REGULATING BEST-CASE SCENARIOS

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Over the last decade, an increasingly robust interdisciplinary literature has developed to guide policymakers in managing worst-case scenarios—catastrophes, natural hazards, disasters, and ecological collapse. As of yet, however, there is no reciprocal literature for the opposite of such catastrophic risk: for regulating and managing phenomena that expose society to the possibility of "wonders" or "miracles": extreme-upside events, such as might result from geoengineering, an effective COVID vaccine, successfully colonizing other planets, eradicating mosquito-borne illnesses, curing cancer, or implementing other socially or environmentally transformational new technologies. A careful comparison of the policy implications of extreme-upside outcomes with extreme-downside outcomes suggests at least a partial explanation for the asymmetric attention to extreme-downside events: psychological phenomena like loss aversion lead to greater attention to, and care for, what are perceived as potential extreme losses than for concomitant extreme gains. Unfortunately, while understandable, this asymmetric focus on perceived losses may also generate unnecessary and even counterproductive despair, while simultaneously obscuring extraordinary opportunities for improving social welfare and environmental quality, and for using law and policy to achieve wonderful outcomes.

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I. INTRODUCTION

The last decade has been a gloomy one for risk regulation generally, and for environmental law and policy more specifically. In some ways, this gloom is reasonable: the world faces unprecedented catastrophic risk from climate change, ecosystem degradation, and developing technology—all of which must now be managed in the face of the unfolding COVID-19 pandemic.[1] We now recognize that plants, animals, ecosystems, and countless humans can be placed at global risk not only from single human actions, as might follow from nuclear war, but also from countless individual human actions, such as those that contribute to climate change or communicable disease. The emerging pandemic has only underscored the magnitude of what can happen when many individual behaviors combine to generate mass disaster. Worst-case scenarios—for pandemic, for climate change, for emerging technologies like nanotechnology, genetically modified foods, and artificial intelligence, as well as for nuclear war and nuclear winter—are thus gaining increasing (and deserved) attention, and policymakers are now taking seriously the possibility that humans can generate globally catastrophic events.[2]

But while the new move to incorporate the possibility of extreme environmental and social downsides into social policies is a valuable, even necessary, adaptation in times when human behavior in one area of the globe can truly generate risks for all of mankind, there are downsides to an exclusive focus on the negative.

One set of downsides is psychological. Learning about pending global suffering, mass extinctions, migrations, climate conflicts, thermonuclear winters, and pandemics can be deeply upsetting, frightening, and depressing. In the environmental realm, "ecoanxiety" about these concerns is now a recognized psychological phenomenon. Indeed, research suggests that anxiety about the catastrophes attached to anthropogenic climate change and other environmental disasters is already causing clinical anxiety, post-traumatic stress disorder (PTSD), and depression on a mass scale.[3]

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[1] For a discussion of the emerging impacts of the COVID-19 pandemic on environmental law in particular, see generally Arden Rowell, *COVID-19 and Environmental Law*, 50 ENV'T L. REP. 10881 (2020).

[2] *See infra* Part I.

[3] *See* SUSAN CLAYTON ET AL., AM. PSYCHOLOGICAL ASS'N, MENTAL HEALTH AND OUR CHANGING CLIMATE: IMPACTS, IMPLICATIONS, AND GUIDANCE 27 (2017), https://perma.cc/HE3Z-D6S9 (reporting that the "unrelenting day-by-day despair" caused by climate change "cause some of the most resounding chronic psychological consequences"). *See also* Glenn Albrecht, *Chronic Environmental Change: Emerging 'Psychoterratic' Syndromes*, *in* CLIMATE CHANGE AND HUMAN WELL-BEING 43, 43 (Inka Weissbecker ed., 2011) (reviewing a set of psychological syndromes following from environmental concerns). For a more general treatment of the impact of psychology in environmental law, see ARDEN ROWELL & KENWORTHEY BILZ, THE PSYCHOLOGY OF ENVIRONMENTAL LAW (forthcoming 2021).

But thinking (only) about negatives is not just depressing, it can also distort decision making, undermine decision-making quality, and constrain the ability of individuals and institutions to develop meaningful solutions to policy problems and effective approaches to promoting environmental quality and human flourishing. Indeed, concern about the distorting impact created by thinking only about bad things formed the basis, in psychology, of what is now known as the positive psychology movement.[4] The psychologist Abraham Maslow eloquently sketched his concern about this tendency in his landmark book *Motivation and Personality* (1954), saying:

> The science of psychology has been far more successful on the negative than on the positive side; it has revealed to us much about man's shortcomings, his illnesses, his sins, but little about his potentialities, his virtues, his achievable aspirations, or his full psychological height. It is as if psychology had voluntarily restricted itself to only half its rightful jurisdiction, and that the darker, meaner half.[5]

More recently, Maslow's insights have been picked up by psychologists like Martin Seligman and Mihaly Csikszentmihalyi[6] and Steven Pinker[7] who have charted new directions in exploring positive emotions and motivations, like hope, joy, and aspiration.

Law, like psychology, has a long tradition of focusing on the negative. Consider Holmes's "bad man" theory of human behavior, long unbalanced by a reciprocal "good man" theory;[8] or the sustained attention in law and

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[4] *See* Jeffrey J. Froh, *The History of Positive Psychology: Truth be Told*, NYS PSYCHOLOGIST, May/June 2004, 18, 18, https://perma.cc/KZ3A-4QD3 (providing a brief history of the development of positive psychology).

[5] A. H. MASLOW, MOTIVATION AND PERSONALITY 354 (1954).

[6] *See, e.g.*, Martin E. P. Seligman & Mihaly Csikszentmihalyi, *Positive Psychology: An Introduction*, 55 AM. PSYCHOLOGIST 5, 5 (2000) (arguing that "[a] science of positive subjective experience, positive individual traits, and positive institutions promises to improve quality of life and prevent the pathologies that arise when life is barren and meaningless").

[7] *See, e.g.*, STEVEN PINKER, ENLIGHTENMENT NOW: THE CASE FOR REASON, SCIENCE, HUMANISM AND PROGRESS (2018) (considering enlightenment through the values of reason, science, and humanism which, in turn, create progress, and marking a series of positive developments in the world that tend to be psychologically discounted); STEVEN PINKER, THE BETTER ANGELS OF OUR NATURE: WHY VIOLENCE HAS DECLINED (2011) (asserting that violence has declined and that modern day is the most peaceable era for our species).

[8] *See* O.W. Holmes, *The Path of the Law*, 10 HARV. L. REV. 457, 461 (1897) (discussing the relationship of legal duty and morals in regards to what defines a bad man). *Cf.* H.L.A. HART, THE CONCEPT OF LAW 40 (3rd. ed. 2012) (criticizing Holmes' approach on several grounds, including that it undervalues "the ways in which the law is used to control, to guide, and to plan life out of court;" even Hart, however, offered only the possibility of the "puzzled man" or the "ignorant man" in contrast to the "bad man"—rather than any affirmative concept of the "good man."). *But see* Marco Jimenez, *Finding the Good in Holmes's Bad Man*, 79 FORDHAM L. REV. 2069, 2072–73 (2011) (tracking the development and influence of Holmes's "bad man" theory, and presenting an alternative "good man" theory based on presumptions of moral behavior).

economics, following Coase, to "transaction costs," without a similar concurrent literature for "transaction benefits."[9]

Indeed, as this Article shall discuss, there are deep cognitive reasons why people—in law, psychology, or any field—tend to focus on the negative.[10] This negative focus in the law has not been complete—some of the fruits of positive psychology research, for instance research on subjective happiness,[11] have made their way into legal literatures in many areas—and yet, the dark and negative side of human behavior and legal impacts remain by far the norm within many subfields. This may be particularly true in environmental law—where the common feeling remains there is a great deal to be reasonably gloomy about. Even within environmental policy—a broader field than environmental law alone—it is rare (though not impossible) to find optimistic voices.[12]

I am increasingly concerned that the dispositional gloominess of environmental law—with its focus on losses, degradation, disasters, and crisis—generates real costs. The psychological and emotional cost is grave enough, and might even generate political distortions, insofar as it leads people to avoid thinking about—and thus acting on—depressing information.[13] But there is also the analytical cost: namely, the general

9 *See* R.H. Coase, *The Problem of Social Cost*, 3 J.L. & ECON., Oct 1960, at 1, 15 (presenting the classic account of transaction costs); Carl J. Dahlman, *The Problem of Externality*, 22. J.L. & ECON. 141, 142 (1979) (explaining that "in the theory of externalities, transaction costs are the root of all evil"); Harold Demsetz, *The Problem of Social Cost: What Problem? A Critique of the Reasoning of A.C. Pigou and R.H. Coase*, 7 REV. L. & ECON. 1, 10 (2011) (arguing that transaction costs are really just costs that should be figured into the calculation of efficient outcomes—but again, without addressing benefits); Lee Anne Fennell, *The Problem of Resource Access*, 126 HARV. L. REV. 1472, 1477 (2013) (providing a thoughtful analysis of the centrality of transaction costs in property theory, but with no treatment of transaction benefits); Carol M. Rose, *The Shadow of* The Cathedral, 106 YALE L.J. 2175, 2184 (1997) (providing an influential typology of transaction costs—with no related typology for transaction benefits); Richard N. Langlois, *The Secret Life of Mundane Transaction Costs*, 27 ORG. STUD. 1389, 1389–90 (2006) (presenting another analysis of transaction cost absent benefits).

10 *See infra* Part I.B.1. *See also* ROWELL & BILZ, *supra* note 3 (describing the phenomenon of loss aversion as it applies both generally and to environmental questions).

11 *See, e.g.*, JOHN BRONSTEEN ET AL., HAPPINESS & THE LAW (2014) (pulling on research addressing the psychology, neuroscience, and economics of happiness, and applying that research to law and policy seeking to improve social welfare).

12 One counterexample is what is sometimes called the "bright green" movement, based on a term originally coined by author Alex Steffen. *See* Alex Steffen, *Bright Green, Light Green, Dark Green, Gray: The New Environmental Spectrum*, WORLD CHANGING (Feb. 27, 2009), https://perma.cc/5K2R-R3JT (distinguishing between different approaches to environmentalism, and describing bright green environmentalism as distinctive for its focus on finding sustainable and environmental solutions through a convergence of technological change and social innovation). Though by no means (yet?) mainstream in environmental policy or law, this movement has gained some policy traction. The city of Vancouver, for example, incorporated bright green environmentalism into its strategic planning document. *See* VANCOUVER 2020: A BRIGHT GREEN FUTURE 6 (2016) (describing the city's strategy to achieve a "bright, green future.").

13 *See, e.g.*, ROWELL & BILZ, *supra* note 3 (describing psychological phenomena that may lead people to "turn off" politically from depressing environmental information).

tendency people exhibit to focus on losses may obscure real and meaningful opportunities to improve the environment and to promote human flourishing. To be clear, these psychological and analytical costs may apply in any field that manages large-magnitude risks and opportunities, including in conflict and the laws of war, technology policy, and public health, as well as in environmental law and policy. Yet as Kenworthey Bilz and I have argued at length elsewhere, environmental law is distinctively vulnerable to a set of cognitive, emotional, and motivational phenomena that make people subject to heuristic shortcuts, and to emotional and motivational distortions.[14] As a result, people often struggle to perceive, understand, and attach value to environmental impacts.[15] The psychological challenges inherent within environmental law, combined with the potential for environmental change to have extraordinary magnitude, may help to explain why environmental law and policy has developed such a focus on downsides.

Yet, as with Maslow's concern about the field of psychology, it is worrisome for legal scholarship to have "voluntarily restricted itself to only half its rightful jurisdiction"—"the darker, meaner half."[16] On the other hand, past preoccupation with downsides may mean that there are now marvelous and exciting opportunities to reimagine the positive side of human behavior and environmental quality. People have the potential to do great things as well as terrible; perhaps they have the capacity to make the world better as well as worse. Law should work to preserve this possibility, and seek out opportunities to purposefully harness the power of people to create anti-catastrophes: to generate extraordinary and wonderful things.

Of course, risk regulation and legal policy often already account for the possibility of *some* good things happening: the practice of regulatory cost-benefit analysis, for example—now so influential within U.S. regulation—carefully systemizes consideration of the positive impacts of proposed regulations, and in fact, as currently practiced, generally requires the expected positive impact of a regulation to exceed its expected negatives.[17] Yet even this relatively systematic approach allows for substantial discretion in determining which impacts will be identified and quantified.[18] This discretion is psychological as well as institutional:

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14 *See id.*

15 *See id.*

16 MASLOW, *supra* note 5, at 354.

17 *See* Exec. Order No. 12,866, 58 Fed. Reg. 51,735 (Oct. 4, 1993) (requiring that expected regulatory benefits "justify" expected costs). *See also* OFFICE OF MGMT. & BUDGET, EXEC. OFFICE OF THE PRESIDENT, OMB CIRCULAR A-4, REGULATORY ANALYSIS (2003). For a discussion of the centrality of cost-benefit analysis within U.S. environmental law in particular, see ARDEN ROWELL & JOSEPHINE VAN ZEBEN, A GUIDE TO U.S. ENVIRONMENTAL LAW 79–89 (forthcoming 2021).

18 *See* ROWELL & BILZ, *supra* note 3, at 266 (explaining that "cost-benefit analysis is dependent upon the identification of costs and benefits to compare," and that this makes it subject to psychological biases and heuristics that affect people's ability to notice and care about some kinds of impacts). *See also* Cass R. Sunstein, *The Limits of Quantification*, 102

it allows for the operation of significant psychological heuristics and biases in determining which benefits or costs make their way into the analysis.[19] It may also lead to a failure to notice, care about, and, therefore, include whole categories of benefits.[20]

Unfortunately, the possibility of extremely large positive outcomes is one category of benefits that is systematically neglected within cost-benefit analysis and other serious legal and regulatory analysis . This neglect is particularly striking because of the increased and increasingly systematic treatment of the reciprocal of such benefits, in the form of catastrophe and disaster risk management. In some ways, the neglect and sometimes outright omission of the possibility of extremely large benefits, which present the best-case scenario for many regulations, may be a symptom of what may be a larger tendency in law and regulatory policy to undervalue benefits. Yet, even as a category unto itself, the analytical neglect of extreme-upside benefits is worth recognizing and interrogating.

The first task in the road to establishing extreme-upside impacts as a legitimate field of inquiry—in environmental law or indeed elsewhere in risk regulation—is to simply show extreme-upside policy events can happen, and that their likelihood or occurrence might be affected by policy choices. This observation, in turn, can ground a straightforward set of initial prescriptions, which can be used to improve environmental policy analysis and risk regulation. The claim here is not meant to be an extreme one. I am not claiming, for instance, that no one in environmental law or policy ever thinks about anything good. Rather, I argue that, while extremely *bad* things—catastrophes—are increasingly given the careful policy attention they deserve, that attention is asymmetric, and widely neglects the positive possibilities at the other end of the impact spectrum. Or, in other words, while policymakers are (rightly) paying more and more rigorous attention to *worst*-case scenarios, there is no similar movement towards regularizing consideration of *best*-case scenarios. As a result, we may be adopting policies that underprovide extreme-upside impacts—we may be dismantling our wonders before they ever have the chance to be built.

These basic claims—extreme-upside events can happen; their likelihood can be affected by policy; they are therefore worth the attention of policymakers—comprise the first and fundamental claims of this Article. Early literature on catastrophe policy had a similarly modest set of goals.[21] Early catastrophe scholars, however, did not have the luxury

CALIF. L. REV. 1369, 1371 (2014) (detailing challenges regulators face in quantifying benefits).

19 *See* ROWELL & BILZ, *supra* note 3.

20 *See id.*

21 *See, e.g.*, Richard Posner's early call for law and policy to take "catastrophic risks seriously and address[] them constructively." RICHARD A. POSNER, CATASTROPHE: RISK AND RESPONSE 8 (2005) [hereinafter CATASTROPHE: RISK AND RESPONSE]. *See also* Matthew D. Adler, *Policy Analysis for Natural Hazards: Some Cautionary Lessons from Environmental Policy Analysis*, 56 DUKE L.J. 1, 2 (2006) (criticizing scholars and policymakers for having

of a pre-existing scholarly literature on the management of extreme-impact events. Such a literature now exists in the form of the catastrophe literature itself. This pre-existing literature allows for two useful extensions in best-case-scenario analysis that would not have been available to early catastrophe scholars: first, in exploring the similarities between catastrophe and wonder management; and second, in exploring what (if anything) is so distinctive about wonders (or catastrophes) that it is sensible to treat them differently from one another. These two applications limit one another: to the extent extreme-upside and downside scenarios are merely flip sides of the same coin, the catastrophe literature can be leveraged to generate valuable insights for managing upsides. To the extent they are importantly different, extreme-upsides and catastrophes may justify different and even asymmetric policy responses—though in this case, it would be best if this asymmetry were deliberate rather than inadvertent. My secondary goal, then, is to build on the existing catastrophe literature to generate tools for managing the possibility of extreme policy upsides that are sensitive both to important similarities between extreme-upsides and catastrophes, and to where there are important differences.

To these ends, the remainder of this Article is structured as follows. Part II attempts to establish there is, in fact, a gap—in common parlance as well as scholarship—in the treatment of enormously beneficial events, and of the possibility of best-case scenarios. Generally speaking, the neglect of extreme-upsides is so acute that regulatory analysis lacks even a term for these sorts of impacts—even as it discusses catastrophes, disasters, and global catastrophic risks that populate the other end of the regulatory spectrum. In the absence of a pre-existing and commonly recognized term for extreme policy upsides, as I discuss in this Part, I will call policy outcomes with enormously large benefits "wonders" or "miracles."

Part II then argues that, whatever else might explain long-time neglect of wonders (and some ideas are proffered in subsequent Parts), it is not that there are no wonders to generate. The argument that it is possible to generate wonders using policy is presented in two phases: first, by identifying examples of past legal policies that have had transformative, beneficial impacts—including mandated vaccines and air pollution controls—and then, by identifying a set of potential policies that could generate such impacts in the future, such as a treatment or vaccine for COVID or other grave diseases, geoengineering, or colonizing other planets. The takeaway of Part II is that it is possible to use policy to generate transformative benefits. But my more ambitious hope is that by the end of Part II, it will begin to seem bizarre and even perhaps slightly unbelievable that although anti-catastrophe policy is an increasingly robust field, there is no reciprocal field for pro-wonder policy.

"given relatively little systematic attention" to the question of how "policy analysis for natural hazards [should] be structured") [hereinafter *Policy Analysis for Natural Hazards*]. For significant further discussion, see *infra* Part I.

Part III moves more deeply into developing policy prescriptions for wonders, by distinguishing between the ways in which wonders, and catastrophes are similar—and thus may justify similar policy prescriptions—and where they differ, and thus, may demand different policy responses. This extended comparison allows for leveraging of insights from the catastrophe literature to apply where catastrophes and wonders are importantly similar, without—I hope—overgeneralizing where extreme-upside events differ from extreme-downside events in policy-relevant ways. Ultimately, Part III attempts to illuminate whether wonders, like catastrophes, are worthy not only of policy attention but possibly some form of special solicitude.

Part IV explores implications that should follow from the recognition that extreme-upside events can happen, that policy can sometimes contribute to them, and that they are susceptible to analytical neglect. It begins by evaluating the policy impact of current approaches to wonders, noting that adopting asymmetric catastrophe and wonder policies—as policymakers have implicitly done in the past—creates a systematic skew in policies that present possibilities of both catastrophic and wonderful outcomes. When policymakers adopt policy approaches that preference catastrophe prevention while comparatively under-weighting similar-magnitude wonders, they embed a form of institutionalized loss-aversion that should be controversial. It would be a mistake—for all the reasons chronicled in the catastrophe literature—for policymakers to return to neglecting catastrophes. But it is also a mistake—for those same reasons—to continue neglecting wonders; a mistake that in some cases is compounded when catastrophic outcomes are addressed absent treatment of wonderful outcomes. It thus becomes increasingly important for policymakers to develop a systematic approach to addressing extreme upsides, as they continue to incorporate more and more policies' potential extreme downsides.

In the end, the Article concludes with the general takeaways: policies can generate wonders, or events with extremely high-magnitude, positive impacts; current approaches to catastrophe policy, unattended by corollary wonder policy, institutionalize loss-aversion; and it would be preferable for us all to live in environments where policymakers have at least a reflective consideration of the possibility of wonderful, transformative events, even as they continue to also manage potential catastrophes. In the current historical moment, when so much of the world has been turned upside-down waiting for a cure or a treatment for COVID-19, I hope the need for recognizing, investing in, and purposefully generating wonders will be as clear as it is urgent.

II. SETTING THE STAGE: COMPARING REGULATORY TREATMENT OF WORST- AND BEST-CASE SCENARIOS

A. Managing Catastrophes

There is a robust and growing literature dedicated to the management of extreme-downside risks. This literature, situated within a larger body of work on risk analysis and risk management, is distinctive for its focus on extreme-downside events and for its increasing attempts to develop policy tools for addressing risks with small probability, very high magnitude, or both.

1. The Genesis of Modern Catastrophic Risk Management

Until the turn of the 21st century, serious scholarly work on catastrophe policy was unusual. Scholars addressing disaster ran the risk of being branded as crackpot "doomsayers," "dismissed as fanatics on the left (limits-to-growth alarmists crying wolf) or on the right (religious zealots who may even invite the end)."[22] At the turn of the century, however, two things started to change.

First, through the 1990s and 2000s, high-impact negative events began increasing in magnitude and frequency. [23] This was in large part because of increases in climate-related natural disasters,[24] although

[22] *See* Jonathan Wiener, *Book Review*, 24 J. POLICY ANALYSIS & MGMT. 885, 887 (2005) (reviewing RICHARD A. POSNER, CATASTROPHE: RISK AND RESPONSE (2005)).

[23] Until the 1990s, insurers often bore their own catastrophe risk, but by the late 1990s, this had become increasingly impossible. *See* Paul R. Kleindorfer & Howard C. Kunreuther, *Challenges Facing the Insurance Industry in Managing Catastrophic Risks*, *in* THE FINANCING OF CATASTROPHE RISK 149, 149 (Kenneth A. Froot ed., 1999) (explaining, as early as 1999, that "[t]he private insurance industry feels that it cannot continue to provide coverage against hurricanes and earthquakes as it has done in the past without opening itself up to the possibility of insolvency or a significant loss of surplus. This concern stems from a series of natural disasters in the United States since 1989 that have resulted in unprecedented insurance loss"). Many in the insurance industry perceived the increase in risk to be a sudden one: although Hurricane Hugo in 1989 marked the first instance of the insurance industry being subject to losses from a single disaster exceeding $1 billion, there were ten more disasters exceeding this amount in the following decade, including a single event (Hurricane Andrew in 1992) causing insured damages exceeding $15 billion. *Id.* at 149.

[24] For an overview of the impact of climate change on extreme events and weather disasters, see INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, MANAGING THE RISKS OF EXTREME EVENTS AND DISASTERS TO ADVANCE CLIMATE CHANGE ADAPTATION (2012) (describing the impacts of climate change on natural hazard rates and magnitudes, and detailing the challenges of understanding and managing the risks of climate extremes to help advance climate change adaptation). In addition to increasing mega-events, such as Hurricane Katrina (which caused $62 billion in insured losses), even seemingly small and localized climate and weather changes have had significant impact on the exposure of the insurance industry to high-impact and correlated claims. Lloyd's of London, for example, estimates that for Superstorm Sandy, which caused $30 billion in insured losses, "the approximately 20 centimeters of sea-level rise at the southern tip of Manhattan Island increased . . . surge losses by 30% in New York alone." *See* LLOYD'S, CATASTROPHE MODELLING

insurance losses from the terrorist attacks of 9/11 also occurred during the same period.[25] The increase in high-impact disasters created an opportunity for scholars of catastrophe and increased private demand for such work from the insurance industry, which was pressured by the need to insure increasingly common and increasingly bad catastrophic losses.[26]

Second, and perhaps partially in response to then-recent events, two respected scholars—Richard Posner[27] and Jared Diamond[28]—published books that took catastrophe, and catastrophe policy, seriously.[29] The combination of increasing practical relevance and scholarly imprimatur opened the floodgates, and the subsequent decade saw a deluge of work

AND CLIMATE CHANGE (2014), https://perma.cc/S8XF-4B77 (describing the approximate sea level rise around Manhattan Island and how it contributed to Hurricane Sandy's storm surge); *see also* MUNICH RE, LOSS EVENTS WORLDWIDE 1980-2014 (2015), https://perma.cc/53NY-ANTV (depicting the number of catastrophic events worldwide from 1980 to 2014). With the increased frequency and magnitude of insured catastrophes, the importance of risk-spreading to the insurance industry grew substantially around the turn of the 21st century, creating a demand for new and creative mechanisms for managing highly correlated, extreme-downside risks. Though the typical response to this increasing exposure has been for insurers to rely upon catastrophe reinsurance to spread the risk of a sudden and highly correlated influx of catastrophe claims, the industry continues to work on developing additional risk management strategies for spreading and managing catastrophic risk. *See* AM. ACAD. OF ACTUARIES, CATASTROPHE EXPOSURES AND INSURANCE INDUSTRY CATASTROPHE MANAGEMENT PRACTICES 2 (2001) (noting that "[r]einsurance is the traditional method used by insurers to transfer risk," but that "capital markets are a growing source of alternate capacity," and listing "insurance-linked notes and bonds, exchange-traded products, and other structured products" as relevant capital market products).

[25] Insured losses from the terrorist attacks of 9/11 were $32.5 billion, which has been cited as the largest insurance loss in history up to that point. *See* INS. INFO. INST., *Terrorism and Insurance: 13 Years After 9/11 The Threat of Terrorist Attack Remains Real* (Sept. 9, 2014), https://perma.cc/9GAV-ZF8E.

[26] Perhaps in part because of this demand, scholarship on natural hazard policy now forms a rich vein in modern catastrophe scholarship. *See, e.g.*, RISK ANALYSIS OF NATURAL HAZARDS: INTERDISCIPLINARY CHALLENGES AND INTEGRATED SOLUTIONS (Paolo Gardoni et al. eds., 2015); DANIEL A. FARBER ET AL., DISASTER LAW AND POLICY 3 (Wolters Kluwer Law & Business 3rd ed., 2015) (focusing primarily, though not exclusively, on natural hazards); *see generally* NAT'L ACADS. PRESS, DISASTER RESILIENCE: A NATIONAL IMPERATIVE (2012) (describing the increase cost in responding to disasters due to more people and more structures in harm's way as well as the overall effects of the extreme events themselves); DANIEL J. ALESCH ET AL., NATURAL HAZARD MITIGATION POLICY: IMPLEMENTATION, ORGANIZATIONAL CHOICE, AND CONTEXTUAL DYNAMICS (2012).

[27] Richard Posner, one of the founders of modern law and economics, and a widely respected jurist and legal scholar, published CATASTROPHE: RISK AND RESPONSE (2005). *See* CATASTROPHE: RISK AND RESPONSE, *supra* note 21 and accompanying text (discussing early literature on catastrophes and the goals associated with handling them).

[28] Jared Diamond, a Pulitzer-Prize-winning ecologist and science writer, published COLLAPSE: HOW SOCIETIES CHOOSE TO FAIL OR SUCCEED (2005). *See* JARED DIAMOND, COLLAPSE: HOW SOCIETIES CHOOSE TO FAIL OR SUCCEED (2005) (discussing twelve environmental problems that threaten the planet and are globally critical to address).

[29] *See* Wiener, *supra* note 22, at 887 ("The most important quality of these two books . . . is neither the specific risks they assess nor the specific remedies they favor. It is that serious, thoughtful experts are saying that worrying about disaster is not crazy.").

assessing and developing policy approaches and tools for managing and evaluating catastrophic risk.[30]

2. Policy Approaches for Managing Catastrophic Risk

As scholarly and practical approaches to catastrophic risk have developed, it is possible to characterize policymakers' approaches to extreme-downslide events as falling into one of three categories: neglect, addressing expected value (as through cost-benefit analysis), and applying some form of special solicitude (as through the precautionary principle).

First, consider the option of neglect. Policymakers often have the option of minimizing or even omitting extreme-downside risks from their analyses entirely, an approach I am calling "catastrophe neglect." Policymakers do not always have complete discretion in the scope of their analyses, of course; they may be constrained by a number of legal, institutional, or political factors.[31] Yet scoping choices are imbedded into policy analyses in a number of pervasive, though often unstated, ways—as when policymakers choose to omit foreign impacts from domestic policy analyses[32] or to ignore the impacts of current policies on the distant future or on future generations[33]—and can have determinative impacts on policy

[30] As a sampling, *see, e.g.*, ALESCH ET AL., *supra* note 26; GLOBAL CATASTROPHIC RISKS (Nick Bostrom & Milan M. Cirkovic eds., 2011); ROSEMARY LYSTER, CLIMATE JUSTICE AND DISASTER LAW (2015) (discussing the emergence of Disaster Law in America); NAT'L ACADS. PRESS, *supra* note 26 (discussing the federal, state, and local recommendations regarding hazard and disaster policies); POLICY SHOCK: RECALIBRATING RISK AND REGULATION AFTER OIL SPILLS, NUCLEAR ACCIDENTS, AND FINANCIAL CRISES (Edward J. Balleisen, et al., eds., 2017) (describing the effect of major disasters on public awareness and policy approaches); RISK ANALYSIS OF NATURAL HAZARDS: INTERDISCIPLINARY CHALLENGES AND INTEGRATED SOLUTIONS, *supra* note 26 (discussing the interactions between the natural environment, human decisions about the built environment, and social vulnerability in relation to the associated risk management frameworks); CASS R. SUNSTEIN, WORST-CASE SCENARIOS (2009) (detailing how individuals and public officials respond to disasters and the limits of a cost-benefit analysis when dealing with these disasters) [hereinafter SUNSTEIN, WORST-CASE SCENARIOS].

[31] *See, e.g.*, Arden Rowell, *Foreign Impacts and Climate Change*, 39 HARV. ENV'T L. REV. 371, 373–74 (2015) (discussing legal and institutional constraints on agencies in selecting a global versus domestic scope for climate change impacts) [hereinafter Rowell, *Foreign Impacts*].

[32] *See* Arden Rowell & Lesley Wexler, *Valuing Foreign Lives*, 48 GA. L. REV. 499, 502, 562–71 (2014) (identifying "multiple potentially defensible methods" for valuing foreign impacts in domestic policy analyses, including the option of "zero valuation," where foreign impacts are excluded from the analysis).

[33] *See* Arden Rowell, *Time in Cost-Benefit Analysis*, 4 U.C. IRVINE L. REV. 1215, 1230–37 (2014) (discussing the impact of temporal scoping decisions, and particularly temporal cut-off points, on regulatory analysis) [hereinafter Rowell, *Time*]. *See also* Eric A. Posner, *Agencies Should Ignore Distant-Future Generations*, 74 U. CHI. L. REV. 139, 140–42 (2007) (identifying the role of future generations and the ethical weight that should be given towards considering the wants and needs of future generations) [hereinafter Posner, *Agencies*].

outcomes.[34] Such choices to omit a set of policy impacts from an analysis may be accidental or purposeful, atheoretical or justified.[35] It can also be a matter of degree rather than kind, as where agencies undervalue particular types of regulatory impacts, such as environmental impacts,[36] or where legislators allocate minimal or even token funding to large-scale problems or opportunities.[37] While minimization of impacts is a form of neglect, however, it is clearly a more aggressive point to say that Congress or regulators have invested "too little" in particular issues, than to make the more straightforward point that they have neglected an issue when it is omitted entirely from their analyses. And indeed, a focus on omission has special relevance both in administrative law, where "entirely fail[ing] to consider an important aspect of the problem" is one of the core bases for overturning agency action as arbitrary and capricious,[38] and in

[34] *See, e.g.*, Rowell & Wexler, *supra* note 32, at 570–72 (applying and comparing methods of valuation to show that scope can determine whether policies appear cost-justified).

[35] *See, e.g.*, *id.* at 502 (articulating a series of possible deliberate approaches to geographic scoping of domestic policy decisions, while suggesting that much current policy analysis is atheoretical and opaque in omitting foreign impacts from domestic analyses). *See also* Posner, *Agencies*, *supra* note 33, at 140–42 (arguing that distant-future generations should be purposefully excluded from regulatory policy analyses).

[36] *See* ROWELL & BILZ, *supra* note 3, at 213–17 (discussing systematic psychological challenges in valuing environmental impacts, which can lead to undervaluation); Arden Rowell, *The Psychology of Environmental Valuation*, 95 NOTRE DAME L. REV. (forthcoming 2021).

[37] *See, e.g.*, Howard Kunreuther, *Mitigating Disaster Losses Through Insurance*, 12 J. RISK & UNCERTAINTY 171, 174 (1996) (arguing that governments as well as individuals underinvest in otherwise cost-justified disaster precautions); Eric Neumayer et al., *The Political Economy of Natural Disaster Damage*, 24 GLOBAL ENV'T CHANGE 8, 9 (2013) (arguing that governments have political incentives to under-invest in disaster prevention policies and damage mitigation regulations); *It Pays to Prepare for Natural Disasters*, PEW CHARITABLE TR. (May 8, 2017), https://perma.cc/Y9Z5-K4LD (arguing that "while the payoff is clear, the federal government has historically underinvested in [disaster] risk reduction").

[38] *See* Judulang v. Holder, 565 U.S. 42, 64 (2011) (holding that the method used by the Board of Immigration Appeals' method for adjudicating deportation relief was arbitrary because the agency completely failed to consider important factors); Motor Vehicle Mfrs. Ass'n v. State Farm Mut. Auto. Ins. Co., 463 U.S. 29, 57 (1983) (interpreting Administrative Procedure Act, 5 U.S.C. § 706(2)(A) (2018), and providing the touchstone standard for arbitrary and capricious review, such that an agency decision is arbitrary "if the agency has relied on factors which Congress has not intended it to consider, entirely failed to consider an important aspect of the problem, offered an explanation for its decision that runs counter to the evidence before the agency, or is so implausible that it could not be ascribed to a difference in view or the product of agency expertise."). *See, e.g.*, Ctr. for Biological Diversity v. NHTSA, 538 F.3d 1172, 1200 (9th Cir. 2008) (overturning the Department of Transportation's complete omission of climate change impacts from its regulatory analyses as arbitrary and capricious, because "while the record shows that there is a range of values, the value of carbon emissions reduction is certainly not zero"). Although giving clearly insufficient weight to an issue can still be arbitrary and capricious—*State Farm* itself overturned the Department of Transportation's passive restraint rule not only for failing to consider important aspects of the problem, but also because it failed (in the court's view) to attach appropriate weight to the factual evidence supporting the benefits of automatic seatbelts—courts are often hesitant to evaluate whether agency actors have attached the appropriate weight to an issue that they have considered. *See, e.g.*, FCC v. Fox Television Stations, Inc., 556 U.S. 502, 513 (2009) (articulating concern that "a court is not to substitute its judgement for that of the agency"). *See also* Thomas J. Miles & Cass Sunstein, *The Real World of*

environmental law, where there are multiple procedural requirements to "consider" environmental impacts, even where the weight to be attached to those impacts is left to policymaker discretion.[39] Thus, although later analyses may expand to include minimization as well, the analysis of neglect in this Article focuses on the most straightforward instances, which are of omission rather than minimization.

And indeed, for many years, catastrophe neglect was the default across multiple policy contexts. In fact, early catastrophe scholars were primarily concerned with encouraging policymakers to move away from catastrophe neglect.[40] Richard Posner's primary concern in his book, *Catastrophe*, for example, was that "law, policy, and the social sciences" were not "taking . . . catastrophic risks seriously and addressing them constructively."[41] Accordingly, the book is given over to convincing readers and policymakers that very high-impact extreme events (like asteroid strike, a pandemic of gene-spliced smallpox, or a strangelet disaster) are sufficiently likely to warrant careful study.[42] Similarly, Jared Diamond's book, *Collapse: How Societies Choose to Fail or Succeed*, was devoted to convincing readers and policymakers societies can (and have) collapsed because of ecological and environmental damage, and a society's responses to its environmental problems can be significant in

Arbitrariness Review, 75 U. CHI. L. REV. 761, 776–84 (2008) (evaluating the extent to which arbitrary and capricious decisions by judges may reflect political views or ideology of judges).

[39] *See* National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321–4370h (2012); Robertson v. Methow Valley Citizens Council, 490 U.S. 332, 350 (1989); Strycker's Bay Neighborhood Council v. Karlen, 444 U.S. 223, 227–28 (1980). *See also* discussion *infra* Part II.C.1.

[40] *See, e.g.*, *Policy Analysis for Natural Hazards*, *supra* note 21, at 2, 4 (arguing that academics had "given relatively little systematic attention" to the question of how "policy analysis for natural hazards [should] be structured," and that "academics and policymakers need to engage in more sustained discussion about how to evaluate the threats that natural hazards pose to human life, health, property, and other human interests, and the desirability of governmental policies for reducing those threats"). *See also* DIAMOND, *supra* note 28, at 14–15, 522 (including society's response to problems and long-term planning in a comparative analysis of societal collapses to which environmental problems contribute); CATASTROPHE: RISK AND RESPONSE, *supra* note 21, at 8 (encouraging those in the fields of law, policy, and social sciences to start taking catastrophic risk seriously and addressing it constructively).

[41] *See* CATASTROPHE: RISK AND RESPONSE, *supra* note 21, at 8 (explaining the author's reasoning for writing the book).

[42] *Id.* at 6–8, 12–14. The book focused on the role of policymaking and institutions in affecting very extreme-downside risks: globally catastrophic events with very low or unknown probabilities, and very high impacts, which would threaten human survival, or all life on Earth. Posner worried that unlikely but enormous risks—massive asteroid strike; abrupt, runaway climate disruption leading to a hothouse or snowball planet; the creation of a "strangelet" cluster of quarks in a particle accelerator that converts the Earth (and possibly the universe) into a lump of particles; the conversion of all biomass into grey goo via buggy molecular nanotechnology; extinction-level bioterrorism—are subject to neglect by policymakers, because they seem so extraordinarily unlikely. At the same time, he worried that neglect of these scenarios was dangerous, not least because many of them offer no warning signs, little or no time to respond, and no opportunity for second chances.

determining the likelihood of future disaster.[43] For both of these authors, catastrophe neglect was the chief harm they sought to remedy.

One clear alternative to catastrophe neglect is the calculation of catastrophes' expected value. In fact, Posner's primary prescription for responding to catastrophe neglect was to encourage the use of catastrophe policies' expected value in cost-benefit analyses.[44] This approach requires calculation of two things: the expected probability of a catastrophe occurring and a quantified estimate of its magnitude.[45] As such, the approach provides guidance to policymakers (only) when policymakers can develop meaningful estimates of both the probability and the magnitude of catastrophes.[46]

Using expected value to evaluate catastrophic losses, however, poses two important limitations. First, catastrophic losses tend to be highly correlated.[47] For private (and even sometimes public) insurers, this can create significant liquidity demands and therefore generate insolvency and other systemic risks.[48] Second, expected value calculations, such as those used in cost-benefit analysis, are notoriously poor at managing conditions of uncertainty where there is insufficient information to calculate probabilities or the extent of possible damage.[49] One response to these limitations is to invest further in developing better estimates of magnitude and probability.[50] But where this approach is ineffective, or

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[43] In *Collapse*, Jared Diamond wrote particularly of the risks created by resource depletion—risks not just of slow decline, but of (eventual) complete environmental and social failure. *See* DIAMOND, *supra* note 28, at 486–521. Building on a then-growing strand of research in archaeology and environmental biology, he chronicled, depressingly, society after society where mis- and over-use of resource leads, in his view, to economic and political ruin: Easter Island, the Mayans, Pitcairn and Henderson Island, the Anasazi, Norse Greenland, the Khmer Empire, Rwanda, Haiti. *Id.* at 20–22.

[44] *See* CATASTROPHE: RISK AND RESPONSE, *supra* note 21, at 8 (discussing that "cost-benefit analysis of possible responses has unexplored potential"). *See also* Richard A. Posner, *Efficient Responses to Catastrophic Risk*, 2 CHI. J. INT'L L. 511, 511–12, 515 (2006) (arguing the role economic analysis and cost-benefit analysis has to play regarding devising responses to catastrophic risk).

[45] For an authoritative overview of the theoretical foundations of cost-benefit analysis, see MATTHEW D. ADLER & ERIC POSNER, NEW FOUNDATIONS OF COST-BENEFIT ANALYSIS (2009). For a discussion of the analytical requirements of cost-benefit analysis as applied to natural hazards, see *Policy Analysis for Natural Hazards*, *supra* note 21, at 5–6.

[46] For discussion of some of the complexities of these calculations, as well as some ideas about how to address those complexities, see HOWARD KUNREUTHER & ADAM ROSE, THE ECONOMICS OF NATURAL HAZARDS (2004).

[47] *See* AM. ACAD. OF ACTUARIES, *supra* note 24, at 7 (explaining that "[s]ignificant or high correlation among exposures is a key feature of catastrophe risk").

[48] *See id.* at 1 (explaining that "[c]atastrophe exposures place special demands on insurer capitalization and require a distinct risk management approach").

[49] *See* Daniel A. Farber, *Uncertainty*, 99 GEO. L.J. 901, 907–09 (2011) (discussing conventional risk assessment, cost-benefit analysis, and the blind spots associated with these types of analyses) [hereinafter Farber, *Uncertainty*]; Cass R. Sunstein, *Irreversible and Catastrophic*, 91 CORNELL L. REV. 841, 876 (2006) (discussing the difference between acting in a situation of uncertainty versus acting in a situation of risk).

[50] This was Richard Posner's response to these challenges in CATASTROPHE: RISK AND ASSESSMENT. Posner attempted to generate monetary figures to represent the quantified

where policy decisions must be made prior to the acquisition of additional information, cost-benefit analysis struggles to manage existing uncertainty.[51]

Many scholars believe that these limitations are at least partially addressed by a third approach to addressing catastrophic risk, which is to offer it some form of special solicitude beyond what would be justified by an expected-value analysis. The most familiar and widespread implementation of this approach is the precautionary principle, an approach to risk management that attempts to prioritize (some) risks so as to be "better safe than sorry."[52] The trigger for and extent of special solicitude offered to risks via precautionary principles varies widely.[53] One of the most popular formulations, however, has come to address catastrophic risk.[54]

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value of extinction of the human race (a figure he calculated "conservatively" at $600 trillion, by multiplying a very-low $50,000 value of a statistical life by the projected population of the Earth), and to assign back-of-the-envelope probabilities to the catastrophes he addressed. *See, e.g.*, CATASTROPHE: RISK AND RESPONSE, *supra* note 21 , at 31 (conceding that his estimates of likely particle accelerator catastrophe were "speculat[ive]"). These attempts at calculation were criticized on a number of grounds. *See, e.g.*, Lisa Heinzerling, *The Accidental Environmentalist: Judge Posner on Catastrophic Thinking*, 94 GEO. L.J. 833, 834 (2006) (arguing that "Posner unfortunately mars what could have been a good, humble, important book with his continued insistence on the central role of cost-benefit analysis and with futile efforts to patch up the holes in the analysis he favors"); SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 214–18 (criticizing the methodology of Posner's monetization, while accepting the helpfulness of monetization as a project). Posner responded to some of these criticisms in his later article. *See* Posner, *Efficient Responses to Catastrophic Risk*, *supra* note 44, at 512–13 (discussing the determination of costs and considering both high- and low-probability catastrophic risks).

[51] *See* Sunstein, *Irreversible and Catastrophic*, *supra* note 49, at 889–90 (presenting a thorough though sympathetic discussion of the problems uncertainty presents to cost-benefit analysis); *see also* Farber, *Uncertainty*, *supra* note 49, at 909 (discussing the quantification of risk analysis).

[52] For an authoritative treatment of precautionary principles as they are used around the world, see JONATHAN B. WIENER ET AL., THE REALITY OF PRECAUTION: COMPARING RISK REGULATION IN THE UNITED STATES AND EUROPE 3 (2010). *See also* CASS SUNSTEIN, LAWS OF FEAR: BEYOND THE PRECAUTIONARY PRINCIPLE 5 (2006) (arguing that precautionary principles are necessarily selective about the risks they prioritize) [hereinafter SUNSTEIN, LAWS OF FEAR]. The principle remains particularly central to European environmental law. *See* JOSEPHINE VAN ZEBEN & ARDEN ROWELL, A GUIDE TO EU ENVIRONMENTAL LAW 77–87 (forthcoming 2021).

[53] *See* WIENER ET AL., *supra* note 52, at 184–85 (comparing various applications in the U.S. and Europe); Jonathan Wiener, *The Rhetoric of Precaution*, in THE REALITY OF PRECAUTION: COMPARING RISK REGULATION IN THE UNITED STATES AND EUROPE 3, 3–4 (2011) (laying out the principle's popularity and outlining its ascent, particularly in environmental contexts). Though it remains controversial, the precautionary principle has become a particularly central approach to regulating environmental harm around the world. *See, e.g.*, Daniel Bodansky, *Deconstructing the Precautionary Principle*, *in* BRINGING NEW LAW TO OCEAN WATERS 381, 381 (D.D. Caron & H.N. Scheiber eds., 2004) ("If international environmental law were to develop Ten Commandments, the precautionary principle would be near the top of the list"); Sunstein, *Irreversible and Catastrophic*, *supra* note 49, at 841, 843–45, 848–53 (detailing the precautionary principle used in many international documents).

[54] *See* SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 1, 118–19.

The debate between cost-benefit and precautionary approaches to risk management remains a staple of risk analysis, particularly within environmental law.[55] Notably, however, catastrophic risk presents a space where familiar battle lines are differently shaped. Even passionate proponents of cost-benefit analysis and critics of the precautionary principle for *non*-catastrophic risks have come out in favor of using some form of special solicitude for catastrophes.[56] Cass Sunstein, for example, has rejected the precautionary principle as ineffective, misleading, and fundamentally subject to cognitive bias in other contexts.[57] He wrote an entire book—*Worst-Case Scenarios*—however, addressing the unusual qualities of catastrophes, advocating for an "Anti-Catastrophe Precautionary Principle," and exploring multiple potential formulations of such a principle that might offer different levels of special solicitude.[58]

Why prioritize catastrophic risks over and above what might be justified by those risks' expected value? Commentators have proffered a range of explanations for offering special solicitude in discussions of

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[55] *Compare, e.g.*, SUNSTEIN, LAWS OF FEAR, *supra* note 52, at 3–4, 6 (2005) (suggesting that cost-benefit analysis has an advantage over the precautionary principle in the context of risk assessment), *and* RICHARD L. REVESZ & MICHAEL A. LIVERMORE, RETAKING RATIONALITY: HOW COST-BENEFIT ANALYSIS CAN BETTER PROTECT THE ENVIRONMENT AND OUR HEALTH 3, 9–10 (2010) (challenging the "liberal camp to rethink its position on cost-benefit analysis"), *with* Gregory N. Mandel & James Thuo Gathii, *Cost-Benefit Analysis Versus the Precautionary Principle: Beyond Cass Sunstein's* Laws of Fear, 5 U. ILL. L. REV. 1037, 1078 (2006) (recommending a reconceptualization of the precautionary principle that would address common criticism levied against it, particularly from Sunstein), *and* DOUGLAS A. KYSAR, REGULATING FROM NOWHERE: ENVIRONMENTAL LAW AND THE SEARCH FOR OBJECTIVITY 21–22 (2010) (addressing the limitations of regulatory cost-benefit analysis). Though most scholars continue to think of the two approaches as distinct, a few scholars have tried to reconcile them. *See, e.g.*, David M. Driesen, *Cost-Benefit Analysis and the Precautionary Principle: Can They be Reconciled?*, 2013 MICH. ST. L. REV. 771, 771–73 (2013) (concluding that cost-benefit analysis is "impossible without either a precautionary or anti-precautionary approach" and that "precaution might prove possible *within the [cost-benefit analysis] framework*").

[56] *See, e.g.*, Sunstein, *Irreversible and Catastrophic*, *supra* note 49 (discussed *infra*); CATASTROPHE: RISK AND RESPONSE, *supra* note 21, at 14, 148 (arguing for a form of cost-benefit analysis with risk aversion for uncertain catastrophes).

[57] *See* Sunstein, *Irreversible and Catastrophic*, *supra* note 49, at 841 (arguing that "when catastrophic outcomes are possible, it makes sense to take special precautions against the worst-case scenarios—the Catastrophic Harm Precautionary Principle"); SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 119 (advocating for an "Anti-Catastrophe Precautionary Principle"). *See also* SUNSTEIN, LAWS OF FEAR, *supra* note 52, at 5–6. *But cf.* Cass R. Sunstein, *Beyond the Precautionary Principle*, 151 U. PA. L. REV. 1003, 1003 (2003) (arguing that common forms of the precautionary principle "lead[] in no direction at all," and only appear to offer guidance because of asymmetric focus created by behavioral biases such as loss aversion and the availability heuristic) [hereinafter Sunstein, *Beyond*]. *See* SUNSTEIN, LAWS OF FEAR, *supra* note 52, at 5–6.

[58] *See* SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30 (contrasting a "modest" form of the principle that would look much like an expected-value analysis, to a "mildly more aggressive version" that would account for the social amplification of risk). *See also* CATASTROPHE: RISK AND RESPONSE, *supra* note 21, at 265 (indicating a willingness to adopt a form of cost-benefit analysis "with risk aversion"—a form of special solicitude—for catastrophes whose probabilities cannot be identified).

catastrophic risk. These include the size of the catastrophe; potential uncertainty; the distribution of impacts through time; and the cognitive limitations each of these factors implicate from members of the public and from policymakers who attempt to process their size, uncertainty, and intertemporal distribution.[59]

Each of these arguments has been used as a justification not only for paying some attention to catastrophes, but for attaching a kind of social premium to reducing catastrophic risk. These are reasonable arguments, the boundaries and limitations of which are discussed in more detail below.[60] Before examining those arguments in greater detail,[61] however, it is important to note that, at least at first blush, each of these same arguments might reasonably apply not only to the possibility of extreme-*downside* events (i.e., catastrophes), but also to the possibility of extreme-*upside* events, where the impacts of possible policies are enormously good rather than enormously bad. As is the case with catastrophes, upside events might be large; might offer uncertain outcomes; might engender potential irreversibility while affecting intertemporal distributions; and might trigger cognitive heuristics and biases related to size, probability, and time. And yet, in regard to these happy events, the risk management literature remains strangely quiet—so quiet risk management lacks even a commonly-used word to denote extreme upside events.

B. Catastrophe and Its Opposite

1. Setting the Stage

Although the Greek word *katastrophē* (καταστροφή) is often translated as "destruction" or "disaster,"[62] its etymology grounds its meaning in transformation: from *kata-* ("over") + *strophē* ("turning").[63] It is this etymology that explains, perhaps, the use of the word to also describe the final act in a tragedy.[64]

Of course, overturning and final acts need not always be tragic. But our vocabulary to describe such happy events remains sadly scarce. In a

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59 *See infra* Part III.

60 *See infra* Part III.

61 *See infra* Part IV.

62 *See Catastrophe*, MERRIAM-WEBSTER DICTIONARY, https://perma.cc/8XHD-8N2P (last visited Sept. 11, 2020) (providing as its first definition (1) "a momentous tragic event ranging from extreme misfortune to utter overthrow or ruin"); *Catastrophe*, OXFORD LIVING DICTIONARIES (North American English), https://perma.cc/LYR2-PE7P (last visited Sept. 11, 2020) ((1) "An event causing great and often sudden damage or suffering; a disaster.").

63 *See Catastrophe*, OXFORD LIVING DICTIONARIES, https://perma.cc/LYR2-PE7P (last visited Sept. 15, 2020) (noting that *strophē* is from the verb *streiphen* ("to turn")).

64 *See Catastrophe*, MERRIAM-WEBSTER DICTIONARY, https://perma.cc/8XHD-8N2P (last visited Sept. 11, 2020) (providing as its fourth definition (4) "the final event of the dramatic action especially of a tragedy," and explaining that the earliest adoptions of the Greek word into English were for the purpose of describing the final act of a dramatic work).

remarkable essay "On Fairy-Stories," linguist and author J.R.R. Tolkien wrote of this linguistic gap,[65] coining the word *eucatastrophe*[66] to capture "the sudden happy turn in a story which pierces you with a joy that brings tears."[67] Thinking, perhaps, of both the critics' response to his fiction and of the unfolding narrative of WWII, Tolkien wrote in defense of "fairy-stories" like *The Hobbit* and *Lord of the Rings*, arguing passionately for the relevance and importance of beliefs in the possibility of happy endings. Such beliefs should not, he argued, be dismissed as foolish or trivial:

> [T]he joy of the happy ending: or more correctly of the good catastrophe, the sudden joyous "turn". . . : this joy, which is one of the things which fairy-stories can produce supremely well, is not essentially "escapist," nor "fugitive". . . . It does not deny the existence of *dyscatastrophe*, of sorrow and failure: the possibility of these is necessary to the joy of deliverance; it denies . . . universal final defeat and in so far is evangelium, giving a fleeting glimpse of Joy, Joy beyond the walls of the world, poignant as grief.[68]

In a long letter to his youngest son a few months after D-Day, and a half-year before the final capitulation of Nazi Germany to the Allies, Tolkien spoke longingly of this notion of "good catastrophes," and of the role of the idea in his own work:[69] "I knew I had written a story of worth in 'The Hobbit' when reading it (after it was old enough to be detached from me) I had suddenly in a fairly strong measure the 'eucatastrophic' emotion at Bilbo's exclamation: 'The Eagles! The Eagles are coming!'"[70]

For Tolkien, as for his friend and contemporary C.S. Lewis, this concept of a "good catastrophe" had inescapable religious overtones.[71]

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65 J.R.R. Tolkien, *On Fairy-Stories*, *in* THE MONSTERS AND THE CRITICS AND OTHER ESSAYS 153 (1983) ("Tragedy is the true form of Drama, its highest function; but the opposite is true of Fairy-story. Since we do not appear to possess a word that expresses this opposite — I will call it Eucatastrophe. The eucatastrophic tale is the true form of fairy-tale, and its highest function.") [hereinafter Tolkein, *On Fairy-Stories*].

66 From the Greek *eu* ("good") + *kata* ("over") + *strophē* ("turning"). *Eu*, OXFORD LIVING DICTIONARIES, https://perma.cc/8BMV-L54D (last visited Sept. 12, 2020); *Cata*, OXFORD LIVING DICTIONARIES, https://perma.cc/7B6V-CLZY (last visited Sept. 14, 2020); *Strophe*, OXFORD LIVING DICTIONARIES, https://perma.cc/499A-FQ8W (last visited Sept. 14, 2020).

67 *See* J.R.R. Tolkien, *Letter 89* (Nov. 7–8, 1944), *in* THE LETTERS OF J.R.R. TOLKIEN 99–102 (1981) (writing to his son, Christopher Tolkien, of the essay and explaining that "I have coined the word 'eucatastrophe,' the sudden happy turn in a story which pierces you with a joy that brings tears (which I argued it is the highest function of fairy-stories to produce).") [hereinafter, Tolkien, *Letter 89*].

68 Tolkien, *On Fairy-Stories*, *supra* note 65, at 153 (emphasis added).

69 Tolkien, *Letter 89*, *supra* note 67, at 100.

70 *Id.* at 101.

71 *See* Tolkien, *On Fairy-Stories*, *supra* note 65, at 153. *See also* C. S. Lewis, *Myth Became Fact*, *in* GOD IN THE DOCK 63 (1970) (suggesting that the story of Aslan's sacrifice and sudden joyous reappearance in battle, just as the White Witch seems to be winning the climactic battle of *The Lion, the Witch, and the Wardrobe*, was a studied allegory of the Christian gospel). Some scholars have suggested that, for Tolkien and Lewis, the "consolation of the happy ending" of the Christian story of resurrection was a central distinction between the Christian "fairy-story" and other—particularly Norse—mythologies. *See*

Notably, though it has drifted from its underpinnings in modern parlance, the concept of catastrophe also has religious foundations. For most of Western history, the primary source of knowledge about catastrophes was religious texts or story cycles,[72] and in the Western world, the occurrence of catastrophes, such as the Black Plague, were taken historically as evidence not only of divine will, but also of the fulfillment of New Testament prophecies of the end of the world.[73] Nor are such divine accounts of catastrophe limited to Western tradition: the Qur'an, too, describes catastrophes as God's punishment for sin;[74] in Japan, disasters were often traced to mythological creatures: earthquakes, for example, were ascribed to the catfish "namazu;" [75] and the modern Chinese word for "catastrophe," *tianzai* (天災), translates literally as "heavenly disaster."[76]

Timothy Willard, *Eucatastrophe: J.R.R. Tolkien & C.S. Lewis's Magic Formula for Hope*, A PILGRIM IN NARNIA (Dec. 21, 2015), https://perma.cc/GS4A-AR3B (discussing J.R.R. Tolkien and C.S. Lewis' use of eucatastrophe in their writings). *See also* Tom Shippey, *Tolkien and the Appeal of the Pagan:* Edda *and* Kalevala, *in TOLKIEN AND THE INVENTION OF MYTH: A READER 151–52* (Jane Chance ed., 2004) (arguing that Tolkien's concept of eucatastrophe as applied in *The Hobbit* and *The Lord of the Rings* was his attempt to "retain the feel or 'flavor' of Norse myth, while hinting at the happier ending of Christian myth behind it."). In ancient Norse mythology, Ragnarők, or "Doom of the Gods," was the end of the mythical cycle, during which the cosmos was destroyed and subsequently recreated. *See* JOHN LINDOW, NORSE MYTHOLOGY: A GUIDE TO GODS, HEROES, RITUALS, AND BELIEFS 254, 256–57 (2002); *Ragnarők, Scandinavian Mythology*, BRITANNICA (Aug. 28, 2020), https://perma.cc/EQT9-SYTK.

[72] *See* Russell R. Dynes, *Noah and Disaster Planning: The Cultural Significance of the Flood Story*, 11 J. CONTINGENCIES & CRISIS MGMT. 170, 170 (2003) (reviewing the Bible as source material for information on historical disaster in the West and arguing that "the Biblical flood—the Deluge—with the central figure of Noah, his family, and the ark and its inhabitants has provided the central cultural image of disaster for those in the Western World"). Non-Biblical Western traditions also give divine accounts of catastrophe; consider, for example, Norse cycles of catastrophe. *See* Willard, *supra* note 71 (discussing the cycle of Ragnarök in Norse mythology).

[73] *See* JOHN KELLY, THE GREAT MORTALITY: AN INTIMATE HISTORY OF THE BLACK DEATH, THE MOST DEVASTATING PLAGUE OF ALL TIME, at xv–xvi (2006).

[74] *See, e.g.*, QURAN IN ENGLISH, *Surah Al-'Ankabut* ("*The Spider*") 29:40 (Talal Itani, trans.) ("Each We seized by his sin. Against some We sent a sandstorm. Some were struck by the Blast. Some We caused the ground to cave in beneath them. And some We drowned."); QURAN IN ENGLISH, *Surah An-Nahl* (*"The Bees"*) 16:26 (Talal Itani, trans.) ("Those before them also schemed, but God took their structures from the foundations, and the roof caved in on them. The punishment came at them from where they did not perceive.").

[75] *See* R.T. Severn, *Understanding Earthquakes: From Myth to Science*, 10 BULL. EARTHQUAKE ENGINEERING 351, 352 (2011) (discussing the mythological role of the "namazu" in causing earthquakes and describing ways in which "it is still used as a metaphor for earthquakes in official Japanese disaster prevention activities").

[76] The word traces to Imperial China, when disasters were seen as a form of divine retribution. Such retribution responded differentially to human behavior depending upon the weighted importance of the acting individual: The Emperor's behavior was seen as most causal, with bureaucrats' actions being more important than those of the common people. *See generally* Mark Elvin, *Who Was Responsible for the Weather? Moral Meteorology in Late Imperial China*, BEYOND JOSEPH NEEDHAM: SCI., TECH., AND MED., IN E. AND SE. ASIA,1998, at 213, 213 (describing how the responsibility of drought was allocated to worldly actors by divine entities). The author would like to thank Howard Li for help with translation.

In the Western world, early non-religious accounts of catastrophe were often seen as controversial, even heretical.[77] Yet through the Enlightenment and the scientific revolution, scientific explanation for natural disasters gained increasing emphasis in the West, and eventually developed into the modern regulatory approach to catastrophe, which focuses on science rather than religion as the primary mechanism for explaining and understanding catastrophic events.[78] It is this scientific perspective on causation which provides the foundation on which modern catastrophe policies are built.[79]

No (secular) policy tradition of recognizing and affirmatively managing the *positive* corollaries of catastrophes has emerged, however. J.R.R. Tolkien was right to recognize the need for a term for such positive phenomena, though his recommendation—to adopt a distinction between *eucatastrophe* ("bad catastrophe") and *dyscatastrophe* ("bad catastrophe")—has never gained traction; most people continue to think and talk about "catastrophes" as only bad. The easier way forward, therefore, may be not to attempt a new distinction between *eucatastrophe* and *dyscatastrophe*, but instead to agree to a separate term for extreme-upside events that can be used in future analyses.

Upon reflection, the best option may be "wonders,"[80] most familiar for its evocation of the ancient Seven Wonders of the World[81]—lasting

77 The transition was gradual. In England, for example, throughout the early nineteenth century, geologists evaluating the fossil record continued to link evidence of ancient sea floors with the biblical flood. *See* MARTIN J. S. RUDWICK, THE MEANING OF FOSSILS: EPISODES IN THE HISTORY OF PALAEONTOLOGY 133–34 (1976).

78 For a chronicling of this shift in the context of earthquakes, see Severn, *supra* note 75.

79 *See, e.g.*, REID BASHER, SCIENCE AND TECHNOLOGY FOR DISASTER RISK REDUCTION: A REVIEW OF APPLICATION AND COORDINATION NEEDS 2 (Mar. 31, 2013), https://perma.cc/6C6R-2C54 (explaining that "[t]he task of managing disaster risks and disaster events is heavily dependent on scientific knowledge and evidence-based technique"). *Cf.* Dynes, *supra* note 72, at 170 (discussing historical religious approaches to disaster). Surveys suggest that members of the public who report that religion is very important in their lives tend nevertheless to describe earthquakes in exclusively natural terms, and as resulting from scientific precursors. *See* ROBERT A. STALLINGS, PROMOTING RISK: CONSTRUCTING THE EARTHQUAKE THREAT 113–14 (1995) (citing RALPH. H. TURNER, JOANNE M. NIGG & DENISE HELLER PAZ, WAITING FOR DISASTER: EARTHQUAKE WATCH IN CALIFORNIA 275 (1986) ("Although the great majority of our respondents said that religion is important in their lives, very few of them suppose that religious leaders can forecast earthquakes and few tried to explain earthquakes in religious terms.").

80 "Miracles" would be another option, though responses to early drafts of this work suggest that for some people, the term "miracle" has inescapable religious overtones, which may be distracting or in some cases even offensive in secular policy contexts.

81 First described by Philo of Byzantium in 225 BCE, and further detailed by the Greek historian Herodotus, the seven wonders of the ancient world are conventionally listed as the Great Pyramid at Giza, the Hanging Gardens of Babylon, the Statue of Zeus at Olympia, the Temple of Artemis at Ephesus, The Mausoleum at Halicarnassus, the Colossus of Rhodes, and the Lighthouse of Alexandria. Of these seven, the oldest—the Great Pyramid at Giza—still remains. *See* Timothy Darvill, *Seven Wonders of the Ancient World*, *in* THE CONCISE OXFORD DICTIONARY OF ARCHAEOLOGY 413 (2008) (describing the seven wonders of the ancient world).

testaments to the aspirations and accomplishments of the past. Like the Wonders of the Ancient World, modern regulatory wonders present the opportunity and backdrop for human striving, inspiration, accomplishment, and hope—just as their flipside, catastrophes, present the backdrop for human suffering, despair, failure, and fear. At the same time, the word may leave space for nuance and for disagreement: for example, for the possibility that pursuing wonders—as with the construction practices of the Great Pyramid at Giza[82]—can be done in good or in bad ways; the mere achievement of a great outcome may or may not be worth the cost. Such debates should happen, however, against a backdrop that recognizes it may sometimes be possible for people—and for the laws and policies that shape people's behaviors—to accomplish substantial positive improvements in social welfare and perhaps even to achieve such improvements in the quality of the environment that surrounds them. The benefits of such achievements can be comparable in magnitude to catastrophes—just with a positive rather than a negative impact on the status quo.

On the margins, of course, it may be difficult to know just how large positive impacts must be to qualify as a wonder—just as it can be difficult to determine exactly what events are so awful that they justify being labeled as catastrophe. These challenges, and their implications, are discussed below.[83] As a general matter, however, this Article will use the word "wonder" to refer to a policy scenario that involves extremely high-magnitude positive impacts. Such scenarios[84] should be thought of as the flipside of catastrophes: the sort of outcomes that occur when policies trigger extraordinarily positive scenarios (instead of extraordinarily negative ones). To the extent that anything seems strange or awkward about this usage—and that there is no widely-used alternative term for extreme-upside events—this can be taken as the first point of evidence of the striking way in which extreme-upside events are approached differently, in policymaking as in common parlance, than are events with extreme downsides.

2. Examples of "Wonderful" Possibilities

In the past, where neglect of extreme-upside events has been deliberate rather than accidental, it seems to originate from a general presumption that consideration of extreme upsides will (always) be

82 Jonathan Shaw, *Who Built the Pyramids?*, HARVARD MAGAZINE (July 2003), https://perma.cc/TK3F-DSTT (summarizing, in a readable fashion, continuing debates about ancient Egyptian labor practices, particularly regarding whether workers were enslaved); Kathlyn M. Cooney, *Labour*, *in* THE EGYPTIAN WORLD 167 (Toby Wilkinson ed., 2007) (discussing ancient Egyptian conceptions of labor and labor practices, including the sometimes porous distinctions between forced and unforced labor, and noting that "we have almost no written information about one of Egypt's largest state construction projects—the Giza pyramids of the Old Kingdom").

83 *See infra* Part III.A.1.

84 *See infra* Part II.B.2.

unreasonably optimistic.[85] But *is* it always unreasonably optimistic to consider that policies might sometimes generate the possibility of extremely large benefits—benefits so large, in some instances, that the sum of their social impact might be greater than their parts? Although happy endings have long been considered the province of fiction and fairy tales,[86] the remainder of this Part argues that it is by no means fantastical to believe policies can sometimes create transformative, large policy benefits that produce enormous gains from the status quo. Such wonderful impacts have occurred as a result of past policies, and a number of potential future policies offer similar opportunities. Indeed, the possibility of such future policies may be particularly obvious in the historical moment when this Article is being published, when so much is resting on the successful development of a treatment or a vaccine for COVID-19.

a. Some Past Policies with Wonderful Impacts

History is studded with policies that transformed people's lives for the better.[87] Sometimes these policies addressed novel technologies; other times they were directed towards more general human behaviors.

Think, for instance, of past vaccine policies. At the beginning of the 20th century, few effective measures existed to prevent infectious diseases, and the average life expectancy in the United States was 47.3 years.[88] In an average year, hundreds of thousands of Americans fell ill from dangerous and agonizing diseases: annually, smallpox sickened 48,164; paralytic polio, 16,316; diphtheria, 175,885; measles, 503,282; and rubella, 47,745.[89] That was the norm, but in a bad year, millions might sicken from a single illness: an epidemic of rubella in 1964–1965—the last major epidemic since the rubella vaccination program started in 1969—infected 12.5 million Americans.[90]

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[85] *See, e.g.*, SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 6–7 (discussing the role emotions play and the tendency to focus on bad outcomes). For a further discussion of optimism, see *infra* Part III.

[86] *See* Tolkien, *On Fairy-Stories*, *supra* note 65 and accompanying text.

[87] For an extraordinary—and uplifting!—catalog, see PINKER, ENLIGHTENMENT NOW *supra* note 7, at 59–66.

[88] Rino Rappuoli et al., *Vaccines, New Opportunities for a New Society*, 111 PROC. NAT'L ACAD. SCI. 12288 (2014). Life expectancy in the U.S. is now 78.6 years. KENNETH D. KOCHANEK ET AL., NAT. CTR FOR HEALTH STATS., DATA BRIEF NO. 293, MORALITY IN THE UNITED STATES, 2016, at 1 (Dec. 2017). *See also*, U.S. Ctrs. for Disease Control and Prevention, *Achievements in Public Health, 1990–1999: Impact of Vaccines Universally Recommended for Children—United States, 1900–1998*, 48 MORBIDITY & MORTALITY WKLY REP. 243 (Apr. 2, 1999), https://perma.cc/SDH6-35MU [hereinafter *Impact of Vaccines Universally Recommended for Children*].

[89] *Impact of Vaccines Universally Recommended for Children*, *supra* note 88 (calculating baseline 20th century annual morbidity for nine infectious diseases with vaccines recommended before 1990 for universal use in children).

[90] The outbreak also killed 2,000 infants, caused 11,000 miscarriages, and gave 20,000 babies congenital rubella syndrome. *See* U.S. CTRS. FOR DISEASE CONTROL AND PREVENTION, *Chapter 20: Rubella*, *in* EPIDEMIOLOGY AND PREVENTION OF VACCINE-

Large-scale national efforts to promote vaccine use began with appropriation of federal funds for polio vaccination in 1955,[91] the year that Joseph Salk's vaccine against polio was announced. Historical accounts of that announcement are particularly moving during the current period of pandemic; historian Richard Carter has lyrically described the moment, explaining that when scientists announced the vaccine on April 12, 1955:

> A contagion of love swept the world. People observed moments of silence, rang bells, honked horns, blew factory whistles, fired salutes, kept their traffic lights red in brief periods of tribute, took the rest of the day off, closed their schools or convoked fervid assemblies therein, drank toasts, hugged children, attended church, smiled at strangers, and forgave enemies.[92]

Of course—and again, as seems particularly poignant to recognize now, in the midst of the coronavirus pandemic—polio was not eliminated suddenly on April 12, 1955. Salk's invention did, however, set the stage for the development of large-scale national and international vaccination policies. And indeed, over the subsequent decades, U.S. policies promoting production and use of the polio and other vaccines were implemented, including substantial federal support for basic research and development through the National Institutes of Health (NIH); federal and state funding for public health infrastructure development, outreach, and vaccine purchase; the regulation of vaccine quality through the Food and Drug Administration (FDA) and safety through the Center for Disease Control (CDC); state mandates of immunization via school entry requirements; and public sector purchases of vaccines (through the Department of Defense, the Veterans Administration, state governments, and federally funded vaccine programs for low-income children).[93] Because national and international vaccination policies have taken effect, infectious diseases that were once common began a remarkable decline:[94]

PREVENTABLE DISEASES 326 (2015) [hereinafter *Rubella*]; KARIE YOUNGDAHL ET AL., THE HISTORY OF VACCINES 32 (2013).

91 *See* Poliomyelitis Vaccination Assistance Act of 1955, Pub. L. No. 863–377, 69 Stat. 704 (funding federal grants to the states for purchase of poliomyelitis vaccines, and for the costs of planning and conducting vaccination programs); YOUNGDAHL ET AL., *supra* note 90, at 28–29 (presenting the history of the polio vaccine). For a thorough overview of vaccine policy in the United States, see NATIONAL ACADEMIES, *Origins and Rationale of Immunization Policy*, Table 2-1, *in* FINANCING VACCINES IN THE 21ST CENTURY: ASSURING ACCESS AND AVAILABILITY 40–41 (2004), https://perma.cc/VJ48-SXYC [hereinafter NATIONAL ACADEMIES, *Origins and Rationale of Immunization Policy*].

92 *See* RICHARD CARTER, BREAKTHROUGH: THE SAGA OF JONAS SALK 1 (1966). Steven Pinker discusses these historical accounts and other evidence of the euphoria of the polio vaccine in PINKER, ENLIGHTENMENT NOW *supra* note 7, at 63–67, adding that "[t]he city of New York offered to honor Salk with a ticker-tape parade, which he politely declined."

93 *See generally* NATIONAL ACADEMIES, *Origins and Rationale of Immunization Policy*, *supra* note 91 (providing a valuable overview of government roles in immunizations).

94 *See Impact of Vaccines Universally Recommended for Children*, *supra* note 88, at 1482–83 (estimating that "[d]ramatic declines in morbidity have been reported for the nine vaccine-preventable diseases for which vaccination for children was universally

smallpox has been globally eradicated,[95] polio eradicated domestically and is nearing global eradication,[96] two cases of diphtheria have been reported since 2004, and most U.S. doctors have never seen a case of the measles.[97] Overall, existing vaccines have averted a total of 103 million cases of childhood diseases.[98] These past benefits might be categorized as wonderful on their own,[99] but the benefits of vaccines continue to mount: the Center for Disease Control (CDC) estimates that (non-COVID) vaccinations will prevent more than 322 million illnesses, 21 million hospitalizations, and 732,000 deaths among children born in the last twenty years.[100] In lives saved alone, and just in impacts on children born in the last twenty years, these benefits are roughly equivalent in

recommended for use in children before 1990 (excluding hepatitis B, rotavirus, and varicella.) Morbidity associated with smallpox and polio caused by wild-type viruses has declined 100% and nearly 100% for each of the other seven diseases [diphtheria, pertussis, tetanus, measles, mumps, rubella, flu]"); Walter A. Orenstein & Rafi Ahmed, *Simply Put: Vaccination Saves Lives*, 114 PROC. NAT'L ACAD. SCI 4031, 4031 (2017) ("Few measures in public health can compare with the impact of vaccines."). *See generally*, YOUNGDAHL ET AL., *supra* note 90 and accompanying text. *See also* PINKER, ENLIGHTENMENT NOW *supra* note 7, at 63–67 (describing the extraordinary impact of historical advances in battling infectious diseases).

95 Smallpox was eradicated in 1977 in large part through active global eradication efforts coordinated by the World Health Organization (WHO). The eradication of smallpox allowed for discontinuation of continued prevention and treatment efforts, such as vaccination. *See* F. FENNER ET AL., SMALLPOX AND ITS ERADICATION, at vii (World Health Org. 1989) (discussing the role the World Health Organization had regarding the eradication of Smallpox). Analysts have estimated that by 1985, the United States was recouping its investment in worldwide eradication every 26 days. *See Impact of Vaccines Universally Recommended for Children*, *supra* note 88, at 1482.

96 *See Two Out of Three Wild Poliovirus Strains Eradicated: Global Eradication of Wild Poliovirus Type 3 Declared on World Polio Day*, WORLD HEALTH ORG. (Oct. 24, 2019), https://perma.cc/V24F-8N86 (reporting that two strains of wild poliovirus appear to have been eradicated, but that one remaining strain, "type 1," polio remains endemic in only two countries: Afghanistan and Pakistan). *See also CDC Continues to Support the Global Polio Eradication Effort*, U.S. CTRS. FOR DISEASE CONTROL AND PREVENTION (Mar. 18, 2016), https://perma.cc/W3B7-UT3P [hereinafter *CDC Continues to Support the Global Polio Eradication Effort*].

97 *See What Would Happen If We Stopped Vaccinations?*, U.S. CTRS. FOR DISEASE CONTROL AND PREVENTION, https://perma.cc/G9U7-Y2LM (last visited Sept. 30, 2020) [hereinafter *What Would Happen if We Stopped Vaccinations?*].

98 *See* Rappuoli et al., *supra* note 88.

99 *See* Francis E. André, *Vaccinology: Past Achievements, Present Roadblocks and Future Promises*, 21 VACCINE 593, 593 (2003) (arguing that "Of all the branches of modern medicine, vaccinology can claim to be the one that has contributed most to the relief of misery and the spectacular increase in life expectancy in the last two centuries. It is the only science that has eradicated an infectious disease—smallpox—responsible for 8–20% of all deaths in several European countries in the 18th century.").

100 *See* U.S. Ctrs. for Disease Control and Prevention, *Benefits from Immunization During the Vaccines for Children Program Era—United States, 1994–2013*, 63 MORBIDITY & MORTALITY WKLY RPT. 352, 354 (2014) (estimating the monetized benefit of these impacts at $1.4 trillion in total societal costs, including $295 billion in direct costs) [hereinafter *Benefits from Immunization*].

magnitude to preventing the deaths of every person in the city of Boston.[101]

Or consider the wonderful health and environmental implications of air pollution control. In the middle of the 20th century, air quality in much of the United States was dreadful. Choking smog and carcinogenic air pollutants pervaded many cities and industrial areas, and periodic "smog disasters" would blanket whole towns in lethal haze.[102] In 1970, the United States passed the Clean Air Act directing the newly-created Environmental Protection Agency to set National Ambient Air Quality Standards for common dangerous air pollutants.[103] Between 1970 and 2017, aggregate national emissions of the six criteria pollutants dropped an average of seventy-three percent.[104] Reducing pollution from fine particles and ground level ozone pollution alone save the lives of an estimated 230,000 Americans each year who would otherwise have died from air-pollution-related illnesses.[105]

To put the magnitude of this impact in context, consider that, pre-pandemic, there were about 2.7 million deaths in the United States per year from all causes;[106] at rough estimate, then, these two air pollution control policies alone reduce overall annual mortality in the United States by about eight percent.[107]

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101 U.S. Census Bureau, *Quick Facts: Boston City, Massachusetts* (July 1, 2019) https://perma.cc/K8KD-LMVT (reporting the population of Boston as 692,600). *See also* U.S. Ctrs. for Disease Control and Prevention, *Vaccines for Children: 20 Years of Protecting America's Children* (2014), https://perma.cc/5QUH-Y994 (calculating the total societal benefit at approximately $4,473 for each American and noting that the averted illnesses exceed the current population of the United States).

102 In October of 1948, for example, the industrial town of Donora, Pennsylvania was enveloped in a thick blanket of poisonous smog. Over five days, half of the town's 14,000 residents sickened. A few residents died almost immediately, but many thousands more developed chronic health conditions, such that even ten years after the incident, mortality rates in Donora were significantly higher than in neighboring communities. *See* Elizabeth T. Jacobs et al., *The Donora Smog Revisited: 70 Years After the Event that Inspired the Clean Air Act*, 108 AM. J. PUB. HEALTH S85, S85–S86 (2018) (discussing the health consequences of the Donora Smog).

103 *See* Clean Air Act, 42 U.S.C. §§ 7401–7671q (2012). The Act directs EPA to set National Ambient Air Quality Standards (NAAQS) at levels "requisite to protect the public health" with an "adequate margin of safety." *Id.* § 7409(b)(1).

104 *See* U.S. Env't Prot. Agency, *Clean Air Act Overview: Progress Cleaning the Air and Improving People's Health*, https://perma.cc/UW5C-Q5BP (last updated Aug. 14, 2019) [hereinafter *Clean Air Act Overview*].

105 *See* U.S. ENV'T PROT. AGENCY, BENEFITS AND COSTS OF THE CLEAN AIR ACT, 1990 TO 2020, at 14 (Mar. 2011), https://perma.cc/PB8U-6MU9 (estimating, by the year 2020, additional annual benefits including 200,000 averted heart attacks, 120,000 averted emergency room visits, 135,000 averted hospital admissions, 2.4 million averted asthma attacks, 5.4 million averted lost school days, and 17 million averted lost workdays) [hereinafter BENEFITS AND COSTS OF THE CLEAN AIR ACT].

106 JIAQUAN XU ET AL., NAT. CTR. FOR HEALTH STATS. DATA BRIEF No. 267, MORTALITY IN THE UNITED STATES, 2015, at 5 (Dec. 2016) (reporting 2,712,630 deaths in 2015).

107 This is a rough estimate, but generally speaking, if we divide averted deaths per year (230,000) by the sum of total annual deaths (2,612,630) and the additional people who would die without the policy (230,000), it produces 230,000 / (2,712,630 + 230,000) = 7.8%.

Alternatively, consider other examples of policies with significant, transformative benefits to human welfare, such as drinking water treatment,[108] automobile safety laws[109] or iodization of salt.[110] Or consider that a broader conception of wonderful impact might include policy impacts that go beyond health and safety benefits. This might include transformational environmental benefits like the establishment of the National Parks, social transformations such as were accelerated by the emancipation of women or abolition, or aspirational achievements such as landing on the moon. Though the impacts of these policies varied in type, immediacy, and predictability, a common denominator is they generated enormous societal benefits. Indeed, the scale of the upsides of these policies is comparable to—if not larger than—the scale of many extreme-downsides typically categorized as disasters.[111] And as with many catastrophes, the impact of these policies has spread far beyond a simplistic counting of associated deaths. Parents may now rest easy

108 *See* David Cutler and Grant Miller, *The Role of Public Health Improvements in Health Advances: The Twentieth Century United States*, 40 DEMOGRAPHY 1, 15 (2005) (concluding that clean water technologies, including chlorination and filtration, were responsible for reducing average mortality by 13%, infant mortality by 46%, and child mortality by 50% in major U.S. cities, in large part through the near-eradication of typhoid fever, and estimating—with extremely conservative assumptions—$23 in benefits from drinking water treatment for every $1 invested in public health).

109 *See* NAT'L HIGHWAY TRAFFIC SAFETY ADMIN., DOT HS 812 069, LIVES SAVED BY VEHICLE SAFETY TECHNOLOGIES AND ASSOCIATED FEDERAL MOTOR VEHICLE SAFETY STANDARDS, 1960 TO 2012—PASSENGER CARS AND LTVS, i (Jan. 2015) (estimating that safety technologies saved 613,501 lives between 1960 and 2012).

110 Iodine is a micronutrient required for healthy thyroid function, and we now know that iodine deficiency, particularly during pregnancy, causes stillbirth and congenital abnormalities, including congenital iodine deficiency syndrome, or "cretinism," a severe form of irreversible mental retardation. *See* WORLD HEALTH ORGANIZATION [WHO], *Micronutrient Deficiencies: Iodine Deficiency Disorders*, https://perma.cc/9H3L-TTRK (last visited Oct. 1, 2020) (discussing the effect of iodine deficiency disorders on children). *See also* Gregory A. Brent & Anthony P. Weetman, *Hypothyroidism and Thyroiditis*, *in* WILLIAMS TEXTBOOK OF ENDOCRINOLOGY 416, 431 (13th ed. 2016) ("[E]ndemic cretinism is a developmental disorder that occurs in regions of severe endemic goiter . . . endemic cretins often have deaf-mutism, spasticity, motor dysfunction, and abnormalities in the basal ganglia."). Salt iodization—first implemented as a policy in the 1920s—was initially undertaken to address goiter, a swelling of the thyroid gland. James Feyrer et al., *The Cognitive Effects of Micronutrient Deficiency: Evidence from Salt Iodization in the United States*, 15 J. EUR. ECON. ASS'N 355, 356–57 (2017). In the U.S., in areas where iodized salt was made available, not only did goiter rates (predictably) decline, but IQ rates increased simultaneously. *Id.* at 363, 385. Indeed, modern evidence suggests that the effect of salt iodization in high-goiter regions may have generated an average of an additional fifteen IQ points per person. *Id.* at 385. For a helpful evaluation of these results, see Thomas Sittler, *Did Iodized Salt Raise the IQ of 50 Million Americans by 15 Points?*, GIVING WHAT WE CAN (Jan. 7, 2016), https://perma.cc/JWV7-ECQY (summarizing different studies on the benefits of iodized salt).

111 *Compare* BENEFITS AND COSTS OF THE CLEAN AIR ACT, *supra* note 105, at 14 (finding that fine particulate and ozone regulations save 230,000 Americans a year), *with* NAT'L WEATHER SERV., SUMMARY OF NATURAL HAZARD STAT. FOR 2016 IN THE UNITED STATES (2017) https://perma.cc/2AKE-8RLQ (reporting a ten-year average (2007–2016) of 541 deaths resulting from natural hazards).

knowing that their vaccinated children will almost certainly never suffer—much less die—from the non-COVID-19 communicable diseases that, within living memory, sickened hundreds of thousands each year, and millions of families will not suffer through the anxiety and sadness of having a loved one diagnosed with cancer from air pollution.[112] Countless children born without congenital iodine deficiency have the opportunity to live full and productive lives. Over 300 million people will be inspired by, and accrue both quantitative and qualitative benefits from, visiting National Parks,[113] and the Apollo 11 moon landing remains a central and inspirational memory for millions of Americans.[114]

b. Some Future Policies with Potential for Wonderful Impacts

Modern policymakers also have the power to develop and manage policies that provide the potential for generating transformational, wonderful outcomes. Of course, the timeliest example of such opportunities is the possibility of generating an effective and administrable treatment, vaccine, or both, for COVID-19, the novel coronavirus that continues to sweep the globe. COVID-19 has already imposed and continues to impose catastrophic losses, as well as profound personal, social, and even environmental effects.[115] Finding a way to prevent or cure the disease would be a transformative change, which would positively affect the lives of essentially every person living on the planet. Such a development would be, to put it simply, wonderful. While policymakers around the globe continue to unveil policies encouraging research and development in this realm, a looming question for both policymakers and constituents is just how much to invest in generating a wonderful future that is not—or at least is less—constrained by COVID-19.

While the possibility of developing a prevention or a cure for COVID-19 may be top-of-mind for many readers, however, it is by no means the

112 Even children whose parents have chosen not to protect them from communicable diseases with vaccinations, and those who are unable to have vaccinations for medical reasons, benefit from a smaller, but still substantial, reduction in risk, from herd immunity. *See* Peter G. Smith, *Concepts of Herd Protection and Immunity*, 2 PROCEDIA IN VACCINOLOGY 134, 134 (2010) ("[V]accination may increase the level of population (or herd) immunity by increasing the proportion of the population who are immune from infection.").

113 *See* Terry L. Maple & Megan C. Morris, *Behavioral Impact of Naturalistic and Wilderness Settings*, *in* ENV'T PSYCHOLOGY AND HUMAN WELL-BEING: EFFECTS OF BUILT AND NATURAL SETTINGS 253, 254, 269 (Ann Sloan Devlin ed., 2018) (finding that exposure to the natural world improves human behavior, emotion, and cognition in a number of ways). *See also* ROWELL & BILZ, *supra* note 3 (summarizing the measurable psychological and emotional benefits of time in nature); *Annual Visitation Highlights*, NAT'L PARK SERV., https://perma.cc/KXB2-GDK9 (last updated Feb. 27, 2020) ("In 2019, the National Park Service received over 327.5 million recreation visits.").

114 *See* Elizabeth Tammi, *Memories of Apollo from People All Over the World*, NAT'L AERONAUTICS & SPACE ADMIN. (Jul. 12, 2019), https://perma.cc/UD38-25XX (recounting individuals' memories of the Apollo 11 moon landing).

115 *See* Rowell, *supra* note 1 and accompanying text.

only potential wonder that policy has the potential to help build over the long term. As a non-COVID example, consider the regulation of geoengineering. Due to the emission of so-called greenhouse gases, including carbon dioxide, the global climate is changing.[116] This manifests itself through an increase of average global temperatures and more extreme weather patterns.[117] In addition, higher carbon dioxide concentrations cause oceans to acidify,[118] precipitation patterns to shift,[119] and ecosystems to crumble.[120] Based on greenhouse gases already emitted, scientists are generally unified in predicting that global average temperature will almost certainly rise by at least two degrees Centigrade.[121] Even if current emissions are drastically reduced, climate change from past emissions is expected to lead to the extinction of the world's tropical reefs from growing ocean acidification; mass plant and animal extinctions from ecosystem degradation and loss; millions of additional cases of malnutrition from agricultural pattern shifts; and the destruction and abandonment of many low-lying areas, including the Persian Gulf, Polynesia, Venice, and Bangladesh, because of meters of sea level rise.[122]

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116 *See, e.g.*, Intergovernmental Panel on Climate Change [IPCC], *Climate Change 2014: Synthesis Report*, at 44–47 (2015), https://perma.cc/L3PL-YAD9 (summarizing the causes and impacts of climate change, including the role of greenhouse gas emissions) [hereinafter *Climate Change 2014: Synthesis Report*].

117 *See id.* at 48, 53 (concluding that some extreme weather events have been correlated with human activities, and that "[i]t is *extremely likely* that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by the anthropogenic increase in [greenhouse gas] concentrations and other anthropogenic forcings together").

118 *See id.* at 4 ("Since the beginning of the industrial era, oceanic uptake of CO_2 has resulted in acidification of the ocean. . .").

119 *See* Chelsea Harvey, *CARBON BUDGET: CO2 Can Sharpen Extreme Weather Without Higher Temps*, E&E News (June 21, 2018), https://perma.cc/2FLK-H7FR ("One 2013 study found that carbon dioxide levels alter precipitation and atmospheric circulation patterns independently of average warming.").

120 *See Climate Change 2014: Synthesis Report*, *supra* note 116, at 8 (concluding that future emissions of greenhouse gases, which include carbon dioxide, "will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems").

121 *See, e.g.*, Intergovernmental Panel on Climate Change [IPCC], *Global Warming of 1.5°C: A Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission on Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, at vi (2019) (explaining that "[w]ithout increased and urgent mitigation ambition in the coming years, leading to a sharp decline in greenhouse gas emissions by 2030, global warming will surpass 1.5°C in the following decades"). By one recent respected estimate, the chance of holding warming to below two degrees Centigrade is estimated to be about one in twenty. Adrian E. Raftery et al., *Less than 2 °C Warming by 2100 Unlikely*, 7 NATURE CLIMATE CHANGE, Sept. 2017, at 637, 639–40.

122 *Climate Change 2014: Synthesis Report*, *supra* note 116, at 67; *see also* U.N. World Food Programme, *How Climate Drives Hunger: Food Security Climate Analyses, Methodologies & Lessons 2010–2016*, at 7, 12 (Oct. 2017) (finding that climate change is expected to increase world hunger by 20% by 2050); IPCC, *Climate Change 2014: Impacts, Adaptation, and Vulnerability: Part A: Global and Sectoral Aspects*, at 76-80 tbl.TS.5 (2014)

Policy responses to the risks of climate change are conventionally separated into "mitigation" strategies, which attempt to reduce the eventual impacts of climate change through addressing its causes (e.g. by reducing emissions); and "adaptation" strategies, which attempt to reduce the eventual impacts of climate change through limiting its effects (e.g. by building sea walls to prevent coastal flooding).[123] Geoengineering—the purposeful manufacturing of desired climactic conditions—presents a possible third route: a way of counteracting the harms from climate change by reversing some of its causes.[124]

Scientists are exploring several possible technological vehicles for geoengineering a desired climate. These include solar radiation management (SRM) technologies, such as installing "solar mirrors" that would reflect some of the sun's rays back toward the universe; replicating the cooling effect of volcanic eruption by purposefully injecting the atmosphere with volcanic gases; and methods of generating carbon dioxide removal (CDR), such as "carbon sinks," by fertilizing oceans with iron to promote the growth of carbon dioxide-consuming plankton and algae; or mass afforestation.[125] More ambitiously, scientists and entrepreneurs might find ways to scrub carbon from the atmosphere and transform it into valuable products.[126]

The potential upsides of geoengineering technologies vary with the method developed; solar geoengineering strategies, which rely on reducing the temperature of the Earth, would not, for example, address ocean acidification or some of the agricultural impacts of climate change;[127] they might, however, slow some of the sea-ice melt leading to rising sea levels, ocean warming (which, in turn, causes increased

https://perma.cc/4ZLZ-XU56 (depicting risk factors to different continents in the world) (summarizing environmental impacts on low-lying areas and consequential impacts on human behavior) [hereinafter *Climate Change 2014: Impacts, Adaption, and Vulnerability*].

123 Reflecting this distinction, the IPCC actually developed two separate reports for mitigation and adaptation. *See Climate Change 2014: Impacts, Adaptation, and Vulnerability*, *supra* note 122 (discussing different adaption strategies for addressing climate change). *See also* Intergovernmental Panel on Climate Change [IPCC], *Climate Change 2014: Mitigation of Climate Change* (2014) (discussing different mitigation strategies to reduce the impacts of climate change) [hereinafter *Climate Change 2014; Mitigation of Climate Change*]. The synthesis report, *Climate Change 2014: Synthesis Report*, *supra* note 116, summarizes both.

124 *See* DAVID KEITH, A CASE FOR CLIMATE ENGINEERING 8–9 (2013) (reviewing the promise and dangers of slowing global warming by injecting reflective particles into the upper atmosphere); OLIVER MORTON, THE PLANET REMADE: HOW GEOENGINEERING COULD CHANGE THE WORLD 26 (2015) (reviewing multiple possible methods of geoengineering, and their relative likelihood of success).

125 *See* KEITH, *supra* note 124, at 8; MORTON, *supra* note 124, at 149.

126 *See* Phil McKenna, *From Greenhouse Gas to the Dreamliner, Nanofibers Offer New Life for CO2*, INSIDE CLIMATE NEWS (Aug. 19, 2015), https://perma.cc/4A6S-QYYX (describing the construction of carbon nanofibers, which are useful in modern manufacturing, for example of wind turbine blades and of Boeing's high efficiency "Dreamliner" airplane).

127 *See* Robinson Meyer, *A Disappointing New Problem with Geo-Engineering: Dimming the Sky Won't Save the World's Harvests*, ATLANTIC (Aug. 8, 2018), https://perma.cc/CT2K-Y9UY (exploring the effects of volcanic gas on global temperatures); KEITH, *supra* note 124, at 8 (the "addition of sulfates to the atmosphere does nothing to stop ocean acidification").

hurricanes), as well as the frequency and severity of deadly extreme heat waves. Carbon dioxide removal technologies, on the other hand, have a chance of succeeding at counteracting both the temperature impacts of climate change and the other environmental impacts of increased carbon emissions.[128]

The decision of whether to invest in developing geotechnologies, and of what type—and once developed, of how and whether to deploy those technologies—are policy decisions with potentially wonderful impact. At the least, policymakers should make climate and geoengineering policy decisions in recognition that such impacts are possible; ideally, they would also calibrate investment to (at a minimum) expected value. If successful, such technologies could well be transformative in scale, and development of effective geoengineering technologies presents one of—if not the—best-case scenario for climate policy. Yet, such potential has often been omitted from systematic and mainstream discussions of the likely scenarios and impacts of anthropogenic climate change, including from the calculation of the Social Cost of Carbon.[129] Indeed, even the most nuanced scholarly conversations about the appropriate mechanisms for regulating geoengineering generally downplay its potential for generating optimal climatic conditions and for helping to avert wide-scale climate catastrophe.[130]

i. Colonizing Other Planets

Alternatively, consider the potential offered by human colonization of other planets, perhaps accompanied by extraterrestrial terraforming. Although humans currently only live on Earth,[131] colonizing other planets has been a science-fiction staple for many decades.[132] In the last decade,

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[128] *See* Umair Irfan, *Sucking CO2 Out of the Atmosphere, Explained*, Vox, https://perma.cc/DFS2-UAQN (last updated Oct. 25, 2018) (In its most recent assessment, the Intergovernmental Panel on Climate Change (IPCC) reported that we may have as little as 12 years to cut our greenhouse gas emissions in half compared to today's levels to limit average global warming to 1.5 degrees Celsius, a benchmark to avoid some of the worst impacts of climate change. It also reports that every scenario for doing this requires pulling carbon dioxide out of the air, also known as 'negative emissions.' . . . Given the very high likelihood we will overshoot our emissions reduction targets, carbon removal is now an absolute necessity for avoiding worst-case scenarios.").

[129] See *infra* Part II.C.2.

[130] *See, e.g.*, ALEJANDRO E. CAMACHO & ROBERT L. GLICKSMAN, REORGANIZING GOVERNMENT: A FUNCTIONAL AND DIMENSIONAL FRAMEWORK 221 (2019) (suggesting that geoengineering should be regulated in a "precautionary" fashion to limit its potential downsides—without addressing the potential for what are arguably similarly-sized potential upsides).

[131] Or within Earth's orbit, as on the International Space Station. For an updated number of people who are in space at any given moment, see HOW MANY PEOPLE ARE IN SPACE RIGHT NOW, https://perma.cc/F2P2-T47U (last visited Oct. 1, 2020) (as of October 1, 2020, there are three people in space).

[132] *See, e.g.*, RAY BRADBURY, THE MARTIAN CHRONICLES (1950); EDGAR RICE BURROUGHS, A PRINCESS OF MARS (1917); C.S. LEWIS, OUT OF THE SILENT PLANET (1938); ROBERT A. HEINLEIN, RED PLANET: A COLONIAL BOY ON MARS (1949). *See also* CARL SAGAN, COSMOS

significant advancements in reducing the costs of space flight have made that possibility increasingly plausible.[133] Elon Musk, the founder of the private space company SpaceX (and the transportation and energy company Tesla), has published specific plans to launch flights to Mars as early as 2022, to establish a colony on Mars by 2030, to have a "self-sustaining city" by 2050, and to have a million humans living on Mars by the 2060s.[134] While Musk's timeline is widely viewed as aggressive, even NASA is working on sending humans to Mars in the 2030s.[135] In addition to offering the opportunity to build entirely new societies in wholly new environments,[136] a possibility many people may find qualitatively inspirational, advocates of interplanetary colonization have also noted living on multiple planets would substantially reduce the risk of human extinction via global catastrophic risk.[137] Yet scholarship and serious policy treatment of the possibility of extraterrestrial colonization remains vanishingly scarce, and I know of no systematic attempt on the part of health, safety, or environmental regulators—even when considering global catastrophic risk—to simultaneously consider the possibility of extraterrestrial colonization, either on its own or as a mitigation factor on global catastrophic risk.

These examples are meant to present reasonably plausible vectors for incorporating best-case scenarios into regulatory policies, but the potential of policy wonders is by no means constrained to them. For

86 (1980) ("Mars has become a kind of mythic arena onto which we have projected our earthly hopes and fears.").

133 *See* Elon Musk, *Making Humans a Multi-Planetary Species*, 5 NEW SPACE 46, 47–48 (2017) (identifying, as a goal, to "get the cost of moving to Mars to be roughly equivalent to a median house price in the United States, which is around $200,000" and claiming that such a cost is achievable with reusable spaceship parts, making fuel on Mars, launching enormous spaceships into orbit where they can be refueled by boosters, and establishing interplanetary fuel-filling stations). *See also* Andrew Coates, *How Plausible is Elon Musk's Plan to Colonize Mars?*, SLATE (June 26, 2017), https://perma.cc/Q5W2-NSMH (conceding that portions of Musk's plans are plausible, though flagging continued concerns about managing Mars' temperature and about radiation exposure at interplanetary fuel-filling stations). *But see* Dave Mosher, *Elon Musk Wants to Colonize Mars with SpaceX but Has Yet to Explain How People Will Survive There*, BUSINESS INSIDER (Oct. 5, 2017), https://perma.cc/8YSV-GYDA (arguing that Mars colonies would require bioregenerative life support beyond what currently exists).

134 *See* Nadia Drake, *Elon Musk: A Million Humans Could Live on Mars by the 2060s*, NAT'L GEOGRAPHIC (Sept. 27, 2016), https://perma.cc/YKZ2-5VBZ (describing Elon Musk's plan for life on Mars); Musk, *supra* note 133, at 46, 58 (depicting a timeline for getting life on Mars).

135 *See NASA's Journey to Mars*, NASA (Dec. 1, 2014), https://perma.cc/T844-AG7S ("NASA is developing the capabilities needed to send humans to an asteroid by 2025 and Mars in the 2030s—goals outlined in the bipartisan NASA Authorization Act of 2010 and in the U.S. National Space Policy, also issued in 2010.").

136 *See* MICHIO KAKU, THE FUTURE OF HUMANITY: TERRAFORMING MARS, INTERSTELLAR TRAVEL, IMMORTALITY, AND OUR DESTINY BEYOND EARTH 62 (2018) ("Musk concluded that the risk of human extinction could only be avoided by reaching for the stars.").

137 *See, e.g.*, *id.* at 3 (arguing that humans "must leave the Earth or we will perish."). *See generally* GLOBAL CATASTROPHIC RISKS, *supra* note 30, at 1, 68 (addressing a range of issues related to global catastrophic risk).

example, other transformative opportunities might include addressing malnutrition with genetically modified foods,[138] the transformation of transportation with autonomous vehicles,[139] curing cancer,[140] eradicating malaria,[141] the development of viable nuclear fusion electrical generation,[142] or contacting extraterrestrials.[143] These are meant to be

[138] *See* Geoffrey Barrows, et al., *Agricultural Biotechnology: The Promise and Prospects of Genetically Modified Crops*, 28 J. ECON. PERSP., 2014, at 99, 100 ("[T]he next wave of genetic engineering has potential to improve crop response to climate change and boost the nutrient density of staple crops.").

[139] In a recent report, RAND has estimated that, even if autonomous vehicles were only 10% safer than human-driven automobiles when widely introduced to the market, they would be expected to save 1,100,000 American lives over 50 years. *See generally* NIDHI KALRA & DAVID G. GROVES, RAND CORP., THE ENEMY OF GOOD: ESTIMATING THE COST OF WAITING FOR NEARLY PERFECT AUTOMATED VEHICLES 12 (2017) (explaining the benefit of autonomous vehicles). *See also* Melissa Bauman, *Why Waiting for Perfect Autonomous Vehicles May Cost Lives*, RAND CORP., https://perma.cc/9M8Z-NMXC (last updated Dec. 22, 2017) (discussing the safety benefits of autonomous vehicles).

[140] Note that this is one area in which Congress has acted substantially to promote wonder development, through "cancer moonshot" legislation intended to accelerate the fight against cancer. Passed under the leadership of then-Vice President Joe Biden, the 21st Century Cures Act (Cures Act) authorized $6.3 billion in funding over 10 years for promoting cancer research and encouraging discovery of a cure. *See* 21st Century Cures Act, Pub. L. No. 114-255, 130 Stat. 1033 (2016). *See also* Paula T. Hammond, *Shooting for the Moon: Nanoscale Approaches to Cancer*, 10 ACS NANO 1711, 1711 (2016). In considering whether the 21st Century Cures Act is a *sufficient* level of investment given the upside potential, it is worth noting that cancer is one of the top three causes of death in the United States (even during the COVID-19 pandemic), with over half a million deaths each year. *See Cancer Facts & Figures 2019*, AMERICAN CANCER SOC'Y, https://perma.cc/EES7-EP9F (last visited Nov. 12, 2020) (estimating 606,880 deaths in 2019, and 1.7 million new cancer cases). Conventional valuation procedures used by federal agencies justify expenditures of about $10 million per life saved. *See* W. KIP VISCUSI, PRICING LIVES: GUIDEPOSTS FOR A SAFER SOCIETY 25–37 (2018) (discussing calculations of the Value of a Statistical Life and its use in agency analyses). Simple math multiplying $10 million times 600,000 suggests that preventing deadly cases of cancer would justify over $6 trillion *a year* under conventional agency valuation methods—without even considering morbidity impacts. That is about 1,000 times the total amount dedicated to cancer research and treatment under the Cures Act.

[141] Malaria has declined substantially over the last two decades as a result of a series of global and national health policies; between 2000 and 2015, case incidence was reduced by 41% and mortality rates by 62%. WORLD HEALTH ORGANIZATION, WORLD MALARIA REPORT, at xv–xvi (2016), https://perma.cc/BWB7-9UB4. However, over 200 million cases and 400,000 global deaths (mostly of small children) continue to occur annually. WORLD HEALTH ORGANIZATION, WORLD MALARIA REPORT, at xii (2019), https://perma.cc/2V9K-9ZPA (reporting 405,000 global deaths and 228 million global cases in 2018). Many national malaria programs already consider elimination to be an attainable goal. *See* Rima Shretta et al., *Malaria Elimination and Eradication*, *in* MAJOR INFECTIOUS DISEASES 315, 315 (King K. Holmes et al. eds., 2017). From a global perspective, scholars have suggested that malaria eradication "within a generation" is achievable. *See generally* Richard Feachem et al., *Malaria Eradication Within a Generation: Ambitious, Achievable, and Necessary*, 394 LANCET 10203 (Sept. 9, 2019).

[142] *See, e.g.*, Tom Metcalfe, *The Long Wait for Fusion Power May Be Coming to an End*, NBC NEWS (Dec. 29, 2017), https://perma.cc/F8KD-GRY5 (discussing the likelihood of nuclear fusion).

[143] *See* Seth D. Baum et al., *Would Contact with Extraterrestrials Benefit or Harm Humanity? A Scenario Analysis*, 68 ACTA ASTRONAUTICA 2114, 2114 (2011) (arguing that

charismatic examples, but more homely possibilities abound as well: policymakers might develop strategies to drastically reduce gun violence,[144] promote basic science and the arts,[145] or further extend life expectancy with public health interventions or subsidized medical breakthroughs.[146] Policymakers could also build on past wonders: they might further reduce the burden of traditional air pollutants,[147] continue vaccination efforts, [148] or invest in greater access to iodized salt.[149] It is possible to quibble about the likelihood of any of these events coming to fruition and even to argue about the magnitude of the benefits if they did. But the point for now is each of these policy interventions offers at least the possibility of wonderful benefits.

contact with extraterrestrial intelligence "would be one of the most important events in the history of humanity, so the possibility of contact merits our ongoing attention, even if we believe the probability of contact to be low," and concluding that contact could be beneficial, neutral, or harmful).

144 *See generally* AM. PSYCHOLOGICAL ASS'N, GUN VIOLENCE: PREDICTION, PREVENTION, AND POLICY 2 (2013), https://perma.cc/XF3V-TNSJ (recommending policies to predict, reduce, and prevent gun violence).

145 *See, e.g.*, David Skorton, *Branches from the Same Tree: The Case for Integration in Higher Education*, 116 PROCEEDINGS OF THE NAT'L ACAD. OF SCI. OF THE U.S. 1865, 1865–67 (2019) (arguing for an integrative approach to science and arts education, emphasizing that one should not come at the expense of the other).

146 *See* Goodarz Danaei et al., *The Promise of Prevention: The Effects of Four Preventable Risk Factors on National Life Expectancy and Life Expectancy Disparities by Race and County in the United States*, PLOS MEDICINE, Mar. 23, 2010, at 2, 10 (discussing life expectancy disparities in the United States and the way to reduce preventable risk factors); Chhabi L. Ranabhat et al., *The Influence of Universal Health Coverage on Life Expectancy at Birth (LEAB) and Healthy Life Expectancy (HALE): A Multi-Country Cross-Sectional Study*, FRONTIERS IN PHARMACOLOGY, Sept. 18, 2018, at 8 (concluding that vaccination, sanitation, and Universal Health Coverage affect life expectancy at birth and healthy life expectancy).

147 Some recent estimates suggest that air pollution continues to kill an estimated 200,000 people a year in the United States. Fabio Caiazzo et al., *Air Pollution and Early Deaths in the United States. Part I: Quantifying the Impact of Major Sectors in 200*5, 79 ATMOSPHERIC ENV'T 198, 204 (2013). As a more specific example, one recent study found that 12,000 American lives could be saved each year by cutting the level of fine particulate matter nationwide by one microgram per cubic meter of air. *See* Qian Di et al., *Air Pollution and Mortality in the Medicare Population*, 376 NEW ENG. J. MED. 2513, 2513 (2017). Globally, environmental experts estimate that 6.5 million premature deaths per year—more than one in ten of all deaths—are directly linked to air pollution. *See* Philip J. Landrigan et al., *The Lancet Commission on Pollution and Health*, 391 LANCET 462, 471 (2018) (noting that water pollution is linked to 1.8 million deaths annually).

148 For example, by some estimates, further increasing global vaccine programs could reasonably be expected to save the lives of two million to three million children a year. *See, e.g.*, André, *supra* note 99, at 594 (arguing that vaccination could save three million children a year); *More Than Two Million Children Continue to Die Each Year from Vaccine-Preventable Diseases*, GAVI (Sept. 17, 2009), https://perma.cc/DG57-ZZRQ (estimating that 2.3 million children die each year from preventable disease).

149 *See Sustaining the Elimination of Iodine Deficiency Disorders (IDD)*, WORLD HEALTH ORGANIZATION [WHO], https://perma.cc/A6HL-N7DY (last visited Oct. 1, 2020) (reporting that iodine deficiency is a serious public health threat for 2 billion people worldwide).

C. Wonder Neglect

The prior Part suggests it is possible—at least sometimes—to generate transformational and wonderful impacts through policy.

Yet importantly, although disaster policy has developed substantially over the last decades, both scholars and policymakers have been largely silent regarding the possibility of extreme-upside events: policies leading to best-case scenarios instead of worst-case scenarios. As a result, although policymakers have increasing and important guidance from scholars in how to prevent and manage catastrophes, they are left without substantial scholarly guidance in deciding whether and how much to invest in generating wonders. The vacuum of guidance in this realm should be particularly concerning in a time when the stakes of getting the calculus on wonder-generation right are so high and so urgent.

To understand how policymakers and scholars approach potential wonderful impacts, it is helpful to consider what options they might have available to them to respond to and anticipate wonders. At least in theory, policymakers could reasonably choose to model their policy approaches on those they have used for catastrophes. This would give them three general options (see Figure 1). First, policymakers could neglect the possibility of policy wonders, either deliberately or inadvertently. Second, policymakers could attempt to calculate the expected value of wonderful opportunities and incorporate that value into their decisions on how to allocate resources. This is comparable to the way policymakers respond to catastrophic risks when they incorporate them into cost-benefit analyses. Third, policymakers could treat the possibility of wonderful impacts with some level of special solicitude, implementing some kind of proactive reciprocal of the precautionary principle used against catastrophe.

FIGURE 1: POLICY APPROACHES FOR CATASTROPHES AND WONDERS

	Neglect	**Expected Value**	**Special Solicitude**
Catastrophes/ Extreme Downsides	*Ignore the possibility of catastrophe.*	*Calculate the expected value of the magnitude of the catastrophe and multiply by its probability.*	*Attach some additional weight to the possibility of catastrophe beyond its expected value.*
Wonders/ Extreme Upsides	*Ignore the possibility of wonder.*	*Calculate the expected value of the magnitude of the wonder and multiply by its probability.*	*Attach some additional weight to the possibility of wonder beyond its expected value.*

As with catastrophes, different approaches to managing wonderful opportunities may be reasonable in different contexts. The option of neglect, for example, might be sensible where transformative benefits are seen as a kind of accidental or divine windfall—nice to have, but not worth planning for. In such cases, the option of neglecting upsides may be a reasonable option that will minimize administrative burdens. On the other hand, it is at least worth noting that this option—of letting extremely high impact events fall where they might—has been widely rejected in the context of catastrophe management. In fact, many scholars have opted to slide to the other end of the spectrum entirely and, in many cases, to prioritize catastrophic risk over and above what might be justified by an expected value analysis.[150]

Furthermore, policymakers' choices about how to treat wonders do not occur in a vacuum: in many cases, their treatment of extreme upsides will interact with their treatment of extreme downsides.[151] If they choose to adopt different approaches for wonders than for catastrophes, they risk putting a "thumb on the scale" for minimizing catastrophic losses—at the expense of forgoing wonderful gains. The policy implications of such a choice are thorny and worth significant attention.[152]

Unfortunately, there is no substantial evidence that policymakers who address catastrophic risks consider these implications or, indeed, that they systematically consider the possibility of wonders at all. Although this untheorized neglect appears to be relatively pervasive, it is particularly notable in the areas of law and policy where policymakers have addressed catastrophic risk in relatively systematic ways—through adopting information-based disclosure requirements that combat catastrophe neglect,[153] incorporating catastrophic scenarios into expected value through cost-benefit analyses,[154] or by explicitly addressing catastrophic risks with the precautionary principle.[155] Each of these examples presents a concrete opportunity where consideration of extreme upsides could be incorporated into policy—and where continued failure to do so could lead to inadvertent skewing of analyses to underweight extreme benefits in comparison to extreme potential risks. These examples of (apparently untheorized) neglect are discussed further below.

150 *See* discussion *supra* Part I. *See, e.g.*, Sunstein, *Irreversible and Catastrophic*, *supra* note 49, at 844–45 (discussing the prioritization of irreversible loss). *See also* Alan R. Johnson, *Avoiding Environmental Catastrophes: Varieties of Principled Precaution*, ECOLOGY & SOC'Y, 2012, https://perma.cc/D6ZY-XMMF (noting how Congress has abstained from approving Arctic drilling to avoid the risk of oil spills).

151 For further discussion on this point, *see infra* Part III.

152 *See infra* notes 241–263 and accompanying text.

153 *See infra* notes 156–165 and accompanying text.

154 *See infra* notes 166–177 and accompanying text.

155 *See infra* notes 178–181 and accompanying text.

Example 1: Worst-Case Scenarios and The National Environmental Policy Act

First, consider the treatment of catastrophic risks under the National Environmental Policy Act (NEPA).[156] NEPA requires federal agencies to prepare an analysis of expected environmental impacts for every "major federal action[] significantly affecting the quality of the human environment."[157] For many years, there has been an ongoing debate about the extent to which agencies should address "worst-case scenarios" in environmental impacts statements required under NEPA.[158] For some years, both the executive and courts explicitly required agencies to incorporate a "worst case analysis and an indication of the probability or improbability of its occurrence."[159] The requirement was justified by the Council on Environmental Quality (CEQ) on the grounds that "one of the federal government's most important obligations is to present to the fullest extent possible the spectrum of consequences that may result from agency decisions, and the details of their potential consequences for the human environment."[160] In recent years, and particularly in light of the

156 National Environmental Policy Act of 1969, 42 U.S.C. §§ 4321–4370h (2012).

157 *Id.* § 4332(c).

158 *See, e.g.*, Todd S. Aagaard, *A Functional Approach to Risks and Uncertainties Under NEPA*, 1 MICH. J. ENV'T & ADMIN. L. 87, 88–90 (2012) (arguing against proposals that require agencies to analyze worst-case scenarios in NEPA analyses); SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 19–21 (discussing the Council for Environmental Quality's (CEQ) deletion of the worst-case analysis requirement in NEPA analyses and the subsequent challenge in court); Sandra Zellmer et al., *Throwing Precaution to the Wind: NEPA and the Deepwater Horizon Blowout*, J. ENERGY & ENV'T L., Summer 2011, 62, 64–66 (blaming the Deepwater Horizon blowout at least in part on the CEQ's failure to require worst-case scenario analysis under NEPA).

159 *See* Implementation of Procedural Provisions, 43 Fed. Reg. 55,978, 55,997 (Nov. 29, 1978) (codified at 40 C.F.R. § 1502.22) ("If (1) the information relevant to adverse impacts is essential to a reasoned choice among alternatives and is not known and the overall costs of obtaining it are exorbitant or (2) the information relevant to adverse impacts is important to the decision and the means to obtain it are not known (e.g., the means for obtaining it are beyond the state of the art) the agency shall weigh the need for the action against the risk and severity of possible adverse impacts were the action to proceed in the face of uncertainty. If the agency proceeds, it shall include a worst case analysis and an indication of the probability or improbability of its occurrence."). *See also* Save Our Ecosystems v. Clark, 747 F.2d 1240, 1243, 1245–46 (9th Cir. 1984) (finding worst-case analysis deficient without full assessment of environmental effects or likelihood of event occurring); Sierra Club v. Sigler, 695 F.2d 957, 973 (5th Cir. 1983) (holding that remoteness does not obviate obligation to perform a worst-case analysis and should instead be considered in the assessment).

160 Forty Most Asked Questions Concerning CEQ's National Environmental Policy Act Regulations, 46 Fed. Reg. 18,026, 18,032 (Mar. 23, 1981). This executive requirement was relaxed in 1986, on the theory that requiring consideration of worst-case scenarios made NEPA analyses too "sensational," and that they risked misleading the public with "endless hypothesis and speculation." National Environmental Policy Act Regulations; Incomplete or Unavailable Information, 51 Fed. Reg. 15,618, 15,618, 15,620, 15,624 (Apr. 25, 1986) (codified at 40 C.F.R. § 1502.22). That said, the new requirement "retains the duty to describe the consequences of a remote, but potentially severe impact, but grounds the duty in evaluation of scientific opinion rather than in the framework of a conjectural 'worst case analysis.'" National Environmental Policy Act Regulations, 50 Fed. Reg. 32,234, 32,237 (Aug. 9,

Deepwater Horizon disaster and the catastrophe at Fukushima, there has been increasing pressure to reinstate the explicit worst-case scenario analysis requirement, on the theory that failure to systematically consider worst-case scenarios may lead agencies to inappropriately neglect potential extreme impacts.[161]

No reciprocal requirement to consider best-case scenarios has ever been imposed under NEPA. Yet at least at first blush, the stated legal and policy justification for presenting "to the fullest extent possible the spectrum of consequences that may result from agency decisions,"[162] and the concern failing to consider such consequences might skew policy analysis, would seem to apply just as reasonably to extreme-upside events as to extreme-downside events.[163]

Might it be possible to justify asymmetrical treatment of best- and worst-case scenarios in NEPA? Perhaps. It depends upon whether there

1985). Like the prior requirement, however, this relaxed version was focused on "adverse impacts," rather than on any remote, albeit severe (positive or negative), impact. *See* 40 C.F.R. § 1502.22(b) (2019) (including "a summary of existing credible scientific evidence which is relevant to evaluating the . . . adverse impacts" and an "evaluation of such impacts based upon theoretical approaches or research methods generally accepted in the scientific community"). *See also Robertson*, 490 U.S. 332, 354 (1989) (holding that the statute itself does not impose a requirement to prepare a worst case analysis, and noting that "although the prior regulations may well have expressed a permissible application of NEPA, the Act itself does not mandate that uncertainty in predicting environmental harms be addressed exclusively in this manner").

161 *See supra* notes 56–58 and accompanying text. *See also* James Acton & Mark Hibbs, *Why Fukushima Was Preventable*, CARNEGIE ENDOWMENT FOR INT'L PEACE 27–28 (Mar. 2012), https://perma.cc/CFV6-YDFB (arguing that resistance to consideration of worst-case scenarios may have been at least a partial cause of the Fukushima disaster); Holly Doremus, *A Great Case for Worst Case Analysis*, LEGAL PLANET (May 1, 2010), https://perma.cc/H8X2-K6VF ("The recent Gulf oil disaster offers a powerful argument for going back to the original requirement for worst-case analysis, which the current regulation allows agencies to avoid."); Daniel H. Cole, *NEPA and the Deepwater Horizon Oil Spill*, LAW, ECON. & CYCLING (May 2, 2010), https://perma.cc/F8CK-SKLD ("[A]n EIS that includes a worst-case analysis is more likely to result in additional safety measures being imposed than an EIS that does not include one. For that reason, I support Holly [Doremus]'s call for CEQ to reintroduce a worst-case analysis requirement into its NEPA regulations."); Dennis Takahashi Kelso, Exec. Vice President, Ocean Conservancy, Written Testimony for the National Commission on the BP *Deepwater Horizon* Oil Spill and Offshore Drilling 8 (Sept. 22, 2010) (transcript available at Ocean Conservancy) (arguing that the failures leading to the Deepwater Horizon oil spill "point to the need for more rigorous requirements for worst-case scenario analyses").

162 46 Fed. Reg. at 18,032.

163 Of course, reasons to *not* consider worst-case scenarios also might apply equally as reasons to *not* consider best-case scenarios. One justification for the current practice of omitting best-case scenarios from NEPA analysis would be the same justification currently used to justify rescinding the requirement for worst-case scenario analysis: that considering such scenarios leads to unproductive "speculation." 51 Fed. Reg. at 15,620. Whether this justification is persuasive such that agencies should omit both worst-case and best-case scenarios from their analyses is worth additional consideration, some of which is provided in the following Part. Either way, though, policymakers should note when they treat the two types of extremes differently. For further treatment of similarities and differences of catastrophes and wonders, see discussion *infra* Part III.

are important and meaningful distinctions to be drawn between the two categories of potential extreme impacts. This question is discussed in significantly more detail in Part III below.[164] To start with, however, it is worth noting the CEQ has never offered such an analysis, even in defense of its now controversial choice to pull back on its worst-case scenario analysis.[165]

Example 2: The Social Cost of Carbon and Regulatory Impact Analyses

Alternatively, consider that worst-case scenarios are at least sometimes incorporated into expected-value analyses in Regulatory Impact Analyses—but even where calculation of corollary best-case scenarios would be relatively easy, there is no general practice of including them. One particularly important example of this comes from the calculation of the "Social Cost of Carbon" (SCC), a monetized estimate of the social harm caused by each incremental emission of a ton of carbon dioxide.[166] From 2010 to 2017, agencies were explicitly required to incorporate estimates of the SCC generated by an Inter-Agency Working Group (IWG) into cost-benefit analyses of rules that affected greenhouse gas emissions,[167] and as a functional matter, agencies are often still guided by those figures.[168] As a result, the way the SCC is calculated can have a very powerful impact on U.S. climate policy.[169]

The estimates for the SCC generated by the IWG were based on a detailed review of scientific evidence and models for predicting the likely

164 *See infra* notes 231–263 and accompanying text.

165 *See* Steph Tai, *Scientific Uncertainty and the Council on Environmental Quality's Proposed Changes to its National Environmental Policy Act Regulations*, TRENDS, May/June 2020, at 11, 12–13 (discussing the effect of the CEQ's NEPA changes on scientific uncertainty).

166 For a description of the methods used to calculate the SCC, and a summary of then-current agency practice, see Rowell, *Foreign Impacts*, *supra* note 31.

167 *See* INTERAGENCY WORKING GRP. ON SOC. COST OF CARBON, U.S. GOV'T, TECHNICAL SUPPORT DOCUMENT: SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866, at 1 (2010) [hereinafter IWG 2010].

168 The status of the SCC between 2017 and 2020 is somewhat ambiguous. President Trump rescinded President Obama's direction to rely on the IWG's estimate of the SCC, leaving agencies with the task of determining appropriate valuations without the help of a central reference. *See* Promoting Energy Independence and Economic Growth, Exec. Order No. 13,783, 82 Fed. Reg. 16,093, 16,095 (Mar. 28, 2017). Past judicial precedent suggests that agencies who ignore the SCC entirely are likely to have their actions overturned as arbitrary and capricious, but there is likely a range of permissible values. *See* Ctr. For Biological Diversity v. Nat'l Highway Traffic Safety Admin., 538 F.3d 1172, 1200 (9th Cir. 2008) ("[W]hile the record shows that there is a range of [permissible] values, the value of carbon emissions reduction is certainly not zero."). Recent agency actions have still relied at least partially on IWG estimates. *See, e.g.*, KATE C. SHOUSE, CONG. RES. SERV., R45119, EPA'S PROPOSAL TO REPEAL THE CLEAN POWER PLAN: BENEFITS AND COSTS 10 (2018) (relying on IWG estimates to estimate domestic SCC).

169 *See* Rowell, *Foreign Impacts*, *supra* note 31, at 372 (describing the SCC as "the often-overlooked centerpiece of the United States' current policy on climate change," and describing agencies' use of the SCC in their cost-benefit analyses).

impacts of climate change.[170] The IWG then selected four estimates: three driven by different choices of discount rate (and modeled on the likeliest scenarios), and one as an estimate of "high impact"—the catastrophic or "worst case" ninety-fifth percentile scenario estimate of potential climate damage.[171]

Notably, no corollary optimistic scenario was addressed or estimated: the IWG presented no estimates of the low-end, fifth percentile estimate of potential climate damage.[172] Similarly, the IWG reports, which discussed in some detail the need for additional work on potential catastrophic outcomes, did not even mention the possibility of low-end outcomes.[173]

Of course, even the plausible "best case" of forthcoming climate change impacts is likely to look dreary compared to the current status quo,[174] but it may look excellent—even wonderful—in comparison to the baseline of the likeliest future scenarios, such as those presented in the IWG's central estimates.[175]

Is it good policy to exclude best-case scenarios from climate policy, while incorporating worst-case scenarios? Possibly, but if so, the asymmetric exclusion should be reasoned and should be justified on the basis of some principled difference between extreme-upside and extreme-downside impacts. Again, some possibilities for such a distinction are discussed in the subsequent Part[176]—but at least, at first blush, it is worth noting that no discussion of any such reasoning has yet been incorporated into the IWG's calculations.[177]

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170 *See* INTERAGENCY WORKING GRP. ON SOC. COST OF GREENHOUSE GASES, U.S. GOV'T, TECHNICAL SUPPORT DOCUMENT: TECHNICAL UPDATE OF THE SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866, at 3 (2016) [hereinafter IWG 2016].

171 *See* IWG 2010, *supra* note 167, at 1. *See also* IWG 2016, *supra* note 170, at 3.

172 *See* IWG 2010, *supra* note 167, at 1.

173 *See id.* at 29.

174 For example, one recent study based on current emissions trends, suggests that the goals of the Paris climate agreement—which would hold warming to 2° Celsius over pre-industrial levels—have about a one in twenty chance of succeeding. *See* Raftery et al., *supra* note 121, at 637. If these estimates are sound, this would make a 2° Celsius increase in temperatures by 2100 approximately comparable in likelihood to the ninety-fifth percentile "catastrophic" estimate incorporated into the IWG reports.

175 For a readable summary of the likely impacts of a 2° Celsius increase, see Nathaniel Rich, *Losing Earth: The Decade We Almost Stopped Climate Change: A Tragedy in Two Acts*, N.Y. TIMES, Aug. 1, 2018, (Magazine), at 8. https://perma.cc/5NLJ-QN8M ("If by some miracle we are able to limit warming to two degrees, we will only have to negotiate the extinction of the world's tropical reefs, sea-level rise of several meters and the abandonment of the Persian Gulf . . .Three-degree warming is a prescription for short-term disaster: forests in the Arctic and the loss of most coastal cities . . . Four degrees: Europe in permanent drought; vast areas of China, India and Bangladesh claimed by desert; Polynesia swallowed by the sea; the Colorado River thinned to a trickle; the American Southwest largely uninhabitable. The prospect of a five-degree warming has prompted some of the world's leading climate scientists to warn of the end of human civilization.").

176 *See infra* notes 231–263 and accompanying text.

177 *See* IWG 2010, *supra* 167, at 1. *See also* IWG 2016, *supra* 170, at 3.

Example 3: The Anti-Catastrophe Precautionary Principle

As a final example of asymmetric policy treatment, consider the basic structure of the precautionary principle often invoked against catastrophic risks—but without any reciprocal treatment of extreme upsides. Consider, on this front, that conditions of uncertainty are commonly used to justify deployment of the precautionary principle.[178] The Catastrophic Harm Precautionary Principle, for example, holds that when catastrophic outcomes are possible, it makes sense to take precautions against the worst-case scenarios.[179] A straightforward application of the same tools to wonders would suggest that, when the probability of an extreme-upside event is uncertain, it is sensible to apply the opposite of precaution. Here, it is possible to imagine a Wonderful Benefit Proactive Principle, a "miracle maker" principle that would hold that when wonderful outcomes are possible, it makes sense to take action furthering the best-case scenarios. Such a principle would have important implications for, for example, the adoption of novel technologies, such as geoengineering, nanotechnology, and genetic modification. In some cases, those implications would be in tension with those of the Catastrophic Harm Precautionary Principle, with one principle pulling towards precaution and the other towards competing action.[180] The implications and desirability of such a principle deserve additional treatment. But at least insofar as the precautionary principle purports to offer a partial solution to problems of outcome uncertainty in extreme-downside events, it seems a proactive principle may offer a partial solution to problems of outcome uncertainty in extreme-upside events. Yet, I can find no example of any such principle being used in policy today and, even thoughtful treatments of important regulatory topics, such as geoengineering, often underplay or even ignore the potential for wonderful impacts, while simultaneously recommending adoption of anti-catastrophe principles.[181]

178 *See, e.g.*, Sunstein, *Irreversible and Catastrophic*, *supra* note 49, at 876 (discussing situations of uncertainty and the risks associated with those time periods); Daniel A. Farber, *Coping with Uncertainty: Cost-Benefit Analysis, The Precautionary Principle, and Climate Change*, 90 WASH. L. REV. 1659, 1672 (2015) (describing how uncertainty is a factor in determining how to respond to climate change) [hereinafter Farber, *Coping with Uncertainty*]; Farber, *Uncertainty*, *supra* note 49, at 905 (analyzing the relationship between uncertainty and the precautionary principle).

179 *See* SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 119 (describing the catastrophic harm precautionary principle); Sunstein, *Irreversible and Catastrophic*, *supra* note 49, at 846 (similarly describing the catastrophic harm precautionary principle).

180 The question of how policy approaches to catastrophic and miraculous impacts should interact is difficult. I discuss some of the complexities in Part IV, *infra*.

181 *See* SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 7. *E.g.*, CAMACHO & GLICKSMAN, *supra* note 130, at 221 (applying a precautionary approach to address the magnitude and level of uncertainty of geoengineering activities).

III. COMPARING CATASTROPHES AND WONDERS

The prior Part has—I hope—established that scholars and policymakers routinely treat catastrophic risks differently than wonderful opportunities. *Should* they do so? This Part explores that question by examining ways in which catastrophes and wonders are similar and different from one another. At a basic level, it argues that catastrophes and wonders should be treated similarly where they are importantly similar, while recognizing that important differences may justify periodic asymmetry.

More specifically, this Part argues wonders share many of the core qualities of catastrophes, including high magnitude, an unusual relationship with uncertainty, intertemporal impacts, and the triggering of related behavioral phenomena. Insofar as scholars have used these qualities to at least justify incorporating catastrophes into expected-value—and in some cases, to justify treating catastrophic risks with special solicitude—these arguments should be understood to apply with equal force towards wonders. To the extent these qualities should truly be understood to justify use of the precautionary principle for catastrophes, for example, they should also be understood to similarly justify use of a reciprocal proactivity principle for wonders.

It is also important to reflect on where and when differences between catastrophes and wonders explain or justify asymmetric policies. The second section of this Part suggests that several differences are worth considering as potential bases for policy divergence: first, that wonders are good while catastrophes are bad; second, that catastrophes are more likely to be perceived as losses from the status quo and so trigger loss aversion; third, that wonders make people healthier and wealthier while catastrophes do the opposite; and fourth, that wonders trigger optimism and hope while catastrophes trigger pessimism and fear. Identifying these potential bases for divergence may be helpful in answering both the descriptive question of why catastrophes and wonders are treated asymmetrically, and the normative question of whether catastrophes and wonders *should* be treated asymmetrically (and if so, how).

Ultimately, this Part concludes that the determination of whether wonders and catastrophes should be treated similarly or differently for purposes of policy analysis should flow from a reasoned and deliberate analysis of what is importantly different about the two categories of extreme impact.

A. Important Similarities in Catastrophes and Wonders

This section articulates four ways catastrophes and wonders are similar, such that they might justify similar management approaches by policymakers. First is the basic observation catastrophes and wonders

have a very large magnitude.[182] Second, both categories implicate risk and uncertainty.[183] Third, both trigger thorny questions of intertemporal distribution and the ability of legal institutions to effectively respond to those distributions.[184] And fourth, many of the same cognitive phenomena that affect the processing of large, probabilistic, uncertain, or intertemporal events should be expected to apply to processing wonders much the same as they would apply to processing catastrophes.[185] These qualities are the same characteristics that catastrophe scholars have emphasized justify attention to and/or special treatment of catastrophic risk; the straightforward observation here is that those characteristics apply to wonders as well as catastrophes. Policy approaches built on any of these shared qualities should apply equally to wonders and catastrophes, and the substantive similarities between extreme upsides and extreme downsides should create a rebuttable presumption that the two categories should be treated similarly in policy analyses.

1. Both Catastrophes and Wonders Involve Enormously Large Impacts

Both extreme-upside and extreme-downside events involve the chance of enormous policy impacts—impacts that may trigger the possibility of any combination of fundamental social shifts, huge adaptation impacts, and mass differences in the magnitude of human suffering and environmental degradation. This is a fundamental similarity between catastrophes and wonders, and to the extent sheer magnitude of potential impacts justifies policy attention, it should be understood to do so whether the expected impacts are above or below the status quo. Indeed, from the perspective of expected utility theory, a policy that prevents a "catastrophe" by preventing 5 million people from dying prematurely (say from preventing a pandemic) has the same magnitude of impact as a policy that assured a "wonder" by saving the lives of 5 million people who would otherwise have died (say from a previously incurable disease).[186]

How large must impacts be to constitute a catastrophe or a wonder—must five million lives be at stake, or are 5,000 sufficient? Literature on catastrophe provides varied answers, and continues to struggle to identify a consensus definition and particularly to differentiate a consensus bright line between catastrophes and "less-bad" bad events.[187] Indeed, these

182 *See infra* notes 186–195 and accompanying text.

183 *See infra* notes 196–209 and accompanying text.

184 *See infra* notes 210–221 and accompanying text.

185 *See infra* notes 222–230 and accompanying text.

186 The predictions of prospect theory, under which the status quo plays a determinative role, are discussed further in the subsequent Part. *See infra* notes 232–240 and accompanying text.

187 *See, e.g.*, RICK BISSELL, PREPAREDNESS AND RESPONSE FOR CATASTROPHIC DISASTERS 5 (2013) (explaining, after a review of the catastrophe literature, that "none of the definitions we have offered thus far has a single clear tipping point at which an event converts from being [very bad] to taking on the characteristics of a catastrophe. This 'loose definition'

definitional struggles are so pervasive some commentators have gone so far as to characterize the looseness of the definition of catastrophe as an enduring characteristic of catastrophe management.[188] To the extent the definitional challenge of determining what counts as extreme magnitude is indeed an important characteristic of work on extreme-magnitude events, it is worth noting this definitional ambiguity applies as well to extreme-upside wonderful events as it does to extreme-downside catastrophic events.

Whether or not definitional ambiguity is a necessary condition of work on extreme-magnitude events, there has certainly been extraordinarily broad variation in the magnitude, geographic, and temporal scope commentators have required for extreme-downside events to qualify as catastrophic. In his book *Catastrophe*, for example, Richard Posner was worried about what has, in the modern literature, come to be called "existential risk": risks of global, terminal, trans-generational catastrophe, such as extinction of humans or of life on Earth.[189] But these risks, while now a scholarly cottage industry of their own,[190] are by no means the sole target of scholarship on catastrophe policy. Rather, like Jared Diamond, many catastrophe scholars are also concerned about slower and (sometimes) less-terminal catastrophes, such as those created by terrorism, natural disasters, ecosystem degradation, and gradual climate change.[191]

Though different catastrophe scholars focus on different thresholds for catastrophe, such thresholds can often be categorized by some

phenomenon is one of the enduring (if not endearing) qualities of extreme event preparedness and response.").

188 *See id.*

189 CATASTROPHE: RISK AND RESPONSE, *supra* note 21, at 5–6 (discussing various risks that threaten the survival of the human race). *See* Nick Bostrom, *Existential Risk Prevention as Global Priority*, 4 GLOBAL POL'Y 15, 19, 26 (2013) (depicting classes of existential risk). *See generally* GLOBAL CATASTROPHIC RISKS *supra* note 30, at 2–3 (offering an introduction to the range of global catastrophic risks facing humanity both now and in the future).

190 *See, e.g.*, JAMES BARRAT, OUR FINAL INVENTION: ARTIFICIAL INTELLIGENCE AND THE END OF THE HUMAN ERA 3–4, 12–13 (2013) (describing "superintelligent" AI); Seth D. Baum & Bruce E. Tonn, *Confronting Future Catastrophic Threats to Humanity*, 72 FUTURES 1, 1 (2015) (discussing the threats to human viability); NICK BOSTROM, SUPERINTELLIGENCE: PATHS, DANGERS, STRATEGIES 115 (2014) (addressing global catastrophic risks from artificial intelligence); JOSEPH CIRINCIONE, BOMB SCARE: THE HISTORY & FUTURE OF NUCLEAR WEAPONS, at xi (2008) (addressing global catastrophic risks from nuclear weapons); OLLE HÄGGSTRÖM, HERE BE DRAGONS: SCIENCE, TECHNOLOGY, AND THE FUTURE OF HUMANITY 184, 188, 193 (2016) (detailing the "complex intermingled" system of causes that contributed to human extinction); MARTIN REES, OUR FINAL HOUR: A SCIENTIST'S WARNING: HOW TERROR, ERROR, AND ENVIRONMENTAL DISASTER THREATEN HUMANKIND'S FUTURE IN THIS CENTURY—ON EARTH AND BEYOND 2, 4 (2003) (detailing the prospective benefits of genetics, robotics, and nanotechnology against risk); THE TECHNOLOGICAL SINGULARITY: MANAGING THE JOURNEY 5–6, 12 (Victor Callaghan et al. eds., 2017) (addressing potential issues with "superintelligent" AI). S*ee generally* GLOBAL CATASTROPHIC RISKS, *supra* note 30, at 1.

191 *See, e.g.*, DIAMOND, *supra* note 28, at 7 (discussing twelve environmental problems affecting civilization today).

interaction of high severity and scope, which might be either geographic or temporal.[192] Catastrophe management thus uses a wide variety of definitions for identifying catastrophes and therefore for triggering any special treatment that catastrophes receive within risk management approaches. Because extreme-upside impacts have yet to generate substantial discussion, no such controversy about the appropriate magnitude required to justify categorization of impacts as "wonderful" or "miraculous" has yet developed. Yet, once extreme-upside events are recognized as a legitimate target of scholarly attention, it would be strange if such a debate failed to materialize. Benefits, like harms, can range in severity and in how they are distributed across space and time. The core of what makes beneficial impacts wonderful, and harmful impacts catastrophic, is that the magnitude of those impacts is extreme. Questions about just how extreme those impacts must be to justify categorization as "wonderful" or "catastrophic" are thus both inevitable and productive. And just as with catastrophes, different reasonable people working in different contexts might select different threshold determinations for extreme-upside impacts.

The task of generating hypothetical "wonders," and of conceiving of how they might vary from one another in magnitude and scope, may be made easier by existing work on catastrophes. Consider, for example, the influential (albeit not consensus) approach to typologizing catastrophes proffered by philosopher Nick Bostrom, who distinguishes catastrophic harms by looking at "severity" and (geographic) "scope" (see Figure 2). [193] The existence of typologies like this one, which categorize very large risks along multiple parameters,[194] converts the creation of typologies for very large benefits into something like an exercise in gap-filling. As a first attempt at filling out such a scheme, consider the following, comparing increasingly *good* impacts over increasing geographic scales, to Bostrom's

192 Individual scholars vary in what they define as catastrophes along these ranges. Philosopher Nick Bostrom, for example, focuses on "global catastrophic risks" that present possibilities of global impact, even human extinction. Bostrom, *supra* note 189, 15. Posner's primary concerns, by contrast, are the terminal, trans-generational risks that Bostrom calls "existential." *See* CATASTROPHE: RISK AND RESPONSE, *supra* note 21, at v (identifying global catastrophic risks as asteroid collision, global bioterrorism, and abrupt global warming). Other scholars, such as Cass Sunstein, would be willing to include even local endurable risks, such as the risk of recession, in the category of catastrophe. *See, e.g.*, SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 135 (arguing that regulators should consider the value of the catastrophic risk, even if it is unlikely). This broader conception of catastrophe is congruent with the definition typically used in the insurance industry, where catastrophes are events that cause severe loss to a large population. *See, e.g.*, AM. ACAD. OF ACTUARIES, *supra* note 24, at 1 ("For property and casualty insurers, catastrophes are defined as infrequent events that cause severe loss, injury, or property damage to a large population of exposures.").

193 Bostrom, *supra* note 189, at 17.

194 *See id.* (categorizing the scope of a risk as personal, local, global, trans-generational, or pan-generational and classifying the severity of a risk as imperceptible, endurable, or crushing).

increasingly *bad* impacts over similar geographic scales.[195] As with catastrophes, particular thresholds selected might be understood to trigger categorization of different events as "wonders."

FIGURE 2: COMPARING THE SCOPE AND MAGNITUDE OF POTENTIAL CATASTROPHES AND WONDERS

SEVERITY/MAGNITUDE →

SCOPE ↑

	Imperceptible		Endurable/Delightful		Terminal	
	Bad	Good	Bad	Good	Bad	Good
Trans-Generational	*Loss of one beetle species.*	*Evolution of one new beetle species.*	*Drastic loss of bio-diversity.*	*Drastic gain in bio-diversity.*	*The total destruction of life on Earth.*	*Successful colonization of other planets.*
Global	*Global warming by 0.01 K.*	*Global cooling by 0.01 K.*	*Destruction of ozone layer.*	*Geo-engineering of desired climate.*	*Aging.*	*Cure for Cancer.*
Local	*Congestion from one extra vehicle.*	*Reduced congestion from one vehicle.*	*Recession in one country.*	*Economic boom in one country.*	*Genocide.*	*Abolition of slavery.*
Personal	*Loss of one hair.*	*Repair of one cell.*	*One's car is stolen.*	*One receives a new car.*	*Fatal car crash.*	*Life-saving organ transplant.*

As a starting point, it should be clear that the basic puzzles underlying the definition of "catastrophes" are identical to those underlying the definition of "wonders." That said, any of these individual examples might generate quibbles, and the structure of the combined typology invites comparisons: Is the geoengineering of desired climate really comparable in goodness to how bad it is to have the ozone layer destroyed? Is the abolition of slavery really as good as genocide is bad? Is aging as bad as a cure for cancer would be good? These are interesting and difficult questions and exploring them in more detail may generate productive improvements in how we think systematically not only about catastrophic risks, but also about wonderful benefits.

2. Both Catastrophes and Wonders Implicate Risk and Uncertainty

In risk literatures, it is conventional to distinguish between conditions of risk (where probabilities and possible outcomes are known) and conditions of uncertainty (where possible outcomes are known, but probabilities are not).[196] Typologies of risk and uncertainty abound,

195 *See id.* (measuring examples of bad impacts ranging from global catastrophic risk to existential risk); *see also infra* Figure 2.

196 For the classic distinction, see FRANK H. KNIGHT, RISK, UNCERTAINTY AND PROFIT 43–44 (1921) (describing the class distinction of taking known risks). For a discussion, see

ranging from Donald Rumsfeld's now-famous distinctions between "known knowns, known unknowns, and unknown unknowns,"[197] to a distinction between "subway uncertainty" (the relatively narrow band of uncertainty associated with predicting how much time it will take you to reach your place of employment on the subway) to "coconut uncertainty" (the larger band of uncertainty associated with seemingly-random, uncommon, but high-stakes events, such as being killed by a coconut falling on your head).[198]

While these typologies are generally used to categorize the possibility of bad things happening, similar distinctions should also be understood to apply to the prospect of good things happening. Sometimes, the probability and possible outcomes of a good event are understood: the chance that any individual player wins a fair lottery, for example, is a function of well-understood probabilities. The same holds true for many social projects: the population-wide benefits of chlorinating drinking water can be relatively well-quantified, for example, though the probabilities and outcomes are admittedly harder to quantify than with a lottery. Other potential wonders should be understood as presenting uncertainties, such that possible outcomes may be known, but the probabilities of those outcomes cannot be reliably generated. The benefits of a novel vaccine against a novel virus, for example, may be wonderful, even as they present greater uncertainty than the benefits of a well-studied vaccine (say, against measles) against a well-known disease. As with uncertainty about negative outcomes, uncertainty about positive outcomes is more likely where the outcomes depend on complex and interactive systems that are difficult to model ahead of time, on stochastic events that are so rare that it is difficult or impossible to attach a probability to them, or both. For example, the possibility that gene-hacked mosquitos eliminate or significantly curtail transmission of mosquito-borne illnesses depends on a number of natural, geographic, and social factors that remain challenging for scientists to model.[199] Other uncertain wonders would include those triggered by not-yet-invented

Farber, *Uncertainty*, *supra* note 49, at 903 (discussing the legal and policy implications of what Knight classified as uncertainty and risk).

197 Donald Rumsfeld, Sec'y of Def., U.S. Dep't of Def., Department of Defense News Briefing (Feb. 12, 2002) (transcript available at Department of Defense Press Operations) https://perma.cc/XEP6-SEQF. For a discussion of multiple typologies of risk and uncertainty, see Farber, *Uncertainty*, *supra* note 49, at 914–17 (describing attempts to clarify the application of the precautionary principle to different categories of uncertainty).

198 *See* Spyros Makridakis et al., *Forecasting and Uncertainty in the Economic and Business World*, 25 INT'L J. FORECASTING 794, 802–03 (2009) (describing subway uncertainty).

199 For a discussion of gene-hacked mosquitoes, see Gantz et al., *Highly Efficient Cas9-Mediated Gene Drive for Population Modification of the Malaria Vector Mosquito* Anopheles stephensi, 112 PROC. NAT'L ACAD. SCI., E6736, E6742 (2015), https://perma.cc/3325-JF2E. Scientists continue to struggle even to understand the extent to which resistant mosquitoes crop up in gene-hacked populations. *See* Pub. Library of Sci., *Gene Drives Have the Potential to Suppress Mosquito Populations, but Resistant Mosquitoes Crop Up*, SCIENCEDAILY (Oct. 10, 2017), https://perma.cc/3WQB-EY89 (describing the gene modified mosquitos and the resistance they developed).

technologies: the process and timing of invention remains sadly opaque, so predicting the likelihood of inventions of new geoengineering techniques, cures for cancer, vaccines against COVID, or cost-effective desalinization technologies is uncertain in important ways.

From a policy perspective, it would make sense to model responses to known-probability wonders to responses to known-probability catastrophes, and responses to uncertain wonders to responses to uncertain catastrophes. Analyses requiring expected value, such as cost-benefit analysis, will be most sensible where it is possible to generate meaningful estimates of probability. This holds true for extreme upsides as it does for extreme downsides. But cost-benefit analysis is likely to prove less helpful to wonderful uncertainties, as it has to catastrophic uncertainties. When the possibility of a high-magnitudehappy outcome remains uncertain, policymakers ought at least to consider the policy approaches they have developed specifically to deal with uncertainty in high-magnitude sad outcomes. Here, the anti-catastrophe precautionary principle should be understood as having a reciprocal pro-wonder proactive principle. Where there are extreme-magnitude impacts on both sides of a policy, policymakers should balance precaution against catastrophe with proactivity towards wonders. The uncertainty of catastrophic vaccine side effects, for example, should not blind policymakers to the possibility of miraculous vaccine benefits: both scenarios present the possibility of extreme-magnitude impact, and focusing on only one side of the equation may mislead policymakers in dangerous and even tragic ways.

Another probability-related similarity between extreme-upside and extreme-downside events relates to the possibility of non-normal probability distributions. Traditionally, economic modeling and policy analysis were often based on probability distributions that presumed that extreme impacts were highly unlikely.[200] This presumption follows from assuming that probabilities follow a normal distribution, or a bell curve: such distributions have a thin, or long, tail.[201] In recent years, economists and policy scholars have warned about the possibility of probability distributions with so-called "fat tails," where the probability of extreme events occurring is significantly more likely than in thin-tail distributions.[202] Fat-tail distributions are particularly likely in complex

[200] For a useful discussion, see Farber, *Uncertainty*, *supra* note 49, at 904 (explaining that, because conventional analyses assumed extreme impacts to be highly unlikely, these models underestimate extreme risk).

[201] *See id.* at 923 ("If the average cat weighs ten pounds, we can expect that most cats will be within a few pounds of the average, so a vet buying a scale could safely disregard the possibility of a two-hundred-pound Siamese.").

[202] *See* Martin L. Weitzman, *Additive Damages, Fat-Tailed Climate Dynamics, and Uncertain Discounting*, ECON.: THE OPEN-ACCESS, OPEN-ASSESSMENT E-J., Oct. 28, 2009, at 1, 1, https://perma.cc/2BV3-SVU4 (exploring the "fat-tail" of climate sensitivity and the infinite variance associated with it).

systems,[203] and have a number of policy-relevant characteristics[204]—not least being that, when tails are thick enough, extreme (albeit still relatively unlikely) impacts may end up swamping the analysis.[205]

Work on the policy implications of fat tails has focused on one side of the probability distribution, where harms may be catastrophic.[206] The potential catastrophic effects of climate change have been a particular focus,[207] and for good reason. Indeed, policy work by Weitzman and others was likely a significant reason that the United States S.C.C. incorporated a ninety-fifth percentile "worst case" scenario into its calculations of the likely impacts of climate change. Yet, while distributions can be asymmetrical, it is also perfectly possible to have a two-tailed probability distribution where both tails are fat.[208] Where there is a fat-tail distribution of extreme upside potential, policymakers ought to at least consider policy instruments developed to address fat-tail downsides.[209]

3. Both Catastrophes and Wonders Implicate Intertemporal Distributions of Costs and Benefits

The costs and benefits of policies addressing both extreme upsides and extreme downsides tend to be spread out over time, rather than bunched into a single decision point. For policy intended to minimize extreme downsides, investment in prevention or mitigation must often predate triggering events: building a sea wall, for example, may accrue cost for years—if not decades—before it accrues the benefit of averting future flooding. The same might be said of policies intended to maximize

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203 For discussion of where fat-tail distributions are likely to arise in policy contexts, see Farber, *Uncertainty*, *supra* note 49, at 925–28.

204 *See, e.g.*, Robert S. Pindyck, *Fat Tails, Thin Tails, and Climate Change Policy*, 5 REV. ENV'T ECON. & POL'Y 258, 260 (2011) (discussing how fat-tails and cost-benefit analysis can be misleading).

205 *See id.* (describing a *T* tail distribution).

206 *See, e.g.*, Farber, *Uncertainty*, *supra* note 49, at 920 (explaining how fat-tailed distributions are linked with catastrophic outcomes); Pindyck, *supra* note 204, at 262 (utilizing a fat-tailed distribution in assessing the probability of catastrophic global temperature changes); Weitzman, *supra* note 202, at 10 (discussing the concerns of appropriately representing damages from global warming).

207 *See* Farber, *Uncertainty*, *supra* note 49, at 944 (looking at climate models and their utility in planning for climate change adaptation); Pindyck, *supra* note 204, at 272 (relying on fat-tailed distributions to reduce the uncertainty of temperature changes, economic impact, and welfare effect of climate change); Weitzman, *supra* note 202, at 20 (discussing the dynamics of fat-tailed distributions as applied to the high-variance additive damages of climate change).

208 In fact, a classic "fat tail" distribution, also called leptokurtic distribution, is typically portrayed as having two fat tails. Lawrence T. DeCarlo, *On the Meaning and Use of Kurtosis*, 2 PSYCH. METHODS 292, 292–93 (1997).

209 For a thoughtful treatment of fat-tailed catastrophic risk and its policy implications, see Farber, *Uncertainty*, *supra* note 49, at 935 (utilizing theories of ambiguity to analyze uncertainties). Farber's alpha precautionary principle—the instrument he chooses to recommend for catastrophic risks—could presumably be applied as a proactive principle to miraculous opportunities. *Id.* at 905.

many extreme upsides: investing in geoengineering research might accrue costs for years, if not decades, before it accrues benefits in the form of a reliable, useable technology.

This temporal separation of costs and benefits—with costs frontloaded and benefits backloaded—is familiar in many policy contexts and is particularly common in environmental regulation.[210] When the triggering events for benefits accrual are uncommon, however—as they are likely to be in many catastrophic and wonderful scenarios—there may be even greater latency between the time a policy is "paid for" and the time benefits accrue.

This presumptively longer latency period has several implications that would seem to apply equally either to catastrophe or wonder policy.

First, long latency periods put substantial pressure on political and psychological processes for addressing distant-future benefits.[211] Across multiple contexts, individuals tend to struggle to process future impacts. This difficulty manifests in multiple forms. People struggle to accurately predict their own future preferences[212] and make substantively different tradeoffs depending upon whether they are choosing for the near- or far-future.[213] Perhaps most problematically, in making tradeoffs between the present and the future, people exhibit what is sometimes called "present bias," attaching a stronger weight to immediate impacts than to latent ones.[214] This often leads people to exhibit time-inconsistent preferences: for example, if people are asked to choose between $1 today and $2 tomorrow, many will choose the $1 today. But the very same people asked to choose between receiving $1 in one year and $2 in a year and a day will often choose the $2.[215] These phenomena pose challenges to policies—such as environmental policies, or as posited here, extreme-impact policies—where costs are frontloaded, and benefits are backloaded. As Howard Kunreuther, Robert Meyer, and Erwann Michel-Kerjan have

210 *See, e.g.*, REVESZ & LIVERMORE, *supra* note 55, at 3, 9, 108 (describing the influence of cost benefit analysis on regulation).

211 *See* ROWELL & BILZ, *supra* note 3, 50–51 (discussing the psychological implications of latency).

212 *See* Jeremy A. Blumenthal, *Law and the Emotions: The Problems of Affective Forecasting*, 80 IND. L.J. 155, 166–67 (2005) (describing the relationship between emotions and predictions); George Loewenstein & David Schkade, *Wouldn't It Be Nice? Predicting Future Feelings*, *in* WELL-BEING: THE FOUNDATIONS OF HEDONIC PSYCHOLOGY 85, 86, 88, 94 (Daniel Kahneman et al. eds., 1999).

213 *See* Nira Liberman & Yaacov Trope, *The Role of Feasibility and Desirability Considerations in Near and Distant Future Decisions: A Test of Temporal Construal Theory*, 75 J. PERSONALITY & SOC. PSYCH. 5, 5, 10 (1998) (finding that students given the choice between high-interest, high-difficulty assignments and low-interest, low-difficulty assignments chose the difficult, interesting assignments for the far-future, and the easier, less-interesting assignments for the near-future; thus the relative weights of interest and ease changed as a function of temporal distance).

214 *See, e.g.*, Ted O'Donoghue & Matthew Rabin, *Doing It Now or Later*, AM. ECON. REV., Mar. 1999, at 103, 103 (describing present-biased preferences).

215 *See generally* Shane Frederick et al., *Time Discounting and Time Preference: A Critical Review*, 40 J. ECON. LITERATURE 351, 351–52, 360–61 (2002) (discussing the evolution of understanding of intertemporal choice).

argued in the context of catastrophes, "[t]he effect of placing too much weight on immediate considerations is that the up-front costs of [catastrophe] mitigation will loom disproportionately large relative to the delayed expected benefits in losses over time."[216] As a result, individuals are less likely to take individual precautions, and citizens are less likely to call for—or even to support—political actions that require immediate investment for future benefits.[217] These concerns apply as well to wonder-promoting policies that require immediate investment for future payoff, just as they do to catastrophe-mitigating policies that have the same intertemporal distribution of costs and benefits.

Second, long latency periods put substantial pressure on institutions' practices for comparing costs and benefits across time. In the United States, the convention is to monetize all of these benefits and to attach a discount rate to future impacts.[218] Future impacts can then be discounted to present value, and compared to any immediate costs or other impacts.[219] Generally speaking, higher discount rates make future impacts look small in today's dollars, whereas lower discount rates make future impacts look relatively larger today.[220] The longer the latency period, the more it is likely to matter which particular discount rate regulators choose: more time gives small differences in rates longer to compound.[221] This holds true when the impacts to be discounted are wonderful or catastrophic; high discount rates can make distant future extreme impacts look negligible today, whether those impacts are good or bad.

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216 Howard Kunreuther et al., *Overcoming Decision Biases to Reduce Losses from Natural Catastrophes*, *in* BEHAVIORAL FOUNDATIONS OF POLICY 398, 401 (Eldar Shafir ed., 2013).

217 *See id.* at 401–02, 408 (describing the effects of uncertainty in real life situations, like purchasing a house).

218 For a review of agency practice, and a qualified defense of U.S. discounting practice, see Cass R. Sunstein & Arden Rowell, *On Discounting Regulatory Benefits: Risk, Money, and Intergenerational Equity*, 74 U. CHI. L. REV. 171, 171–74 (2007). *See also* Rowell, *Time*, *supra* note 33, at 1216 (exploring the role discounting with performing cost-benefit analysis). Agencies, operating under institutional and practical constraints, are not always able to ideally implement this theory. *See* Arden Rowell, *The Cost of Time: Haphazard Discounting and the Undervaluation of Regulatory Benefits*, 85 NOTRE DAME L. REV. 1505, 1505–09 (2010) (arguing that agency practice is sometimes undermined by the time-indeterminacy of elicited preferences) [hereinafter Rowell, *The Cost of Time*].

219 *See* Sunstein & Rowell, *supra* note 218, at 171–72 (illustrating what discounting looks like).

220 *See* Emilio Padilla, *Intergenerational Equity and Sustainability*, 41 ECOLOGICAL ECON. 69, 69–70 (2002) (explaining that higher discount rates lead to devaluation of future impacts and lower discount rates imply greater environmental degradation to future generations); Rowell, *The Cost of Time*, *supra* note 218, at 1515–16 (showing that the value of a human life today using a 10% discount rate is drastically lower than the value one hundred years later).

221 Rowell, *The Cost of Time*, *supra* note 218, at 1520, 1528.

4. Both Catastrophes and Wonders May Trigger Cognitive Phenomena Related to Processing Large Impacts and Probabilistic, Uncertain, and Intertemporal Events

Another important way to compare wonders and catastrophes is to consider the cognitive phenomena triggered by perceiving them. It has become commonplace in catastrophe analysis, as in so many areas of law, to point to a long list of cognitive biases and heuristics to which people are susceptible, and which might be expected to affect the management of catastrophic risks either by individuals or by public actors.[222] Where these cognitive phenomena are triggered by the processing of large impacts and/or future probabilistic or uncertain events, they should be understood to apply not only to how people process possible catastrophe, but also how they process possible wonders. One aspect of these psychological similarities relates to intertemporal impacts, which have already been discussed. Another relates to how people struggle to understand large impacts of any type. Indeed, the psychology of large impacts is complex and implicates competing cognitive phenomena. Some research suggests people tend to anticipate catastrophic risk in two competing modes:[223] either they neglect it entirely, treating it as essentially zero,[224] or they become highly sensitized to it, focusing on the possible bad outcome with little to no attention to its attendant probability.[225] One useful way of constructing these competing strands is to recognize that uncommon, hard-to-imagine outcomes can trigger what Jonathan Wiener has called a "tragedy of the uncommons," leading people to neglect possible outcomes they find difficult to visualize.[226] For outcomes that are hard to visualize, such as climate change, a responsive policy prescription is to try to increase the cognitive salience—or at least the imaginability—of hard-to-imagine events.[227] On the other hand,

222 *See, e.g.*, Howard Kunreuther & Geoffrey Heal, *Managing Catastrophic Risk*, *in* 3 ENCYCLOPEDIA OF ENERGY, NATURAL RESOURCE, & ENVIRONMENTAL ECONOMICS 52, 52–54 (Jason F. Shogren ed., 2013) (listing budgeting heuristics, hyperbolic discounting, myopia, procrastination, and "underestimation of risk" as behavioral explanations for underinvestment in measures to reduce or adapt to catastrophic risk).

223 SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 5.

224 *See* CATASTROPHE: RISK AND RESPONSE, *supra* note 21, at 8–9 (explaining that human minds neglect catastrophic risks as survival depended on high-probability, rather than low-probability, events); JONATHAN BARON, THINKING AND DECIDING 255 (2000) (finding that, when people are told that the probability of being killed in an automobile accident is 0.00000025 per trip, 90% reported unwillingness to wear seat belts).

225 SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 6–7. *See, e.g.*, Kunreuther & Heal, *supra* note 222, at 54 (stating that protection decisions are rarely based on formal beliefs about probabilities).

226 *See* Jonathan B. Wiener, *Tragedy of the Uncommons: On the Politics of Apocalypse*, 7 GLOBAL POL'Y 67, 69 (2016) (stating that a low-frequency nature of a risk contributes to neglect because research shows people are more concerned with risks that they can imagine).

227 *See id.* at 76 (recommending that public awareness to uncommons risks be heightened through the use of films, virtual reality, and precursor events); SUNSTEIN, WORST-CASE

outcomes that are easy to visualize are commonly perceived as more likely.[228] In the literature on catastrophe, this dynamic is commonly invoked to explain why the public is generally more fearful of high-salience catastrophes, such as terrorism, than are experts; while simultaneously less fearful of low-salience catastrophes, such as climate change.[229]

Further exploration of these interactions as they apply to extreme-upside events would be a fruitful project in its own right. At first blush, however, it should be noted these psychological phenomena in aggregate can lead to either underestimation or overestimation of risks and to either significant concern or general neglect under uncertainty.[230] Thus, at least for these cognitive responses, there seems little reason to treat either catastrophes or wonders with a single broad brush. Rather, in considering catastrophe and wonder perception, policymakers should be aware of a complex set of interacting cognitive phenomena, which might lead either to neglect or to obsession about any particular high-impact event.

B. Important Differences in Catastrophes and Wonders

The previous Part argued that catastrophes and wonders are importantly similar insofar as they share a large magnitude; implicate probabilistic, uncertain outcomes, or both; have intertemporal impacts; and implicate cognitive phenomena based on each of these qualities.[231] Policies built on these qualities should apply equally to extreme-upside and extreme-downside events.

But catastrophes and wonders also have important differences. Where differences exceed similarities in importance, it may be sensible to craft wonder policies that differ from those that manage catastrophes. Such distinctions should be principled, however, rather than a result of accidental neglect of wonders, or justified on the basis of a misunderstanding of the psychology underlying good and bad events.

1. Catastrophes are Bad, While Wonders are Good

The most important difference between wonders and catastrophes is the obvious one: wonders are good, while catastrophes are bad. The clear implication of this observation is that while some of the mechanisms

SCENARIOS, *supra* note 30, at 277–78 (describing the public's lack of intense emotions and imagination regarding climate change, despite vivid incidents and images).

228 *See* Wiener, *supra* note 226, at 69, 72 (explaining that people are more worried about risks of events they are able to envision and feel the importance of, such as airplane accidents or events with a single victim, and not events they have become numb to, such as automobile accidents or events with multiple victims).

229 *See* Wiener, *supra* note 226, at 67–68 (discussing why some events may be more salient than climate change). *See also* SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 26–27 (applying this explanation to terrorism).

230 *See* SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 6–7.

231 *See supra* notes 222–230 and accompanying text.

developed for catastrophe management might also be applied to wonder management, these mechanisms will need to be applied to opposite ends: to discourage catastrophes while encouraging wonders. Thus, a Wonderful Benefit Proactive Principle should seek to *encourage* the creation of extreme-impact (good) events, whereas the Catastrophic Harm Precautionary Principle should seek to *discourage* extreme-impact (bad) events.

Less intuitively, and as discussed further below, differing perceptions of bad and good may trigger distinct cognitive and emotional responses.

2. Catastrophes are Likely to Invoke Loss Aversion Because They Implicate Losses from the Status Quo, Whereas Wonders Are Likely to be Viewed as Potential Gains

Because wonders are good, and catastrophes are bad, behavioral and psychological research suggests they are likely to be processed very differently from one another. More specifically, catastrophes are likely to invoke loss aversion, leading them to be systematically weighted more heavily than wonders—even when the magnitude of both is comparable.

The phenomenon of loss aversion—and related phenomena of status quo bias and the endowment effect—famously grew out of research from psychologists Daniel Kahneman and Amos Tversky, who proposed a theory—"prospect theory"—that describes people's observed behavior under conditions of risk.[232] The basic thrust of prospect theory is people value losses differently than gains, and these values can be observed in their resulting behavior, in which they seek far more strongly to minimize losses than they seek to maximize gains.[233] The resulting heightened sensitivity to loss is what is typically called loss aversion. Subsequent scholars have built on the basic findings underlying prospect theory to identify a constellation of related phenomena, including status quo bias[234] and the endowment effect.[235]

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[232] For the touchstone piece see Daniel Kahneman & Amos Tversky, *Prospect Theory: An Analysis of Decision Under Risk*, 47 ECONOMETRICA 263, 263 (1979) [hereinafter *Prospect Theory*]. *See also* Amos Tversky & Daniel Kahneman, *Loss Aversion in Riskless Choice: A Reference-Dependent Model*, 106 Q. J. ECON. 1039, 1039 (1991) [hereinafter *Loss Aversion in Riskless Choice*] ("The central assumption of the theory is that losses and disadvantages have greater impact on preferences than gains and advantages.").

[233] *See Prospect Theory*, *supra* note 232, at 274 (explaining how individuals analyze prospects to maximize the value of their decision). *See also* Eyal Zamir, *Law's Loss Aversion*, *in* THE OXFORD HANDBOOK OF BEHAVIORAL ECONOMICS AND THE LAW 268, 268 (2014) (describing how losses are valued more than gains regardless of risk).

[234] *See* Daniel Kahneman et al., *Anomalies: The Endowment Effect, Loss Aversion, and Status Quo Bias*, 5 J. ECON. PERSP., Winter 1991, at 193, 194, 197–98 (1991) (describing *status quo* bias). *See also* William Samuelson & Richard Zeckhauser, *Status Quo Bias in Decision Making*, 1 J. RISK & UNCERTAINTY 7, 8 (1988) (describing status quo bias).

[235] *See* Kahneman et al., *supra* note 234, at 194 (discussing the endowment effect and loss aversion). *See also* Russell Korobkin, *Behavioral Economics, Contract Formation, and*

Scholars continue to research and debate the exact mechanisms that lead people to perceive a particular outcome as the status quo against which gains and losses will be measured.[236] Often, perceptions are at least partially responsive to the way questions are framed.[237] But the basic empirical finding—that across multiple contexts, people systematically weight losses more heavily than they weight similar gains—has grown remarkably robust.[238]

From a descriptive standpoint, the impact of loss aversion may go some additional way to answering the question of why catastrophe policy has developed so much more quickly than wonder policy. Nor should risk scholars feel particularly sheepish about this lopsided development; disproportionate attention to losses and costs continues to be characteristic of many related fields, possibly for the same reason.[239] Scholars are people too, and it is easy for us to think first about losses and only then to circle around to consider potential gains.

Loss aversion, then, creates a potentially important distinction in the way that catastrophes are perceived and weighted, in comparison to wonders. Whether that distinction *should* drive differences in the management of wonders and catastrophes is a different and deeply difficult question, one that touches on deeply controversial puzzles about whether—and if so, when—public policies should ever be based on cognitive biases and heuristics.[240]

3. Catastrophes Make People Poorer and Sicker; Wonders Make People Wealthier and Healthier

Another important distinction between catastrophic loss and wonderful gain may be the impact of such events on the status of affected people: catastrophes will tend to make people poorer and sicker, whereas

Contract Law, *in* BEHAVIORAL LAW AND ECONOMICS 116 (Cass Sunstein ed., 2000) (describing the perceived relationship between status quo bias and the endowment effect).

236 *See, e.g.*, John T. Jost et al., *A Decade of System Justification Theory: Accumulated Evidence of Conscious and Unconscious Bolstering of the Status Quo*, 25 POL. PSYCHOL. 881, 887 (2004) (reviewing the tendency towards "system justification," or towards rationalizing what is perceived to be the status quo).

237 Framing effects arise where people's expressed preferences can be shifted in response to non-substantive changes in how information is presented. *See, e.g.*, DANIEL KAHNEMAN & AMOS TVERSKY, CHOICES, VALUES AND FRAMES 5 (Daniel Kahneman & Amos Tversky eds., 2000); Mark Kelman et al., *Context-Dependence in Legal Decision Making*, 25 J. OF LEGAL STUD. 287, 288 (1996) (discussing the compromise effect and the context effect).

238 For an overview of continued research on loss aversion and on its role in behavioral legal theories, see Jonathan Baron, *Heuristics and Biases*, *in* THE OXFORD HANDBOOK OF BEHAVIORAL ECONOMICS AND THE LAW 3, 4 (Cass Sunstein ed., 2014).

239 Consider, for example, the relatively late development of positive psychology, or the remarkably voluminous literature on transaction costs, with no corollary literature on transaction benefits. *See, e.g.*, Kirsimarja Blomqvist et al., *Filling a Gap in Traditional Transaction Cost Economics: Towards Transaction Benefits-Based Analysis*, INT'L J. PRODUCTION ECON., Sept. 1, 2002, at 1, 2.

240 I cannot do this important debate justice here, though I touch on a few aspects of it. *See infra* Part IV.

wonders will tend to make them wealthier and healthier. Both of these observations have potential import for policymakers seeking to develop sensible wonder and catastrophe policies.

First consider the impact of extreme-impact events on wealth. Economists have chronicled a wide array of ways in which people's levels of wealth affect their preferences.[241] As a general matter, people will allocate more resources when they have more resources: wealthier people can and will pay more both to reduce risk and to secure benefits. This phenomenon has been particularly well-chronicled in the context of differences between people's "willingness to pay" (WTP) to reduce risk and "willingness to accept" (WTA) additional risk.[242] Extreme events could generate extreme wealth effects, so policymakers might do well to consider those impacts in deciding how to allocate resources.[243]

Second, and somewhat relatedly, consider the impact of extreme-impact events on the equity of distribution of goods and harms across a population. Depending upon the policy goals selected, such impacts may have important policy implications. For example, Matt Adler—a prioritarian who believes that society should prioritize the needs of the least well-off—has argued natural hazards policy should be set by reference to "equity analysis," an approach to policy-setting that seeks at minimum to avoid serious deprivations.[244] Are catastrophes or wonders more likely to affect the equity of risk and benefit distributions? The question deserves additional analysis. At least at first cut, however, it seems hard to say as a general rule either catastrophes or wonders will routinely generate more equitable impacts. Catastrophes can obviously decrease well-being below minimal thresholds, and indeed can be particularly dangerous to the most vulnerable.[245] But they can also sometimes disproportionately affect the wealthy, as with hurricanes that

241 For an overview, see ADLER & POSNER, *supra* note 45, at 142–46.

242 For a review of the research, see John Horowitz & Kenneth McConnell, *A Review of WTA/WTP Studies*, 44 J. ENV'T ECON. & MGMT. 426, 426–27 (2002).

243 Thus far, there seems to be much better-specified methods for sensitizing cost-benefit analysis to wealth effects than there are methods for sensitizing precautionary approaches. *See, e.g.*, ADLER & POSNER, *supra* note 45, at 142–46, 188–89 (outlining multiple approaches to managing wealth effects in cost-benefit analysis, including distributional weighting). There seems to be no reason, however, that precautionary approaches would be immune to wealth effects. *See id.* at 142–43.

244 Matthew D. Adler, *Equity Analysis and Natural Hazards Policy*, *in* ON RISK AND DISASTER: LESSONS FROM HURRICANE KATRINA 129, 129–30 (Ronald J. Daniels, Donald F. Kettl & Howard Kunreuther eds., 2006). *See also* MATTHEW D. ADLER, WELL-BEING AND FAIR DISTRIBUTION: BEYOND COST-BENEFIT ANALYSIS, at xiii (2012) (specifying how equity concerns can be incorporated into social welfare functions).

245 *See* Mark Coeckelbergh, *Vulnerability to Natural Hazards: Philosophical Reflections on the Social and Cultural Dimensions of Natural Disaster Risk*, *in* 3 RISK ANALYSIS OF NATURAL HAZARDS 27, 31 (Paolo Gardoni, Colleen Murphy, Arden Rowell eds., 2016) (discussing the vulnerabilities that were seen after Hurricane Katrina). Consider, for example, the January 2010 Haiti earthquake, a humanitarian disaster of epic proportions. *See* John Vidal, *Haiti Earthquake: City's Plight Leads to Worst Humanitarian Crisis in Decades*, GUARDIAN (Jan. 17, 2010), https://perma.cc/QSA7-X2Y5 (discussing Haiti's vulnerability to the earthquake based on the nation's wealth).

destroy expensive vacation homes along the Outer Banks.[246] Wonders are by definition improvements from the status quo, but where there is a status quo where many are subject to fundamental deprivation, such as malnutrition, wonderful improvements may in some cases improve social equity even more than averted catastrophes.[247] Consider, for example, policies such as GMO promulgation that reduce malnutrition, or micronutrient supplementation for pregnant women in developing countries. At least as an initial approach, then, it may make sense for equitable analyses comparing catastrophes and wonders to focus on distributions of risks and benefits generated by particular extreme events, rather than on whether those events are improvements or losses from the perceived status quo.

4. Catastrophes Implicate Fear and Pessimism, Whereas Wonders Implicate Hope and Optimism

As discussed above, to the extent the literature has addressed the possibility of transformative or wonderfully beneficial events, it has generally been to suggest consideration of them would either be unreasonably optimistic of policymakers, or they might invoke unreasonable optimism by members of the public.[248] To some extent, similar concerns arise in some catastrophe contexts; particularly those, such as terrorism, where the public tends to perceive the worst case as more probable than do experts.[249] And indeed, in some circumstances, this concern has been thought sufficient to justify purposefully omitting catastrophic scenarios from policy analysis. Worries about public preoccupation with extremely unlikely scenarios, for example, justified the executive walk back of a judicial requirement to consider worst-case scenarios in National Environmental Policy Act (NEPA) environmental impact analyses.[250] Yet the mere possibility of excessive weighting of some worst-case scenarios has not led catastrophe scholars to advocate for leaving catastrophic risk and uncertainty out of policy analyses

246 *E.g.*, Rob Morris, *Dare Damage Hits $2.5 Million, One House Destroyed by Storm*, OUTER BANKS VOICE (Sept. 6, 2016), https://perma.cc/5QKG-AR4J (describing the value of property damage as a result of Tropical Storm Hermine).

247 *See* Kosuke Kawai et al., *Maternal Multiple Micronutrient Supplementation and Pregnancy Outcomes in Developing Countries: Meta-Analysis and Meta-Regression*, 89 BULL. WORLD HEALTH ORGANIZATION [WHO] 402, 402, 405 (2010).

248 *See, e.g.*, SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 22 (arguing that "[u]nrealistic optimism" can "breed best-case thinking," leading people to unreasonably underestimate catastrophe risk), *See also* Katie Steele, *The Precautionary Principle: a New Approach to Public Decision-Making?*, 5 LAW, PROBABILITY & RISK 19, 27 (2006) (disposing of best-case scenario analysis in a single sentence, saying merely that "[i]t seems indefensibly optimistic to base public choices on the best possible outcome of options").

249 *See, e.g.*, SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 6–7.

250 *See supra* notes 159–161 and accompanying text. *See also* SUNSTEIN, WORST-CASE SCENARIOS, *supra* note 30, at 19–21 (justifying limitations on considerations of worst-case scenarios by suggesting that "[i]f the government discusses a worst-case scenario in public, people might well fixate on it, even if it is most unlikely to come to fruition").

generally; on the contrary, the literature is generally unified in exhorting policymakers at least to consider the possibility of catastrophes, particularly when their magnitude is very large.[251] Literature on public communication about catastrophes is similarly more nuanced than a blanket ban on discussing catastrophes: it might be reasonably constructed as encouraging policymakers to be strategic in conveying information about catastrophes to the public—sometimes framing such communication to reduce fear (when public perceptions are perceived as over-responsive) and sometimes framing such communication to attract additional attention (when public perceptions are perceived as under-responsive).[252]

The most straightforward application of this approach to wonder policy would be to recognize that wonderful scenarios can arise, and to apply—as a starting point—at least the same discipline to analyzing their probability and magnitude that is currently used in developing worst-case scenarios. This might, as with catastrophes, require some careful contextual thinking. If people are generally unaware of the transformative potential benefits of GMOs in reducing global suffering, for example, policymakers might emphasize those benefits when analyzing and communicating about GMO funding, research, and regulation. On the other hand, if people are overly hopeful about the "best case scenario" of climate change, policymakers might work to develop and convey such a scenario is extremely unlikely or not likely to be as beneficial as people often believe and to increase the relative salience of more realistic but less-hopeful scenarios. Such communications will face many of the same challenges as communications about catastrophic risk[253] but are still entirely comprehensible as policy prescriptions.

If something is wrong, or at least missing, from this analysis, it may trace back to the potential qualitative difference between catastrophes as bad and wonders as good, and to the cognitive implications of that difference. Two potential distinctions are worth further consideration: the possibility that general tendencies towards optimism should lead to different default policies for wonders than for catastrophes; and the possibility that fear (generated by catastrophes) and hope (generated by wonders) are more complex than mere mirror images of each other, such that prescriptions built on fear may not be easily transferrable to contexts of hope.

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251 *See* discussion *supra* Part II.

252 *See, e.g.*, Wiener, *supra* note 226, at 69 (distinguishing between the two categories of catastrophe).

253 For discussion of the complexities of communicating about catastrophes, see COMMUNICATING CLIMATE-CHANGE AND NATURAL HAZARD RISK AND CULTIVATING RESILIENCE, at xii, xii–ix (Jeanette Drake et al. eds., 2016). *See also* Dan M. Kahan et al., *Fear of Democracy: A Cultural Evaluation of Sunstein on Risk*, 119 HARV. L. REV. 1071, 1071 (2006) (book review) (on the difficulties of conveying risk from climate impacts).

First, consider optimism. Most people tend to be optimistic.[254] Optimistic biases towards favorable outcomes manifest in a number of ways and are particularly powerful as applied to personal predictions of likely outcomes in negative events.[255] In the catastrophe context, for example, research suggests people believe they are less likely to be hurt in a natural disaster, such as an earthquake, than other similarly-situated people.[256] People also appear to be optimistic—though less so—about the likelihood of particularly good events happening to them.[257]

While these phenomena are well-documented, the mere existence of optimistic biases does not justify the presumption (sometimes explicit and more often nascent in the catastrophe literature) that any systematic analysis of wonders is misguided. The phenomenon of optimism does not operate in a vacuum; other contextual cues and cognitive phenomena might matter as well. Management of competing behavioral phenomena remains at the forefront of behavioral science, but at the least, it is worth noting that, while optimism might pull people to at least marginally overweight best-case scenarios, loss aversion might be expected to pull them at least as much—if not more—to overweight worst-case scenarios.[258] As a general rule of thumb, researchers often assume that

254 For a helpful overview of the cognitive mechanisms of optimism, see David Hecht, *The Neural Basis of Optimism and Pessimism*, 22 EXPERIMENTAL NEUROBIOLOGY 173, 174 (2013) (explaining the cognitive mechanisms of optimism, as well as their differences from pessimism). For an overview of research on optimism, and its critiques, see James A. Shepperd et al., *Taking Stock of Unrealistic Optimism*, 8 PERSP. PSYCH. SCI. 395, 395 (2015) (evaluating the past 30 years of work on "unrealistic optimism, comparative optimism, optimistic bias, optimism bias, and illusion of invulnerability"). *See also* Ola Svenson, *Are We All Less Risky and More Skillful Than Our Fellow Drivers?*, 47 ACTA PSYCHOLOGICA 143, 143, 147 (1981) (noting that multiple studies have found that drivers tend to believe they are more skilled than the average driver, leading to over optimism). Note that, while there are a number of optimistic tendencies, there is also significant personal variation in levels of optimism. *See* Hecht, *supra*, at 173–74 (noting tendencies towards pessimism); Shepperd et. al, *supra*, at 396 (noting that there are different types of optimism which are distinct in operation); Neil D. Weinstein, *Unrealistic Optimism About Future Life Events*, 39 J. PERSONALITY & SOC. PSYCH. 806, 811–14 (1980) (creating an "Unrealistic Optimism Scale" to measure interpersonal variations).

255 *See* Shepperd et al., *supra* note 254 (noting that optimistic biases appear for a variety of negative events, such as natural disasters and cancer).

256 *See* Jerry M. Burger & Michele L. Palmer, *Changes in and Generalization of Unrealistic Optimism Following Experiences with Stressful Events: Reactions to the 1989 California Earthquake*, 18 PERSONALITY & SOC. PSYCH. BULL. 39, 42 (1992) (analyzing responses from university students who experienced the earthquake and noting the differences in their perceived vulnerability).

257 *See* Shepperd et al., *supra* note 254 (noting that optimistic effects exist, "albeit often less strongly, for positive events, such as graduating from university, getting married, and having favorable medical outcomes").

258 *See, e.g.*, *Loss Aversion in Riskless Choice*, *supra* note 232, at 1053 (introducing a loss aversion coefficient of the ratio of Gains/Losses that makes an even chance to gain G or lose L acceptable). For some of the difficulties in evaluating the magnitude of even a single cognitive phenomenon, see Fieke Harinck et al., *Measurement-Induced Focusing and the Magnitude of Loss Aversion: The Difference Between Comparing Gains to Losses and Losses to Gains*, 7 JUDGMENT & DECISION MAKING 462, 462 (2012) ("[T]he measurement of loss aversion itself can induce a focus on either losses or gains, and that this measurement-induced

potential gains need to be about twice as large as potential losses to offset the effects of loss aversion. From this standpoint, there is roughly half the reason to dismiss consideration of wonders because people are often optimistic, then to dismiss consideration of catastrophes because people are generally loss averse.

Nevertheless, recognition of the different psychological phenomena pulling decisionmakers towards best-case scenarios (such as optimism) and worst-case scenarios (such as loss aversion) might justify adoption of differing default policies when addressing the two types of scenarios. Where optimism is a policy concern, policymakers might do well to adopt policies, such as disclosure policies, designed to debias unreasonable optimism.[259] Where loss aversion is the concern, policymakers might do better to adopt policies directed towards reframing losses as gains.[260] That said, in many contexts, policymakers may find addressing both best- and worst-case scenarios can act as an effective tonic to both unreasonable optimism and undesirable loss aversion. In this sense, the cure for both ills—optimism and loss aversion—may sometimes be to address catastrophes and wonders symmetrically.

Another possibility to consider is that there may be policy-relevant differences between fear and hope. Although there is literature addressing appropriate policy responses to public fear,[261] the literature on addressing appropriate policy responses to public hope is far more limited.[262] Nor is it obvious that the fear literature can be directly applied

focus influences the strength of loss aversion" such that "the ratio is approximately 2 when people focus on gains compared to a loss, but that the ratio increases when people focus on losses compared to a gain.").

259 *See, e.g.*, Christine Jolls, *Product Warnings, Debiasing, and Free Speech: The Case of Tobacco Regulation*, 169 J. INSTITUTIONAL & THEORETICAL ECON. 53, 55–56 (2013) (discussing the effect of disclosure requirements on smoking risks), *See also* Ryan Bubb, Book Note, *TMI? Why the Optimal Architecture of Disclosure Remains TBD*, 113 MICH. L. REV. 1021, 1022–23 (2015) (reviewing OMRI BEN-SHAHAR & CARL SCHNEIDER, MORE THAN YOU WANTED TO KNOW: THE FAILURE OF MANDATED DISCLOSURE (2014)). Note that optimism, even if unreasoned, might not always demand debiasing. For an intriguing discussion, see Anneli Jefferson et al., *What is Unrealistic Optimism?*, 50 CONSCIOUSNESS & COGNITION 3, 3 (2017) (reviewing ongoing debates in philosophy and psychology as to whether optimistically false beliefs are epistemically irrational and/or have pragmatic benefits).

260 *See, e.g.*, Christine Jolls & Cass R. Sunstein, *Debiasing Through Law*, 35 J. LEGAL STUD. 199, 205–06 (2006) (noting the importance of framing effects as it affects how people respond and "losses matter more than gains").

261 *See, e.g.*, Paul R. Portney, *Trouble in Happyville*, 11 J. POL'Y ANALYSIS & MGMT. 131, 131 (1992) (posing the question of whether—and if so, how much—policymakers in the town of "Happyville" should spend public resources to eliminate a naturally occurring substance in a water supply, when they believe the substance to be safe, but where the public remains truly frightened of the risk); Matthew D. Adler, *Fear Assessment: Cost-Benefit Analysis and the Pricing of Fear and Anxiety*, 79 CHI.-KENT L. REV. 977, 977–78 (2004) (arguing that fear assessment should be part of the cost-benefit analysis); Graciela Chichilnisky, *Catastrophic Risks*, 3 INT. J. GREEN ECON. 130, 131 (2009) (addressing the impact of fear on understanding and responding to catastrophic risks).

262 One limited but intriguing exception appears to be addressed to morale in wartime. *See, e.g.*, ROBERT MACKAY, HALF THE BATTLE: CIVILIAN MORALE IN BRITAIN DURING THE SECOND WORLD WAR 9 (2002).

to managing hope: are fear and hope really flip sides of one another, such that they deserve and respond to identical policies? The interaction with loss aversion may mean people's subjective experiences of fear are worse than their subjective experiences of hope are good. If so, fear may be more easily generated than hope, and by lesser stakes. Furthermore, the two emotions may respond differently to attempted interventions. This may be particularly likely if, as some neural research suggests, there are different physiological bases for positive and negative emotions.[263] More research is needed, however, before this would become a principled reason for treating catastrophes and wonders asymmetrically.

IV. INTERACTIONS AND IMPLICATIONS

This Part maps several of the implications that flow from the observation that wonders, though often neglected by scholars and policymakers, can be encouraged through policy choices. In particular, it takes up the question of the relationship between catastrophe and wonder policy. Wonders do not occur in a vacuum, and whichever policy approach policymakers adopt for managing wonders will necessarily interact with their approach to catastrophe. The following analysis makes two primary points. First, it notes many policy choices present simultaneous possibilities of catastrophic risk and wonderful opportunity. Consider, for example, the policy questions of whether to release genetically modified mosquitoes,[264] the speed at which autonomous vehicles should be adopted,[265] geoengineering the climate,[266] whether to seek extraterrestrial contact,[267] and whether to promote nanotechnology;[268] each of these policies may trigger catastrophic and/or wonderful outcomes. Second, the way catastrophic risks and transformative benefits are balanced against one another—and whether a thumb is placed on one side of the scale—may be outcome-determinative in at least some cases. Where policymakers adopt approaches that weight catastrophes either by expected value or with precautionary special solicitude, while simultaneously neglecting the possibility of policy wonders—a combination of approaches that thus far has been adopted as the unreflective norm—they institutionalize a form of loss aversion, which seeks to avoid large losses more than it seeks to secure concomitantly large gains. The question of whether it is normatively appropriate to imbed loss aversion in catastrophe policy is complex and should be

263 *See* Hecht, *supra* note 254, at 187 (summarizing existing research on optimistic and pessimistic feelings and concluding that pessimistic views are generally mediated by the right hemisphere of the brain, whereas optimistic attitudes are generally mediated by the left hemisphere).

264 *See infra* note 277 and accompanying text.

265 *See infra* note 272 and accompanying text.

266 *See supra* notes 127–130 and accompanying text.

267 *See infra* note 274 and accompanying text.

268 *See infra* note 275 and accompanying text.

controversial. Such controversy has been obscured by the general neglect not only of serious opportunities for policy wonders but also of the relationship between extreme upsides and downsides.

A. Countervailing Wonders and Catastrophes

It is a core observation in the field of risk analysis that there are risks on all sides of every policy.[269] There are also possible benefits on all sides, and sometimes both risks and benefits are potentially extreme.

A timely example, and one already alluded to above, is to consider the potential risks associated with a COVID-19 vaccine.[270] While the impacts of an effective vaccine would be wonderful, the potential harm of a rushed vaccine could be catastrophic.[271] These countervailing risks and benefits—both extraordinarily (albeit not necessarily equally) large—bear importantly on questions of vaccine approval and distribution.

Another example likely to arise in the next decade is the question of the speed at which autonomous vehicles should be adopted by society—a question likely to have substantial environmental and social implications. Earlier, less-developed autonomous vehicles are more likely to fail in a number of ways and may also be far more likely to be subject to systemic failures, such as those that might come if an entire smart-grid hooked up to autonomous vehicles would be hacked.[272] This suggests fast adoption of autonomous vehicles will tend to increase the chance of catastrophic system failure, of a number of individual deaths occurring because of software limitations that might be prevented or ameliorated with a slower schedule of adoption, or both. At the same time, recent projections suggest earlier adoption of even slightly temperamental autonomous vehicles could largely ameliorate one of the largest mortality risks that most Americans face on a daily basis, which is to travel in cars driven by even-more-temperamental humans.[273]

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269 *See* RISK VERSUS RISK: TRADEOFFS IN PROTECTING HEALTH AND THE ENVIRONMENT 1–3 (John D. Graham & Jonathan Baert Wiener eds., 1995) (describing risk tradeoff and its commonplace in decision making); Cass Sunstein, *Health-Health Tradeoffs*, 63 U. CHI. L. REV. 1533, 1535–36 (1996) (discussing the problem of when "the diminution of one health risks simultaneously increases another health risk").

270 *See* William A. Haseltine, *The Risks of Rushing a COVID-19 Vaccine*, SCIENTIFIC AMERICAN (June 22, 2020), https://perma.cc/U2YK-U9W4 (addressing the risks associated with a fast-tracked vaccine).

271 *See id.* ("While preclinical trials to evaluate the potential safety and efficacy of vaccine candidates are likely to include tens of thousands of patients, it is still unclear whether that number will be large enough and a trial will last long enough to evaluate safety for a drug that would be administered to so many. The US alone plans to vaccinate hundreds of millions of people with the first successful candidate. One serious adverse event per thousand of a vaccine given to 100 million people means harm to 100,000 otherwise healthy people.")

272 Peter Behr, *The Driverless Revolution Confronts a Hacking Menace*, E&E NEWS (Apr. 11, 2019), https://perma.cc/UNW3-2GBC.

273 *See* discussion *supra* Part II; *see also* Bauman, *supra* note 139 ("[I]f we wait for" autonomous vehicles to be "perfect" before adopting their use, "we'll be waiting for a very, very long time"); KALRA & GROVES, *supra* note 139, at 29 (arguing that earlier deployment of

Alternatively, consider that actively seeking extraterrestrial contact might generate unimaginable wonders or, as Stephen Hawking warned, might instead trigger utter planetary devastation.[274] Growing and distributing genetically modified foods might help fight malnutrition and drastically reduce food costs, and/or it might lead to genetic drift that results in substantial decreases in plant biodiversity.[275] Promoting nanotechnology might generate transformative cures to diseases that cause great suffering, and/or it might generate self-replicating ecophagic nanobots that consume all the biomass on Earth and convert it into grey goo.[276] Gene-hacked mosquitoes might eradicate malaria, and/or they might crush whole ecologies dependent upon mosquitoes as a food source.[277]

imperfect autonomous vehicles will still save significantly more lives in the short and long term than waiting until the technology is perfect).

274 *See, e.g.*, STEPHEN HAWKING'S FAVORITE PLACES (Curiosity Stream 2016) (arguing that humans' first contact with alien civilizations could be the equivalent to Native Americans encountering Christopher Columbus, an encounter he notes "didn't turn out so well"). *See also* Baum et al., *supra* note 143, at 2114 (comparing beneficial, neutral, and catastrophic contact scenarios). Stephen Hawking has also argued that "[t]he rise of A[rtificial] I[ntelligence] could be the worst or the best thing that has happened for humanity." John Koetsier, *Stephen Hawking Issues Stern Warning on AI: Could Be 'Worst Thing' For Humanity*, FORBES (Nov. 6, 2017), https://perma.cc/B9CU-RJDX.

275 *Cf.* Barrows et al., *supra* note 138, at 99–100, 107 (discussing the risks and benefits of genetically modified crops); Olivier Sanvido et al., *Evaluating Environmental Risks of Genetically Modified Crops: Ecological Harm Criteria for Regulatory Decision-Making*, 15 ENV'T SCI. & POL'Y 82 (2012) (proposing a systematic approach on how the potential harm of genetically modified crops can be explicitly and operationally defined for decision-making, allowing for a more transparent evaluation of the probability of harm); L.L. Wolfenbarger & P.R. Phifer, *The Ecological Risks and Benefits of Genetically Engineered Plants*, 290 SCIENCE 2088, 2088 (2000) (synthesizing currently available research of the risks and benefits of genetically engineered plants and underscoring a lack of key experiments).

276 Such nanobots are sometimes called "von Neumann machines" after mathematician John von Neumann, who first described macroscopic self-replicating robots in the 1940s. *See* Jay Bennett, *Could We Explore the Entire Galaxy with Self-Replicating Robots*? POPULAR MECHANICS (Sept. 15, 2016), https://perma.cc/WK6A-8PLE. The term "gray goo" traces to scientist Eric Drexler, who coined the term in his book ENGINES OF CREATION (1986). *See* Fred Hapgood, *Tinytech*, 9 OMNI 56, 56 (1986) (popularizing Drexler's account of the risks of nanotechnology and explaining that "in the worst-case scenario of the gray-goo problem, lethal, damaged nanomachines will reproduce to infinity, and life on the earth will end"). Nanotechnology presents a number of other potential catastrophic risks as well, some of which may be significantly more likely. *See* Chris Phoenix & Eric Drexler, *Safe Exponential Manufacturing*, 15 NANOTECHNOLOGY 869, 870–71 (2004) (suggesting that "gray goo" scenarios are unlikely and can be limited by restricting the construction of autonomous self-replicating nanomachines, and highlighting the alternative catastrophic risks posed by weaponized nanotechnology).

277 *See* Yuemei Dong et al., *CRISPR/Cas9-mediated Gene Knockout of* Anopheles gambiae *FREP1 Suppresses Malaria Parasite Infection*, 14 PLOS PATHOGENS 3, 8 (2018) (highlighting the potential of mosquito gene modification in combating malaria), *Cf.* Gantz et al., *supra* 199, at E6742 (noting that uncertainties in genetically-modified mosquito technology remain, and scientists need to conduct more lab research to assess risk before implementation); Jeantine Lunshof, *Regulating Gene Editing in Wild Animals*, 521 NATURE 127, 127 (2015) (noting that genetically-modified mosquitos have the potential to rapidly alter ecosystems in irreversible and damaging ways).

In developing sensible wonder *or* catastrophe policy, then, policymakers can start by recognizing the countervailing risks and benefits of the policies they choose. Those policies may present wonderful—as well as catastrophic—tradeoffs. In weighing and balancing those tradeoffs, policymakers would ideally ground treatment of both wonderful and catastrophic outcomes in a reasoned consideration of the similarities and differences of wonders and catastrophes. And, if, or where they choose to treat wonders and catastrophes differently, they should justify that distinction, and recognize the potential impacts of resulting asymmetry.

B. Asymmetric Policies and Loss Aversion

To end, it is worth spelling out a bit further how general policies towards catastrophic risks are likely to interact with general policies towards wonderful benefits, and how those interactions generate puzzles for policymakers.

To see the different options that policymakers have at their disposal, recall that policymakers have the option of treating very large policy impacts—either wonders or catastrophes—in at least three ways: by neglecting them entirely, treating them according to a calculation of their expected value, or offering them some level of special solicitude. The combination of these three options for both types of impact generates nine combinations (see Figure 3).

FIGURE 3: INTERACTIVE EFFECTS OF CATASTROPHE AND WONDER POLICIES

		APPROACH TO MANAGING WONDERS		
		Neglect	**Expected Value**	**Special Solicitude**
APPROACH TO MANAGING CATASTROPHES	**Neglect**	*Equal neglect.*	*Moderated benefits-seeking.*	*Extreme benefits seeking.*
	Expected Value	*Moderated loss aversion.*	*Pure expected value.*	*Moderated benefits-seeking.*
	Special Solicitude	*Extreme loss aversion.*	*Moderated loss aversion.*	*Equal solicitude.*

Policymakers have three options to adopt symmetrical policies: by neglecting both wonders and catastrophes, using expected value for everything, or offering equal levels of special solicitude. For all other combinations, the treatment of wonders and catastrophes is asymmetric.

Where wonders are weighted more heavily than catastrophes, the policy will look relatively more beneficial, introducing a skew towards benefits-seeking. On the margins, these approaches will emphasize wonder production and maximization over catastrophe prevention and mitigation. Where wonders are weighted less heavily than catastrophes, the policy will look relatively riskier, introducing a skew towards loss aversion. On the margins, these approaches will emphasize catastrophe prevention and mitigation over wonder production and maximization.

Note that, in various circumstances, different approaches may be justifiable. This is particularly clear for the options that treat catastrophes and wonders symmetrically. One tempting and simple response to the observation that many policy options can generate wonderful as well as catastrophic scenarios, for example, would be to assume such scenarios cancel each other out, such that it might be reasonable to neglect both ends of the impact distribution. This would be the "equal neglect" option identified above. That option is insensitive to both the probability and magnitude of the extreme scenario, however. It could be suboptimal or even misleading when probability and magnitude data are available, or where the tails on either side of the distribution are known to differ in "fatness." In such circumstances, an expected value calculation—and a "pure expected value" approach—would give more and better guidance to regulators. Yet under conditions of real uncertainty, where the likelihood of both the best- and worst-case scenario fall somewhere between 0% and 100%, equal neglect might be justifiable. Alternatively, in such cases, and where the magnitude of the best- and worst-case scenarios is known to be particularly high, "equal solicitude" may present a better option. Indeed, the option of pursuing "maximin"—maximizing the highest lowest utility, or choosing the option with the best worst-case scenario—is a venerable (though by no means universally popular) approach to limiting uncertainty.[278] Where there are truly uncertain but wonderful outcomes on the other side, a corollary "maximax"—maximizing the highest, highest utility, or choosing the option with the best best-case scenario—might be taken as a kind of analytical tonic.[279] Such approaches might seek simultaneously to minimize worst-case pandemic scenarios, for instance, while simultaneously maximizing best-case scenarios for disease cures and treatments.

The asymmetrical approaches are more troublesome. The problem is that, by choosing to treat upsides and downsides differently, policymakers risk putting a thumb on the scale, either by favoring

[278] For a readable summary of the maximin approach to uncertainty, key objections to it, and responses to those objections, see Sunstein, *Irreversible and Catastrophic*, *supra* note 49, at 879–89.

[279] This approach might, for example, be justified in the case of considering best- and worst-case scenarios of extraterrestrial contact, for which attaching probabilities is extremely speculative. For a discussion of various scenarios, see Baum et al., *supra* note 143, at 9–25.

downsides over upsides or vice-versa. Or in other words, choosing different approaches for managing extreme upsides and extreme downsides introduces an institutional analytical skew, which will imbed either loss aversion or benefits-seeking into the policies that are chosen. The common practice of implementing anti-catastrophe policies without developing complementary pro-wonder policies, for example, institutionalizes loss aversion—though the extent of this loss aversion will vary depending upon the extent to which catastrophic risks are prioritized and the extent to which wonderful opportunities are neglected.

What amount—if any—of loss aversion is the right amount for policymakers to adopt regarding catastrophes and wonders? This question implicates a number of difficult behavioral and democratic puzzles about the rationality of loss aversion and cognitive bias, the appropriate role of rationality in policymaking, and the extent to which democratic policies should be based on public preferences even when those preferences are known to be affected by bias.[280] These debates are at their thorniest where it becomes difficult to disentangle people's perceptions of risk and their normative values[281]—as arguably is the case when evaluating people's preferences about avoiding catastrophic loss and about securing wonderful gain. Different strands in this debate should be understood to generate different prescriptions for policymakers regarding wonders and catastrophes.[282] For example, one view—under what Dan Kahan et al. refer to as the "democratic" view[283]—might be that it is appropriate to adopt loss averse approaches to extreme impacts, because people tend to exhibit loss aversion, and implementing loss averse preferences is a way of respecting those preferences. This runs

[280] *Compare* SUNSTEIN, LAWS OF FEAR, *supra* note 52, at 1, 3, 89 (arguing that public estimations of risks are affected by a variety of cognitive and social mechanisms, and that policymakers should seek to counter the impact of irrational public fear), *and* Cass R. Sunstein, *Misfearing: A Reply*, 119 HARV. L. REV. 1110, 1110–11 (2006) (noting that bounded rationality leads the public to adopt irrational fears, and it is not undemocratic for officials to ignore people's errors of fact), *with* Kahan, et al., *supra* note 253, at 1072 (arguing that people's risk perceptions reflect and reinforce their cultural worldviews, and suggesting that ignoring risk perceptions and preferences is therefore undemocratic), *and* Dan M. Kahan & Paul Slovic, Reply, *Cultural Evaluations of Risk: "Values" or "Blunders"?*, 119 HARV. L. REV. F. 166, 166, 169 (2006) (arguing that cultural worldviews play a role in risk assessments among the public, and that democracy forbids the dismissal of those assessments, even if they may be irrational).

[281] *See, e.g.*, Kahan & Slovic, *supra* note 280, at 171 (discussing people's normative values and that their factual assessment of risk is comingled and hard to distinguish).

[282] Democratic accounts of risk management, which would implement people's preferences even where they are subject to cognitive bias, should approve of catastrophe and wonder policies that imbed loss aversion, insofar as people tend to care more about catastrophic losses than they do about miraculous gains. Andreas Christiansen & Bjorn Gunnar Hallsson, *Democratic Decision Making and the Psychology of Risk*, LES ATELIERS DE L'ÉTHIQUE, Winter 2017, at 51, 52, 60. Behavioral and debiasing accounts of risk management, on the other hand, should prefer neutral or possibly even *benefits-seeking* approaches to managing catastrophes and wonders, to offset the (arguably irrational) loss aversion with which people tend to approach catastrophic loss.

[283] *See* Kahan et al., *supra* note 253 and accompanying text.

directly counter, however, to libertarian paternalist and behavioral law and economics approaches, such as those articulated by Cass Sunstein and his coauthors,[284] which might seek to debias decisions distorted by loss aversion, on the assumption that loss aversion fails to represent either the true preferences or the most welfare-enhancing choices of a reflective decisionmaker. A strong version of this view might even advocate for adopting purposefully benefits-seeking approaches to extreme events, on the theory that doing so might debias and offset the strong tendency people otherwise exhibit towards loss aversion. Or, an economic approach might advocate for policies that are symmetrical, on the theory that doing so will tend to maximize social welfare without making policy choices contingent on framing or on perceptions of the status quo.

I do not seek to resolve this complex controversy here, in what is already a long article. For now, it is important to recognize that policies regarding extreme upside and extreme downside events will often interact with one another. Current approaches will tend to produce institutionalized loss aversion. This should generate normative controversy over whether policies regarding extreme outcomes *should* be loss averse—putting a thumb on the scale to prevent catastrophic losses, at the potential cost of forgoing wonders. At the least, policymakers should recognize that treating wonders and catastrophes differently introduces a predictable skew into their decisions, and stakeholders—and courts—should require policymakers to explain their reasoning when they choose to adopt asymmetric approaches.

V. CONCLUSION

In recent years, risk regulation in general—and environmental law in particular—has focused heavily on the dark side of human behavior—including on the extreme-downside catastrophic impacts of some policies. Attention to catastrophes—environmental and otherwise—is valuable and needed. And yet exclusive focus on the downside of human behavior has costs as well and may obscure real and meaningful opportunities to promote environmental quality and human flourishing. This Article has focused on some such opportunities—those where the expected impact might reasonably be considered to be so large as to constitute a reciprocal to catastrophe. These extreme-upside impacts, which I have called "wonders," have been neglected, especially in comparison to extreme-downside impacts, or catastrophes. This neglect is unfortunate, as it systematically devalues the possibility of transformative, wonderful impacts occurring—a possibility that is all the more urgent in this time of pandemic. Scholars and policymakers should recognize policies can

284 For a classic presentation of the law's debiasing function, see generally Christine Jolls & Cass Sunstein, *Debiasing Through Law*, 35 J. LEGAL STUD. 1999 (2006). For a presentation of the libertarian paternalist approach, see generally Cass Sunstein & Richard Thaler, *Libertarian Paternalism is Not an Oxymoron*, 70 U. CHI. L. REV. 1159 (2003).

have extreme impacts that are good as well as bad and should work to further develop strategies for managing the possibility of policy wonders. Literature on catastrophic risks can offer a valuable point of departure for generating practical and normative prescriptions for creating policies that promote wonders.