of significant health or environmental damage to others or to future generations, and when there is scientific uncertainty as to the nature of that damage or the likelihood of the risk, then decisions should be made so as to prevent such activities from being conducted unless and until scientific evidence shows that the damage will not occur.[35]

What is striking about this passage is its requirement that potentially hazardous activities be prevented until they are shown to be safe. I have noted that the Final Declaration of the First European "Seas At Risk" Conference goes so far as to say that "[i]f the 'worst case scenario' for a certain activity is serious enough, then even a small amount

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30 Second International Conference on the Protection of the North Sea, Nov. 25, 1987, *Ministerial Declaration Calling for Reduction of Pollution*, art. VII, 27 I.L.M. 835, 838 (1988) (emphasis omitted).

31 Morris, *supra* note 8, at 5 (quoting Wingspread Statement on the Precautionary Principle, Jan. 26, 1998). Another strong version is defended in Carolyn Raffensperger & Peter L. deFur, *Implementing the Precautionary Principle: Rigorous Science and Solid Ethics*, 5 HUM. & ECOLOGICAL RISK ASSESSMENT 933, 934 (1999).

32 *See* LOMBORG, *supra* note 9, at 349.

33 Precautionary Principle, Word Spy, http://www.wordspy.com/words/precautionaryprinciple.asp (last visited Feb. 15, 2006).

34 *See Introduction* to THE PRECAUTIONARY PRINCIPLE IN THE 20TH CENTURY (Poul Harremoës et al. eds., 2002).

35 *Cloning, 2002, Hearings Before the Subcomm. on Departments of Labor, Health and Human Servs., and Education, and Related Agencies of the S. Comm. on Appropriations*, 107th Cong. 19 (2002) (statement of Brent Blackwelder, President, Friends of the Earth), *available at* http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=107_senate_hearings&docid=f:80530.pdf.

of doubt as to the safety of that activity is sufficient to stop it taking place."[36]

A. Hazardous Precautions

The weak versions of the Precautionary Principle are unobjectionable and important. Every day, individuals and nations take steps to avoid hazards that are far from certain. We do not walk in moderately dangerous areas at night. We exercise. We buy smoke detectors. We buckle our seatbelts. We might even avoid fatty foods (or carbohydrates). Sensible governments regulate risks that in individual cases or even in the aggregate have a well under 100% chance of coming to fruition.[37] An individual might ignore a mortality risk of 1/500,000 because that risk is quite small, but if 100 million citizens face the same risk, then the expected number of deaths is 200, and the nation as a whole should take the problem seriously.

For the moment, let us understand the Precautionary Principle in its strong form, to suggest that regulation is required whenever there is a possible risk to health, safety, or the environment, even if the supporting evidence remains speculative and the economic costs of regulation are high. Recall that under the Final Declaration of the First European "Seas At Risk" Conference, a serious worst-case scenario is said to justify abandonment of activity even if there is only "a small amount of doubt as to the safety of that activity";[38] recall, too, that under the National Environmental Policy Act, agencies must pay close attention to risks that have only a small probability of occurrence.[39] To avoid absurdity, any emphasis on the idea of "possible risk" must be understood to require a certain threshold of scientific plausibility. To support regulation, no one thinks that it is enough if someone, somewhere, urges that a risk is worth taking seriously. But under the Precautionary Principle in its stronger forms, the threshold burden is minimal, and once it is met, there is a presumption in favor of regulatory controls. These versions, as we shall see, help to clarify a significant problem with the idea of precaution in a way that bears on the more refined versions of the principle as well.

The real problem with the Precautionary Principle, thus understood, is that it offers no guidance—not that it is wrong, but that it forbids all courses of action, including regulation. Taken seriously, it is paralyzing, banning the very steps that it simultaneously requires. In some cases, it should be easy to see that in its own way, stringent regulation would actually run afoul of the Precautionary Principle.

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36 Stewart, *supra* note 11, at 78.

37 *See* 42 U.S.C. § 7412 (2000).

38 Stewart, *supra* note 11, at 78.

39 *See supra* notes 17–20, 32 and accompanying text.

Consider the "drug lag," produced whenever the government takes a highly precautionary approach to the introduction of new medicines and drugs onto the market.[40] If a government insists on this approach, it will protect people against harms from inadequately tested drugs in a way that fits well with the goal of precaution; but it will also prevent people from receiving potential benefits from those very drugs, and hence subject people to serious risks that they would not otherwise face. Is it "precautionary" to require extensive premarket testing, or to do the opposite? Or consider the case of DDT, often banned or regulated in the interest of reducing risks to birds and human beings.[41] The problem with such bans is that in poor nations, they eliminate what appears to be the most effective way of combating malaria—and thus significantly undermine public health.[42] Precautionary steps seem both mandated and forbidden by the idea of precaution in its strong forms.

Similar issues are raised by the continuing debate over whether certain antidepressants impose a (small) risk of breast cancer.[43] A precautionary approach might seem to caution against use of such antidepressants because of their carcinogenic potential. But the failure to use those antidepressants might well impose risks of its own, certainly psychological and possibly even physical (because psychological ailments are sometimes associated with physical ones as well). Or consider the decision by the Soviet Union to evacuate and relocate more than 270,000 people in response to the risk of adverse effects from the Chernobyl fallout.[44] It is not clear that on balance, this massive relocation project was justified on health grounds: "A comparison ought to [have been] made between the psychological and medical burden of this measure (anxiety, psychosomatic diseases, depression and suicides) and the harm that may have been prevented."[45] More generally, a sensible government might want to ignore the small risks associated with low levels of radiation, on the ground that precaution-

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40 The drug-lag concept describes the delay of new drugs on the American market compared to other countries; the drug lag is produced by regulatory requirements. *See* HENRY G. GRABOWSKI & JOHN M. VERNON, THE REGULATION OF PHARMACEUTICALS 5–6 (1983); Kenneth I. Kaitin & Jeffrey S. Brown, *A Drug Lag Update*, 29 DRUG INFO. J. 361, 361 (1995).

41 *See* ROBERT V. PERCIVAL ET AL., ENVIRONMENTAL REGULATION 1122–23 (4th ed. 2003).

42 *See id.*; GOKLANY, *supra* note 10, at 13–27.

43 *Compare, e.g.*, Judith P. Kelly et al., *Risk of Breast Cancer According to Use of Antidepressants, Phenothiazines, and Antihistamines*, 150 AM. J. EPIDEMIOLOGY 861 (1999) (finding no association between antidepressant use and breast cancer), *with* C.R. Sharpe et al., *The Effects of Tricyclic Antidepressants on Breast Cancer Risk*, 86 BRIT. J. CANCER 92 (2002) (finding an elevated risk of breast cancer with heavy use of tricyclic antidepressants).

44 *See* Maurice Tubiana, *Radiation Risks in Perspective: Radiation-Induced Cancer Among Cancer Risks*, 39 RADIATION & ENVTL. BIOPHYSICS 3, 9 (2000).

45 *Id.* at 9–10.

ary responses are likely to cause a level of fear that outweighs any health benefits from those responses.[46]

The Precautionary Principle is often invoked in connection with genetic modification of food[47]—a plausible invocation in light of the multiple risks created by that practice.[48] But many people believe that a failure to allow genetic modification might well result in numerous deaths.[49] The reason is that genetic modification holds out the promise of producing food that is both cheaper and healthier—resulting, for example, in "golden rice," which might save many lives in developing countries.[50] The point is not that genetic modification will likely have those benefits, or that the benefits of genetic modification outweigh the risks. The claim is only that if the Precautionary Principle is taken literally, it is offended by regulation as well as by nonregulation.

These examples suggest that regulation sometimes violates the Precautionary Principle because it gives rise to "substitute risks," in the form of hazards that materialize, or are increased, as a result of regulation.[51] It is possible to go much further. A great deal of evidence suggests the possibility that an expensive regulation can have adverse effects on life and health.[52] An early study found that a statistical life can be lost for every expenditure of $7.25 million;[53] a later study suggests that an expenditure of $15 million produces a loss of life.[54] Another suggests that poor people are especially vulnerable to this effect—that a regulation that reduces wealth for the poorest 20% of the population will have twice as large a mortality effect as a regulation that reduces wealth for the wealthiest 20%.[55] To be sure, both

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46 For some counterevidence in another important context, see Lennart Hardell et al., *Further Aspects on Cellular and Cordless Telephones and Brain Tumours*, 22 INT'L J. ONCOLOGY 399 (2003), which discusses evidence of an association between analog cellular telephones and cancer.

47 *See, e.g.*, GOKLANY, *supra* note 10, at 29–56.

48 *See* Morel et al., *supra* note 1, at 185–86.

49 *See, e.g.*, Kym Anderson & Chantal Pohl Nielsen, *Golden Rice and the Looming GMO Trade Debate: Implications for the Poor* (Centre for Econ. Policy Res., Discussion Paper No. 4195, 2004), *available at* http://papers.ssrn.com/sol3/papers.cfm?abstract_id=508463.

50 *See id.*; *see also* GOKLANY, *supra* note 10, at 30–41 (discussing environmental and health benefits of engineered crops).

51 See the discussion of risk-related tradeoffs in RISK VERSUS RISK (John D. Graham & Jonathan Baert Wiener eds., 1995) and CASS R. SUNSTEIN, RISK AND REASON 133–52 (2002).

52 Ralph L. Keeney, *Mortality Risks Induced by Economic Expenditures*, 10 RISK ANALYSIS 147 (1990) (explaining results that "suggest that some expensive regulations and programs intended to save lives may actually lead to increased fatalities"); Randall Lutter & John F. Morrall III, *Health-Health Analysis: A New Way to Evaluate Health and Safety Regulation*, 8 J. RISK & UNCERTAINTY 43, 49 tbl.1 (1994).

53 *See* Keeney, *supra* note 52, at 155.

54 *See* ROBERT W. HAHN ET AL., DO FEDERAL REGULATIONS REDUCE MORTALITY? 7 (2000).

55 *See* Kenneth S. Chapman & Govind Hariharan, *Do Poor People Have a Stronger Relationship Between Income and Mortality than the Rich? Implications of Panel Data for Health-Health Analysis*, 12 J. RISK & UNCERTAINTY 51, 58–60 (1996).

the phenomenon and the underlying mechanisms are disputed.[56] It is unnecessary to accept any particular figures here, or even to suggest that there has been an unambiguous demonstration of an association between mortality and regulatory expenditures. The only point is that reasonable people believe in that association. It follows that a multi-million-dollar expenditure for "precaution" has—as a worst-case scenario—significant adverse health effects, with an expenditure of $600 million leading to perhaps as many as sixty lives lost.

This point makes the Precautionary Principle hard to implement not merely when regulation removes opportunity benefits, or introduces or increases substitute risks, but in any case in which the regulation costs a significant amount. If this is so, the Precautionary Principle, for that very reason, raises doubts about many regulations. If the principle argues against any action that carries a small risk of imposing significant harm, then regulators should be reluctant to require large expenditures to reduce risks, simply because those expenditures themselves carry risks. Here is the sense in which the Precautionary Principle is paralyzing: It stands as an obstacle to regulation and nonregulation, and to everything in between.

A nation-by-nation study commissioned by the German Federal Environmental Agency goes so far as to conclude that there are two separate camps in the industrialized world: "precaution countries" (Germany, Sweden, the Netherlands, and the United States) and "protection countries" (Japan, France, and the United Kingdom).[57] If the argument thus far is correct, this conclusion is implausible—not empirically but conceptually. The universe of risks is far too large to permit categorizations of this kind. The most general point is that no nation is precautionary in general, and costly precautions are inevitably taken against only those hazards that seem especially salient or insistent.[58] Taken in its strongest and crudest forms, the Precautionary Principle wrongly suggests that nations can and should adopt a general form of risk aversion. It is possible to take precautions against particular risks, but it is not possible to take precautions against all of them. It is possible to display aversion to particular hazards, but it is not possible to display aversion to all of them.[59]

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56 See Lutter & Morrall, *supra* note 52.

57 *See* Peter H. Sand, *The Precautionary Principle: A European Perspective*, 6 HUM. & ECOLOGICAL RISK ASSESSMENT 445, 448 (2000).

58 *See* David Vogel, *The Hare and the Tortoise Revisited: The New Politics of Consumer and Environmental Regulation in Europe*, 33 BRIT. J. POL. SCI. 557, 570–71 (2003) (attributing Europe's increased enthusiasm for precautionary regulation to past regulatory failures).

59 It might be tempting to defend the Precautionary Principle—certainly in the health, safety, and environmental context—on the ground that early warnings, offering only suggestive evidence of harm, often turn out to be correct. *See* THE PRECAUTIONARY PRINCIPLE IN THE 20TH CENTURY, *supra* note 34. And it is right to insist that indisputable proof of harm should not be required to justify regulation; this is the sense in which the

B. A Note on Distributional Issues

Those who endorse the Precautionary Principle often do so on grounds of fairness, believing that the principle will assist the most vulnerable members of society.[60] Does the principle actually have that effect? In the United States, the Clean Air Act takes a highly precautionary approach, requiring an "adequate margin of safety" and hence regulation in the face of scientific uncertainty.[61] At the same time, the Clean Air Act delivers especially large benefits to poor people and members of minority groups—larger benefits, on balance, than it gives to wealthy people.[62] In the international domain, aggressive action to combat climate change might benefit poor countries more than wealthy ones.[63] In the context of global warming, at least, the Precautionary Principle could be invoked to prevent especially severe burdens on those in the worst position to bear them.

It makes a great deal of sense to emphasize the distribution of domestic or international risks, and the distributional effects of global warming are among the strongest points in favor of aggressive regulation of greenhouse gases.[64] But in many cases, the Precautionary Prin-

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weak version of the principle is both unobjectionable and important. But the fact that suggestive evidence must be taken seriously does not render the strong version coherent, simply hecause suggestive evidence of harm is often on all sides. In any case, suggestive evidence of harm has often been found not to be an early warning worth heeding, but instead a false alarm, producing unjustified fear and significant social losses of many kinds. *See* ALLAN MAZUR, TRUE WARNINGS AND FALSE ALARMS 2 (2004). Consider the fears of fluoridated water in tbe 1950s, contaminated cranberries in 1959, MSG in Chinese food in 1968, cyclamate in 1968, or mercury in tuna in 1970. None of these widely publicized "hazards" posed a serious threat. *Id.* at 110–41. Mazur makes a valuable effort to distinguish between prescient warnings and false ones, *see id.* at 87–96, suggesting that "[t]he clearest hallmark of a true public warning during the period 1948–1971 was a reputable scientific news source. Warnings reaching the press from scientists operating in a conventional way at an orthodox scientific institution were true more than twice as often as those reaching the news from government officials or citizen advocates," *id.* at 97.

60 *See, e.g.*, FRANK ACKERMAN & LISA HEINZERLING, PRICELESS: ON KNOWING THE PRICE OF EVERYTHING AND THE VALUE OF NOTHING 230 (2004).

61 *Supra* note 20; *see* Am. Petroleum Inst. v. Costle, 665 F.2d 1176, 1186 (D.C. Cir. 1981) ("In setting margins of safety the Administrator need not regulate only the known dangers to health, but may 'err' on the side of overprotection by setting a fully adequate margin of safety.").

62 *See* Matthew E. Kahn, *The Beneficiaries of Clean Air Act Regulation*, REGULATION, Spring 2001, at 34, 37 (showing that poorer people experienced greater overall improvements in air quality than wealthier people based on spatial distributions of pollution).

63 *See, e.g.*, LOMBORG, *supra* note 9, at 291–302 (noting that "developing countries will be hit much harder by global warming, partly because they are much poorer and consequently have less adaptive capacity"); Joseph E. Aldy, Peter R. Orszag & Joseph E. Stiglitz, Climate Change: An Agenda for Global Collective Action 7 (Oct. 2001) (unpublished manuscript, *available at* http://www.pewclimate.org/docUploads/stiglitz.pdf).

64 Note, however, that if the concern involves poor countries, it is not entirely clear that global warming is an especially high priority, in light of perhaps more pressing needs of those countries—needs that might be more efficiently met by resources that wealthy nations would otherwise devote to regulating greenhouse-gas emissions. For controversial

ciple, as applied, would have unfortunate distributional effects. Consider the case of DDT. A ban on DDT, often supported by reference to the Precautionary Principle,[65] is eminently justified in wealthy nations. But such a ban is likely to have—and is actually having—unfortunate effects in at least some poor countries, where DDT is the cheapest and most effective way of combating serious diseases, most notably malaria.[66] The case of genetic modification of food might well be a similar example; according to some projections, the benefits are likely to be enjoyed by poor people, not the wealthy.[67] And recall that expensive regulations have a disproportionately serious effect on poor people, simply because any price increases are hardest for them to handle and because the costs of regulation may well manifest themselves in fewer and less remunerative jobs.[68]

Distributional issues should indeed be a central concern of a system of risk regulation,[69] but the Precautionary Principle is a crude, indirect, and sometimes perverse way of incorporating distributional concerns. As a result, an emphasis on distribution does not rescue the Precautionary Principle from the charge of incoherence. The real question is whether more refined understandings of the principle can be developed.

II
UNCERTAINTY, OPTIONS, AND IRREVERSIBILITY

It is possible to identify an Irreversible Harm Precautionary Principle, applicable to a subset of environmental risks.[70] On plausible assumptions, the problem of irreversibility does justify aggressive measures to combat environmental risks, under a general attitude of "act, then learn," as opposed to the tempting alternative of "wait and learn." With respect to global warming, for example, some people believe that it is most sensible to use research as the first line of defense, refusing to commit substantial resources until evidence of harm is clear.[71] But if research alone allows continued emissions to pro-

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but illuminating treatments, see GOKLANY, *supra* note 10, at 71–88; LOMBORG, *supra* note 9, at 322–23.

65 *See* GOKLANY, *supra* note 10, at 14.

66 *See id.* at 13–27; SUNSTEIN, *supra* note 51, at 14.

67 *See* GOKLANY, *supra* note 10, at 47–50.

68 *See* Keeney, *supra* note 52, at 148.

69 On some of the complexities involved here, see SUNSTEIN, *supra* note 51, at 124–26.

70 *See* Scott Farrow, *Using Risk-Assessment, Benefit-Cost Analysis, and Real Options to Implement a Precautionary Principle*, 24 RISK ANALYSIS 727, 728 (2004) (discussing option theory and reversibility).

71 *See, e.g.*, WILFRED BECKERMAN, SMALL IS STUPID 102–03 (1995); Robert Mendelsohn, *Perspective Paper 1.1*, *in* GLOBAL CRISES, GLOBAL SOLUTIONS 44, 47 (Bjørn Lomborg ed., 2004). The cautious approach of the Bush Administration can be understood in this light. *See* THE WHITE HOUSE, GLOBAL CLIMATE CHANGE POLICY BOOK (2002), *available at* http://

duce irreversible risks, it might be best to take precautions now as a way of preserving future flexibility.[72] In the environmental context in general, this point suggests that regulators should proceed with far more aggressive measures than would otherwise seem justified.[73]

A. Option Value Versus Use Value

Begin with the monetary valuation of an environmental amenity, such as a pristine area. Some people will be willing to pay to use the area; others will be willing to pay to preserve it, even if they will not use it. Hence, "existence value" is sometimes included in the valuation of environmental amenities,[74] and indeed federal courts have insisted that agencies pay attention to that value in assessing damages to natural resources.[75] But some people are also willing to pay for the *option* to use an environmental amenity in the future, even if they are unsure whether they will exercise that option.[76] Suppose that a pristine area might be developed in a way that ensures irreversible change. Many people would be willing to pay a significant amount to preserve their option. Under federal law, option value must also be considered in the assessment of natural resource damages.[77] Many regulations explore the role of option value in the environmental context.[78]

Here, then, is a simple sense in which irreversible environmental harm causes a loss that is not adequately captured in the standard

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www.whitehouse.gov/news/releases/2002/02/climatechange.html; *see also* Chuck Hagel & Frank Murkowski, *High Costs of Kyoto*, WASH. POST, Jan. 29, 2000, at A17 (explaining the need for research). Economists Nordhaus and Boyer find that extremely little is lost by a ten-year delay in emissions reductions. *See* WILLIAM D. NORDHAUS & JOSEPH BOYER, WARMING THE WORLD: ECONOMIC MODELS OF GLOBAL WARMING 127 (2000) (describing the net loss as "trivially small"). For a technical discussion, see Alistair Ulpb & David Ulph, *Global Warming, Irreversibility and Learning*, 107 ECON. J. 636 (1997).

72 *See* POSNER, *supra* note 3, at 161–62.

73 *See* Graciela Chichilnisky & Geoffrey Heal, *Global Environmental Risks*, J. ECON. PERSP., Fall 1993, at 65, 80.

74 *See* Charles J. Cicchetti & Louis L. Wilde, *Uniqueness, Irreversibility, and the Theory of Nonuse Values*, 74 AM. J. AGRIC. ECON. 1121, 1121 (1992); David A. Dana, *Existence Value and Federal Preservation Regulation*, 28 HARV. ENVTL. L. REV. 343, 345 (2004).

75 *See, e.g.*, Ohio v. U.S. Dep't of the Interior, 880 F.2d 432, 464 (D.C. Cir. 1989).

76 *Cf.* Cicchetti & Wilde, *supra* note 74, at 1122 (noting Weisbrod's analogy of such amenities to public goods, in that "individuals who may never purchase the commodity still hold a value for the option to do so"). The independent use of option value is, however, challenged in various places. *See, e.g.*, A. MYRICK FREEMAN III, THE MEASUREMENT OF ENVIRONMENTAL AND RESOURCE VALUES 249–51 (2003) (suggesting that "what has been called an option value is really just the algebraic difference between the expected values of two different points on a WTP [willingness-to-pay] locus").

77 *See Ohio*, 880 F.2d at 464.

78 *See, e.g.*, Endangered and Threatened Wildlife and Plants; Determination of Critical Habitat for the Mexcian Spotted Owl, 60 Fed. Reg. 29,914, 29,928 (June 6, 1995) (to be codified at 50 C.F.R. pt. 17); Natural Resource Damage Assessments, 59 Fed. Reg. 1062, 1078 (proposed Jan. 7, 1994) (to be codified at 15 C.F.R. pt. 990).

economic measure of value. Some skeptics contend that it "is hard to imagine a price for an irreversible loss,"[79] but people do identify prices for such losses.[80]

B. The Basic Argument

The idea of option value, as used in the monetary valuation literature just discussed, is closely related to the use of the notion of "options" in the domain that I shall be emphasizing here. The simple claim is that when regulators are dealing with an irreversible loss, and when they are uncertain about the timing and likelihood of that loss, they should be willing to pay a sum—the option value—in order to maintain flexibility for the future.[81] The option might not be exercised if it turns out that the loss is not a serious one. But if the option is purchased, regulators will be in a position to forestall the loss if it turns out to be large.

In the domain of finance, options take multiple forms.[82] An investor might be willing to purchase land that is known to have deposits of gold; even if the cost of extraction is currently too high to justify mining, ownership of the land creates an option to mine if the market price for gold increases, the cost of mining decreases, or both.[83] A standard "call option" is the right but not the obligation to purchase an asset prior to a specific date at a specified price.[84] In another variation, people might seek the right to abandon a project at a fixed price, perhaps on the occurrence of a specified set of events. Alternatively, they might obtain the right to scale back a project, to expand it, or to extend its life. Options that recognize multiple sources of uncertainty of the sort that can be found for many environmental problems are termed "rainbow options."[85]

Option theory has countless applications outside of the domain of investments. Suppose, for example, that because of law or social norms, it is difficult to divorce, so that a decision to marry cannot

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79 *See* ACKERMAN & HEINZERLING, *supra* note 60, at 185.

80 For a helpful overview, see Richard C. Bishop, *Option Value: An Exposition and Extension*, 58 LAND ECON. 1 (1982). In recognizing the existence of option value, I do not mean to make any controversial suggestions about the role of "willingness to pay" in environmental policy. The only point is that people do place a value on preserving environmental options, and that it would be foolish for regulators to refuse to do so.

81 *See* Claude Henry, *Investment Decisions Under Uncertainty: The "Irreversibility Effect,"* 64 AM. ECON. REV. 1006, 1006 (1974) ("A decision is considered irreversible if it significantly reduces for a long time the variety of choices that would be possible in the future."). On precommitment value, see Part II.D.3.

82 *See* TOM COPELAND & VLADIMIR ANTIKAROV, REAL OPTIONS: A PRACTITIONER'S GUIDE 12–13 (2001).

83 *See* RICHARD A. BREALEY & STEWART C. MYERS, PRINCIPLES OF CORPORATE FINANCE 563 (2003).

84 *See id.* at 564.

85 COPELAND & ANTIKAROV, *supra* note 82, at 13.

readily be reversed. If so, prospective spouses might be willing to incur costs to maintain their flexibility before marrying—higher costs than they would be willing to incur if divorce were easier.[86] Narrow judicial rulings, of the sort celebrated by judicial minimalists,[87] can be understood as a way of "buying" an option, or at least of "paying" a certain amount in return for flexibility. Judges who leave things undecided and who focus their rulings on the facts of particular cases are in a sense forcing themselves, and society as a whole, to purchase an option in return for flexibility in the resolution of subsequent problems. Whether that option is worthwhile depends on its price and the benefits that it provides.

It should be readily apparent that an understanding of option value might explain the emphasis in NEPA and other environmental statutes on irreversible losses. The central point of NEPA is to ensure that environmental factors receive serious consideration,[88] and if irreversible losses are involved, the delay produced by the duty to generate an environmental impact statement can be seen as payment for an option. It should also be clear that the idea of option value might help give content to the Precautionary Principle, which would, on this view, be understood as requiring societies to pay a kind of premium in the face of potentially irreversible losses.[89] An important implication involves global warming: The argument for a global carbon tax is significantly strengthened by an appreciation of the option value of conserving the atmospheric environment.[90] Let us elaborate the argument for the Irreversible Harm Precautionary Principle.

In a classic essay, Arrow and Fisher demonstrate that the ideas of uncertainty and irreversibility have considerable importance to the theory of environmental protection.[91] They imagine a situation in which the question is whether to preserve a virgin redwood forest for wilderness recreation, or instead, to open it to clear-cut logging.[92] Assume that if the development option is chosen, then the destruction of the forest is effectively irreversible.[93] Arrow and Fisher argue that it matters whether the authorities cannot yet assess the costs or benefits

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86 *See* AVINASH K. DIXIT & ROBERT S. PINDYCK, INVESTMENT UNDER UNCERTAINTY 24–25 (1994).

87 *See generally* CASS R. SUNSTEIN, ONE CASE AT A TIME (1999) (discussing judicial minimalism on the Supreme Court).

88 *See* Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 348–49 (1989).

89 *See* Morel et al., *supra* note 1.

90 *See* Chichilnisky & Heal, *supra* note 73, at 80.

91 *See* Arrow & Fisher, *supra* note 4.

92 *Id.* at 314.

93 The assumption may be unrealistic, under ordinary understandings of what counts as irreversibility. If seeds are retained, the forest can be recreated, though perhaps with a significant interim loss. I deal below with some of the complexities in the notion of irreversibility.

of a proposed development. If development produces "some irreversible transformation of the environment, hence a loss in perpetuity of the benefits from preservation," then it is worth paying something to wait to acquire the missing information.[94] Their suggestion is that "the expected benefits of an irreversible decision should be adjusted to reflect the loss of options it entails."[95]

Much more recently, Fisher has generalized this argument to suggest that "[w]here a decision problem is characterized by (1) uncertainty about future costs and benefits of the alternatives, (2) prospects for resolving or reducing the uncertainty with the passage of time, and (3) irreversibility of one or more of the alternatives, an extra value, an option value, properly attaches to the reversible alternative(s)."[96] To pass a cost-benefit test, it follows that an irreversible decision must clear a higher hurdle than a reversible one. The intuition here is both straightforward and appealing: More steps should be taken to prevent harms that are effectively final than to prevent those that can be reversed at some cost. If an irreversible harm is on one side and a reversible one on the other, an understanding of option value suggests that it is worthwhile to spend a certain amount to preserve future flexibility by paying a premium to avoid the irreversible harm.

Judge Richard Posner has invoked a point of this sort as a justification for aggressive steps to combat global warming.[97] Judge Posner acknowledges that the nature of the threat of global warming is disputed, and hence, it is tempting to wait to regulate until we have more information. But there is a serious problem with waiting, which is "the practically irreversible effect of greenhouse-gas emissions on the atmospheric concentration of those gases."[98] Thus, Judge Posner reasons that "[m]aking shallower cuts now can be thought of as purchasing an option to enable global warming to be stopped or slowed at some future time at a lower cost."[99] The reduction in total cost as a result of current steps could result from lowering current emissions or simply from increasing the rate of technological innovations that make pollution reduction less costly in the future. Judge Posner concludes that "[t]he option approach is applicable to other

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94 *See* Arrow & Fisher, *supra* note 4, at 313–14.

95 *Id.* at 319.

96 *See* Anthony C. Fisher, Uncertainty, Irreversibility, and the Timing of Climate Policy 9 (Oct. 2001) (unpublished manuscript, *available at* http://www.pewclimate.org/docUploads/timing%5Ffisher%2Epdf).

97 *See* POSNER, *supra* note 3, at 161–62. A more technical discussion to the same effect is contained in Chichilnisky & Heal, *supra* note 73, emphasizing the need for a distinctive approach to "risks that are *poorly understood, endogenous, collective and irreversible.*" *Id.* at 67. For a more detailed treatment of option value and irreversibility, see *id.* at 76–84.

98 POSNER, *supra* note 3, at 161–62.

99 *Id.* at 162.

catastrophic risks as well, such as the risks associated with genetically modified crops."[100]

The general point here is that, as in the stock market, those involved in environmental protection are trying to project a stream of costs and benefits over time; the ability to project the revenue stream will improve and hence much can be gained from being able to make the decision later in time rather than earlier.[101] If more accurate decisions can be made in the future, then there is a (bounded) value to putting the decision off to a later date.[102] The key point is that uncertainty and irreversibility should lead to a sequential decision-making process.[103] If better information will emerge, regulators might seek an approach that preserves greater flexibility.[104]

C. Irreversibilities

Unfortunately, the idea of irreversibility is highly ambiguous. On one view, an effect is irreversible when restoration to the status quo is impossible or at best extremely difficult, at least on a relevant timescale. For example, "[t]he decision not to preserve a rich reservoir of biodiversity such as the 60 million-year-old Korup forest in Nigeria is irreversible. The alteration or destruction of a unique asset of this type has an awesome finality . . . ."[105] If this is the appropriate interpretation of irreversibility, then it is an aspect of seriousness. An alternative interpretation, familiar in the economic literature on options, sees irreversibility in terms of sunk costs. The two interpretations lead to different understandings of the Irreversible Harm Precautionary Principle.

1. *Irreversibility and Seriousness*

From one point of view, no clear line separates the reversible from the irreversible. The question is not whether some effect can be reversed, but instead at what cost; areas that have been developed or otherwise harmed can often be returned to their original state, even if at considerable expense. Lost forests, for example, can be restored. But for the Irreversible Harm Precautionary Principle, there is a more serious conceptual difficulty, which is that *whether a particular act is irre-*

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100 *Id.* at 163.

101 See Gollier & Treich, *supra* note 7, at 84, for the definition of irreversibility used in the real options approach. See also *id.* at 87–91 for distinctions among stock externalities, environmental irreversibility, and capital irreversibility.

102 *Id.* at 88.

103 *See* Chan S. Park & Hemantha S.B. Herath, *Exploiting Uncertainty—Investment Opportunities as Real Options: A New Way of Thinking in Engineering Economics*, 45 ENGINEERING ECONOMIST 1, 3–4 (2000).

104 *See* Arrow & Fisher, *supra* note 4, at 313–14.

105 *See* Chichilnisky & Heal, *supra* note 73, at 76.

versible depends on how it is characterized. Any death, of any living creature, is irreversible, and those who invoke irreversibility do not intend the notion of irreversible harm to apply to each and every mortality risk. What is true for living creatures is true for rocks and refrigerators, too; if these are destroyed, they are destroyed forever. And because time is linear, every decision is, in an intelligible sense, irreversible. If I play tennis at 11:00 a.m. today, that decision cannot be reversed, and what might have been done at that time will have been permanently lost. If the government builds a new highway in upstate New York in May, that particular decision will be irreversible, even though the highway can be replaced or eliminated. This is the sense in which irreversibility depends on how the underlying act is characterized; if we characterize it narrowly, to be and to do precisely what it is and does, any act is irreversible by definition.

Environmentalists who are concerned about irreversibility must have something far more particular in mind. They must mean something like a large-scale alteration in environmental conditions, one that imposes permanent, or nearly permanent, changes on those subject to them. But irreversibility in this sense is not a sufficient reason for a highly precautionary approach. At a minimum, the irreversible change has to be for the worse, and it must also rise to a certain level of magnitude. A truly miniscule change in the global temperature, even if permanent, would not justify expensive precautions if it is benign or if it imposes little in the way of harm.[106] For this reason, it is tempting to understand the idea of irreversibility, for environmental purposes, as inseparable from that of seriousness. A loss of a wisdom tooth is irreversible, but it is not a reason for particular precautions; a loss of an extremely small forest, with little wildlife, hardly justifies a special principle, even if that loss cannot be reversed.

At first glance, then, irreversibility matters only because of its connection with the magnitude of the harm—an issue I explore below in connection with potentially catastrophic risks. Compare in this regard the standard of irreparable harm as a precondition to the grant of a preliminary injunction.[107] If a harm is irreparable, it can be avoided only by grant of the injunction, but irreparability is not a sufficient condition for granting the injunction; the harm must be serious as well as irreparable.[108] And if irreversibility in environmental protection is to be analyzed in the same way, then an Irreversible Harm Precautionary Principle is part of a Catastrophic Harm Precautionary

106 *Cf.* Mendelsohn, *supra* note 71, at 47 (arguing against costly steps for global warming).

107 *See, e.g.*, Sierra Club v. Marsh, 872 F.2d 497, 499–501 (1st Cir. 1989) (discussing irreparable harm in the environmental context).

108 *See id.*

Principle, or at least a Significant Harm Precautionary Principle. If so, the Irreversible Harm Precautionary Principle is not distinctive. The principle is also vulnerable, some of the time, to the same objections that apply to the Precautionary Principle as a whole. As we have seen, significant harms may well be on all sides of risk-related problems, and a focus on one set of risks will give rise to others, perhaps environmental risks as well.

2. *Irreversibility and Sunk Costs*

Analysts of real options understand the idea of irreversibility in a technical way.[109] Irreversible investments are sunk costs—those that cannot be recovered. Examples include expenditures on advertising and marketing, or even capital investments designed to improve the performance of a factory.[110] In fact the purchase of motor vehicles, computers, and office equipment is not fully reversible, because purchase cost substantially exceeds resale value.[111] Examples of reversible investments include the purchase of ordinary stocks and bonds. The problem with an investment that is irreversible is that those who make it relinquish "the possibility of waiting for new information to arrive that might affect the desirability or timing of the expenditure[,] . . . [and] [t]his lost option value is an opportunity cost that must be included as part of the investment."[112]

Everyone agrees that we should characterize as irreversible harms environmental effects that are both serious and extremely expensive and time consuming to reverse.[113] This is the factor that leads Judge Posner and others to argue for the purchase of an "option" to slow down global warming at a lower rate in the future.[114] Immediate adoption of a policy produces a "sunk benefit." But this argument ignores an important point: *Irreversibility, in this sense, lies on all sides.*[115] Regulation that reduces one environmental risk might well increase another. Efforts to reduce dangers associated with fossil-fuel use, for example, may lead to increased dependence on nuclear energy, as has happened in China.[116] As with the Precautionary Principle in gen-

109 *See* DIXIT & PINDYCK, *supra* note 86, at 6.

110 *See id.* at 8.

111 *See id.*

112 *Id.* at 6.

113 *See* Fisher, *supra* note 96, at 5–9.

114 *See supra* notes 87–90 and accompanying text.

115 *See* Fisher, *supra* note 96, at 10.

116 *See, e.g.*, Ling Zhong, Note, *Nuclear Energy: China's Approach Towards Addressing Global Warming*, 12 GEO. INT'L ENVTL. L. REV. 493 (2000). It is, of course, possible to urge nations to reduce their reliance on coal or nuclear power and move instead toward alternatives that would be preferable on risk-related grounds, such as solar power. For a general discussion, see RENEWABLE ENERGY (Godfrey Boyle ed., 1996); Dan E. Arvizu, *Advanced Energy Technology and Climate Change Policy Implications*, 2 FLA. COASTAL L.J. 435 (2001). But

eral, so it is with the Irreversible Harm Precautionary Principle in particular: Measures that the principle requires on grounds of safety and health might well be prohibited on those same grounds. And there is a more general point. If steps are taken to reduce greenhouse-gas emissions, capital costs will be incurred, and they cannot be recouped. Sunk costs are a familiar feature of environmental regulation, in the form of mandates that require technological change.[117] We are dealing, then, with irreversibilities, not irreversibility.

This point complicates the case for an Irreversible Harm Precautionary Principle. As Fisher writes for global warming, "[I]t is not clear whether the conditions of the problem imply that investment in control ought to be slowed or reduced, while waiting for information needed to make a better decision, or that investment should come sooner to preserve the option to protect ourselves from impacts that may be revealed in the future as serious or even catastrophic."[118] It is for this reason that many economists have concluded, unlike Judge Posner, that the existence of uncertainty and irreversibility argue for less, not more, in way of investments in reducing greenhouse-gas emissions.[119] Everything depends on the likelihood and magnitude of the losses on all sides.

Judge Posner's analysis does not use the idea of options in the technical sense. He emphasizes, correctly, that because of the cumulative effect of emissions on the atmospheric concentration of carbon dioxide, a steady or even declining rate of emissions will cause that concentration to increase.[120] He emphasizes that it may be more costly to slow global warming in the future than in the present[121]—a point that comes close to the technical understanding of irreversibility in the economic literature. But it is a gap in Judge Posner's analysis that he neglects to attend to the irreversible losses associated with greenhouse-gas *reductions.* On the other hand, any advice to wait and learn depends on a contentious empirical assumption, which is that we lose very little if we defer investments while waiting to obtain more information about the benefits.[122] If a great deal is lost by deferring

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these alternatives pose problems of their own, involving feasibility and expense. *See, e.g.*, LOMBORG, *supra* note 9, at 118–36.

117 *See, e.g.*, BRUCE A. ACKERMAN & WILLIAM T. HASSLER, CLEAN COAL/DIRTY AIR (1981) (discussing the Clean Air Act).

118 Fisher, *supra* note 96, at 11.

119 *See, e.g., id.* at 19 ("[T]he sense one gets from the . . . economic literature . . . is that [uncertainty and irreversibility] cut in the direction of slowing or reducing investment in control of greenhouse gas emissions rather than speeding or increasing it.").

120 POSNER, *supra* note 3, at 161–63.

121 *See id.*

122 *See generally* William R. Cline, *Rejoinder to Perspective Papers 1.1 and 1.2, in* GLOBAL CRISES, GLOBAL SOLUTIONS, *supra* note 71, at 56, 57 (critiquing a global-warming model for its reliance on a wait-and-learn approach).

such investments, then the judgment should be reversed. There is reason to believe that for global warming, the irreversible losses associated with climate change do indeed justify the irreversible losses associated with greater investments in emissions reductions worldwide.[123]

D. Qualifications and Conclusions

The arguments for an Irreversible Harm Precautionary Principle, along with an understanding of its central limitations, are now in place. But there are three important qualifications, involving optimal delay, distributional considerations, and precommitment value. Let us briefly explore each of these.

1. *Irreversibilities and Optimal Delay*

The general notion of optimal delay provides important countervailing considerations. Future generations will almost certainly be both wealthier and more knowledgeable than the present generation; for this reason, they will be in a far better position, or possibly an unimaginably better position, to handle environmental problems that materialize in their time.[124] In the view of one commentator, the nearly inevitable increase in wealth over time means that it "makes no sense to make current generations 'pay' for the problems of future generations."[125] In addition, expensive investments in greenhouse-gas reduction may well diminish available resources for future generations, leaving them with less "to devote to subsequent damage control."[126] There is a final point. For many environmental problems, the irreversible costs of emissions *reductions* are incurred immediately, whereas the irreversible costs of emissions will be incurred in the future. This difference strengthens public resistance to emissions reductions in a way that fits with standard claims about the need to discount future effects.[127]

The argument for the wait-and-learn approach is strengthened by these points. But any such argument must also take into account the

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123 *See, e.g.*, NORDHAUS & BOYER, *supra* note 71, at 121–44. This point is not meant to endorse any particular set of responses to climate change; it is simply meant to suggest that some such response is justified, in substantial part, because of the risk of irreversible harm. A good discussion can be found in *id.* and in RICHARD B. STEWART & JONATHAN B. WIENER, RECONSTRUCTING CLIMATE POLICY: BEYOND KYOTO 21 (2003).

124 *See* Jagdish N. Bhagwati et al., *Expert Panel Ranking*, *in* GLOBAL CRISES, GLOBAL SOLUTIONS, *supra* note 71, at 605, 635 (remarks of Vernon L. Smith).

125 *Id.* at 627 (remarks of Thomas C. Schelling).

126 *Id.* at 635 (remarks of Vernon L. Smith).

127 For a statement and criticism of the standard claims, see Richard L. Revesz, *Environmental Regulation, Cost-Benefit Analysis, and the Discounting of Human Lives*, 99 COLUM. L. REV. 941 (1999).

incontrovertible fact that waiting simultaneously threatens to diminish the flexibility of future decision makers, and perhaps severely.[128]

2. *Irreversibilities and Distribution*

At first glance, an Irreversible Harm Precautionary Principle might seem to be especially beneficial to disadvantaged people.[129] In the context of global warming, aggressive precautions are projected to give far more to poor countries than to rich ones, partly because rich nations are so much less dependent on agriculture.[130] Nonetheless, there is no simple connection between distributional goals and an emphasis on irreversible harms. Some of the risks associated with genetic engineering are irreversible,[131] but as we have seen, the benefits of genetic engineering are likely to be felt most in poor nations.[132] The analysis of distributional goals must be undertaken separately from the analysis of irreversibility.

3. *Precommitment Value*

In some domains, future flexibility is undesirable, and people are willing to pay a great deal to eliminate it. The tale of Ulysses and the Sirens is perhaps the most familiar example,[133] and the idea of precommitment has many legal applications.[134] In the environmental context, regulators might be willing to pay for precommitment strategies that will operate as a constraint on interest-group power, myopia, weakness of will, excessively high discount rates, cognitive biases, or other problems. Indeed, the conventional Precautionary Principle, understood to place a thumb on the scales in favor of environmental protection, might be explained in these terms.[135]

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128 *See, e.g.*, Cline, *supra* note 122, at 56–57. Cline emphasizes that both the slowness of political processes and the gradual nature of climate change make it nearly impossible to make such changes "on a dime." *Id.* at 56.

129 *See generally* Juan Almendares, *Science, Human Rights, and the Precautionary Principle in Honduras*, *in* PRECAUTION, ENVIRONMENTAL SCIENCE, AND PREVENTIVE PUBLIC POLICY, *supra* note 28, at 55 (discussing advantages to Third World countries offered by the Precautionary Principle).

130 *See* NORDHAUS & BOYER, *supra* note 71, at 161–68.

131 *See generally* Wesseler, *supra* note 1, at 214 (discussing the threat of pest resistance as an irreversible event related to the use of transgenic crops).

132 *See* THOMAS R. DEGREGORI, BOUNTIFUL HARVEST: TECHNOLOGY, FOOD SAFETY, AND THE ENVIRONMENT 100–06 (2002); GOKLANY, *supra* note 10, at 48–49.

133 *See, e.g.*, JON ELSTER, ULYSSES AND THE SIRENS: STUDIES IN RATIONALITY AND IRRATIONALITY (rev. ed. 1984) (discussing precommitment strategies and self-binding, as in the case of Ulysses and the Sirens).

134 *See, e.g.*, STEPHEN HOLMES, PASSIONS AND CONSTRAINT: ON THE THEORY OF LIBERAL DEMOCRACY (1995) (emphasizing precommitment strategies in the constitutional domain).

135 *See* David A. Dana, *A Behavioral Economic Defense of the Precautionary Principle*, 97 NW. U. L. REV. 1315 (2003).

The difficulty, for any such explanation, should now be familiar: Any precommitment strategy may give rise to problems, including environmental problems, for which a precommitment strategy might also be justified. It is nonetheless important to see that option value is sometimes paralleled by "precommitment value," for which regulators might also be willing to spend a great deal. The literature on options, and on the need to maintain flexibility, has not yet come to terms with situations in which flexibility is a problem rather than a solution.

4. *Conclusions*

There is a coherent and distinctive Irreversible Harm Precautionary Principle, which takes the form of a willingness to pay a premium to maintain flexibility for the future. 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. If irreversible losses are on both sides, then it is necessary to assess their likelihood and their magnitude. We can find an implicit understanding of option value in the emphasis on irreversibility in NEPA and other federal statutes, along with many international agreements. 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.

E. Environmental Injunctions

An understanding of these issues helps to explain some longstanding disputes about the issuance of preliminary injunctions in environmental cases. For many years, some courts of appeals, particularly the Ninth Circuit, held that when a party alleges environmental harm, district courts should adopt a presumption of irreparable damage and indeed a presumption in favor of injunctive relief.[136] In NEPA cases, the result was a likely injunction if the agency had failed to prepare an adequate environmental impact statement: "Irreparable damage is presumed when an agency fails to evaluate thoroughly the environmental impact of a proposed action."[137] But what is the basis for this presumption? And what follows from it? Does it follow, for example, that the United States Navy must be enjoined from conducting weapons-training operations before it has obtained a permit to discharge ordnance into the sea?

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136 *See, e.g.*, Thomas v. Peterson, 753 F.2d 754, 764 (9th Cir. 1985).

137 *See* Save Our Ecosystems v. Clark, 747 F2d 1240, 1250 (9th Cir. 1984). For a general discussion, see Zygmunt J.B. Plater, *Statutory Violations and Equitable Discretion*, 70 CAL. L. REV. 524 (1982).

In response to the last question, the Supreme Court said no.[138] Rejecting the suggestion that environmental violations should give rise to automatic injunctions, the Court said that an injunction is an equitable remedy, subject to traditional balancing, and that it would "not lightly assume that Congress has intended to depart from established principles" permitting district courts to exercise their discretion.[139] In a subsequent case, involving the Alaska National Interest Lands Conservation Act, the Court underlined the point and expressly rejected the presumption of irreparable harm in environmental cases.[140] In the Court's words, "This presumption is contrary to traditional equitable principles . . . ."[141] Nonetheless, the Court stressed that environmental problems raise distinct issues because "[e]nvironmental injury, by its nature, can seldom be adequately remedied by money damages and is often permanent or at least of long duration, *i.e.*, irreparable."[142] It follows that if an environmental injury is likely, "the balance of harms will usually favor the issuance of an injunction to protect the environment."[143]

When courts of appeals spoke in terms of a presumption in favor of injunctive relief, they might be understood as adopting a version of the Irreversible Harm Precautionary Principle—assuming that environmental harm is irreversible in the relevant sense, and requiring a strong showing by those who seek to proceed in the face of that harm. This interpretation helps to explain the simplest exception to the lower courts' presumption: cases in which "irreparable harm *to the environment* would result if such relief were granted."[144] If, for example, an injunction against the use of a logging road would prevent the removal of diseased trees and thus allow the spread of infection through national forests, no injunction would issue.[145]

Here, then, is a clear recognition of the existence of environment-environment tradeoffs, in a way that requires a qualification of any Irreversible Harm Precautionary Principle. And when the Supreme Court rejected the presumption, it did so in favor of traditional equitable balancing, recognizing that serious harms, and perhaps irreversible harms, are on all sides. But even in doing so, the Court endorsed a kind of Irreversible Harm Precautionary Principle through

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138 Weinberger v. Romero-Barcelo, 456 U.S. 305 (1982).

139 *Id.* at 313.

140 Amoco Prod. Co. v. Vill. of Gambell, 480 U.S. 531, 544–45 (1987).

141 *Id.* at 545.

142 *Id.*

143 *Id.*

144 Vill. of Gambell v. Hodel, 774 F.2d 1414, 1424 (9th Cir. 1985), *rev'd in part, vacated in part, sub nom. Amoco Prod. Co.*, 480 U.S. 531.

145 Alpine Lakes Prot. Soc'y v. Schlapfer, 518 F.2d 1089 (9th Cir. 1975).

its explicit recognition that environmental injury "is often permanent or at least of long duration."[146]

What still remains undecided after the Court's decisions in the 1980s is the appropriate judicial posture in the face of violations of NEPA.[147] The Court's rejection of a presumption in favor of preliminary injunctions might well be taken to suggest that courts should rarely issue such injunctions in NEPA cases[148]—especially, perhaps, in light of the fact that NEPA is a purely procedural statute, one that imposes information-gathering duties on agencies without requiring them to follow a particular course of action.[149] If courts cannot forbid agencies to act as they choose after producing an adequate environmental impact statement, injunctions might seem an odd remedy in the NEPA setting. But in the most elaborate discussion of the question, then–Circuit Judge Breyer suggested that injunctions are often appropriate in NEPA cases.[150] The discussion endorses an appropriately constrained Irreversible Harm Precautionary Principle, adapted to the NEPA setting.[151]

Judge Breyer did not contend that a presumption in favor of injunctive relief would be appropriate for environmental cases in general. Instead, he argued that NEPA is meant to prevent a particular kind of injury, one that should play a central role in the decision whether to grant an injunction. The purpose of NEPA is to ensure that officials take environmental considerations into account *before* they embark on a course of action.[152] Judge Breyer writes, "'[W]hen a decision to which NEPA obligations attach is made without the informed environmental consideration that NEPA requires, the harm that NEPA intends to prevent has been suffered.'"[153] That harm is the increased risk of irreparable damage to the environment that arises "when governmental decisionmakers make up their minds with-

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146 *Amoco Prod. Co.*, 480 U.S. at 545.

147 For a general discussion, see Leslye A. Herrmann, Comment, *Injunctions for NEPA Violations: Balancing the Equalities*, 59 U. CHI. L. REV. 1263 (1992).

148 *See, e.g.*, New York v. Nuclear Regulatory Comm'n, 550 F.2d 745, 754–55 (2d Cir. 1977), *superceded on other grounds by statute*, FED. R. CIV. P. 52(a), *as recognized in* Zervos v. Verizon New York, Inc., 252 F.3d 163 (2d Cir. 2001); Conservation Soc'y of S. Vt., Inc. v. Sec'y of Transp., 508 F.2d 927, 933–34 (2d Cir. 1974), *vacated sub nom.* Coleman v. Conservation Soc'y of S. Vt., Inc., 423 U.S. 809 (1975); United States v. 27.09 Acres of Land, 737 F. Supp. 277, 283–84 (S.D.N.Y. 1990); Stand Together Against Neighborhood Decay, Inc. v. Bd. of Estimate, 690 F. Supp. 1192, 1199–1200 (E.D.N.Y. 1988).

149 *See* Sierra Club v Marsh, 872 F.2d 497, 502 (1st Cir. 1989).

150 *See id.* at 503–04.

151 *See id.* Also in this vein, see *Wash. County, N.C. v. U.S. Dep't of the Navy*, 317 F. Supp. 2d 626, 633–37 (E.D.N.C. 2004); *Crutchfield v. U.S. Army Corps of Eng'rs*, 192 F. Supp. 2d 444, 455–65 (E.D. Va. 2001).

152 *See Sierra Club*, 872 F.2d at 503–04.

153 *Id.* at 500 (emphasis omitted) (quoting Massachusetts v. Watt, 716 F.2d 946, 952 (1st Cir. 1983)).

out having before them an analysis (with prior public comment) of the likely effects of their decision upon the environment."[154]

Irreversibility is central here, for it is simply the case that administrators are less likely to destroy a nearly completed project than one that has only started. The relevant harm "may well have to do with the psychology of decisionmakers, and perhaps a more deeply rooted human psychological instinct not to tear down projects once they are built."[155] Judge Breyer's point, then, is that "the district court should take account of the potentially irreparable nature of this decisionmaking risk to the environment when considering a request for preliminary injunction."[156]

None of this means that in NEPA cases, preliminary injunctions should issue as a matter of course; that view would endorse the Irreversible Harm Precautionary Principle in its crudest form. Sometimes injunctions will themselves impose serious harm, and sometimes the risk to the environment is trivial.[157] But in NEPA cases, it makes sense to consider, as a relevant factor, the risk that an inadequately informed decision to proceed will alter the status quo, ensuring that once an environmental impact statement is produced, it will be too late to have a meaningful effect on the outcome. If delay is not exceedingly costly, and if the risk of environmental harm is serious, injunctive relief is appropriate for NEPA violations. An understanding of the risk of irreversibility helps to explain why.

III
ON CATASTROPHES AND WORST-CASE SCENARIOS

On one understanding of irreversibility, the real problem is seriousness: A loss of a species, or of a pristine area, is far worse if the loss is permanent. Many international treaties focus on serious and, in particular, catastrophic harm.[158] The line between a noncatastrophic and a catastrophic harm rests on the magnitude of the adverse effects. For present purposes, let us simply understand a catastrophic harm to involve a large number of human deaths—not thousands, but at least hundreds of thousands, or perhaps millions.[159]

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154 *Id.*

155 *Id.* at 504.

156 *Id.* at 501.

157 *See, e.g.*, Amoco Prod. Co. v. Vill. of Gambell, 480 U.S. 531 (1987).

158 *See, e.g.*, Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on Their Destruction, Jan. 13, 1993, S. TREATY DOC. No. 103-21, 1975 U.N.T.S. 469.

159 A narrower definition, involving threats to the survival of the human race, is adopted in POSNER, *supra* note 3, at 6.

A. Against Catastrophic Risk 1: A Modest Principle

Environmental regulation is often concerned with low probability events having especially bad worst-case scenarios. The standard approach to risk regulation fully supports that concern. To see why, consider three stylized environmental problems, creating three quite different sorts of risks: (a) The first problem creates a 999,999 in a million chance that no one will die, and a one in a million chance that 200 million people will die. (b) The second problem creates a 50% chance that no one will die and a 50% chance that 400 people will die. (c) The third problem creates a 100% chance that 200 people will die. Suppose that the government can eliminate all three problems at a specified cost.

Each of these risks presents an expected loss of 200 lives. If outcomes and probabilities are simply multiplied, the three problems will be seen as equivalent. In problem (a), my special concern, it would be difficult to defend the view that no resources should be devoted to eliminating the underlying risk. Suppose that a human life is valued at $6 million. If so, then $1.2 billion should be expended for eliminating the risk involved in problem (a). And in fact, this is the government's current approach to risk reduction.[160] Let us begin, then, with the most modest kind of Catastrophic Harm Precautionary Principle—one that favors precautionary steps based on expected value calculations of this sort. Note that under this approach, catastrophes are not receiving any particular attention. The central point is that they do not deserve *less* attention than higher probability harms with equivalent expected outcomes.

Despite its modesty, this form of the Precautionary Principle has important uses. In many contexts, human beings treat low-probability risks as if they were zero, especially if those risks are unlikely to come to fruition in the near future.[161] And because judgments about

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160 *See, e.g.*, National Primary Drinking Water Regulations; Arsenic and Clarifications to Compliance and New Source Contaminants Monitoring, 66 Fed. Reg. 6976, 7012 (Jan. 22, 2001) (to be codified at 40 C.F.R. pts. 9, 141–42). Agencies use a value of a statistical life (VSL) of about $6 million, independent of the probability that the relevant risk will come to fruition. For an overview, see Eric A. Posner & Cass R. Sunstein, *Dollars and Death*, 72 U. CHI. L. REV. 537 (2005). In its July 2003 regulation governing food labeling of trans fatty acids, the Food and Drug Administration used a VSL of $6.5 million. *See* Food Labeling: Trans Fatty Acids in Nutrition Labeling, Nutrient Content Claims, and Health Claims, 68 Fed. Reg. 41,434, 41,489 (July 11, 2003) (to be codified at 21 C.F.R. pt. 101). In its March 2003 proposed rule on dietary ingredients and dietary supplements, the same agency suggested a VSL of $5 million. *See* Current Good Manufacturing Practice in Manufacturing, Packing, or Holding Dietary Ingredients and Dietary Supplements, 68 Fed. Reg. 12,158, 12,230 (Mar. 13, 2003) (to be codified at 21 C.F.R. pts. 111–12) (using this value to calculate the "value of a statistical life day").

161 *See generally* MAX H. BAZERMAN & MICHAEL D. WATKINS, PREDICTABLE SURPRISES: THE DISASTERS YOU SHOULD HAVE SEEN COMING, AND HOW TO PREVENT THEM 84–87 (2004) (discussing "Discounting the Future").

probability are often driven by the "availability heuristic,"[162] people may well treat low-probability risks as if they were zero-probability risks. By their very nature, low-probability risks are unlikely to be accompanied by "available" instances of real-world harm. The importance of the Catastrophic Harm Precautionary Principle stems from the fact that when a risk probability is below a certain threshold, people often treat the risk as essentially zero, and are willing to pay little or nothing for insurance in the event of loss.[163] Such responses provide support for the intuitive suggestion that some risks are simply "off-screen"—whereas other risks, which are not statistically much larger, can come "on screen" and produce behavioral changes. The central idea behind the most modest form of the Catastrophic Harm Precautionary Principle is that low-probability, high-harm risks should be treated in accordance with their expected values.

This principle, based on expected value, might well provide more protection than accords with ordinary intuitions. In order to obtain a preliminary understanding of those intuitions, I conducted an experiment with 176 law students,[164] who were asked the following question:

> *The government is considering two environmental problems. The first creates a one in one million risk of killing 200 million people, and a 999,999 in one million risk of killing zero people. The second creates a one in ten risk of killing 2000 people, and a nine in ten risk of killing zero people. Do you think:*
>
> *(a) the first problem has higher priority?*
>
> *(b) the second problem has higher priority?*
>
> *(c) the two problems have equal priority?*

A strong plurality of 41% chose (b), whereas 36% chose (c) and only 22% chose (a).[165] In short, far more respondents were risk-seeking than risk-averse in the domain of low-probability catastrophes; for low-probability risks of disaster, they were willing to take their chances, at least when the comparison risk involves a higher-probability risk with an equivalent expected value. Of course, law stu-

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162 *See* Amos Tversky & Daniel Kahneman, *Judgment Under Uncertainty: Heuristics and Biases*, *in* JUDGMENT UNDER UNCERTAINTY: HEURISTICS AND BIASES 3, 11–14 (Daniel Kahneman et al. eds., 1982).

163 *See* Gary H. McClelland et al., *Insurance for Low-Probability Hazards: A Bimodal Response to Unlikely Events*, 7 J. RISK & UNCERTAINTY 95, 108–09 (1993).

164 One hundred and four were at the University of Alabama Law School and seventy-two were at the University of Chicago Law School.

165 These statistics were substantially the same across the two schools sampled. Notably, over one-third of respondents in this experiment were risk neutral, perhaps because law students are taught to attend to expected value—a tendency that would likely be less pronounced in the general population. It might have been anticipated that University of Chicago law students would be more inclined to risk neutrality than University of Alabama law students, because of the prevalence of economic analysis at the former institution, but the figures were essentially the same: 37.5% of Chicago students were risk neutral, compared to 35.5% of Alabama students.

dents at particular institutions may not be representative of the population as a whole, but it is reasonable to expect that the relatively lower concern for a low-probability, high-harm risk would be even more pronounced within the general population. If so, attending to expected value would have significant effects in the case of potentially catastrophic harm. To the extent that many people show little concern about global warming, part of the explanation may well lie in the fact that human beings often neglect low-probability, high-harm risks, especially if the costs would be incurred immediately and if the benefits would not be realized until the distant future.[166]

B. Against Catastrophic Risk 2: Expected Value, Prospect Theory, and (Bounded) Risk Aversion

A Catastrophic Harm Precautionary Principle, emphasizing expected value, raises several questions. The first is whether a low-probability risk of catastrophe might not deserve *more* attention than higher-probability risks with apparently equivalent expected value. Perhaps people should be especially attentive to low-probability, high-consequence hazards. The reason is that it is plausible to think that the loss of 200 million people is more than 1,000 times worse than the loss of 2,000 people. Indeed, the former loss might be dramatically worse than a mere exercise in multiplication might suggest. Consider the real-world meaning of a loss of 200 million people in the United States. In that event, the nation would find it extremely hard to recover. Its private and public institutions would be damaged for a long time, perhaps forever. What kind of governance structure would it have? What would its economy look like? Future generations would inevitably suffer. The effect of a catastrophe greatly outruns a simple multiplication of a certain number of lives lost.

It follows that the overall costs of losing two-thirds of the American population are far more than 100,000 times the costs of losing 2,000 people. Consider in this regard the "Buffalo Creek Syndrome," documented several times in the aftermath of major disasters.[167] Nearly two years after the collapse of a dam that left 120 people dead and 4,000 homeless, psychiatric researchers continued to find significant psychological and sociological changes; survivors were characterized by a loss of direction and energy, other disabling character changes, and a loss of communality.[168] One evaluator attributed this loss of direction specifically to "'the loss of the traditional bonds of

166 *See* BAZERMAN & WATKINS, *supra* note 161, at 6.

167 *See* Daniel J. Fiorino, *Technical and Democratic Values in Risk Analysis*, 9 RISK ANALYSIS 293, 295 (1989).

168 *Id.*

kinship and neighborliness.'"[169] Genuine catastrophes, involving the loss of millions of people, would magnify that loss to an unimaginable degree. There is a detailed literature on the "social amplification of risk," exploring secondary social losses, from one or another event, that can greatly outrun the initial effect of that event.[170] A Catastrophic Harm Precautionary Principle, devoting special attention to risks with large secondary losses, is well supported by an understanding of social amplification.

In any case (and this is an independent point), a well-known alternative to expected utility theory—prospect theory—predicts risk aversion in circumstances of just this sort.[171] It follows that if the question is properly framed, people may be willing to devote special priority to a low-probability risk of catastrophe, with the degree of priority depending on the degree of risk aversion.[172] Especially in light of the secondary costs of catastrophe, it might be concluded that whatever the right figure is, the simple aggregation ($6 million multiplied by the number of lives lost) produces implausibly low figures when the question is the death of millions. Perhaps it makes sense to build a distinctive premium, called "catastrophe aversion," into case (a). This idea might be used as the basis for a second and more aggressive kind of Catastrophic Harm Precautionary Principle, embodying that premium.

This claim might be supported by questioning the use of the $6 million figure for the Value of a Statistical Life (VSL). That figure is a product of studies of actual workplace risks, attempting to determine how much workers are paid to assume mortality hazards.[173] The relevant risks usually are in the general range of 1/10,000 to 1/100,000.[174] The calculation of VSL is a product of simple arithmetic. Suppose that workers must be paid $600, on average, to assume a risk of 1/10,000. If so, the VSL would be said to be $6 million. But if people are willing to pay $60 to avoid a risk of 100,000, it does not follow that they would be willing to pay (only) $60 to avoid a risk of 100,000 when

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169 *Id.*; *see* John D. Robinson, Michael D. Higgins, & P. Kenneth Bolyard, *Assessing Environmental Impacts on Health: A Role for Behavioral Science*, 4 ENVTL. IMPACT ASSESSMENT REV. 41, 48–49 (1983).

170 *See, e.g.*, THE SOCIAL AMPLIFICATION OF RISK (Nick Pidgeon et al. eds., 2003).

171 Daniel Kahneman & Amos Tversky, *Prospect Theory: An Analysis of Decision Under Risk*, *in* CHOICES, VALUES, AND FRAMES 17, 28–42 (Daniel Kahneman & Amos Tversky eds., 2000); Amos Tversky & Daniel Kahneman, *Advances in Prospect Theory: Cumulative Representation of Uncertainty*, *in* CHOICES, VALUES, AND FRAMES, *supra*, at 44, 64–65.

172 *See* Tversky & Kahneman, *supra* note 171, at 64–65.

173 *See* W. KIP VISCUSI, FATAL TRADEOFFS 19–20 (1992) (explaining the method by which the value of a worker's life is estimated).

174 *See, e.g.*, W. Kip Viscusi, *The Value of Life: Estimates With Risks by Occupation and Industry*, 42 ECON. INQUIRY 29, 32–33 & tbl.1 (2004) (showing average fatality risks in various industries between 1992 and 1997 to range from less than 1 in 100,000 (administrative support occupations) to 26 in 100,000 (mining laborers)).

that risk might come to fruition for millions of people at the same time. People might be willing to pay a kind of catastrophe premium, stemming not from risk aversion, but from a special distaste for risks of true disaster.

I do not mean to settle the question of monetization here. My only suggestion is that for a number of reasons, it makes sense to pay attention to low-probability risks of catastrophe. If so, a Catastrophic Harm Precautionary Principle is justified. There is a clear implication for such problems as global warming, genetic modification of food, nuclear power, and terrorism: In all of these contexts, attention to the expected value of the harm is warranted, including a premium that recognizes the secondary effects that result from the magnitude of the danger. But from the analysis thus far, what is true in the context of irreversible harms is true for the Catastrophic Harm Precautionary Principle as well. The amount of the premium is bounded, and everything depends on the probability of the risk, its size, and the various costs associated with reducing or eliminating it.

Thus far, then, the territory is conventional. Attention to expected value justifies a concern with low-probability risks of real disaster; the degree of attention must be attuned to the distinctive problems and costs associated with catastrophe. Even if regulators are risk neutral, they will devote substantial resources to the reduction of such risks. In view of the high stakes, a degree of risk aversion may well make sense in this context, complementing a focus on the problem of irreversibility to suggest, for example, that significant resources should be devoted to the problems of global warming and depletion of the ozone layer.[175] On the other hand, it is important to attend to the environmental and other risks associated with reducing those problems.[176] An analysis of this kind might be used to specify appropriate responses.[177] What I am adding here is that this analysis might be undertaken under the general framework of a Catastrophic Harm Precautionary Principle.

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175 On the latter problem, see generally RICHARD ELLIOT BENEDICK, OZONE DIPLOMACY (enlarged ed. 1998) (discussing the role of politics in addressing ozone depletion and emphasizing the importance of devoting resources to combat further environmental harm); PERCIVAL ET AL., *supra* note 41, at 1046–55 (summarizing the history of ozone depletion and discussing the Montreal Protocol, which was intended to minimize the production of substances that deplete the ozone layer).

176 *See, e.g.*, GOKLANY, *supra* note 10, at 57–88 ("[A]n insurance policy itself might raise new—or aggravate existing—threats to human health or the environment"); William R. Cline, *Climate Change*, *in* GLOBAL CRISES, GLOBAL SOLUTIONS, *supra* note 71, at 13, 15–21 (discussing the problem of discounting future costs and benefits to obtain present values of policy judgments).

177 *See* NORDHAUS & BOYER, *supra* note 71; Cline, *supra* note 176, at 19–20 (discussing optimal carbon taxes for reducing climate damage).

C. Catastrophic Harm, Timing, and Politics

The risk of catastrophe can be immediate, as in the case of terrorist attacks, but sometimes it is clear that if a catastrophe will occur, it will not be until the distant future, as may be the case for global warming. When the costs of precautions are incurred immediately, and when the benefits will not be enjoyed until decades later, people are likely to be extremely averse to precautionary steps, even if they are justified. Of course, the aversion might make sense if it is based on a decision to apply the appropriate discount rate to future benefits (a highly controversial question).[178] But it is easy to imagine situations in which future harms are being treated as irrelevant, or nearly so, because of social myopia, wishful thinking,[179] or a simple failure of imagination or empathy with those who will be at risk. For these reasons, there is a particular need for a Catastrophic Harm Precautionary Principle when the risk will not materialize until the distant future.

The point can be fortified with a reference to likely political dynamics. If the costs of precautions will be incurred immediately, and if the benefits will not be enjoyed for many decades, elected officials will have a strong incentive to delay. The reason is that they will face political retribution for imposing immediate costs and might well receive little or no political gain for delivering long-term benefits. In the case of global warming, the temporal disparity between costs and benefits creates a strong incentive to delay even if immediate precautions are justified, simply because those who are most likely to benefit do not vote.[180] This point provides an additional reason to endorse a Catastropbic Harm Precautionary Principle, one that attempts to overcome the danger that future risks will receive less attention than they deserve.

D. Against Catastrophic Risk 3: Uncertainty

Is it possible to support a still more aggressive kind of Catastrophic Harm Precautionary Principle? To approach this question, it is necessary to venture into some technical waters.

In some contexts, environmental and other risk-related problems involve hazards of ascertainable probability, which has been the assumption of the discussion thus far. It may well be possible to say that the risk of death from a certain activity is 1/100,000, or at least that it ranges from (say) 1/20,000 to 1/500,000, with an exposed population of (say) 10 million. Or it may be possible to say that the risk of cata-

178 For a discussion of the cost-benefit analysis in the environmental context, see Revesz, *supra* note 127.

179 *See* George A. Akerlof & William T. Dickens, *The Economic Consequences of Cognitive Dissonance, in* GEORGE A. AKERLOF, AN ECONOMIC THEORIST'S BOOK OF TALES 123 (1984).

180 *See* BAZERMAN & WATKINS, *supra* note 161.

strophic harm from global warming is under 10% but above 1%.[181] But as the economist Frank Knight has maintained, it is possible to imagine instances in which analysts cannot specify even a range of probability.[182] Hence regulators, and ordinary people, are often acting in a situation of uncertainty (where outcomes can be identified but no probabilities can be assigned) rather than risk (where outcomes can be identified and probabilities assigned to various outcomes).[183] And they are sometimes acting under conditions of ignorance, in which they are unable to specify either the probability of bad outcomes or their nature—where regulators do not even know the magnitude of the harms that they are facing.[184]

When existing knowledge allows regulators to identify outcomes, but does not permit them to assign probabilities to them, it is sometimes said to be rational to follow the "maximin principle": Choose the policy with the best worst-case outcome.[185] In the environmental context, perhaps elaborate precautions can be justified by reference to the maximin principle, asking officials to identify the worst case among the various options, and to select that option whose worst case is least bad. Perhaps the maximin principle would lead to an exceptionally aggressive form of the Catastrophic Harm Precautionary Principle by, for example, urging elaborate steps to combat global warming. Suppose that such steps would impose various hardships, but that even in the worst case, these are not nearly so bad as the worst cases associated with global warming. It follows that if aggressive measures are justified to reduce the risks associated with global warming, one reason is that those risks are potentially catastrophic and existing science does not enable us to assign probabilities to the worst-case sce-

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181 NORDHAUS & BOYER, *supra* note 71, at 88 (suggesting a 1.2% probability of a catastrophic impact with 2.5° Celsius warming and a 6.8% probability with 6° Celsius warming).

182 FRANK H. KNIGHT, RISK, UNCERTAINTY, AND PROFIT 215 (London Sch. of Econ. & Political Sci. 1948) (1921). This is Posner's view of abrupt global warming. *See* POSNER, *supra* note 3, at 57 (describing abrupt global warming as a case in which "probabilities cannot be assigned to particular outcomes").

183 *See* KNIGHT, *supra* note 182, at 197–232; Paul Davidson, *Is Probability Theory Relevant for Uncertainty? A Post-Keynesian Perspective*, J. ECON. PERSP., Winter 1991, at 129. Some people object that uncertainty does not exist because it is always possible for decision-makers to produce probability assignments by proposing a series of lotteries over possible outcomes; but such assignments have no epistemic credentials if not rooted in either theory or repeated experiences, and many risk-related problems, such as those involving global warming, are in that category. I take up this point in detail below.

184 On ignorance and precaution, see P. Harremoës, *Ethical Aspects of Scientific Incertitude in Environmental Analysis and Decision Making*, 11 J. CLEANER PRODUCTION 705 (2003).

185 For a technical treatment of the possible rationality of maximin, see Kenneth J. Arrow & Leonid Hurwicz, *An Optimality Criterion for Decision-Making Under Ignorance*, *in* UNCERTAINTY AND EXPECTATIONS IN ECONOMICS 1 (C.F. Carter & J.L. Ford eds., 1972); for a non-technical overview, see JON ELSTER, EXPLAINING TECHNICAL CHANGE app. 1, at 185–207 (1983).

narios.[186] The same analysis might be applied to many problems, including the risks associated with nuclear energy[187] and terrorism.

E. Against Worst-Case Analysis

To understand these claims, we need to back up a bit and investigate maximin in more detail. Does it *generally* make sense to eliminate the worst-case scenario? Put the question of uncertainty to one side and begin with a numerical example that involves risk instead; which would you prefer:

(a) a 99.9% chance of gaining $2,000, and a 0.1% chance of losing $6?
(b) a 50% chance of gaining $5, and a 50% chance of losing $5?

Under maximin, (b) is preferable—but under standard accounts of rationality, it would be much more sensible to select (a), which has a far higher expected value. To choose (b), one would have to show an extraordinary degree of risk aversion.

Now turn to a mundane illustration of the kinds of decisions in which maximin might seem attractive: A reporter living in Los Angeles has been told that he can take one of two assignments. First, he can go to a nation, say Iraq, that is facing a large amount of terrorism. Second, he can go to Paris to cover anti-American sentiment in France. The Iraq assignment has, in his view, two polar outcomes: (a) He might have the most interesting and rewarding experience of his professional life, or (b) he might be killed. The Paris assignment has two polar outcomes of its own: (a) He might have an interesting experience, one that is also a great deal of fun, or (b) he might be lonely and homesick. It might seem tempting for the reporter to choose Paris on the ground that the worst-case scenario for that choice is so much better than the worst-case scenario for Iraq. And if this is correct, the conclusion might bear on regulatory policy when one or another approach has an identifiably worse worst-case scenario.[188]

But maximin is not always a sensible decision rule. Suppose that the reporter now has the choice of staying in Los Angeles or going to Paris; suppose, too, that on personal and professional grounds, Paris is far better. It would make little sense for him to invoke maximin in order to stay in Los Angeles on the ground that the plane to Paris might crash. A plane crash is, of course, extremely unlikely, but it cannot be ruled out. Using an example of this kind, John Harsanyi

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186 *See* POSNER, *supra* note 3, at 49.

187 *See* ELSTER, *supra* note 185, app. 1, at 188–205 (discussing risk models for choosing various types of energy, including nuclear energy).

188 *See id.*; Richard T. Woodward & Richard C. Bishop, *How to Decide When Experts Disagree: Uncertainty-Based Choice Rules in Environmental Policy*, 73 LAND ECONOMICS 492 (1997); *cf.* POSNER, *supra* note 3, at 43–58 (emphasizing the possibility of catastrophe from abrupt global warming).

contends that maximin should be rejected on the ground that it produces irrationality, even madness:

> If you took the maximin principle seriously then you could not ever cross a street (after all, you might be hit by a car); you could never drive over a bridge (after all, it might collapse); you could never get married (after all, it might end in a disaster), etc. If anybody really acted this way he would soon end up in a mental institution.[189]

Harsanyi's argument might also be invoked to contest the use of maximin in the choice between Iraq and Paris. Perhaps the reporter should attempt to specify the likelihood of being killed in Iraq, rather than simply identifying the worst-case scenario. Perhaps maximin is a way of neglecting probability and hence a form of irrationality. In some circumstances, people do display probability neglect in a way that ensures attention to the worst-case scenario.[190] But if probabilities can actually be assessed, and if that scenario is extremely unlikely to come to fruition, probability neglect is hard to defend even for people who are exceptionally risk averse. Suppose that the risk of death in Iraq turns out to be 1/1,000,000, and that the choice of Iraq would be much better, personally and professionally, than the choice of Paris. It is necessary to know something about the reporter's values and tastes to understand how to resolve this problem, but it is certainly plausible to think that the reporter should choose Iraq rather than make the decision by obsessively fixating on the worst that might happen. Recall that the Council on Environmental Quality no longer requires worst-case analysis; it refuses to do so on the ground that extremely speculative and improbable outcomes do not deserve attention.[191] So far, then, Harsanyi's criticism of maximin seems to stand on firm ground.

But something important is missing from Harsanyi's argument and even from the reporter's analysis of the choice between Los Angeles and Paris: Risks, and equally bad worst-case scenarios, are on all sides of the hypothesized situations. If the reporter stayed in Los Angeles, he might be killed in one way or another, and hence the use of maximin does not by itself justify the decision to stay in the United States. And contrary to Harsanyi's argument, maximin does not really mean that people should not cross streets, drive over bridges, and refuse to marry. The reason is that failing to do those three things has worst-case scenarios of its own (including death and disaster). To im-

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189 *See* John C. Harsanyi, *Can the Maximin Principle Serve as a Basis for Morality? A Critique of John Rawls's Theory*, 69 AM. POL. SCI. REV. 594, 595 (1975).

190 *See* Cass R. Sunstein, Essay, *Probability Neglect: Emotions, Worst Cases, and Law*, 112 YALE L.J. 61, 62–63 (2002).

191 *See supra* notes 17–18 and accompanying text; PERCIVAL ET AL., *supra* note 41, at 848–49.

plement maximin, or an injunction to take precautions, it is necessary to identify all relevant risks, not a subset. Harsanyi errs in the same way as those who embrace the strong version of the Precautionary Principle—by neglecting the possibility that precautions against one set of risks will create risks of their own. Alternative decisions may lead to worst-case scenarios that are very bad and even equally bad. A Catastrophic Harm Precautionary Principle, attempting to eliminate the worst cases, might produce nightmarish scenarios, too.

Nonetheless, the more general objection to maximin holds under circumstances of risk. If probabilities can be assigned to the various outcomes, it does not make sense to follow maximin when the worst case is highly improbable and when the alternative option is both much better and much more likely. Of course, many people are risk averse, or averse to particular risks. But when probabilities can be assigned, maximin seems to require infinite risk aversion.[192] It follows that the reporter would do well to reject maximin and to go to Paris, even if the worst-case scenario for Paris is worse than that for Los Angeles, *if* the realistically likely outcomes are so much better in Paris. These points are not meant to suggest that in order to be rational, the reporter must calculate expected values, multiplying imaginable outcomes by probability and deciding accordingly. Life is short, people are busy and occasionally risk averse, and it is far from irrational to create a margin of safety to protect against disaster. But if the likelihood of a bad outcome is extremely small, and if much is to be gained by deciding in accordance with expected values, maximin is foolish.

For environmental policy, the implication is clear. A Catastrophic Harm Precautionary Principle makes sense if it emphasizes expected value; it may even make sense if it embodies a form of risk aversion. But it does not make sense, as a general rule, to identify the worst-case scenario and to attempt to eliminate it. But the problem of uncertainty raises distinctive questions.

F. Maximin and Uncertainty

1. *Precautions, Uncertainty, and Worst-Case Scenarios*

I have suggested that maximin has sometimes been recommended under circumstances of uncertainty rather than risk.[193] In an illuminating effort to recast the Precautionary Principle,[194] Stephen Gardiner invokes John Rawls's argument for maximin in the context of distributive justice.[195] Rawls argues that when "grave risks" are in-

192 *See* R.A. Musgrave, *Maximin, Uncertainty, and the Leisure Trade-Off*, 88 Q.J. ECON. 625, 626–27 (1974).

193 *See, e.g.*, ELSTER, *supra* note 185, app. 1, at 188–205.

194 *See* Stephen M. Gardiner, *A Core Precautionary Principle*, 14 J. POL. PHIL. 33 (2006).

195 *See* JOHN RAWLS, A THEORY OF JUSTICE 132–39 (rev. ed. 1999).

volved, and when probabilities cannot be assigned to the occurrence of those risks, maximin is the appropriate decision rule, at least if the chooser "cares very little, if anything, for what he might gain above the minimum stipend that he can, in fact, be sure of by following the maximin rule."[196] Rawls contends, then, that maximin is justified (a) in the face of potentially catastrophic outcomes, (b) when probabilities cannot be assigned, and (c) when the loss from following maximin is a matter of relative indifference.[197] Gardiner argues that this argument forms the basis for a "core" Precautionary Principle in the environmental setting: When the three conditions are met, precautions—in the form of efforts to avoid the worst-case scenario—should be adopted.[198]

Gardiner adds, sensibly, that to justify maximin, the threats that are potentially catastrophic must satisfy some minimal threshold of plausibility. If they can be dismissed as unrealistic, then maximin should not be followed.[199] Gardiner believes that the problem of global warming can be usefully analyzed in these terms and that it presents a good case for the application of maximin.[200] In a similar vein, Jon Elster, speaking of nuclear power, contends that maximin is the appropriate choice when it is possible to identify the worst-case scenario and when the alternatives have the same best consequences.[201] Here, then, is the basic argument in favor of the most aggressive form of the Catastrophic Harm Precautionary Principle—a principle that calls on regulators, under circumstances of uncertainty, to identify and eliminate the worst-case scenario. Taken seriously, this principle would have large consequences for regulatory policy, at least if conditions of uncertainty are common.

2. *Objection 1: The Argument Is Trivial*

An initial problem with this argument is that it risks triviality, above all because of condition (c).[202] If individuals and societies can eliminate an uncertain danger of catastrophe for essentially no cost,

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196 *Id.* at 134.

197 *See id.* at 134–35. Rawls draws in turn on WILLIAM FELLNER, PROBABILITY AND PROFIT 140–42 (1965). *Id.* at 134 n.20. He offers a somewhat revised defense of maximin in John Rawls, *Some Reasons for the Maximin Criterion*, 64 AM. ECON. REV. 141, 141 (1974).

198 *See* Gardiner, *supra* note 194, at 45–49.

199 *See id.* at 51.

200 *See id.* at 55.

201 *See* ELSTER, *supra* note 185, app. 1, at 203.

202 *Cf.* David Kelsey, *Choice Under Partial Uncertainty*, 34 INT'L ECON. REV. 297, 305 (1993) ("It is often argued that lexicographic decision rules such as maximin are irrational, since in economics we would not expect an individual to be prepared to make a small improvement in one of his objectives at the expense of large sacrifices in all of his other objectives. This criticism is less powerful in the current context since we have assumed that the decision maker has a weak order rather than a cardinal utility function on the space of outcomes. Given this assumption the terms 'large' and 'small' used in the

then of course they should eliminate that risk. If people are asked to pay $1 to avoid a potentially catastrophic risk to which probabilities cannot be assigned, they might as well pay $1. And if two options have the same best-case scenario, and if the first has a far better worst-case scenario, people should of course choose the first option.

There is nothing wrong with this argument, but the real world rarely presents problems of this form. When policy and law are disputed, the elimination of uncertain dangers of catastrophe imposes both costs and risks. In the context of global warming, for example, it is implausible to say that regulatory decision makers can or should care "very little, if anything," for what might be lost by following maximin. If nations followed maximin for global warming, they would spend a great deal to reduce greenhouse-gas emissions.[203] The result would almost certainly be higher prices for gasoline and energy, probably producing increases in unemployment and poverty. A study done at the Wharton School, for example, projected extremely high costs for the United States from the Kyoto Protocol—including a loss of 2.4 million jobs and $300 billion in the nation's GDP, with an average annual cost of $2,700 per household, a 65¢ per gallon increase in the price of gasoline, and a near doubling of the price of energy and electricity.[204] Even if these figures are wildly inflated, as seems likely, any significant effort to curtail global warming would impose significant hardships, especially on poor people, who are least able to bear the relevant cost increases. Something similar can be said about genetic modification of food, because elimination of the worst-case scenario, through aggressive regulation, might well eliminate an inexpensive source of nutrition that would have exceptionally valuable effects on countless people who live under circumstances of extreme deprivation.[205]

The real question, then, is whether regulators should embrace maximin in real-world cases in which doing so is extremely costly. If they should, it is because condition (c) is too stringent and should be abandoned. Even if the costs of following maximin are significant, and even if regulators care a great deal about incurring those costs, the question is whether it makes sense to follow maximin when they face uncertain dangers of catastrophe. In the environmental context,

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above argument are not meaningful."). In many environmental choices, however, decision makers do have a cardinal utility function, not merely a weak order.

203 *See* NORDHAUS & BOYER, *supra* note 71, at 167–68.

204 WHARTON ECONOMETRIC FORECASTING ASSOCIATES, GLOBAL WARMING: THE HIGH COSTS OF THE KYOTO PROTOCOL 2–3 (1998), *available at* http://api-ec.api.org/filelibrary/nt198.pdf.

205 *See* Anderson & Nielsen, *supra* note 49, at 7–8.

some people have so claimed.[206] This claim takes us directly to the next objection to maximin.

3. *Objection 2: Maximin Assumes Infinite Risk Aversion*

Rawls's arguments in favor of adopting maximin for purposes of distributive justice were subject to withering critiques from economists. The central challenge was that the maximin principle would be chosen by those maximizing expected utility only if they showed infinite risk aversion.[207] In the words of one of Rawls's most influential critics, infinite risk aversion "is unlikely. Even though the stakes are great, people may well wish to trade a reduction in the assured floor against the provision of larger gains. But if risk aversion is less than infinite, the outcome will not be maximin."[208] To adapt this objection to the environmental context, it is plausible to assume a bounded degree of risk aversion with respect to catastrophic harms to support some modest forms of the Catastrophic Harm Precautionary Principle. But even under circumstances of uncertainty—the argument goes—maximin is senseless unless societies are to show infinite risk aversion.

This is a standard challenge, but it is wrong because maximin does not assume infinite risk aversion.[209] Suppose that people are in circumstances of genuine uncertainty, also known as Knightian uncertainty, in which probabilities cannot plausibly be assigned to various outcomes.[210] The objection that maximin assumes infinite risk aversion depends on a denial that uncertainty exists; it assumes that subjective choices will be made and that they will reveal subjective probabilities. It is true that subjective choices will be made. But such choices do not establish that objective uncertainty does not exist. To see why, it is necessary to engage that question directly.

4. *Objection 3: Uncertainty Does Not Exist*

Many economists have denied the existence of uncertainty. Milton Friedman, for example, writes of the risk-uncertainty distinction, "I have not referred to this distinction because I do not believe it is valid. I follow L. J. Savage in his view of *personal probability*, which denies any valid distinction along these lines. We may treat people as

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206 *See* Woodward & Bishop, *supra* note 188, at 505–06.

207 *See, e.g.*, Kenneth J. Arrow, *Some Ordinalist-Utilitarian Notes on Rawls's Theory of Justice*, 70 J. PHIL. 245 (1973); Harsanyi, *supra* note 189; Musgrave, *supra* note 192.

208 Musgrave, *supra* note 192, at 627.

209 *See* C.Y. Cyrus Chu & Wen-Fang Liu, *A Dynamic Characterization of Rawls's Maximin Principle: Theory and Implications*, 12 CONST. POL. ECON. 255, 268 (2001).

210 *See id.* at 264–65.

if they assigned numerical probabilities to every conceivable event."[211] Friedman and other skeptics are correct to insist that people's choices suggest that they assign probabilities to events. On a widespread view, an understanding of people's choices can be taken as evidence of subjective probabilities. People's decisions about whether to fly or instead to drive, whether to walk in certain neighborhoods at night, and whether to take risky jobs can be understood as an implicit assignment of probabilities to events. Indeed, regulators themselves make decisions—including decisions about global warming—from which subjective probabilities can be calculated.[212] But none of this makes for a good objection to Knight, who was concerned with objective probabilities rather than subjective choices.[213] Animals, no less than human beings, make choices from which subjective probabilities can be assigned. But the existence of subjective probabilities—from dogs, horses, and elephants—does not mean that animals do not ever face genuine uncertainty.

Suppose that the question is the likelihood that at least 100 million human beings will be alive in 10,000 years. For most people, equipped with the knowledge that they have, no probability can sensibly be assigned. But perhaps uncertainty is not unbounded; the likelihood can reasonably be described as above 0% and below 100%. But beyond that point, there is little to say. Or suppose that I present you with an urn containing 250 balls and ask you to pick one; if you pick a blue ball, you receive $1,000, but if you pick a green ball, you have to pay me $1,000. Suppose that I refuse to disclose the proportion of blue and green balls in the urn—or suppose that the proportion has

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211 *See* MILTON FRIEDMAN, PRICE THEORY 282 (1976); *see also* JACK HIRSHLEIFER & JOHN G. RILEY, THE ANALYTICS OF UNCERTAINTY AND INFORMATION 10 (1992) ("In this book we disregard Knight's distinction, which has proved to be a sterile one. For our purposes risk and uncertainty mean the same thing. It does not matter, we contend, whether an 'objective' classification is or is not possible. For, we will be dealing throughout with a 'subjective' probability concept (as developed especially by Savage, 1954): probability is simply *degree of belief*. . . . [Because we never know true objective probabilities, d]ecision-makers are . . . never in Knight's world of risk but instead always in his world of uncertainty. That the alternative approach, assigning probabilities on the basis of subjective degree of belief, is a workable and fruitful procedure will be shown constructively throughout this book."). For the purposes of the analysis by Hirshleifer and Riley, the assignment of subjective probabilities may well be the best approach. But the distinction between risk and uncertainty is not sterile when regulators are considering what to do and lack information about the probabilities associated with various outcomes.

212 *Cf.* POSNER, *supra* note 3, at 176–84 (discussing inverse cost-benefit analysis as a way to suggest the subjective probabilities of regulators).

213 *See* Stephen F. LeRoy & Larry D. Singell, Jr., *Knight on Risk and Uncertainty*, 95 J. POL. ECON. 394 (1987) (arguing, against many critics, that Knight's work supported the idea of subjective probabilities). For a clear explanation of why uncertainty exists, see ELSTER, *supra* note 185, app. 1, at 193–99 ("One could certainly elicit from a political scientist the subjective probability that he attaches to the prediction that Norway in the year 3000 will be a democracy rather than a dictatorship, but would anyone even contemplate *acting* on the basis of this numerical magnitude?").

been determined by a computer, which has been programmed by someone that neither you nor I know. These examples suggest that it is wrong to deny the possible existence of uncertainty, signaled by the absence of objective probabilities.[214]

For Friedman and other skeptics about uncertainty, there is an additional problem. When necessary, human beings do assign subjective probabilities to future events. But the assignment is a function of how the situation is described, and formally identical descriptions can produce radically different judgments. There is every reason to believe, for example, that people will not give the same answer to the question, "What is the likelihood that 80% of people will suffer an adverse effect from a certain risk?" and to the question, "What is the likelihood that 20% of people will not suffer an adverse effect from a certain risk?"[215] The merely semantic reframing will almost certainly affect probability judgments. In any case, probability judgments are notoriously unreliable because they are frequently based on heuristics and biases that lead to severe and systematic errors.[216] Suppose that subjective probability estimates are rooted in the availability heuristic, leading people to exaggerate risks for which examples readily come to mind ("availability bias") and also to underestimate risks for which examples are cognitively unavailable ("unavailability bias").[217] Why should regulators believe that subjective estimates, subject as they are to framing, heuristics, and biases, have any standing in the face of the objective difficulty or impossibility of making probability judgments? Suppose that Judge Posner is correct to believe that with respect to global warming, it is objectively impossible to assign a probability to the risk of catastrophic harm.[218] Even if individuals and governments assign subjective probabilities, do their assignments bear on what ought to be done?

Writing in 1921, Keynes, often taken to be a critic of the idea of uncertainty, clearly saw the distinction between objective probabilities and actual behavior: "The sense in which I am using the term ['uncertain' knowledge] is that in which the prospect of a European war is uncertain . . . . About these matters there is no scientific basis on which to form any calculable probability whatever. We simply do not

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214 *See* ELSTER, *supra* note 185, app. 1, at 195–99.

215 *See id.* app. 1, at 198–99.

216 For a good overview of this topic, see JONATHAN BARON, THINKING AND DECIDING 125–47 (3d ed. 2000). Elster briefly notes how this point relates to the debate over uncertainty: "There are too many well-known mechanisms that distort our judgment, from wishful thinking to rigid cognitive structures, for us to be able to attach much weight to the numerical magnitudes that can be elicited by the standard method of asking subjects to choose between hypothetical options." ELSTER, *supra* note 185, app. 1, at 199.

217 *See* Timur Kuran & Cass R. Sunstein, *Availability Cascades and Risk Regulation*, 51 STAN. L. REV. 683, 705–07 (1999); Tversky & Kahneman, *supra* note 162, at 11–14.

218 *See* POSNER, *supra* note 3, at 49.

know."[219] This is so even if, as Keynes immediately added, we act "exactly as we should if we had behind us a good Benthamite calculation of a series of prospective advantages and disadvantages, each multiplied by its appropriate probability, waiting to be summed."[220] Even if subjective expected utilities can be assigned on the basis of behavior, regulators (like everyone else) may well be operating in circumstances of genuine uncertainty.

5. *Objection 4: Uncertainty Is Too Infrequent to Be a Genuine Source of Concern for Purposes of Policy and Law*

Perhaps environmental problems rarely involve genuine uncertainty. Perhaps regulators are usually able to assign probabilities to outcomes; and where they cannot, perhaps they can instead assign probabilities to probabilities (or if even this proves impossible, probabilities to probabilities of probabilities). In many cases, regulators might be able to specify a range of probabilities saying, for example, that the probability of catastrophic outcomes from global warming is above 2% but below 30%.[221] Many scientists and economists believe that global warming is not likely to create catastrophic harm and that the real costs—human and economic—will be high but not intolerable. In their view, the worst-case scenarios can be responsibly described as improbable.[222]

Perhaps we can agree that pure uncertainty is rare. Perhaps we can agree that at worst, environmental problems involve problems of "bounded uncertainty," in which we cannot assign probabilities within specified bands. It is possible to think, for example, that the risk of a catastrophic outcome is above 1% but below 10%, without being able to assign probabilities within that band. The pervasiveness of uncertainty depends on what is actually known. As I have emphasized, Judge Posner believes that "no probabilities can be attached to the catastrophic global-warming scenarios, and without an estimate of probabilities an expected cost cannot be calculated."[223] Note in this regard that a 1994 survey of experts showed an extraordinary range of estimated losses from global warming, varying from no economic loss to a 21% decrease in gross world product.[224] This finding, it has been suggested, is enough to support the view that uncertainty is real and

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219 J.M. Keynes, *The General Theory of Employment*, 51 Q.J. OF ECON. 209, 213–14 (1937).

220 *Id.*

221 *See, e.g.*, *supra* note 181.

222 *See* NORDHAUS & BOYER, *supra* note 71, at 96; Mendelsohn, *supra* note 71, at 45. *But see* Cline, *supra* note 176, at 14–15.

223 POSNER, *supra* note 3, at 49–50.

224 *See* William D. Nordhaus, *Expert Opinion on Climatic Change*, 82 AM. SCIENTIST 45, 47 (1994).

must be taken seriously in environmental policy.[225] In my view, uncertainty is both real and rare in the environmental domain; but this is an empirical judgment, and it may be wrong.

6. *On Maximin, Rationality, and Genuine Uncertainty*

Now turn to the most difficult question: What is the appropriate approach to genuine uncertainty? Is maximin a rational strategy? I begin with some points about actual behavior and then turn to normative issues.

a. *Actual Decisions*

As a descriptive matter, it is clear that people sometimes show a degree of uncertainty aversion, in the sense that they will avoid gambles to which probabilities are not assigned. The relevant work was done by Daniel Ellsberg.[226] Assume that people are asked to choose among two lotteries, each involving an urn with 100 balls. All of the balls are either black or red. For the first lottery, the urn contains an equal division of black and red balls. For the second lottery, the urn contains an unknown proportion of black balls and red balls. People receive a specified amount of money for correctly guessing the color of balls randomly chosen from the urn. It turns out that most people prefer the first lottery to the second, and thus display aversion to uncertainty.[227] On the assumption of uncertainty aversion, it might be possible to defend maximin as a decision rule.[228]

Note, however, that uncertainty aversion is bounded. So long as uncertainty aversion is not infinite, maximin will not always be the preferred decision rule. And indeed, it is reasonable to think that most people will reject maximin if the question is properly framed. To test this possibility, I gave seventy-one University of Chicago law students the following question:

> *The government is considering two environmental problems. For the first, the government is able to estimate the probability that a bad outcome will occur. It believes that there is a 90% chance that 600 people will die (and the death of 600 people is the worst-case scenario). It also believes that there is a 10% chance that 400 people will die. For the second problem, the government cannot assign probabilities to the various outcomes. The "worst-case scenario" is that 700 people will die.*
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> *Do you think:*

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225 *See* Woodward & Bishop, *supra* note 188. To be sure, experts' views converge more now than they did in 1994. *See* PERCIVAL ET AL., *supra* note 41, at 1057–60.

226 *See* Daniel Ellsberg, *Risk, Ambiguity, and the Savage Axioms*, 75 Q.J. ECON. 643, 650–56 (1961).

227 *See id.*

228 *See* Chu & Liu, *supra* note 209, at 264–66; Woodward & Bishop, *supra* note 188, at 496–98.

(a) the first problem has higher priority?
(b) the second problem has higher priority?
(c) the two problems have equal priority?

No fewer than 63% chose option (a), with the remainder equally divided between options (b) and (c). As noted above, law students at any particular institution may offer idiosyncratic responses to such questions; but within the general population, it is reasonable to conjecture that most people will show no consistent preference for maximin, and that they will reject an approach that eliminates the worst worst-case scenario under circumstances of uncertainty in favor of an approach that eliminates a highly probable but somewhat less bad worst-case scenario.[229]

Why is this? The Principle of Insufficient Reason says that when people lack information about probabilities (say, 1% to 40%), they should act as if each probability is equally likely.[230] Whatever its normative status,[231] actual decisions may well use that principle, which fits well with the results in the experiment just described. Consider another experiment with a larger group of law students from two institutions (the University of Alabama and the University of Chicago):[232]

> *One thousand people are at risk from an environmental hazard. (a) If one approach is taken, a minimum of 400 people will die, and a maximum of 500 people will die. Regulators are unable to assign probabilities to the various outcomes. (b) If another approach is taken, a minimum of 10 people will die, and a maximum of 600 people will die. Regulators are unable to assign probabilities to the various outcomes. Which approach should be chosen?*
>
> *(a) The first approach*
> *(b) The second approach*

No less than 85.5% of respondents rejected maximin and chose (b). Why did (b) seem better to so many respondents? On a reasonable interpretation, people begin by presuming at least roughly equal probabilities under circumstances of uncertainty, and conclude that they would much rather go the route that has a much higher expected value, given that presumption. This interpretation is supported by the results of the following experiment, which asks people to compare a choice under risk with a choice under uncertainty:[233]

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229 *See supra* note 165.

230 *See* R. DUNCAN LUCE & HOWARD RAIFFA, GAMES AND DECISIONS 284 (1957).

231 *See id.*; Isaac Levi, *On Indeterminate Probabilities*, 71 J. PHIL. 391 (1974).

232 The study surveyed one hundred and seventy-three law students; seventy-one were from the University of Chicago, and one hundred and two were from the University of Alabama. Interestingly, the answers from the two groups were essentially identical.

233 This experiment was limited to seventy-one law students from the University of Chicago.

The government is considering two environmental problems. For the first, the government is able to estimate the probability that a bad outcome will occur. It believes that there is a 60% chance that 500–600 people will die (and the death of 600 people is the worst-case scenario). It also believes that there is a 40% chance that 200–400 people will die. For the second problem, the government cannot assign probabilities to the various outcomes. The worst-case scenario is that 700 people will die.

Do you think:

(a) the first problem has higher priority?

(b) the second problem has higher priority?

(c) the two problems have equal priority?

For this problem, maximin was also rejected by a majority of respondents, but here the margin was much smaller: 52% favored (a), 25% were undecided, and 22% favored (b). The rejection of maximin is the most striking result here, and it is not entirely clear why the choice seemed relatively difficult. But the Principle of Insufficient Reason is consistent with that difficulty. Under the second problem, the expected number of deaths is 350 if equal probabilities are assigned, a number that is close to the expected number of deaths for the first problem; with a small degree of risk aversion, the choice between the two problems becomes extremely difficult.

To see the role of the Principle of Insufficient Reason, suppose that people are asked to choose between

(a) a 99.5% chance of a loss of 200 lives, and a 0.5% chance of a loss of 2 lives, with

(b) an uncertain chance of losing between 2 lives and 205 lives.

For most people, it is reasonable to suppose that (a) is much worse than (b)—and hence that (b) will be the overwhelming choice. Here, then, people will make a choice that allows the worst-case scenario. But compare

(a) a risk of 60% of a loss of 200 lives, and 40% of 2 lives, with

(b) an uncertain chance of losing between 205 lives and 2 lives.

For most people, the choice here is much less clear, and it is likely that many people will choose (a) and thus follow maximin. It follows that people would have a great deal of difficulty in choosing between a 51% risk of a loss of 200 lives, and a 49% chance of a loss of 1 life, as compared with an uncertain risk that threatens to produce losses of between 201 and 1 lives, with no possibility of assigning probabilities to the various possibilities.

The precise role of the Principle of Insufficient Reason and the nature of people's choices under circumstances of uncertainty remain to be established. The discussion thus far should be enough to show that people will often reject maximin and that the Principle of Insufficient Reason is a starting point for their intuitions. The implication

for environmental protection and for other problems involving safety and health is clear. People will not consistently follow maximin under circumstances of uncertainty. If the worst-case scenario is extremely vivid and if it is drawn to their attention, they might neglect the issue of probability and attempt to eliminate it.[234] But under ordinary circumstances, they will select maximin only when the Principle of Insufficient Reason, accompanied by a degree of risk aversion, suggests that they should.

b. *A Cost-Benefit Analysis of Maximin?*

A great deal of work explores the question of whether people should follow maximin under circumstances of uncertainty.[235] Some of this work draws on people's intuitions in a way that illuminates actual beliefs but tells us little about what rationality requires.[236] Those intuitions (of the sort described by the experiments above) may be based on some kind of confusion. Other work is highly formal, adopting certain axioms and seeing whether maximin violates them.[237] The results of this work are not conclusive. Certainly maximin has not been ruled out as a candidate for rational choice under uncertainty.

I cannot resolve these difficult issues here, but will rest content with a general suggestion. In deciding whether to follow maximin in the environmental context, a great deal should turn on two questions: (a) How bad is the worst-case scenario, compared to other bad outcomes? (b) What, exactly, is lost by choosing maximin? Of course, it is possible that decision makers, including regulators, will lack the information that would enable them to answer these questions. But in the regulatory context, answers to both (a) and (b) may well be possible even if it is not possible to assign probabilities to the various outcomes with any confidence. By emphasizing the relative badness of the worst-case scenario and the extent of the loss from attending to that scenario, I am attempting to build on the Rawls/Gardiner suggestion that maximin is the preferred decision rule when little is lost from following it.[238] I have objected that this suggestion threatens to trivialize the case for maximin;[239] but it is possible to develop the underlying intuition into a far more general and useful method for orienting both private and public choice.

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234 *See* Sunstein, *supra* note 190, at 62–63; Cass R. Sunstein, *Terrorism and Probability Neglect*, 26 J. RISK AND UNCERTAINTY 121 (2003).

235 *See, e.g.*, Arrow & Hurwicz, *supra* note 185 (suggesting the rationality of either maximin or maximax (maximizing the best-case scenario)).

236 *See, e.g.*, John C. Harsanyi, *Morality and the Theory of Rational Behaviour*, *in* UTILITARIANISM AND BEYOND 39 (Amartya Sen & Bernard Williams eds., 1982).

237 *See, e.g.*, LUCE & RAIFFA, *supra* note 230, at 286–97.

238 *See supra* Part III.F.1.

239 *See supra* Part III.F.2.

To see the relevance of the two questions, suppose that you are choosing between two options. The first has a best-case outcome of 10 and a worst-case outcome of –5. The second has a best-case outcome of 15 and a worst-case outcome of –6. It is impossible to assign probabilities to the various outcomes. Maximin would favor the first option, to avoid the worse worst-case; but to justify that choice, we have to know something about the meaning of the differences between 10 and 15 on the one hand and –5 and –6 on the other. If 15 is much better than 10, and if the difference between –5 and –6 is a matter of relative indifference, then the choice of the first option is hardly mandated. But if the difference between –5 and –6 greatly matters—if it is a matter of life and death—then maximin is much more attractive.

These points have the important implication of suggesting the possibility of a (rough) cost-benefit analysis of maximin under conditions of uncertainty. Sometimes a rejection of maximin is compelled by that analysis because the worst-case scenario is not much worse than the second worst-case scenario (and hence the benefits of maximin are low), and because we lose much by eliminating the worse worst case. But sometimes the worst-case is the worst by far, and sometimes we lose relatively little by choosing maximin. It is typically thought necessary to assign probabilities in order to engage in cost-benefit balancing; without an understanding of probabilities, such balancing might not seem able to get off the ground. But a useful form of cost-benefit balancing is possible even without reliable information about probability. For the balancing exercise to work, of course, it must be possible to produce cardinal rankings among the outcomes—that is, it must be possible to rank them not merely in terms of their badness but also in at least rough terms of how much worse each is than the less-bad others. That approach will not work if cardinal rankings are not feasible—as might be the case if, for example, it is not easy to compare the catastrophic loss from global warming with the loss from huge expenditures on reductions of greenhouse-gas emissions. Much of the time, however, cardinal rankings are possible.

Irreversibility becomes highly relevant as part of this analysis. Recall that some of the costs of precautions are irreversible. If governments invest a great deal to control greenhouse-gas emissions, they will be forcing private and public actors to incur irreversible costs. It follows that if governments follow maximin, they will be limiting their own flexibility, expending a great deal even though future information might move the situation from uncertainty to risk as regulators learn more about the problem. Suppose that no probability can now be assigned to the catastrophic risk associated with abrupt global warming and that for this reason regulators are tempted to spend a

great deal to eliminate that risk. The relevant expenditures will greatly reduce future flexibility, ensuring sunk costs for a danger that might turn out to be quantifiable or even trivial. This point is not decisive against large expenditures, but it should be part of the analysis of whether worst-case scenarios ought to be eliminated. In this sense, there can be some tension between an Irreversible Harm Precautionary Principle and a Catastrophic Harm Precautionary Principle.

Imagine, then, two polar situations with respect to global warming. First, suppose that the catastrophic dangers associated with global warming could be eliminated if every nation contributed $10 million to a fund to combat that risk. On reasonable assumptions, that cost would be fully acceptable. Second, suppose that the catastrophic dangers associated with global warming could be eliminated only if every nation contributed enough resources to reduce standards of living by 50% worldwide, with a corresponding increase in global poverty. If global warming really does pose an uncertain danger of total catastrophe, maximin argues in favor of this extraordinary reduction in worldwide standards of living. But to incur costs of this magnitude, we might want to insist that the danger of catastrophe rise above the minimal threshold—that there be demonstrable probability (and a not-so-low one) that the catastrophic risk will occur.

To appreciate this point, and the need for an analysis of the effects of following maximin, imagine an individual or society lacking the information that would permit the assignment of probabilities to a *series* of hazards with catastrophic outcomes; suppose that the number of hazards is ten or twenty or a thousand. Suppose, too, that such an individual or society is able to assign probabilities (ranging from 1% to 90%) to an equivalent number of other hazards, with outcomes that range from bad to extremely bad, but never catastrophic. Suppose finally that every one of these hazards can be eliminated at a cost—a cost that is high, but that does not, once incurred in individual cases, inflict harms that count as extremely bad or catastrophic. The maximin principle suggests that our individual or society should spend a great deal to eliminate each of the ten or twenty or thousand potentially catastrophic hazards. But once that amount is spent on even one of those hazards, there might be nothing left to combat the extremely bad hazards, even those with a 90% chance of occurring. We could even imagine that a poorly informed individual or society would be condemned to real poverty and distress—or still worse—merely by virtue of following maximin. In these circumstances, maximin should be rejected.

This suggestion derives indirect support from the empirical finding that when asked to decide on the distribution of goods and ser-

vices, most people reject the two most widely discussed principles in the philosophical literature: average utility, favored by Harsanyi, and Rawls's difference principle (allowing inequalities only if they work to the advantage to the least well off).[240] Instead, people choose average utility with a floor constraint—that is, they favor an approach that maximizes overall well being, but subject to the constraint that no member of society may fall below a decent minimum.[241] Insisting on an absolute welfare minimum to all, they maximize over that floor. Their aversion to especially bad outcomes leads them to a pragmatic threshold in the form of the floor. A similar approach is plausible in the context of precautions against risks. A sensible individual—or society—would not always choose maximin under circumstances of risk or uncertainty. Everything depends on what is lost and what is gained by eliminating the worst-case scenario; much of that time, available information makes it possible to answer those questions at least in general terms.

Nothing here is meant as proof that maximin is forbidden, or even not required, by rationality. To decide on the relationship between rationality and maximin strategies, it is necessary to specify the right account of rationality.[242] I am doubtful that any such specification can establish the status of maximin without making contentious assumptions. My claim is instead that maximin makes the most sense when the worst-case scenario under one course of action is much worse than the worst-case scenario under the alternative course of action, and when the choice of maximin does not result in extremely significant losses.

G. Dealing with Catastrophic Risks

The most general conclusion is that a degree of risk aversion should be expected in cases of catastrophic risks; for such risks, margins of safety are entirely sensible. For this reason, a Catastrophic Harm Precautionary Principle, of the sort suggested by several understandings of the Precautionary Principle, is a coherent and defensible part of environmental policy.[243] Indeed, such a principle might well be the best understanding of the Precautionary Principle itself. It has many uses, not only in environmental policy but in health and safety regulation as a whole, including the war on terrorism.

But maximin is not *generally* a sensible strategy in the environmental context or elsewhere. First, it is senseless under circumstances

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240 NORMAN FROHLICH & JOE A. OPPENHEIMER, CHOOSING JUSTICE: AN EXPERIMENTAL APPROACH TO ETHICAL THEORY 4–5(1992).

241 *See id.* at 82–94.

242 *See* LUCE & RAIFFA, *supra* note 230, at 286–97.

243 *See supra* Part III.E.

of risk, unless we assume an implausibly high degree of risk aversion. Second, regulators are rarely operating under circumstances of pure uncertainty; often rough probabilities can be ascribed to serious outcomes, and if not, at least rough probabilities can be ascribed to probabilities. Third, adoption of maximin under circumstances of genuine uncertainty is most reasonable when the worst-case scenario is exceptionally bad and when removal of that scenario does not inflict serious losses of its own.

It follows that a Catastrophic Harm Precautionary Principle is best understood to embody a form of risk aversion for the most dangerous risks. Its central domain involves uncertain dangers of catastrophe when the costs of reducing those dangers are not huge and when incurring those costs does not divert substantial resources from extremely pressing problems. Four qualifications are important.

First, the Catastrophic Harm Precautionary Principle must be attentive to the full range of social risks; it makes no sense to take steps to avert catastrophe if those very steps would create catastrophic risks of their own. If a preventive war designed to reduce the risks of terrorism from one source would increase those very risks from another source, then the Catastrophic Harm Precautionary Principle is indeterminate. This point is a simple extension of that made earlier with respect to the unrefined Precautionary Principle and the Irreversible Harm Precautionary Principle.

Second, use of the principle should be closely attentive to the idea of cost-effectiveness, which requires regulators to choose the least costly means of achieving their ends. In the context of global warming, there are many methods by which to reduce the relevant risks.[244] Both nations and international institutions should choose those methods that minimize costs. The same is true for efforts to combat terrorism.

Third, distributional considerations matter. The principle should be applied in a way that reduces extreme burdens on those least able to bear them. For global warming, there is a particular need to ensure that citizens of poor nations are not required to pay a great deal to contribute to the solution of a problem for which those in wealthy nations are most responsible.[245] If an antiterrorism policy would impose special burdens on members of racial and religious minority groups—consider racial profiling—it is worth considering other policies that reduce or eliminate those burdens.

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244 For a good discussion of various methods, see NORDHAUS & BOYER, *supra* note 71, at 121–44.

245 For an overview of international environmental regulation, see PERCIVAL ET AL., *supra* note 41, at 1033–1123.

Fourth, costs matter as such. The extent of precautions cannot reasonably be divorced from their expense. In cases of the kind I am discussing, when the worst-case scenario is truly catastrophic and when probabilities cannot be assigned, a large margin of safety makes a great deal of sense.[246]

There is a final point. It is possible to combine a concern about catastrophe with a focus on irreversible harm in a way that generates an Irreversible and Catastrophic Harm Precautionary Principle. Suppose that by adopting environmental controls at the present time, regulators can maintain flexibility to prevent a risk that is not only irreversible but potentially catastrophic as well. Suppose too that the likelihood of catastrophe cannot be specified with much confidence, or even that it is in the domain of uncertainty rather than risk. Risk-neutral, risk-averse, or uncertainty-averse regulators might be willing to pay a great deal to maintain the flexibility that would permit them to avoid the worst-case scenarios. We have seen that significant expenditures can reduce flexibility, too; many problems involve not irreversibility, but irreversibilities. At the same time, the most important irreversibilities may well turn out to be environmental in character.

This argument provides the strongest basis for aggressive measures to combat global warming.[247] The natural objections would either point to the irreversible costs of maintaining flexibility or question the probability that catastrophe will actually occur. The appropriate conclusion rests on an assessment of the empirical questions,[248] but in my view, an appreciation of irreversibility and catastrophe argues for otherwise excessive steps to reduce greenhouse gases.[249]

IV
RIVAL RATIONALITY REVISITED

When it comes to risk, why do experts disagree with ordinary people? Many people think that the reason lies in the fact that ordinary people have a "rival rationality."[250] On this view, experts are concerned with statistics and, above all, with the number of lives at

246 *See* Woodward & Bishop, *supra* note 188, at 505 ("If one considers a spectrum of choice problems from pure uncertainty to pure risk, almost all of the attention of economists has been on one extreme. . . . This has led to policy advice and analysis that either implicitly or explicitly requires policymakers to divine probability distributions. We argue, however, that there are important cases where probability distributions cannot be reasonably formulated and under such conditions dramatically different decision criteria may be rational.").

247 *See* POSNER, *supra* note 3, at 161–65.

248 *See* Fisher, *supra* note 96, for a good discussion.

249 *See id.*; Cline, *supra* note 176, at 15–21.

250 *See, e.g.*, Paul Slovic, *Perception of Risk*, *in* THE PERCEPTION OF RISK, *supra* note 5, at 220, 220–31.

stake.[251] By contrast, ordinary people are concerned with a range of qualitative factors that make certain risks a special cause of concern. Irreversibility and catastrophe are said to loom especially large in ordinary people's reactions.[252] While experts simply calculate expected values, ordinary people—and lay rationality—show special aversion to potentially irreversible and catastrophic harm. If this is so, ordinary people can be said to display rival rationalities. Both sides, expert and layperson, have "something valid to contribute . . . [and] must respect the insights and intelligence of the other."[253]

According to a competing view, the rival rationality of ordinary people is mostly a product of cognitive illusions, ignorance, and confusion.[254] For the critics, ordinary people are also concerned with the central question, which is the number of lives at stake. Unfortunately, they are unable to answer that question well. When ordinary people show a concern about irreversible and catastrophic harms, it is because they fear that many lives are at risk, no less and no more.

The discussion thus far suggests a possible rapprochement between the apparently rival rationalities. Sensible experts do not and should not believe that there is any particular magic in irreversibility, and they do and should insist that the line between catastrophic and noncatastrophic harm is one of degree. But they should also agree that irreversibility matters, in the sense that it makes sense to spend resources to maintain flexibility for the future. Insofar as NEPA instructs agencies to spend time to acquire relevant information before ensuring irreversible losses,[255] it is on firm ground. Experts agree that any cost-benefit analysis that ignores option value is missing an important variable—a standard point in finance though not yet in environmental protection.[256] In this sense, ordinary people are correct to see

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251 *See id.* at 223.

252 *See* Clayton P. Gillette & James E. Krier, *Risk, Courts, and Agencies*, 138 U. PA. L. REV. 1027, 1061–85 (1990). Note that the evidence described above suggests that in certain settings, potentially catastrophic outcomes will receive less—not more—attention than their expected value, perhaps because people treat very low-probability risks (e.g., one in one million) as if they were zero. The framing of the question undoubtedly matters a great deal here. Probably the best generalization is that people sometimes give low-probability risks of catastrophe more attention than their expected value and sometimes give high-probability risks of catastrophe less attention than is warranted. *See* McClelland et al., *supra* note 163, at 95. I suspect that in some of the relevant studies, the evidence of grave concern for catastrophic harms stems from the "affect heuristic," through which a general affective reaction to a risk—often a negative one—leads people to show concern about all aspects of the relevant risk. *See* Paul Slovic et al., *The Affect Heuristic*, *in* HEURISTICS AND BIASES 397 (Thomas Gilovich et al. eds., 2002).

253 Slovic, *supra* note 250, at 231.

254 *See* HOWARD MARGOLIS, DEALING WITH RISK: WHY THE PUBLIC AND THE EXPERTS DISAGREE ON ENVIRONMENTAL ISSUES (1996).

255 *See supra* notes 14–15 and accompanying text.

256 *See* DIXIT & PINDYCK, *supra* note 86, at 4–7.

the significance of irreversibility, and to emphasize the importance, some of the time, of adopting a strategy of "act, and then learn."

What of catastrophic risks? Experts may have little to say on the question of whether it is worse to create a 1/100 risk that 100,000 people will die, or a 1/1,000 risk that 1 million people will die. But they should agree that when regulators are unable to assign probabilities to catastrophic risks, it is worth doing a great deal to avoid those risks—or at least to spend resources as a precaution while more information is acquired. Experts cannot rule out the choice of maximin under circumstances of uncertainty. At the very least, experts know that elimination of the worst-case scenario is sometimes justified by a kind of cost-benefit analysis, one that pays attention to the relative egregiousness of the worst case and the costs of eliminating it. Sensible experts are interested not only in the expected value of catastrophic risks, but also in producing strategies for eliminating them when probabilities cannot be confidently assigned. For these reasons, an understanding of irreversibility and catastrophe help not only to refine but also to vindicate intuitions that have been found to play a significant role in ordinary risk perceptions.

CONCLUSION

The ideas of irreversibility and catastrophe have had a major impact on domestic and international law, and they play a large role in private and public decisions. My major goal in this Article has been to unpack these ideas and to bring them to bear on law and policy. I have suggested the possibility of replacing the Precautionary Principle, which is incoherent in its strong form, with more refined principles that embody an understanding of the distinctive problem of irreversible losses and of the need to attend to low-probability risks of disaster.

We have seen that an Irreversible Harm Precautionary Principle is both plausible and coherent. Drawing on the idea of real options, it suggests that regulators, including those who make environmental policy, should find it worthwhile to invest resources to preserve flexibility for the future. In the context of global warming, the Irreversible Harm Precautionary Principle argues for substantial current investments, above all because emissions of carbon dioxide stay in the atmosphere for an extremely long time. The difficulty here is that emissions reductions also impose irreversible costs. An emphasis on irreversibility does not always favor aggressive environmental regulation, or anything like an attitude of "act, then learn." It is even possible to imagine an Irreversible Harm Precautionary Principle that in

many cases argues for a plan of "wait and learn."[257] Everything depends on the magnitude and likelihood of the full range of irreversible losses. In the context of global warming, the best approach is probably a worldwide agreement to cap greenhouse emissions, with the size of the cap decreasing over time as the expense of controls diminishes.

If expected values matter, then societies should not ignore low-probability risks of catastrophe. A minimal response would be a Catastrophic Harm Precautionary Principle, one that attempts to respond to the serious possibility that both individuals and societies may treat small risks as if they were zero. The argument for this principle is strengthened by the fact that a catastrophic harm typically has secondary adverse effects that go far beyond a simple multiple of the number of deaths. A less minimal approach would build a degree of risk aversion into the Catastrophic Harm Precautionary Principle, so as to treat catastrophic harms as worth more than their expected value. A much more aggressive approach would be to adopt maximin, by which regulators identify the worst-case scenario and attempt to eliminate it. I have argued that for most environmental problems, this last approach is senseless. Under circumstances of risk, maximin is far too cautious, and it would inflict serious harms—often including environmental harms—for no sufficient reason. Environmental 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.

As a matter of theory, pure uncertainty cannot be ruled out of bounds. The fact that people assign probabilities to uncertain outcomes does not negate the possibility that the outcome is objectively uncertain. Under circumstances of uncertainty, maximin has some appeal if the worst-case scenario is truly catastrophic. And if it is not terribly costly to eliminate that scenario, regulators should certainly do so. But maximin can be an unappealing strategy, certainly under risk, and also when the worst-case scenario is not much worse than the second-worst case scenario and when the costs of eliminating the worst-case scenario are extremely high. To operate sensibly, precautionary steps must be attentive to the full range of consequences, not simply to a subset of them. But a Catastrophic Harm Precautionary Principle, applied with a wide viewscreen, has an important role in environmental law as well as ordinary life, and it is a strong candidate for replacing and refining any more general Precautionary Principle.

257 *See* Mendelsohn, *supra* note 71, at 47.