Texas A&M Law Review

Volume 10 | Issue 3

3-3-2023

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Recommended Citation

Richard L. Revesz, *Fallacies in the Design of Climate Change Policies: A Response to Richard Epstein*, 10 Tex. A&M L. Rev. 385 (2023).
Available at: https://doi.org/10.37419/LR.V10.I3.1

FALLACIES IN THE DESIGN OF CLIMATE CHANGE POLICIES: A RESPONSE TO RICHARD EPSTEIN

*by: Richard L. Revesz**

This Essay criticizes Professor Richard Epstein's approach to climate change regulation, which he characterizes as one involving taking modest steps at first, observing the results of these steps, and then using the lessons learned to inform the next steps. Epstein's approach depends critically on a particular class of damage function determining how greenhouse gas emissions cause harm—specifically, damage functions that lack discontinuities. And it also depends on the ability to observe in real time how the function occurs. Neither of these conditions are met with respect to climate change. The Essay also shows that Epstein's approach is further undermined by the structure of energy markets, in which investments are large and lumpy as opposed to small and continuous. For example, Epstein's "small steps" approach might lead to significant current investments in natural gas facilities, like natural gas pipelines, instead of a bolder move to renewables. These lumpy investments cannot be easily undone when it then turns out that our approach to climate change regulation was too cautious, both for economic and public choice reasons.

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DOI: https://doi.org/10.37419/LR.V10.I3.1

* AnBryce Professor of Law and Dean Emeritus, New York University School of Law (on leave). The generous financial contribution of the Filomen D'Agostino and Max Greenberg Research Fund at NYU Law School is gratefully acknowledged. I am enormously grateful for the extraordinary research assistance of Joshua Podolsky and Brittany Shaar. Professor Revesz substantially completed his work on this Essay prior to becoming the Administrator of the Office of Information and Regulatory Affairs, which was before Professor Epstein wrote his response.

I. Introduction

I am very grateful to have been invited to give this talk addressing an aspect of the voluminous work of my NYU Law School colleague Richard Epstein. I regard Professor Epstein as a friend, and I admire the breadth and ambition of his work. He is a true legal polymath. Once, while I was the dean at NYU Law School, I had the honor of introducing him at an event celebrating the award of his endowed chair. I noted that, during his career, he had taught 30 different courses, from Roman Law to Corporate Tax. And that was more than a decade ago. I am sure that by now he has taught a few more. Even more impressively, Epstein's scholarship is as wide-ranging as his teaching.

In this Essay, I focus on Epstein's prescriptions for climate change regulation. Admittedly, this is not an area in which he has done as much work as in the core common law areas of torts, contracts, and property, where he has made his most significant contributions. I am mindful that focusing this Essay on an area outside his core expertise might be regarded as unfair. Or that I could be criticized with the familiar adage that if you have a hammer—in my case, expertise in environmental regulation—everything looks like a nail, and that is why Epstein's work on climate change appears significant to me. But the reason to focus on Epstein's prescriptions for climate change regulation is that Epstein is a highly influential scholar with a deep following. Therefore, it is important to explain the wrongheadedness of his policy prescriptions concerning a critically important matter of public policy.

This Essay proceeds as follows: Part II criticizes Epstein's approach to climate change regulation, which he characterizes as one involving taking modest steps at first, observing the results of these steps, and then using the lessons learned to inform the next steps. It next explains that this approach depends on unstated assumptions about both the physical environment and the operation of energy markets. Epstein's approach depends critically on a particular class of damage function determining how greenhouse gas emissions cause harm—specifically, damage functions that lack discontinuities. And it also depends on the ability to observe in real time how the function occurs. In contrast, if there are latency periods, during which the harm cannot be observed, Epstein's approach simply does not work—particularly if the harms are irreversible once they do occur.

Part III shows how the science of climate change reveals the presence of abrupt changes and tipping points, such as one caused by the melting of ice sheets. Once the melting has occurred as a result of excessive greenhouse gas emissions in the short run, slowing down the emissions subsequently will not bring the ice sheets back.[1] Furthermore, history has shown that these abrupt tipping points create further "impacts [that] cascade through coupled climate-ecological-social systems,"[2] resulting in an even broader scope of harm. Crossing one tipping point affects both the probability of transgressing yet other tipping points and the impact of each tipping element.[3] This interaction among tipping elements makes it difficult to estimate the threshold where any one element tips over.[4] Tipping points are a type of functional discontinuity that renders Epstein's approach inapposite to the actual problem of climate change.

Part IV then shows that Epstein's approach is further undermined by the structure of energy markets, in which investments are large and lumpy as opposed to small and continuous. For example, Epstein's "small steps" approach might lead to significant current investments in natural gas facilities, like natural gas pipelines, instead of a bolder move to renewables. These lumpy investments cannot be easily undone when it then turns out that our approach to climate change regulation was too cautious, both for economic and public choice reasons.

II. Epstein's Approach: Modest Steps and Learning by Doing

Epstein frequently writes essays for the Hoover Institution's *Defining Ideas* journal. In an essay published on August 17, 2021, entitled *Global Warming: How Not To Respond*, Epstein sets out guiding principles for regulatory approaches to addressing climate change.[5] At the outset, he makes clear that he is not a climate denier, indicating that he "take[s] it as a given that everyone has to be concerned about cli-

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[1] *See* Yongyang Cai et al., *Risk of Multiple Interacting Tipping Points Should Encourage Rapid CO_2 Emission Reduction*, 6 Nature Climate Change 520, 523–24 (2016), https://doi.org/10.1038/NCLIMATE2964.

[2] Victor Brovkin et al., *Past Abrupt Changes, Tipping Points and Cascading Impacts in the Earth System*, 14 Nature Geoscience 550, 550 (2021), https://doi.org/10.1038/s41561-021-00790-5.

[3] Cai et al., *supra* note 1, at 520; *see also* Simon Dietz et al., *Economic Impacts of Tipping Points in the Climate System*, PNAS, Aug. 24, 2021, at 2–3, https://doi.org/10.1073/pnas.2103081118.

[4] *See* Robert E. Kopp et al., *Tipping Elements and Climate–Economic Shocks: Pathways Toward Integrated Assessment*, 4 Earth's Future 346, 358 (2016), https://doi.org/10.1002/2016EF000362; *see also* Johan Rockström et al., *Planetary Boundaries: Exploring the Safe Operating Space for Humanity*, Ecology & Soc'y, Dec. 2009, at 1, 2–4, https://www.ecologyandsociety.org/vol14/iss2/art32/.

[5] *See* Richard A. Epstein, *Global Warming: How Not To Respond*, Hoover Inst.: Defining Ideas (Aug. 17, 2021), https://www.hoover.org/research/global-warming-how-not-respond?utm_source=defining+Ideas+Subscribers&utm_campaign=9dfa81c0b8-Defining_Ideas_01_26_17_1_26_2017_COPY_01&utm_medium=email&utm_term=0_31433b2ef9-9dfa81c0b8-72878837 [https://perma.cc/UH7L-LM96].

mate change and how best to deal with it."[6] And, he adds: "The goal here is easy to state: the survival and prosperity of humanity."[7]

Recognizing the significance of the problem, Epstein then poses the correct policy design question: "[H]ow do we best achieve that collective end?"[8] He then calls for the implementation of what he calls "marginalist analysis."[9] Here is what he sees this analysis as entailing:

> The marginalist analysis often starts with some modest step, tries to figure out whether matters have gotten better or worse, and then takes additional steps in that direction so long as the additional results seem promising. Where the initial round of gains seems very large, then the next step could be more comprehensive. If they are small, then the next steps are also smaller, and in some instances the preferred decision might be to reverse course.[10]

This prescription of taking modest steps and learning by doing is undoubtedly a good one for some regulatory programs. It is equally undoubtedly not a good one for others. And, for reasons that will become clear soon, it is a terrible prescription for the regulation of greenhouse gas emissions.

A relatable example is useful to motivate the more technical discussion that will follow. Say that I am running a marathon (which I do not plan to do) and that my goal is to finish in under five hours, covering roughly five miles per hour. I might decide to start running at a speed that appears comfortable and take stock after an hour. If I covered more than five miles in the first hour, I might decide to somewhat slow my pace, expending less energy for the remainder of the race. But if I covered less than five miles, I would, instead, increase my pace, putting myself on track to meet my goal. In this simple example, all that matters is the average speed during the course of the whole race. And, throughout the race, speed adjustments can be made without any adverse consequences.

This strategy, however, would not be optimal under a different set of conditions. Some might be physiological. For example, I might find it taxing to increase my speed after I have been running an hour, but I might, instead, be able to start at a faster speed and then maintain it throughout the race. Other conditions might flow from the rules of the competition. Say that every hour runners are disqualified if they are not on track to finish the race in five hours by maintaining their average speed. Then, it would make sense to have a faster start to avoid the possibility of disqualification. An even different strategy would be optimal if runners did not find out about this disqualification until they finished the race and were unable to monitor their own time.

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[6] *Id.*

[7] *Id.*

[8] *Id.*

[9] *Id.*

[10] *Id.*

Then, an even faster start would be optimal so as to avoid the possibility of running a whole race and not receiving any recognition due to violation of the first-hour progress requirement.

Problems that have this structure are common in the field of environmental regulation. Take, for example, the case of water pollutants that reduce the level of dissolved oxygen in water. Once the level of dissolved oxygen falls under a threshold, all the fish die. Reducing pollution once that has happened does not bring them back to life.[11]

Epstein's prescription of taking modest steps and learning by doing might be plausible if the level of dissolved oxygen can be monitored continuously and adjustments to the levels of pollution can be made quickly. In the marathon example, if I run the first hour too slowly, I can then pick up my speed. However, if it would take time to make these adjustments—for example, because of the time needed to order and install new technology—a more aggressive initial effort would be preferable. In the marathon example, having run too slowly for the first hour, I might not be able to increase my speed sufficiently to meet my goal.

More aggressive initial action would be even more compelling if, because of random variations caused by temperature and rainfall, determining the relevant level of dissolved oxygen could be done only at long intervals. Likewise, I would run faster if I could not find out until the end of the race that I was disqualified for not having made sufficient progress in the first hour.

A different environmental example concerns latent harms. Exposure to many carcinogens does not result in death until after a long latency period, often of two or three decades.[12] Modest steps and learning by doing would be a bad strategy for these problems because the adjustments that Epstein has in mind would not be undertaken for a long time. By then, the environmental problem—the latency of cancer—would be irreversible. Just like fish that die from the absence of sufficient dissolved oxygen cannot be brought back to life, carcinogens in the human body generally cannot easily be removed without leaving a sequel of undesirable consequences.

This discussion illustrates that Epstein's prescription of small steps and learning by doing is not appropriate for certain important environmental problems, and it is definitely not an appropriate prescription for the regulation of greenhouse gases. A full analysis of the limitations of Epstein's approach, and of the optimal regulatory approach to greenhouse gas regulation, is beyond the scope of this Es-

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[11] *See* O. P. Misra & Divya Chaturvedi, *Fate of Dissolved Oxygen and Survival of Fish Population in Aquatic Ecosystem with Nutrient Loading: A Model*, MODELING EARTH SYS. & ENV'T, June 2016, at 1, 10, https://doi.org/10.1007/s40808-016-0168-9.

[12] *See* Lisa Heinzerling, *Environmental Law and the Present Future*, 87 GEO. L.J. 2025, 2052–61 (1999); Richard L. Revesz, *Environmental Regulation, Cost-Benefit Analysis, and the Discounting of Human Lives*, 99 COLUM. L. REV. 941, 977 (1999).

say. But some observations will shed further light on this matter. The optimal policy depends critically on whether there are discontinuities in the function linking pollution concentrations to environmental damage. With a linear damage function—as with the initial, simple marathon analogy—an initial slow start can potentially be undone by more aggressive later action.

But that is not true if there are discontinuities in the damage function. The existence of thresholds in the water pollution example discussed above exemplifies such a discontinuity. The tipping points that are now widely understood to exist in the climate change context are another example. Just like the fish cannot be brought back to life once they die from the lack of sufficient dissolved oxygen, ice sheets cannot be put back together once they melt. That, too, is an irreversible problem.[13] And the consequent rise in sea levels is irreversible as well. This issue is explored in Part III.

The problems of Epstein's approach are compounded by the structure of energy markets, where large, lumpy investments make it difficult to quickly change course and adopt new technologies if things are not going well. The stickiness of the initial decision results in part from economic factors, which make it difficult to phase out a technology until the initial investment has been recovered. But it also results from interest group dynamics. Having obtained a government benefit, such as the approval of a natural gas pipeline, the beneficiaries will fight hard to retain that benefit. This matter is explored in Part IV, using as an illustration the role that natural gas can play as a bridge technology in a transition from coal—which emits roughly twice the volume of greenhouse gases per unit of electricity produced—to renewables, which do not emit any greenhouse gases at all.

III. PHYSICAL DISCONTINUITIES: TIPPING POINTS

Epstein's marginalist approach to climate change—where policymakers take a small step in one direction and, after observing the results of that change, decide to either continue in that direction or reverse course—assumes that the harms associated with climate change are linear and reversible. However, there is significant evidence that increased warming will trigger catastrophic, irreversible changes. The Intergovernmental Panel on Climate Change ("IPCC") defines these "tipping point[s]" as "critical threshold[s] beyond which a system reorganizes, often abruptly and/or irreversibly."[14] According to the latest IPCC report, there is "high confidence" that continued

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[13] Julius Garbe et al., *The Hysteresis of the Antarctic Ice Sheet*, 585 NATURE 538, 542 (2020), https://doi.org/10.1038/s41586-020-2727-5.

[14] Intergovernmental Panel on Climate Change [IPCC], *Summary for Policymakers*, *in* CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS, at 21 n.34 (2021) [hereinafter 2021 IPCC REPORT: SPM], https://www.ipcc.ch/report/ar6/wg1/.

climate trends will drive sensitive ecosystems to these irreversible tipping points.[15]

There are various tipping points associated with increased greenhouse gas emissions, including permafrost thawing,[16] Arctic ice melting,[17] collapse of the Atlantic Meridional Overturning Circulation,[18] dieback of the Amazon rainforest,[19] shift to a more persistent El Niño regime,[20] variability of the Indian summer monsoon and associated floods and droughts in India,[21] dissociation of ocean methane hydrates,[22] changes to Surface Albedo Feedback,[23] and shifts in the West African Monsoon.[24] Some of these near-term outcomes will be irreversible within human timeframes, leading to extreme temperatures and weather events, which will likely persist even if temperatures and CO_2 concentrations return to the levels that existed before the tipping points were reached.[25] These abrupt system changes "occur on timescales short enough to challenge the capacity of human societies to adapt to environmental pressures."[26]

Long-term, slower tipping points may provide an opportunity to reverse damages before the critical threshold is crossed,[27] but with the available data, it is difficult to determine how soon these thresholds will be reached.[28] Passing a tipping point creates additional uncer-

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[15] Intergovernmental Panel on Climate Change [IPCC], *Summary for Policymakers*, *in* CLIMATE CHANGE 2022: IMPACTS, ADAPTATION AND VULNERABILITY, at 19 (2022) [hereinafter 2022 IPCC REPORT: SPM], https://www.ipcc.ch/report/ar6/wg2/.

[16] *See, e.g.*, Timothy M. Lenton et al., *Climate Tipping Points—Too Risky To Bet Against*, 575 NATURE 592, 592–93 (2019), https://doi.org/10.1038/d41586-019-03595-0.

[17] *Id.*

[18] *Id.* at 594.

[19] *See, e.g.*, Cai et al., *supra* note 1, at 521.

[20] *Id.*

[21] *See, e.g.*, Dietz et al., *supra* note 3, at 2.

[22] *Id.*

[23] *Id.*

[24] *See, e.g.*, Kopp et al., *supra* note 4, at 351.

[25] *See The Growing Risk of Climate "Tipping Points": Scientific Evidence and Policy Responses*, COUNCIL ON FOREIGN RELS. (Feb. 4, 2022), https://www.cfr.org/event/growing-risk-climate-tipping-points-scientific-evidence-and-policy-responses (webinar featuring Stewart M. Patrick, presider, and Peter Cox and Kelly Wanser, speakers) (explaining the existence of near-term, fast tipping points that occur over the span of decades and are likely to be irreversible for centuries to come); Intergovernmental Panel on Climate Change [IPCC], *Technical Summary*, *in* CLIMATE CHANGE 2021: THE PHYSICAL SCIENCE BASIS, *supra* note 14, at 71.

[26] Brovkin et al., *supra* note 2, at 550.

[27] Kopp et al., *supra* note 4, at 349 ("[P]rovided that the committed state shift can be detected, lags between realized and committed changes may allow for interventions, either by reversing the forcing that originally tipped the system or by introducing a different forcing.").

[28] *See* Paul D. L. Ritchie et al., *Overshooting Tipping Point Thresholds in a Changing Climate*, 592 NATURE 517, 522 (2021), https://doi.org/10.1038/s41586-021-03263-2; Stewart M. Patrick, *Tipping Points Make Climate Inaction Even More Catastrophic*, WORLD POL. REV. (Feb. 14, 2022), https://www.worldpoliticsreview.com/articles/30322/as-the-world-nears-tipping-points-climate-action-can-t-be-ignored [https://perma.cc/6QGJ-TC7S] ("Unfortunately, scientists haven't yet developed adequate

tainty because merely retreating behind the threshold may not arrest the resulting change.[29] As climate scientists have explained, "[T]ipping points [are] not marginal . . . . They're existential risks."[30] For these reasons, the issue of climate change warrants a swift response that will best prevent these tipping points from occurring. Three tipping points—permafrost thaw, melting of the ice sheets, and transformation of the Amazon rainforest—are discussed below as illustrations of the general concept.

A. *Permafrost Thaw*

The latest IPCC report warns that climate change is driving ecosystem changes that are even more severe than previously reported.[31] Permafrost thaw, one of many known consequences of increased warming, is becoming increasingly serious as temperatures warm.[32] Frozen soils in the Arctic region contain large volumes of organic carbon.[33] Warming temperatures encourage microorganisms in the frozen soil to break down organic carbon and release CO_2 and methane gases back into the atmosphere—a vicious cycle that will exacerbate climate change-related harms.[34] Because these soils contain twice the amount of carbon found in the atmosphere (about 1.6 trillion tons), it is important to analyze how much of the soil will thaw, and how quickly, in order to gauge the extent to which permafrost thaw will further contribute to warming.[35] Some models estimate that about 200 billion tons of CO_2 will be released from permafrost within the next

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models to determine just how close humanity is to any of these cliff edges—and whether the world may be able to reverse any of these changes when and if it reaches net-zero carbon emissions."); Intergovernmental Panel on Climate Change [IPCC], *Technical Summary*, *in* CLIMATE CHANGE 2022: IMPACTS, ADAPTATION AND VULNERABILITY, *supra* note 15, at 69 ("The exact timing and magnitude of climate–biosphere feedbacks and potential tipping points of carbon loss are characterized by large uncertainty . . . .").

[29] *See* Kopp et al., *supra* note 4, at 348 ("[T]he forcing that triggers a transition from the first state to the second state may differ from the forcing that triggers a transition back into the first state.").

[30] Alexandria Herr et al., *Points of No Return*, GRIST (internal quotation marks omitted) (quoting Tim Lenton), https://grist.org/climate-tipping-points-amazon-greenland-boreal-forest [https://perma.cc/PX5Q-LFLJ].

[31] 2022 IPCC REPORT: SPM, *supra* note 15, at 8.

[32] 2021 IPCC REPORT: SPM, *supra* note 14, at 20–21.

[33] *See* E. A. G. Schuur et al., *Climate Change and the Permafrost Carbon Feedback*, 520 NATURE 171, 171 (2015), https://doi.org/10.1038/nature14338.

[34] *See* Merritt R. Turetsky et al., *Permafrost Collapse Is Accelerating Carbon Release*, 569 NATURE 32, 32 (2019), https://doi.org/10.1038/d41586-019-01313-4; Schuur et al., *supra* note 33, at 171; Intergovernmental Panel on Climate Change [IPCC], *Terrestrial and Freshwater Ecosystems and Their Services*, *in* CLIMATE CHANGE 2022: IMPACTS, ADAPTATION AND VULNERABILITY, *supra* note 15, at 202–03 [hereinafter 2022 IPCC REPORT: ECOSYSTEMS] ("Continued climate change substantially increases the risk of carbon stored in the biosphere being released into the atmosphere due to . . . permafrost thaw (*high confidence*).").

[35] *See* Turetsky et al., *supra* note 34, at 32.

three centuries.[36] However, these estimates vary widely due to data gaps and uncertainties,[37] and moreover, these additional emissions have not been fully included in climate change models.[38]

Permafrost thaw also presents critical environmental and social justice issues. Thawing soil creates destabilizations and landslides that pose serious problems for indigenous communities, triggering home and infrastructure collapse and disrupting traditional hunting practices.[39] In one recent case, the collapse of a thawing cliff created a waterfall that drained a nearby lake and polluted the downstream river with heavy metals and sediment.[40] With increasing thawing, similar sedimentation is expected to occur in lakes and streams across the Arctic, which could disrupt fragile aquatic ecosystems.[41] Moreover, warming temperatures will release dormant pathogens from the soil, causing die-off of native species and creating dire consequences for the people that rely on those animals for food.[42] These destabilizing effects will have far-reaching consequences for ecosystems and communities worldwide.

These changes are already visible and are "approaching irreversibility,"[43] warranting immediate reduction of greenhouse gas emissions in order to slow these harms and prevent permanent damage. While scientists cannot definitively predict when this tipping point will occur, some speculate that "permafrost, and indeed the Arctic as a whole, is already at or very near" that threshold point.[44] It is also likely that the temperature at which this tipping point will occur depends on the rate

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[36] *Id.* at 33.

[37] Jordan Wilkerson, *How Much Worse Will Thawing Arctic Permafrost Make Climate Change?*, SCI. AM. (Aug. 11, 2021), https://www.scientificamerican.com/article/how-much-worse-will-thawing-arctic-permafrost-make-climate-change [https://perma.cc/3CQP-H3P6] (referencing the "wide range of estimates" cited in the 2021 IPCC report); *see also* Schuur et al., *supra* note 33, at 171 (explaining that there is "wide uncertainty surrounding processes that are only now being quantified in these remote regions.").

[38] *See generally* 2021 IPCC REPORT: SPM, *supra* note 14, at 26 (charting the projected effects of climatic impact-drivers across the world).

[39] *See* Ed Struzik, *How Thawing Permafrost Is Beginning To Transform the Arctic*, YALE ENV'T 360 (Jan. 21, 2020), https://e360.yale.edu/features/how-melting-permafrost-is-beginning-to-transform-the-arctic [https://perma.cc/277P-CAP2]; *see also* Turetsky et al., *supra* note 34, at 32–33.

[40] Struzik, *supra* note 39.

[41] *See id.*

[42] *See id.*; Ed Struzik, *Is Warming Bringing a Wave of New Diseases to Arctic Wildlife?*, YALE ENV'T 360 (Nov. 6, 2018), https://e360.yale.edu/features/is-warming-bringing-a-wave-of-new-diseases-to-arctic-wildlife [https://perma.cc/XG86-N7BS].

[43] 2022 IPCC REPORT: SPM, *supra* note 15, at 9. The IPCC has reported with high confidence that loss of carbon related to the thawing of permafrost is "irreversible at centennial time scales." 2021 IPCC REPORT: SPM, *supra* note 14, at 21.

[44] Raj Saha, *The Permafrost Bomb Is Ticking*, YALE CLIMATE CONNECTIONS (Feb. 12, 2018), https://yaleclimateconnections.org/2018/02/the-permafrost-bomb-is-ticking/ [https://perma.cc/NJ7Z-N9QN].

of anthropogenic warming.[45] Thus, it is critical that we limit emissions to delay the tipping of this fragile system and slow or lessen the effects of the associated harms.

B. *Melting of the Antarctic and Greenland Ice Sheets*

For decades, the Greenland Ice Sheet has been losing volume due to rising temperatures and increasing summer melting.[46] While the Antarctic Ice Sheet has yet to see widespread melting, some areas of the ice sheet have warmed 3° Celsius over the past century.[47] These ice sheets harbor 99% of the world's freshwater ice, and they play an important role in regulating weather and climate patterns.[48] If these ice sheets continue to melt, they could cause a combined 67.4 meters of global sea level rise.[49]

According to the latest IPCC report, there is high confidence that "[s]ea level rise poses a distinctive and severe adaptation challenge as it implies dealing with slow onset changes and increased frequency and magnitude of extreme sea level events which will escalate in the coming decades."[50] The faster the sea level rises, the sooner vulnerable ecosystems and communities around the world will face severe disruption.[51] Even excluding melting of the Antarctic Ice Sheet, sea level rise is expected to permanently displace 150 million people who reside in coastal areas.[52] Reducing greenhouse gas emissions will slow warming and the rate of ice sheet loss, buying valuable time for those most vulnerable to sea level rise to adapt to these changes.[53]

Recent studies show that the Greenland Ice Sheet—the second largest ice sheet and largest contributor to global sea level rise—has already reached "a new dynamic state of sustained mass loss that

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[45] *See id.*

[46] *Ice Sheets: Quick Facts*, NAT'L SNOW & ICE DATA CTR., https://nsidc.org/learn/parts-cryosphere/ice-sheets/ice-sheet-quick-facts [https://perma.cc/3KRU-NAVF].

[47] *Ice Sheets: Why They Matter*, NAT'L SNOW & ICE DATA CTR., https://nsidc.org/learn/parts-cryosphere/ice-sheets/why-ice-sheets-matter [https://perma.cc/36DQ-JGRL].

[48] *Ice Sheets: Quick Facts*, *supra* note 46.

[49] *Id.* ("If the entire Antarctic Ice Sheet melted, sea level would rise about 60 meters (200 feet). . . . If the entire Greenland Ice Sheet melted, sea level would rise about 7.4 meters (24 feet).").

[50] 2022 IPCC REPORT: SPM, *supra* note 15, at 25.

[51] *See id.*

[52] Grace Palmer, *Greenland Ice Sheet Reached Tipping Point 20 Years Ago, New Study Finds*, COLUM. CLIMATE SCH.: STATE OF THE PLANET (Sept. 2, 2020), https://news.climate.columbia.edu/2020/09/02/greenland-tipping-point-20-years-ago [https://perma.cc/6VKM-YKKD].

[53] *See id.* ("[S]cientists emphasize that reducing emissions remains critical. • • • Rapid international action is needed to limit global warming to 1.5°C, which would allow more time for adaptation to rising sea levels.").

would persist even under a decline in surface melt."[54] Scientists have sounded the alarm on early warning signs that indicate the ice sheet is nearing a "critical transition," a loss of stability that signals an impending tipping point.[55] Some scientists argue that the Greenland Ice Sheet has already reached a "long-term state of persistent loss" that is likely to be irreversible in the near future.[56]

Moreover, the Antarctic Ice Sheet has the potential to become the largest driver of sea level rise if temperatures continue to warm.[57] A recent stability analysis of the Antarctic Ice Sheet found that the ice sheet "exhibits a multitude of temperature thresholds beyond which ice loss is irreversible."[58] At 2° Celsius of warming (above pre-industrial levels), ice sheet instability will lead to long-term collapse in West Antarctica.[59] At higher levels of warming, Antarctica may lose virtually all of its ice.[60] If warming is not kept below 2° Celsius, it is possible that a critical threshold will be crossed, leading to irreversible melting and "sea-level rise of up to dozens of metres."[61] Because scientists do not know exactly when an irreversible tipping point will occur,[62] an urgent reduction in greenhouse gas emissions would best protect against the harmful effects of ice sheet melt and sea level rise.

C. *Transformation of the Amazon Rainforest*

The Amazon rainforest supplies 20% of the Earth's oxygen, and it is an important source of global biodiversity.[63] It stores up to 180 billion tons of carbon, compared to the 10 billion tons emitted by human activities each year.[64] Despite its importance as a vital ecosystem and

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[54] Michalea D. King et al., *Dynamic Ice Loss from the Greenland Ice Sheet Driven by Sustained Glacier Retreat*, 1 COMMC'NS EARTH & ENV'T 1, 1 (2020), https://doi.org/10.1038/s43247-020-0001-2; *see also* Niklas Boers & Martin Rypdal, *Critical Slowing Down Suggests That the Western Greenland Ice Sheet Is Close to a Tipping Point*, PNAS, May 25, 2021, at 1, https://doi.org/10.1073/pnas.2024192118 ("It has been suggested that, in response to anthropogenic global warming, the Greenland Ice Sheet may reach a tipping point beyond which its current configuration would become unstable.").

[55] Boers & Rypdal, *supra* note 54, at 1–3.

[56] King et al., *supra* note 54, at 5; *see also* Palmer, *supra* note 52 ("We've witnessed a step-change that is unlikely to be reversible in the near future . . . .") (internal quotation marks omitted) (quoting Ian Howat).

[57] Garbe et al., *supra* note 13, at 538.

[58] *Id.*

[59] *Id.*

[60] *Id.* at 540.

[61] *Id.* at 543.

[62] *See id.* at 539 ("[L]arge uncertainties remain concerning the warming levels at which these thresholds are reached and which regions of Antarctica could undergo irreversible ice loss under future warming.").

[63] PRINCIPLES FOR RESPONSIBLE INV., THE AMAZON: A CRITICAL CLIMATE TIPPING POINT 10 (2019), https://www.unpri.org/Uploads/s/h/b/pri_theamazon_acriticalclimatetippingpoint_2019_659012.pdf [https://perma.cc/G2LC-7AVJ] [hereinafter THE AMAZON].

[64] *Id.*

carbon sink,[65] the Amazon has continued to experience dieback driven by warming temperatures and deforestation.[66]

Over the past several decades, human activities have contributed to climate change that has increased the dry periods for the Amazon, leading to loss of biodiversity and increased carbon emissions.[67] In fact, as of 2021, parts of the rainforest are emitting more CO_2 into the atmosphere than they absorb,[68] and models show that the rainforest could become a permanent carbon emissions source by 2035.[69] A recent study found that the Amazon has been losing resilience since the 2000s, reflecting a "weakening of negative feedbacks that maintain stability."[70] In the most recent IPCC report, scientists warn that climate change will contribute to "extensive forest dieback and potential biome shifts of up to half of the Amazon rainforest to grassland,"[71] leading to a tipping point with the potential to release 90 gigatons of CO_2—more than twice the current level of yearly emissions.[72] Either climate change or deforestation alone is enough to tip the rainforest into a state of severe dieback, but acting together, these factors could push the Amazon past its tipping point by the end of this century.[73]

Once this tipping point is crossed and a significant amount of dieback occurs, the rainforest will release less water back into the environment through evapotranspiration, further contributing to a drying climate and increased dieback.[74] As trees die, they release CO_2 into the atmosphere, and fewer trees are available to take up these emissions through carbon fertilization.[75] This cycle will not only lead to a changing climate in the Amazon but also have global consequences: increased net emissions will lead to higher temperatures worldwide.[76] Rising temperatures will cause further damage through increased frequency of extreme weather events, ecosystem loss, disruption of the food production system, water scarcity, increased incidence of disease,

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[65] Sharon Pruitt-Young, *Parts of the Amazon Rainforest Are Now Releasing More Carbon than They Absorb*, NPR (July 15, 2021, 3:34 PM), https://www.npr.org/2021/07/15/1016469317/parts-of-the-amazon-rainforest-are-now-releasing-more-carbon-than-they-absorb [https://perma.cc/37CP-3T8H] ("For generations, Amazonia . . . was a reliable carbon sink, meaning that it naturally absorbed high levels of carbon dioxide from the air, and it played an important role in keeping the global environment stable.").

[66] *Id.*

[67] *Id.*

[68] *Id.*

[69] Herr et al., *supra* note 30.

[70] Chris A. Boulton et al., *Pronounced Loss of Amazon Rainforest Resilience Since the Early 2000s*, 12 NATURE CLIMATE CHANGE 271, 271 (2022), https://doi.org/10.1038/s41558-022-01287-8.

[71] 2022 IPCC REPORT: ECOSYSTEMS, *supra* note 34, at 272.

[72] Lenton et al., *supra* note 16, at 594.

[73] THE AMAZON, *supra* note 63, at 10; Boulton et al., *supra* note 70, at 271.

[74] THE AMAZON, *supra* note 63, at 10.

[75] Herr et al., *supra* note 30.

[76] THE AMAZON, *supra* note 63, at 11.

and population displacement.[77] Low-income populations, Indigenous Peoples, and Small Island Developing States are especially vulnerable to these risks.[78]

While it is currently unclear whether these trends can be reversed,[79] the "[r]isk of severe impacts increase with every additional increment of global warming" over 1.5° Celsius.[80] Thus, it is important to implement policies that slow global warming to slow the rate of dieback and protect biodiversity. Reforestation and decreased greenhouse gas emissions are the clearest solutions for preventing irreversible damage.[81]

IV. INVESTMENT DISCONTINUITIES: NATURAL GAS AS A BRIDGE FUEL?

Some commentators view natural gas as a "bridge fuel" that plays an important role in the transition away from coal and toward a low-carbon society.[82] Indeed, natural gas has its benefits: it produces about half as much CO_2 as coal and provides more consistent energy outputs than renewables.[83] The vision of natural gas as a transitional energy source relies on the assumption that natural gas will replace other fossil fuels and will eventually be replaced by renewables, resulting in

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[77] *See* 2022 IPCC REPORT: SPM, *supra* note 15, at 9–13.

[78] *See id.* at 12.

[79] *See* Pruitt-Young, *supra* note 65.

[80] 2022 IPCC REPORT: SPM, *supra* note 15, at 19–20.

[81] *See* Thomas E. Lovejoy & Carlos Nobre, *Amazon Tipping Point*, SCI. ADVANCES, Feb. 2022, at 1, https://doi.org/10.1126/sciadv.aat2340 ("[N]egative synergies between deforestation, climate change, and widespread use of fire indicate a tipping point for the Amazon system[.] • • • [T]he sensible course is not only to strictly curb further deforestation, but also to build back a margin of safety against the Amazon tipping point . . . .").

[82] Amir Safari et al., *Natural Gas: A Transition Fuel for Sustainable Energy System Transformation?*, 7 ENERGY SCI. & ENG'G 1075, 1078 (2019), https://doi.org/10.1002/ese3.380.

[83] *Carbon Dioxide Emissions Coefficients*, U.S. ENERGY INFO. ADMIN. (Oct. 5, 2022), https://www.eia.gov/environment/emissions/co2_vol_mass.php [https://perma.cc/PT7E-ZHT4] (listing CO_2 emissions for various fuel sources, including coal (averaging about 212 pounds per million Btu), diesel fuel (163 pounds per million Btu), gasoline (156 pounds per million Btu), propane (139 pounds per million Btu), and natural gas (117 pounds per million Btu)); C. Gürsan & V. de Gooyert, *The Systemic Impact of a Transition Fuel: Does Natural Gas Help or Hinder the Energy Transition?*, RENEWABLE & SUSTAINABLE ENERGY REVS., Mar. 2021, at 1, 4, https://doi.org/10.1016/j.rser.2020.110552 (discussing advantages and drawbacks of renewable energy sources and natural gas). It is worth noting that greenhouse gas emissions from natural gas production may be higher than estimated due to methane leaks and emissions produced during extraction processes. STEVE WEISSMAN, CTR. FOR SUSTAINABLE ENERGY, NATURAL GAS AS A BRIDGE FUEL: MEASURING THE BRIDGE 5 (2016), https://energycenter.org/sites/default/files/docs/nav/policy/research-and-reports/Natural_Gas_Bridge_Fuel.pdf [https://perma.cc/JN8W-9LY9].

reduced CO_2 emissions.[84] In this optimistic scenario, natural gas serves as a short-term solution to further the long-term goal of decarbonization. However, depending on the availability of natural gas and the existence of low-carbon policies, natural gas may displace both coal and cleaner energy sources, ultimately resulting in increased CO_2 emissions.[85] Without adequate policies in place to limit greenhouse gas emissions, increased investment in natural gas resources may lead to lower prices and greater overall energy consumption, making it more difficult to switch to renewables.[86] This result would be incompatible with a goal of limiting warming to 2° Celsius; all mitigation scenarios contemplated in the latest IPCC report require reliance on fossil fuels to be "greatly reduced" and coal use to be "completely phased out by 2050."[87]

There are important and potentially costly risks associated with increased reliance on natural gas. First, as discussed in Section A, economic incentives associated with the construction and operation of natural gas facilities might undesirably "lock in" natural gas infrastructure, hindering decarbonization efforts.[88] Second, Section B shows that political resistance from powerful interest groups might become stronger over time as communities become more dependent on natural gas production, thereby making a further transition less likely.[89] These complications are overlooked in Epstein's prescription for modest steps and learning by doing.

A. *Lock-In Effects*

The duration of the transitional period will determine whether the effects of increased natural gas production are beneficial or harmful.[90] If natural gas is used as a short-term solution, then society can transi-

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[84] WEISSMAN, *supra* note 83, at 2; *see also* Gürsan & de Gooyert, *supra* note 83, at 15 fig.18 (depicting the ideal relationship between natural gas and other technologies).

[85] STEPHEN P.A. BROWN ET AL., RES. FOR THE FUTURE, NATURAL GAS: A BRIDGE TO A LOW-CARBON FUTURE? 2–3 (2009), https://media.rff.org/documents/RFF-IB-09-11.pdf [https://perma.cc/Y3PZ-B2BD].

[86] *See id.*; Christine Shearer et al., *The Effect of Natural Gas Supply on US Renewable Energy and CO_2 Emissions*, ENV'T RSCH. LETTERS, Sept. 2014, at 1, https://doi.org/10.1088/1748-9326/9/9/094008 ("[A]bundant natural gas may actually slow the process of decarbonization, primarily by delaying deployment of renewable energy technologies.").

[87] *See* Intergovernmental Panel on Climate Change [IPCC], *Mitigation Pathways Compatible with Long-Term Goals*, *in* CLIMATE CHANGE 2022: MITIGATION OF CLIMATE CHANGE, at 333 (2022), https://www.ipcc.ch/report/ar6/wg3/ [https://perma.cc/RZ6Z-FWU5].

[88] Ichiro Sato et al., *What Is Carbon Lock-In and How Can We Avoid It?*, WORLD RES. INST. (May 25, 2021), https://www.wri.org/insights/carbon-lock-in-definition [https://perma.cc/G7BG-7CVT].

[89] Craig Holt Segall, *Just Transitions for Oil and Gas Communities*, 39 VA. ENV'T L.J. 177, 184–85 (2021).

[90] *See* Safari et al., *supra* note 82, at 1079.

tion to renewable energy sources relatively quickly, and emissions will decrease.[91] If, however, the transitional period is relatively long, then the costs of increasing natural gas production may outweigh the benefits gained through the transition.

The economics behind natural gas infrastructure help to explain why natural gas is unlikely to succeed as a short-term transitional solution. Natural gas plants, pipelines, and terminals "require large, upfront multibillion-dollar investments . . . [that] are economically predicated on producing revenue for several decades."[92] And this infrastructure can operate for up to 60 years after it is built.[93] Once these large investments have been made, operators are incentivized to continue producing natural gas "as long as [they] can sell power for more than the marginal cost of producing it—even if it incurs a loss on the invested capital."[94] Thus, even if renewable energy technologies become inexpensive enough to facilitate widespread adoption,[95] natural gas facilities will likely continue production.[96]

Moreover, in the event that natural gas infrastructure is abandoned as renewable energy becomes less expensive to produce, these abandonment costs will likely be passed along to consumers.[97] The Federal Energy Regulatory Commission ("FERC") allows utilities to recover "100 percent of prudently-incurred costs associated with abandoned transmission projects due to factors beyond the control of the public utility."[98] In evaluating the prudence of utility expenditures, FERC almost always defers to the judgment of the utilities; FERC will gener-

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[91] *See id.*

[92] LORNE STOCKMAN, OIL CHANGE INT'L, BURNING THE GAS 'BRIDGE FUEL' MYTH: WHY GAS IS NOT CLEAN, CHEAP, OR NECESSARY 17 (2019), https://priceofoil.org/content/uploads/2019/05/gasBridgeMyth_web-FINAL.pdf [https://perma.cc/GL9A-TRFK].

[93] WEISSMAN, *supra* note 83, at 7; *see also id.* (noting that "60 percent of the country's interstate gas transmission pipeline network was installed prior to 1970" and that "plants applying for permits . . . between 2016 and 2020 . . . would be operating beyond 2050").

[94] STOCKMAN, *supra* note 92.

[95] The IPCC's recent report on climate change mitigation emphasizes that renewables are becoming less expensive compared to traditional energy sources. *See* Intergovernmental Panel on Climate Change [IPCC], *Summary for Policymakers*, *in* CLIMATE CHANGE 2022: MITIGATION OF CLIMATE CHANGE, *supra* note 87, at 28 ("Unit cost reductions in . . . wind power, solar power, and storage, have increased the economic attractiveness of low-emission energy sector transitions through 2030. Maintaining emission-intensive systems may, in some regions and sectors, be more expensive than transitioning to low emission systems.").

[96] *See* STOCKMAN, *supra* note 92.

[97] LAUREN SHWISBERG ET AL., ROCKY MOUNTAIN INST., HEADWINDS FOR US NATURAL GAS POWER 43 (2021), https://rmi.org/wp-content/uploads/2021/12/clean_energy_portfolios_2021.pdf [https://perma.cc/V3BS-XZHM].

[98] Promoting Transmission Investment Through Pricing Reform, No. 679-A, 117 FERC ¶ 61,345, 2006 WL 3792941; *see also* 18 C.F.R. § 35.35(d)(1)(vi) (2021) (defining one type of incentive-based rate treatment as "[r]ecovery of 100 percent of prudently incurred costs of transmission facilities that are cancelled or abandoned due to factors beyond the control of the public utility").

ally accept a utility's justification for an expenditure unless the utility fails to provide a justification or provides only "vague generalizations" about the project and its expenses.[99] Therefore, energy producers can invest in natural gas infrastructure without bearing the risks associated with abandonment because they can shift these costs to consumers. This incentive structure will result in greater than optimal natural gas production, as producers do not have to pay for the negative externalities associated with their investment decisions. And this production may last long past its intended short-term timeframe—as long as the marginal benefits exceed the marginal costs of production.

B. *Interest Group Effects*

Political resistance creates a significant barrier to the shift away from fossil fuels. This resistance can come from both the fossil fuel industry and communities that have grown dependent on fossil fuel production.[100] For communities that depend on oil and gas for economic stability, a transition to renewable energy can have negative effects without the mechanisms in place to mitigate economic disruption.[101] Industry players and interest groups can capitalize on these distributional concerns to create even stronger political resistance and ultimately delay the transition toward renewable energy.[102]

Although communities and environmental justice advocates have emphasized the need for a "just transition" from oil and gas, the current landscape does not provide the structure needed to protect these communities from serious adverse economic effects.[103] Individuals in these communities are therefore vulnerable to loss of employment and tax revenue during the shift toward renewable energy.[104]

Communities dependent on natural gas production are not the only ones that will resist a transition to low-carbon and zero-carbon energy sources. Interest groups that support the continuation of fossil fuels can oppose decarbonization efforts both directly, through lobbying and campaign contributions, and indirectly, through public campaigns

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[99] Anaheim v. Fed. Energy Regul. Comm'n, 669 F.2d 799, 809 (D.C. Cir. 1981); *see also* New Eng. Power Co., 31 FERC ¶ 61,047, 61,084 (1985) ("[T]he appropriate test to be used is whether they are costs which a reasonable utility management . . . would have made, in good faith, under the same circumstances, and at the relevant point in time.").

[100] *See* Segall, *supra* note 89, at 190 ("[I]f communities and workers are abandoned in the shift away from fossil fuels, some of them will resist that shift. And arguments . . . to 'protect' them by delaying or stopping the transition will be available to the same fossil companies that have benefitted from the current state of affairs.").

[101] *See id.* at 181–82.

[102] *See id.* at 191. *See generally* LEAH CARDAMORE STOKES, SHORT CIRCUITING POLICY: INTEREST GROUPS AND THE BATTLE OVER CLEAN ENERGY AND CLIMATE POLICY IN THE AMERICAN STATES (2020) (discussing the conflict between advocate and opponent interest groups).

[103] Segall, *supra* note 89, at 179.

[104] *Id.* at 182.

and litigation.[105] Such efforts can lead to "retrenchment" or weakening of environmental policies.[106] They can also lead policymakers to incorporate transition relief into new laws and regulations, with the hope of mitigating lobbying efforts and wasted expenses.[107] These transition relief provisions lead to socially undesirable results, creating competitive disadvantages for new market entrants and often failing to reduce lobbying expenditures.[108]

Environmental policy expert Leah Stokes argues that interest groups are largely responsible for driving policy change when it comes to clean energy.[109] This theory has proven true in several states, which either weakened or reversed clean energy policies at the behest of powerful industry players, despite the widespread political support for such policies.[110] While new policies tend to "reinforce themselves over time," a phenomenon known as "path dependence" or "lock-in," interest groups in these states successfully leveraged their political power to prevent these policies from taking hold.[111] In Texas, for example, industry players spent years lobbying against solar power initiatives, overpowering environmental advocates and government leaders to resist the implementation of statewide solar energy targets and ultimately slowing the state's progress in reducing emissions.[112]

Given the enormous lobbying power of the fossil fuel industry, any effort to cut back on natural gas will be met with fierce opposition. However, this resistance will only intensify as natural gas production expands and creates more revenue and thus more political power for these groups. On top of their existing efforts, interest groups can leverage valid concerns about equity and environmental justice to further their own political agenda.[113] These effects need to be taken into account in considering the viability of natural gas as a bridge fuel. However, they are ignored by Epstein's regulatory approach of small steps and learning by doing.

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[105] STOKES, *supra* note 102, at 7.

[106] *Id.*

[107] *See* Richard L. Revesz & Allison L. Westfahl Kong, *Regulatory Change and Optimal Transition Relief*, 105 NW. U. L. REV. 1581, 1623–24 (2011). The Clean Air Act's grandfathering of existing coal plants provides a clear example of transition relief. *Id.* at 1623.

[108] *See id.* at 1626–27.

[109] STOKES, *supra* note 102, at 4.

[110] *Id.* (highlighting "four cases where clean energy policy has stalled or been reversed: Arizona, Kansas, Ohio, and Texas").

[111] *Id.* at 3.

[112] *See id.* at 125–40.

[113] *See* Segall, *supra* note 89, at 191–92 ("We can thus expect our sincere and deeply felt concern over transitions that leave communities and workers unprotected to be swiftly mobilized by private interests seeking to continue maximizing fossil energy production.").

V. CONCLUSION

The science of climate change bears little resemblance to the type of problem for which Epstein's approach could be desirable. It simply does not have the functional forms—linearity, lack of discontinuities, ability for quick adaptation—that would make Epstein's policy solutions plausible. Moreover, the structure of technological investments and interest group dynamics further counsel against following his approach.