
VI.13 Precautionary principle

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Abstract

‘Precaution’ has become a major topic of environmental law. Where hazards pose uncertain but serious or even catastrophic risks, precautionary action is urged as essential to preventing future harm – rather than waiting to act after the damage is done and it may be too late to address the cause. Yet the ‘precautionary principle’ is also controversial, variously criticized as incoherent, costly, and posing its own risks. This chapter examines three key aspects of precaution: different versions of the precautionary principle, with different implications for law and policy; the debates over the pros and cons of precaution, including risk reduction and risk-risk tradeoffs; and efforts to reconcile these debates, notably by making precautionary measures less permanent so that, in order to learn in the face of uncertainty, precaution becomes more provisional and adaptive over time.

Keywords

Precaution, risk, regulation, tradeoffs, adaptive

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VI.13.1 Introduction

Few legal concepts have provoked more debate over the last several decades than the precautionary principle, not only in the environmental arena but in law and policy in general. Precaution has been central to debates over whether chemicals or greenhouse gases should be regulated in advance of harm, and whether preventive wars should be waged to prevent future attacks. Versions of the precautionary principle suggest – or command? – taking action in the face of uncertain risks. Where hazards pose uncertain but serious or even catastrophic risks, versions of the precautionary principle urge action to prevent future harm – rather than waiting to act after the damage is done and it may be too late to address the cause. Yet the ‘Precautionary Principle’ is also controversial, variously criticized as incoherent, costly, and posing its own risks. This chapter examines three key aspects of precaution: different versions of the precautionary principle, with different implications for law and policy; the debates over the pros and cons of precaution, including risk reduction and risk-risk tradeoffs; and efforts to reconcile these debates, notably by making precautionary measures less permanent so that, in order to

learn in the face of uncertainty, precaution becomes more provisional and adaptive over time.

VI.13.2 Precautionary principles

It is tempting to try to define 'the precautionary principle' (PP) as a formal principle or doctrine. But there is no single authoritative statement of the PP. Instead there are several different Precautionary Principles.¹

Early versions of the PP emerged by the early 1970s, notably the German *Vorsorgeprinzip*, and related concepts in Swiss and Swedish law.² In the United States, the federal Court of Appeals held in *Ethyl Corp. v EPA*³ that the Clean Air Act is a 'precautionary' law, authorizing regulatory decisions to prevent anticipated but uncertain future harms; and the US Supreme Court held in *TVA v Hill*⁴ that the Endangered Species Act adopts 'institutionalized caution'.

Versions of the PP have now been adopted in more than fifty international agreements.⁵ The Montreal Protocol on Substances that Deplete the Stratospheric Ozone Layer (1987) spoke of 'precautionary measures' in its Preamble. As climate change became the subject of international negotiations, the Bergen Declaration⁶ provided:

In order to achieve sustainable development, policies must be based on the precautionary principle. Environmental measures must anticipate, prevent and attack the causes of environmental degradation. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing measures to prevent environmental degradation.

A widely cited formulation of the PP is the version in the Rio Declaration,⁷ paragraph 15, which provides:

In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

The Rio Declaration was adopted by country governments at the 1992 Earth Summit (UN Conference on Environment and Development). Compared to the earlier Bergen Declaration, the Rio Declaration maintained the core message that where there are

¹ For reviews of precautionary principles in environmental law, see Bodansky (2004); Boehmer-Christiansen (1994); Sandin (1999); Sand (2000); Stone (2001); Trouwborst (2002); VanderZwaag (1999); Wiener (2007); Wiener (2016a).

² Boehmer-Christiansen (1994); Sand (2000).

³ Federal Court of Appeal, *Ethyl Corp. v EPA*, 541 F.2d 1 (D.C. Cir. 1976).

⁴ US Supreme Court, *TVA v Hill*, 437 U.S. 153 (1978). For further discussion of precaution in other areas of US policy, including counterterrorism and preventive war, see Stern and Wiener (2008).

⁵ Trouwborst (2002) at 63.

⁶ Bergen Conference on Sustainable Development, Ministerial Declaration on Sustainable Development in the ECE Region, May 1990.

⁷ United Nations Conference on Environment and Development, Rio Declaration on Environment and Development, June 1992.

‘threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing . . . measures to prevent’ harm, while also introducing several modifications, including the term ‘approach’ in place of ‘principle’, the qualifier ‘by States according to their capabilities’, and the qualifier ‘cost-effective’.

In one of the most detailed versions, the 1992 United Nations Framework Convention on Climate Change (FCCC) called for ‘precautionary measures’ in its Article 3(3):

The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors. Efforts to address climate change may be carried out cooperatively by interested Parties.

Also in 1992, the European Union adopted the Maastricht Treaty on European Union, which provided in Article 130r⁸ that EU policy on the environment ‘shall be based on the precautionary principle’ – though without defining what that meant. Eight years later, the European Commission⁹ issued its explanation of the PP in an important statement, providing that precaution must be based on risk assessment, must consider costs and benefits, ‘must not aim at zero risk’, and must be ‘provisional’, to be revised over time as understanding improves.¹⁰

Some national governments have also formally adopted versions of the PP. In 1999, Canada incorporated the PP in its revised Canadian Environmental Protection Act. In 2005, France adopted the PP as part of its Constitution (including the qualification that precautionary measures must be ‘provisoires et proportionnées’ – provisional and proportionate).

These adoptions of the precautionary principle and related developments have led some to assert that, at least since about 1990, Europe has become more precautionary than the United States.¹¹ But more thorough empirical studies of actual policies show that neither the European nor the American regulatory system is more precautionary across the board: rather, the actual adoption and application of precaution in particular cases has been highly selective, both across countries and across risks within countries.¹²

⁸ Now Article 191 of the Lisbon Treaty on the Functioning of the European Union (TFEU) of 2009.

⁹ European Commission (2000) ‘Communication on the Precautionary Principle’, COM(2000)1.

¹⁰ For additional assessments of precaution in international law, see e.g. Bodansky (2004); De Sadeleer (2002) and (2007); Douma (2003); Fisher et al. (2006); Freestone & Hey (1996); Trouwborst (2002) and (2006); Wiener (2007) and (2016a). For additional assessments of precaution in European risk regulation, see e.g. Alemanno (2016); Sand (2000); Wiener (2006); Wiener et al. (2011); Zander (2010).

¹¹ See e.g. Christoforou (2004); Vogel (2003); Vogel (2012); Bradford (2012) at 15–16.

¹² Brickman et al. (1985); Sand (2000); Wiener and Rogers (2002); Wiener (2004); Hammitt et al. (2005); Jasanoff (2005); Zander (2010); Wiener et al. (2011); Wiener et al. (2013); IRGC (2017).

These selective regulatory differences raise interesting questions about why different societies select different risks for concern; and in some situations these divergences can yield trade disputes.¹³ But the variation in regulatory approaches across jurisdictions and across risks can also offer valuable opportunities for evaluation and learning toward even better regulation.¹⁴

Different versions of the PP are less or more aggressive. Some versions of the PP, like the Bergen and Rio Declarations and the FCCC, quoted above, authorize (but do not mandate) regulation despite uncertainty, by stating that lack of certainty is not a reason for postponing action. Other versions go further, to require regulation or to forbid risky activities. For example, the Wingspread Statement on the PP (drafted by non-governmental organizations) provides:¹⁵ ‘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 fully established’. The UN World Charter on Nature¹⁶ declared that ‘where potential adverse effects are not fully understood, the activities should not proceed’ – but because risks are never ‘fully understood,’ this version would amount to forbidding those activities. The Intergovernmental Panel on Climate Change (IPCC)¹⁷ has recently commented that:

The PP allows policymakers to ban products or substances in situations where there is the possibility of their causing harm and/or where extensive scientific knowledge on their risks is lacking. These actions can be relaxed only if further scientific findings emerge that provide sound evidence that no harm will result.

But if providing ‘evidence that no harm will result’ is effectively impossible (because everything poses some risk in some circumstances), this formulation would amount to a prohibition.

This brief review illustrates the advance of the PP across the terrain of national and international law, and also the variation among its proliferating versions.¹⁸ The result is that there is no single formulation of the PP. Each of these versions was negotiated by a different set of parties for a different time and topic. Several of the official versions quoted above refer not to a ‘precautionary principle’ but rather to the desirability of taking ‘precautionary measures’ or ‘approaches’, and subject to several qualifications. Sandin¹⁹ found 19 versions, with significant differences regarding threat, uncertainty,

¹³ Wiener et al. (2011) ; Hamilton and Pelkmans (2015); van Asselt et al. (2014); IRGC (2017).

¹⁴ Wiener and Alemanno (2015); IRGC (2017).

¹⁵ Conference at Wingspread, Wisconsin, of 23–25 June 1998, Wingspread Statement on the Precautionary principle, <http://www.gdrc.org/u-gov/precaution-3.html>.

¹⁶ United Nations General Assembly, World Charter on Nature, Resolution A/Res/37/7 of 28-10-1982.

¹⁷ Intergovernmental Panel on Climate Change (IPCC), 5th Assessment Report (AR5), 2014, Working Group III: Mitigation, Chapter 2: Integrated Risk and Uncertainty Assessment of Climate Change Response Policies.

¹⁸ For more detailed surveys, see Bodansky (2004); Boehmer-Christiansen (1994); Sand (2000); Sandin (1999); Stone (2001); Trouwborst (2002); VanderZwaag (1999); Wiener (2007); Wiener (2016a); Zander (2010).

¹⁹ Sandin (1999).

action, and command. VanderZwaag²⁰ identified 14 formulations. Stone²¹ found no coherent statement, and only ‘disarray’. Wiener and Rogers²² and Wiener²³ grouped the many versions into three basic approaches: (i) authorization to take policy measures despite uncertain risk; (ii) obligation to take policy measures to address uncertain risk; and (iii) shifting the burden of proof (of safety or of acceptable risk) to the proponent of the activity. Bodansky²⁴ found that versions of the PP differ on multiple dimensions, including the permission to act versus duty to act, the trigger of application, and what action should be taken; he concluded that the PP has ‘not moved . . . towards consensus’ and ‘the only point of overlap is a truism’.

Indeed, prominent versions of the PP typically do not answer the truly challenging questions of risk management. They do not say what level of risk triggers its invocation (beyond terms like ‘serious’). They do not help select *which* risks deserve priority for precautionary measures, among the array of multiple serious and uncertain risks that a society may face. They do not say how early or how anticipatorily measures must be taken. They sometimes say that action need not wait for ‘certainty’ or ‘proof’, but because there is never certainty or conclusive proof of risks – the essence of risk is that there is always uncertainty about the future – any version calling for taking action before certainty or proof is really just describing all decision-making about risks. And they often do not say *which* measures or actions should be taken to anticipate or prevent the risk (unless they call for a prohibition).

Some observers propose the distinction that ‘prevention’ applies to risks that are ‘certain’ and ‘quantifiable’, whereas ‘precaution’ applies to risks that are ‘not certain’ and supposedly therefore ‘not quantifiable’,²⁵ but this distinction is problematic in several ways: first, all risks of future impacts are uncertain – ‘certainty’ would imply a probability of 1, which never actually occurs *ex ante*; second, we can still quantify risks with a probability between 0 and 1, including characterizing our uncertainty about such probability estimates (that is the very idea of risk analysis); and third, the word ‘prevent’ is itself embedded in the definition of the PP (e.g. the Bergen Declaration, the Rio Declaration, and the FCCC all use ‘prevent’ to define ‘precaution’), so they are not separate categories.

It is more meaningful to think of degrees of precaution – how early to anticipate and act, and how stringently.²⁶ Versions of the PP that use words like ‘prevent or minimize’ lean toward more stringent measures, and some of the burden-shifting versions go further toward prohibiting risky activities. Some versions of the PP, notably Rio 15 and FCCC 3(3), qualify the choice of measures with the term ‘cost-effective’ (i.e. achieving benefits at least cost). The European Commission²⁷ called for assessing costs and benefits as well as provisionality, and the French Constitution charter on the environment added

²⁰ VanderZwaag (1999).

²¹ Stone (2001).

²² Wiener and Rogers (2002).

²³ Wiener (2007).

²⁴ Bodansky (2004).

²⁵ Douma (2000).

²⁶ Hammitt et al. (2005); Wiener et al. (2011).

²⁷ European Commission (n 9) above.

in 2005 calls for provisionality and proportionality. But many versions of the PP do not speak to cost, proportion, reasonableness, optimization, or other criteria.

In some cases, these gaps in official formulations of the PP may be intentional. Specifying risk priorities, or regulatory stringency, or cost-benefit balancing, would oblige the drafter to confront the difficult tradeoffs in policy-making and might dilute enthusiasts' support for precaution. Two advocates of the PP have remarked:

Paradoxically, we conclude that the application of precaution will remain politically potent so long as it continues to be tantalizingly ill-defined and imperfectly translatable into codes of conduct, while capturing the emotions of misgiving and guilt . . . [I]t is neither a well-defined nor a stable concept. Rather, it has become the repository for a jumble of adventurous beliefs that challenge the status quo of political power, ideology, and environmental rights.²⁸

An effort by the International Law Commission to draft a report on the 'law of the atmosphere' was constrained to exclude, among other controversial topics, the precautionary principle.²⁹

Trying to distill the main features of precautionary policy from the several versions noted above, the core elements of a precautionary posture appear to include: (i) a threat of serious or irreversible or catastrophic risk or damage; (ii) a stance on knowledge, providing that scientific uncertainty about such risks does not preclude policy measures; (iii) a stance on timing, favoring earlier measures to anticipate and prevent the risk; (iv) a stance on stringency, favoring greater protection (such as prevention, or burden-shifting that prohibits risky activities until they are shown to be safe or acceptable); and (v) a qualifying stance on the impacts of the precautionary measures themselves, calling for them to be cost-effective or weigh costs and benefits, and to be provisional and hence involve reassessment and improvement over time as knowledge is gained. Such a precautionary posture favors earlier measures to prevent important risks, despite uncertainty, rather than waiting, while also recognizing that such early actions should be well-designed to avoid their own drawbacks, and are provisional and should be updated over time in light of learning.

Framing the general precautionary posture in this way enables precaution to be translated into a spectrum or continuous variable (rather than a binary classification of precautionary-or-not), along which the degree of precaution can be measured (e.g. in terms of (iii) timing and (iv) stringency), so that different policies can be scored and compared for their relative precaution.³⁰ And rather than rigidly dictating precaution irrespective of other considerations, this posture leans in favor of precaution, while taking at least some account of costs, complexities, and continued learning over time.

VI.13.3 Pros and cons of precaution

The precautionary principle remains controversial. One appraisal summed up the debate: 'The precautionary principle may well be the most innovative, pervasive, and

²⁸ Jordan and O'Riordan (1999) at 15.

²⁹ See Sand and Wiener (2016).

³⁰ Hammitt et al. (2005); Wiener et al. (2011); Wiener et al. (2013).

significant new concept in environmental policy over the past quarter century. It may also be the most reckless, arbitrary, and ill-advised'.³¹

Precautionary measures (early and anticipatory) can be essential to address the risks of latent impacts. If impacts do not occur until long after their causes, then waiting for proof of the causal relationship or the magnitude of harms can mean waiting until it is too late to address the cause.³² Further, the possibility of catastrophic impact favors precaution.³³ '[T]he prospect of a potential tipping point with unknown location enhances the precautionary motive for climate policy.'³⁴

[T]he principle of precaution emphasizes anticipation and prevention of future risks, even in the absence of full scientific certainty about the impacts of climate change . . . [a] key ongoing debate concerns whether or not this principle implies the need for stringent climate change policies as an insurance against potentially catastrophic outcomes, even if they may have very low probability.³⁵

And yet precaution may also pose problems. First, precautionary measures may be costly. Critics of precaution worry that anticipatory measures to restrict new technologies may inhibit innovation. More moderate versions of the PP do consider cost, such as the Rio Declaration, paragraph 15, and the FCCC, Article 3(3), with their qualification to be 'cost-effective', as well as the European Commission's³⁶ attention to assessing costs and benefits, and perhaps the French version's use of 'proportionate'.³⁷ Well-designed precautionary policies can also stimulate innovation in lower-risk technologies.³⁸

Second, precautionary measures do not affect just one risk at a time. The world is multi-risk.³⁹ Precautionary measures must select which risks to make top priority, and must confront their potential to affect multiple risks at the same time. Precautionary measures to prevent one risk may induce 'side-effects', 'ancillary impacts' or 'risk-risk tradeoffs', such as increases in other countervailing risks (ancillary harms), and decreases in other accompanying risks (ancillary co-benefits).⁴⁰ Yet invocations of the PP tend to target only one salient risk at a time.⁴¹ Sound policy-making needs to assess the full portfolio of policy impacts, including ancillary impacts (both harms and ben-

³¹ Marchant and Mossman (2004) at 1.

³² European Environment Agency (EEA) (2001), *Late Lessons from Early Warnings: The Precautionary Principle 1896–2000*. Environmental Issues Report 22 (Copenhagen); Harremoes et al. (2002).

³³ Posner (2004); Sunstein (2006); Weitzman (2009); Nordhaus (2011); Wiener (2016b).

³⁴ Council of Economic Advisers (USA) (2014) 'The Costs of Delaying Action to Stem Climate Change', available at https://scholar.harvard.edu/files/stock/files/cost_of_delaying_action.pdf at 24–25.

³⁵ IPCC, 5th Assessment Report (AR5) 2014, Working Group III: Mitigation, Chapter 13: International Cooperation: Agreements and Institutions, section 13.2.1.2, p. 10 (citations omitted).

³⁶ European Commission (n 9).

³⁷ French Environment Charter (2005).

³⁸ European Environment Agency (EEA) (2013), *Late Lessons from Early Warnings II: Science, Precaution, Innovation*. EEA Report 1/2013 (Copenhagen).

³⁹ Wiener (2002).

⁴⁰ Graham and Wiener (1995); Wiener (2002); Revesz and Livermore (2008); Shindell et al. (2012); Shindell (2015).

⁴¹ Graham and Wiener (1995); Wiener (1998); Wiener (2002); Heyvaert (2011).

efits), rather than focusing narrowly on just a single target risk. Indeed, if precautionary measures themselves increase some risks, then very stringent versions of the PP (forbidding risky activities) would ironically block the PP itself.⁴² Sunstein⁴³ argues that in a world of risks on all sides, the PP points nowhere. Graham and Wiener⁴⁴ and Wiener⁴⁵ argue that the solution is to take a broader, more holistic approach that confronts the multi-risk reality, assesses the full portfolio of multiple impacts (including both ancillary harms and co-benefits), and seeks ‘risk-superior moves’ that reduce multiple risks in concert.

Advocates of precaution often invoke commonsense adages such as ‘better safe than sorry’. Yet because in reality we face multiple interconnected risks, simple adages are insufficient. Of course one prefers ‘safe’ to ‘sorry’ – almost by definition. The real questions are ‘better safe against this, or against that?’, and ‘how safe – what are the pros and cons of seeking this much safety or in this way?’ In a world of multiple risks, we must ask, ‘which risks should we address more than others?’ and ‘which actions will reduce overall risk rather than create new risks?’ ‘Better safe than sorry’ is an old adage, but the lesson that ‘the cure may be worse than the disease’ has at least as venerable a pedigree.

Despite claims by critics of the PP and some advocates⁴⁶ that the PP opposes consideration of costs and benefits, a sensible precautionary posture need not be opposed to full portfolio analysis of multiple policy impacts. First, in formal law, although some versions of the PP appear insensitive to costs and risk-risk tradeoffs, other versions expressly combine them. As noted above, the Rio Declaration paragraph 15, the UNFCCC Article 3(3), and the European Commission⁴⁷ all included cost-effectiveness or cost-benefit analysis in their formulations of precaution. In fact, the EU’s 1992 Maastricht Treaty adopted not only the PP but also cost-benefit analysis in the very same Article 130r.⁴⁸ And the FCCC called for regulatory impact assessments to address both cost-benefit and risk-risk analyses in its Article 4(1)(f) (requiring parties to ‘employ appropriate methods, for example impact assessments, formulated and determined nationally, with a view to minimizing adverse effects on the economy, on public health and on the quality of the environment, of projects or measures undertaken by them to mitigate or adapt to climate change’).

Second, the basic idea of precaution as a posture for policy-making need not be at odds with cost-benefit analysis or risk-risk tradeoff analysis. As noted above, quantitative economic analyses of optimal policy that incorporate tipping points and uncertainty can favor greater precaution. Precaution and cost-benefit analysis can be combined to favor optimal or robust policies that account for uncertainty, catastrophe, option value, risk-risk tradeoffs, and related factors.⁴⁹

⁴² Cross (1996); Wiener (2002); Wiener (2007).

⁴³ Sunstein (2005).

⁴⁴ Graham and Wiener (1995).

⁴⁵ Wiener (2002).

⁴⁶ See e.g. Christoforou (2004).

⁴⁷ European Commission (n 9).

⁴⁸ Now Article 191 TFEU.

⁴⁹ Graham (2001); DeKay et al. (2002); Stewart (2002); Wiener (2002); Gollier and Treich

VI.13.4 Provisionality

Some versions of the PP provide that precautionary measures are ‘provisional’, that is, adopted under uncertainty and thus to be revised in light of new information and learning.⁵⁰ Many versions of the precautionary principle are predicated on uncertainty, and uncertainty implies that there are opportunities for learning (reducing uncertainty), such as by testing different policy approaches and assessing their results – subject to the costs of errors and of revising those policies over time.⁵¹ The choice is not just between acting now, versus waiting to learn and act later; the choice can be between acting and learning, versus waiting and learning. That is, there can be learning while acting – so long as the actions are selected to experiment with different approaches, monitored to evaluate their full impacts, and designed to avoid ‘lock-in’ so that they can be revised over time.⁵²

The concept of provisionality offers a bridge from precaution to learning and adaptive policy revision. In a section immediately following its discussion of precaution, the IPCC offers: ‘adaptive management represents structured processes for improving decision-making and policy over time, by incorporating lessons learned’.⁵³ The IPCC distinguishes ‘passive adaptive management’ which ‘involves carefully designing monitoring systems, at the relevant spatial scales, so as to be able to track the performance of policy interventions and improve them over time in response to what has been learned’, from ‘active adaptive management’ which ‘design[s] the interventions themselves as controlled experiments, so as to generate new knowledge’.⁵⁴ In the former, observations can track the diffusion of varying policy approaches and compare results. In the latter, experiments can be conducted in the ‘lab’, i.e. with volunteers in a university research setting⁵⁵ or in the ‘field’, i.e. with real policies applied by accountable governments.⁵⁶ Adaptive management can be precautionary against further harms, even if it proceeds over time after initial causes have begun,⁵⁷ but waiting too long can mean forfeiting the opportunity for anticipatory prevention and learning, obliging ‘post-cautionary’ remedial measures.⁵⁸ In both passive and active adaptive regulation, well-designed monitoring and performance evaluation are essential.⁵⁹

Governments conduct such variation and policy experiments all the time – but they often do so haphazardly or unintentionally, and they neglect to structure the experiment carefully to compare treatment options, monitor performance, and evaluate outcomes. Successful provisionality and adaptive management require careful data monitoring and analysis, in order to evaluate policy performance over time (regarding both intended

(2003); Sunstein (2006); Lempert and Collins (2007); Weitzman (2009); Nordhaus (2011); Driesen (2013); Wiener (2016b).

⁵⁰ See e.g. European Commission (n 9); France, Charte de l’environnement de 2005.

⁵¹ Greenstone (2009); Listokin (2008).

⁵² McCray et al. (2010); IPCC (n 17), section 2.8 at 56; Wiener (2015).

⁵³ IPCC (n 17), section 2.5.6, pp. 31–32.

⁵⁴ *Ibid.*

⁵⁵ Ludwig et al. (2011).

⁵⁶ Greenstone (2009); McCray et al. (2010); van Gestel and van Dijck (2011).

⁵⁷ Hartzell-Nichols (2014).

⁵⁸ Heinzerling (2008).

⁵⁹ Wiener (2015); Wiener and Ribeiro (2016); IRGC (2017).

and ancillary impacts), compared to alternative policy designs and compared to the counterfactual scenario of what would have occurred without the policy.⁶⁰

The opportunity to learn from provisional precaution and then undertake adaptive improvements presumes that learning can occur. Thus the strongest case for precaution is, perhaps surprisingly, not to address uncertain risks (as typically asserted), because uncertainty warrants provisionality and learning over time.⁶¹ Rather, the strongest case for precaution is to address extreme catastrophic risks that are so rare, and so utterly devastating, that learning could not occur afterward.⁶² These ‘tragedies of the uncommons’, such as risks to the existence of life on earth,⁶³ tend to be neglected by human psychology (which focuses on ‘available’ risks), and yet pose the greatest need for anticipatory preventive policies before the existential harm occurs, and increasingly so if more familiar ‘tragedies of the commons’ (resource depletion and pollution) are successfully addressed through policy learning.⁶⁴ Yet precaution against these extreme catastrophic risks still faces the challenges of priority-setting and of avoiding risk-risk (or catastrophe-catastrophe) tradeoffs.⁶⁵

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⁶⁰ McCray et al. (2010); Wiener (2015); Wiener and Ribeiro (2016); IRGC (2017).

⁶¹ Listokin (2008); Wiener and Alemanno (2015).

⁶² Wiener (2016b).

⁶³ Bostrom (2013).

⁶⁴ Wiener (2016b).

⁶⁵ *Ibid.*

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