ESSAY

CLIMATE CHANGE AND U.S. INTERESTS

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The climate change debate in the United States has now moved beyond arguments about whether climate change is real and man-made to focus on what the country should do about the threat. This Essay takes on and debunks the "climate change winner" argument. That argument asserts that the United States is likely to fare well in a warmer world, at least compared to most other states, and therefore should invest less, rather than more, in mitigation efforts.

We explain that existing estimates of the impact of climate change on the United States systematically understate the likely economic impact of climate change, and we provide rough estimates of what a more complete accounting would reveal. Existing estimates fail to account for a variety of the costs that climate change will impose, and ignore the ways in which climate change impacts abroad are likely to spill over into the United States. By looking more carefully at these omitted costs, this Essay shows that the United States, acting in its own self-interest, should try to combat climate change.

A more complete accounting of the costs reveals that the United States would be better off paying the full cost of climate change mitigation (if doing so were possible) rather than allowing the world to continue in a "business as usual" fashion. This conclusion is even stronger if Europe and perhaps the rest of the Organisation for Economic Co-operation and Development (OECD) are assumed to shoulder some of the costs. The point is not that the United States or the OECD should actually bear these costs alone, or even that it would be possible to do so, but rather that there is a strong case for action by the United States even if some countries refuse to cooperate. This Essay shows that the United States has reason to take prompt and aggressive action to address climate change, not out of benevolence or guilt, but out of self-interest.

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I. Introduction

There is, after years of debate, a widespread though not universal consensus in the United States that climate change is real, that it is primarily the result of human activity, and that it poses a serious global threat.[1] A consensus on the appropriate U.S. response, however, remains elusive. There are some signs that a program may soon be in place, though the particulars remain uncertain: President Obama has made a cap-and-

1. See Anthony Leiserowitz, Climate Change Risk Perception and Policy Preferences: The Role of Affect, Imagery, and Values, 77 Climatic Change 45, 46 (2006) ("Since the year 2000, numerous public opinion polls demonstrate that large majorities of Americans are aware of global warming (92%) . . . and already view climate change as a somewhat to very serious problem (76%)."); see also Nat'l Acad. of Sci. et al., Understanding and Responding to Climate Change 3 (2008), available at http://dels.nas.edu/dels/rpt_briefs/climate_change_2008_final.pdf (on file with the *Columbia Law Review*) (stating "[t]here is no doubt" climate change is occurring); Nicole Branan, Strange Bedfellows? Evangelicals and Scientists Join Forces on Climate, Geotimes, Sept. 2007, at 24, available at http://www.geotimes.org/sept07/article.html?id=feature_climate.html# (on file with the *Columbia Law Review*) (noting "unprecedented cooperation" between scientists and evangelical Christians on climate change); Andrew C. Revkin, On Global Warming, McCain and Obama Agree: Urgent Action is Needed, N.Y. Times, Oct. 19, 2008, at A22 (describing positions of 2008 Republican and Democratic nominees for presidency); Eric Pooley, Surprise—Economists Agree!, The Big Money, Feb. 11, 2009, at http://www.thebigmoney.com/articles/hey-wait-minute/2009/02/11/surprise-economists-agree (on file with the *Columbia Law Review*) (noting "an emerging economic consensus" regarding costs of climate change).

trade regime a central part of his energy and environment plan,[2] and Congress is actively considering legislation.[3] The new focus on climate change suggests that the United States may play a key role in attempts to negotiate a new international agreement to reduce global emissions.[4] Yet there is serious debate in academic and policy circles over whether doing so would be in the national interest. Indeed, some argue that a straightforward cost-benefit analysis weighs against U.S. action.

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2. Obama for Am., Barack Obama and Joe Biden: New Energy for America 2–3, available at http://www.barackobama.com/pdf/factsheet_energy_speech_080308.pdf (last visited Sept. 15, 2009) (on file with the *Columbia Law Review*); President Barack Obama, Address Before a Joint Session of the Congress (Feb. 24, 2009), available at www.gpoaccess.gov/presdocs/2009/DCPD200900105.pdf (on file with the *Columbia Law Review*) ("[T]o truly transform our economy, to protect our security, and save our planet from the ravages of climate change . . . I ask this Congress to send me legislation that places a market-based cap on carbon pollution and drives the production of more renewable energy in America."); see also Steven Chu, Op-Ed., Cleaning Up: Energy and Climate Bill Will Boost the Economy, Richmond Times-Dispatch, Aug. 18, 2009 (explaining why Secretary of Energy believes cap-and-trade legislation is necessary); Lisa P. Jackson, Op-Ed., Agreeing on Energy Choices, Phila. Inquirer, July 23, 2009, at A19 (explaining why EPA Administrator believes cap-and-trade legislation is necessary); Ken Salazar, Op-Ed., The Way to a New Energy Future, Denver Post, July 19, 2009 (explaining why Department of Interior Secretary believes cap-and-trade legislation is necessary); Tom Vilsack, Op-Ed., Addressing Climate Change Could Revitalize Rural America, Des Moines Reg., July 21, 2009 (explaining why Department of Agriculture Secretary believes cap-and-trade legislation is necessary).

The President's proposed budget for fiscal year 2010 makes clear that he intends to work quickly to enact a cap-and-trade program. Office of Mgmt. & Budget, A New Era of Responsibility: Renewing America's Promise 100 (2009), available at http://www.whitehouse.gov/omb/assets/fy2010_new_era/A_New_Era_of_Responsibility2.pdf (on file with the *Columbia Law Review*). In addition, the Environmental Protection Agency Administrator Lisa P. Jackson has made a proposed finding that CO_2 is within the Clean Air Act's jurisdiction. Press Release, EPA, EPA Finds Greenhouse Gases Pose Threat to Public Health, Welfare/Proposed Finding Comes in Response to 2007 Supreme Court Ruling (Apr. 17, 2009), available at http://yosemite.epa.gov/opa/admpress.nsf/0/0EF7DF675805295D8525759B00566924 (on file with the *Columbia Law Review*).

3. A climate change bill has already passed in the House of Representatives. Press Release, Representative Henry A. Waxman, House Passes Historic Waxman-Markey Clean Energy Bill (June 26, 2009), available at http://waxman.house.gov/News/DocumentSingle.aspx?DocumentID=134768 (on file with the *Columbia Law Review*). The bill is now being considered in the Senate. GPO Access, General Orders 21, available at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=senate_calendar&docid=sc007.pdf (last visited Sept.15, 2009) (on file with the *Columbia Law Review*) (stating H.R. 2454, Waxman-Markey Bill, was placed on legislative calendar on July 7, 2009); see also John M. Broder, Climate Bill Is Threatened by Senators, N.Y. Times, Aug. 7, 2009, at A12 (discussing ten Democratic senators opposing climate bill); Juliet Eilperin, Democrats Pen Principles for Climate Change Bills, Wash. Post, Feb. 4, 2009, at A02 (reporting Senate Democrats announced principles to guide climate change legislation); Suzanne Goldenberg, Democrats Set December Deadline for Cap on U.S. Emissions, Guardian (London), Feb. 3, 2009 (summarizing statements of Sen. Barbara Boxer, D-Cal., Chair of Senate Environment and Public Works Committee).

4. For a collection of proposals for what should replace the Kyoto Protocol, see Architectures for Agreement: Addressing Global Climate Change in the Post-Kyoto World (Joseph E. Aldy & Robert N. Stavins eds., 2007).

The argument against American action goes something like this: Cutting greenhouse gas emissions will be costly for the United States, and it is not entirely clear that the benefits are worth it, especially since a warmer climate will impose fewer costs on the United States than on most countries.[5] The United States should not, the argument goes, impose substantial costs on its own people now, for the benefit primarily of future generations in other nations. Put another way, climate change is a collective action problem, and the best American policy would be to free ride on the efforts of more significantly affected states.[6]

This Essay takes issue with the "climate change winner" argument. In particular, it objects to the claim that harm to the United States will be small or perhaps even nonexistent. We demonstrate that such conclusions reflect a significant misunderstanding of existing studies on the impact of climate change. If one examines those studies critically it becomes clear that the climate change winner argument is fatally flawed. The argument fails to account for the full spectrum of costs that climate change will impose on the United States, and ignores the fact that any coherent assessment of costs must take into account the spillover costs that the United States is almost certain to absorb.[7] Once we account for both of these influences, the climate change winner argument withers, and the case for aggressive American action becomes compelling.

A. *The Climate Change Winner Argument*

The climate change winner argument relies on the consistent projections of both the scientific and economic literature that adverse effects of

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5. For a characterization of this line of thought, see Cass R. Sunstein, The World vs. the United States and China? The Complex Climate Change Incentives of the Leading Greenhouse Gas Emitters, 55 UCLA L. Rev. 1675, 1677 (2008) [hereinafter Sunstein, Complex Incentives]. Though Sunstein advances the argument that the costs of action outweigh the benefits for the United States, he also argues that the United States may wish to act out of a sense of moral responsibility. Id. at 1696–98.

6. Several members of Congress employ this argument. Senator Inhofe, for example, has argued that:

> [I]f you believe that manmade gas is a major cause of climate change, what good would it do for us unilaterally in the United States to impose a financial hardship . . . on people in the United States, when all that would do logically is cause our manufacturing base to further erode and to go to countries such as China and India and Mexico, other countries that have no emission restrictions at all. It would be a $300 billion tax on us every year, and it would have the effect of increasing the net amount of emissions worldwide.

155 Cong. Rec. S202 (daily ed. Jan. 8, 2009); see also 154 Cong. Rec. S4022 (daily ed. May 12, 2008) (statement of Sen. Voinovich) ("Americans should not suffer for symbolism while countries such as China and India emit increasingly large quantities of greenhouse gases without consequences."). But cf. Gregg Easterbrook, Global Warming: Who Loses—And Who Wins?, Atlantic Monthly, Apr. 2007, at 52, 64 (concluding United States should act to control greenhouse gases).

7. See generally infra Part III.

climate change will be distributed unequally.[8] In an especially cruel twist of fate, the most affected countries will by and large be those that have contributed the least to global greenhouse gas concentrations and are the poorest in the world.[9] Poor nations as a group are likely to fare worse than rich ones for three distinct reasons. First, wealthier nations have greater adaptive capacity and can therefore more readily respond to the effects of climatic change.[10] Second, poorer countries tend to depend more heavily on agriculture, a sector that is especially vulnerable to climate change.[11] Third, poorer countries are typically located in warmer, lower latitudes, which is likely to make increases in temperature especially harmful.[12]

That the United States will fare better than most other countries has led some commentators to advance the climate change winner argument, claiming that it is irrational for the United States to take unilateral steps to mitigate climate change or to participate in a globally optimal international agreement to reduce emissions.[13]

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8. See William Nordhaus & Joseph Boyer, Warming the World 96–97 (2000) (noting United States has advantage due to its "relatively temperate climate, small dependence of its economy on climate, the positive amenity value of a warmer climate in many parts of the United States, its advanced health system, and low vulnerability to catastrophic climate change"); Nicholas Stern et al., The Stern Review: The Economics of Climate Change 105 (2006) [hereinafter Stern Review] ("[Climate change] will have a disproportionately harmful effect on developing countries—and in particular poor communities who are already living at or close to the margins of survival.").

9. Robert Mendelsohn et al., The Distributional Impact of Climate Change on Rich and Poor Countries, 11 Env't. & Dev. Econ. 159, 173 (2006) [hereinafter Mendelsohn et al., Distributional Impact]; see also R.O. Mendelsohn et al., Country-Specific Market Impacts of Climate Change, 45 Climatic Change 553, 560–64 (2000) [hereinafter Mendelsohn et al., Country-Specific] (examining forecasts of future climate change and finding countries will not feel impacts uniformly); Richard Tol, Estimates of the Damage Costs of Climate Change Part II: Dynamic Estimates, 21 Envtl. & Resource Econ. 135, 157 (2002) [hereinafter Tol, Dynamic Estimates] ("In the poorer regions . . . the negative impacts tend to dominate the positive impacts.").

10. Stern Review, supra note 8, at 139.

11. Id.; see also William Cline, Global Warming and Agriculture 67–71 (2007) (estimating impact of climate change on agriculture by country).

12. Stern Review, supra note 8, at 139; see also Nordhaus & Boyer, supra note 8, at 91 tbl.4.10 (estimating U.S. damages in 2100 for 2.5°C temperature rise at 0.45% of GDP, reflecting small absolute loss by United States compared to most of global South); Mendelsohn et al., Country-Specific, supra note 9, at 565–66 figs.1 & 2 (using two versions of model that both predict damages to United States will be less, as percentage of GDP, than damages to much of global South from 2°C warming; model predicts net gain of 0.25–0.5% U.S. GDP in 2100 under both scenarios); Tol, Dynamic Estimates, supra note 9, at 156 fig.13 (finding overall aggregate impact for United States and Canada is positive from 2000–2200).

13. Jason Scott Johnston, Climate Change Confusion and the Supreme Court: The Misguided Regulation of Greenhouse Gas Emissions Under the Clean Air Act, 84 Notre Dame L. Rev. 1, 21 (2008) ("In the [twenty-first century] average daily temperature increases in the two to three degree centigrade range will almost surely generate net benefits in many areas of the United States."); Robert Mendelsohn & James E. Neumann, Synthesis and Conclusions, *in* The Impact of Climate Change on the United States

B. *Limits of the Climate Change Winner Argument*

The climate change winner argument relies on economic models of the impact of climate change on the United States.[14] If one believes that the results of these models represent an accurate forecast of climate change impacts, then the climate change winner argument has considerable force. But while these models contribute to our understanding of climate change, they provide only a lower bound on its possible impact rather than an accurate prediction of its likely effects. The models engage in a series of simplifying assumptions that, while necessary to make the models tractable, create a systematic downward bias on the projected impacts.[15] The climate change winner argument fails to adequately consider this bias and so understates the threat of climate change, leading to the flawed conclusion that action by the United States is unnecessary.

No study to date has assessed all of the potential costs of climate change to the United States. Most models calculate direct market impacts to the U.S. economy on a sector-by-sector basis while ignoring cross-sectoral, indirect, and cumulative effects.[16] Most models also ignore nonmarket costs, such as loss of biodiversity and ecosystem services, and fail to consider the possibility of catastrophic losses.[17] These omissions are not anyone's fault, but rather, as many economists point out, result from the inherent limitations of economic modeling.[18] There is a risk

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Economy 315, 321 (Robert Mendelsohn & James E. Neumann eds., 1999) (noting warming may be beneficial to United States economy); Sunstein, Complex Incentives, supra note 5, at 1677 ("[American] unilateral reductions would impose significant costs and by themselves produce no significant benefits."). For a general discussion of what defines "winners" and "losers" in global climate change, see Karen L. O'Brien & Robin M. Leichenko, Winners and Losers in the Context of Global Change, 93 Annals Ass'n Am. Geographers 89, 97–99 (2003) ("Winners are usually referred to in terms of improved conditions, opportunities, positive effects, and benefits, while losers are referred to in terms of negative effects and increasing vulnerability.").

14. See supra notes 8–9.

15. See infra Part II.

16. Most models calculate these costs by estimating direct market losses to agriculture, commercial water supplies, human health, and the like. See generally Cline, supra note 11; Stern Review, supra note 8; Tol, Dynamic Estimates, supra note 9.

17. See generally Robert L. Fischman, The EPA's NEPA Duties and Ecosystem Services, 20 Stan. Envtl. L.J. 497, 498 (2001) ("Purification of air and water, pest control, flood abatement, pollination, climate regulation, and soil nutrient cycling are now among the most frequently cited services for which we depend on ecosystem functioning.").

18. See, e.g., Mendelsohn et al., Country-Specific, supra note 9, at 567 (noting their models exclude nonmarket effects and have various other limitations); Mendelsohn & Neumann, supra note 13, at 317 (noting their model excludes nonmarket impacts, particularly health, aesthetic, and nonmarket ecosystem effects like species and wetlands loss); Sunstein, Complex Incentives, supra note 5, at 1693 (citing Bryan K. Mignone, The National Security Dividend of Global Carbon Mitigation, 35 Energy Pol'y 5403, 5404 (2007)) (speculating on possible national security implications not considered by climate models); Richard S.J. Tol, Estimates of the Damage Costs of Climate Change Part I: Benchmark Estimates, 21 Envtl. & Resource Econ. 47, 63–64 (2002) (noting omitted impacts including: amenity, recreation, tourism, extreme weather, fisheries, construction, transport, energy supply, morbidity, and others, and stating "no comprehensive, quantified

that policy discussions, however, will forget the limitations imposed by these models. The shortcomings of the models lead to a consistent bias toward an understatement of climate impacts.[19] Needless to say, ignoring these shortcomings has serious implications. First, as a conceptual matter, without a more complete cost-benefit analysis we cannot think coherently about the full range of likely impacts of climate change. Second, in terms of practical implications, reliance on these models without a full understanding of their limitations could lead to a misguided policy response.

To date, the primary response to the climate change winner argument has been to insist that regardless of the cost-benefit calculation, the United States is morally obligated to act.[20] This obligation arises, it is said, because the United States has been the largest historic contributor to the problem (the corrective justice argument), or because it is the richest nation on earth and ought to help poorer nations (the distributive justice argument).[21] Alternatively, some suggest that the United States has an ethical obligation to future generations.[22]

In this Essay, by contrast, we address the cost-benefit calculus at the heart of the climate change winner argument head-on. Though we believe the moral arguments for U.S. action on climate change are compelling, we doubt that they will, on their own, convince U.S. policymakers of the need for mitigation. American international environmental policy, as

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impact studies have been reported"); Tol, Dynamic Estimates, supra note 9, at 157 ("One should be careful, however, to base policy conclusions on the finding of [his model] because so many of the assumptions are not properly founded on a good understanding of the [global climate] system."); Richard S.J. Tol, The Economic Impact of Climate Chance [sic] 12–18 (Econ. & Soc. Research Inst., Working Paper No. 255, 2008), available at http://www.esri.ie/UserFiles/publications/20080922144128/WP255.pdf (on file with the *Columbia Law Review*) [hereinafter Tol, Climate Change Impact] (describing integrated assessment models' failure to account for important climate change impacts).

19. See infra Part II.

20. See, e.g., Daniel A. Farber, The Case for Climate Compensation: Justice for Climate Change Victims in a Complex World, 2008 Utah L. Rev. 377, 379 [hereinafter Farber, Climate Compensation] ("[T]he United States has a *duty* to bear some net costs as a result of climate change because of its responsibility for causing the problem.").

21. See Daniel A. Farber, Adapting to Climate Change: Who Should Pay?, 23 J. Land Use & Envtl. L. 1, 18–34 (2007) (considering corrective and distributive justice in determining who should pay for climate change adaptations); Farber, Climate Compensation, supra note 20, at 394–400 (detailing corrective justice argument); Lukas H. Meyer & Dominic Roser, Distributive Justice and Climate Change: The Allocation of Emission Rights, 28 Analyse & Kritik 223, 223–24 (2006) (explaining how climate change disproportionately affects developing nations); Benito Müller, Varieties of Distributive Justice in Climate Change, 48 Climatic Change 273, 277 (2001) (considering distributive justice in emission allocations); Eric Neumayer, In Defence of Historical Accountability for Greenhouse Gas Emissions, 33 Ecological Econ. 185, 187–88 (2000) (arguing for historical accountability in allocating emission rights); see generally Edward A. Page, Climate Change, Justice, and Future Generations (2006) (examining climate change through lens of distributive justice).

22. See Page, supra note 21, at 7–11 (noting ethical challenge of climate change is often framed as intergenerational).

with U.S. foreign policy generally, is typically driven by utilitarian calculations about the national interest.[23] After all, the U.S. Senate could not be persuaded to ratify the Kyoto Protocol even after President Clinton signed it, in part because the benefits of doing so were not perceived to be significant enough to outweigh the potential costs to the U.S. economy.[24] The reluctance to act is remarkably powerful: It persists even in the face of an increasingly solid scientific consensus that climate change is man-made, pressure from a number of American states in the form of state and regional climate programs,[25] a rebuke from the U.S. Supreme Court over the EPA's refusal to decide whether greenhouse gases are "pollutants" to be regulated under the Clean Air Act,[26] demand from powerful industry players that domestic controls are necessary to create a predictable business environment,[27] and intensified moral pressure from other countries for the United States to re-engage in international negotiations over a global climate agreement.[28]

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23. For example, the United States joined the Montreal Protocol, the treaty to eliminate ozone depleting substances, largely because, as a number of commentators have pointed out, the benefits of the agreement to the United States clearly outweighed the costs. See, e.g., Daniel Cole, Climate Change and Collective Action, 61 Current Legal Probs. (forthcoming 2009), available at http://ssrn.com/abstract=1069906 (manuscript at 16-17, on file with the *Columbia Law Review*) (describing role of national cost-benefit analysis in decision to join international environmental treaties); Cass R. Sunstein, Of Montreal and Kyoto: A Tale of Two Protocols, 31 Harv. Envtl. L. Rev. 1, 6 (2007) [hereinafter Sunstein, Montreal] (describing cost-benefit analysis used by United States in deciding to join Montreal Protocol and not Kyoto Protocol). The United States stood to lose considerably from excess cancer risk created by a thinning ozone layer, and stood to gain considerably because U.S. business was poised to be first to market with substitute products. Id. at 14, 17–19.

24. See Byrd-Hagel Resolution, S. Res. 98, 105th Cong. (1997) (enacted) ("[T]he Senate strongly believes that the proposals under negotiation, because of the disparity of treatment between Annex I Parties and Developing Countries and the level of required emission reductions, could result in serious harm to the United States economy.").

25. See, e.g., California Global Warming Solutions Act of 2006, Cal. Health & Safety Code §§ 38500–38599 (West 2007) (detailing California's state program to combat climate change); Reg'l Greenhouse Gas Initiative, Overview of RGGI CO_2 Budget Trading Program (2007), available at http://rggi.org/docs/program_summary_10_07.pdf (on file with the *Columbia Law Review*) (describing cap-and-trade coalition of Northeastern states); W. Climate Initiative, Statement of Regional Goal (2007), available at http://www.azclimatechange.gov/download/082207_statement.pdf (on file with the *Columbia Law Review*) (describing collaboration of Western states dedicated to slowing climate change).

26. Massachusetts v. EPA, 549 U.S. 497, 533–35 (2007).

27. Corporations that have joined the U.S. Climate Action Program, which advocates for strong federal regulation of greenhouse gases, include General Electric, Caterpillar, Shell, and the Environmental Defense Fund. U.S. Climate Action Partnership, at http://www.us-cap.org/ (last visited Aug. 21, 2009) (on file with the *Columbia Law Review*).

28. In January of 2009, for example, Stavros Dimas, the E.U. Commissioner for Environment, published an open letter calling on the United States to take a leadership role in efforts to reduce carbon emissions. Letter from Stavros Dimas, E.U. Commissioner for Environment, to President Barack Obama (Jan. 29, 2009), at http://ec.europa.eu/commission_barroso/dimas/news/doc/letterpresidentObama.pdf (on file with the *Columbia Law Review*); see also Angela Charlton, Help for Poor Countries at Paris Climate

Given this history of inaction even in the face of considerable pressure, we think it especially important to carefully explain the consequences of U.S. inaction: not moral consequences (as substantial as these might be), but rather those we would expect to be taken seriously in a no-nonsense cost-benefit analysis. In our view, the calculation of American self-interest on which the climate change winner argument rests is simply mistaken. This is not because we dispute the general point that the United States may fare well relative to many other states in a warmer world, but because what matters are not the relative costs, but the *absolute* ones. The question for policymakers, after all, should be whether or not the costs of inaction are greater than the costs of action. These are absolute costs, not relative ones. And if the absolute costs justify expenditures for mitigation, the U.S. government should make them.

C. *Costs Omitted from the Climate Change Winner Argument*

One of the more striking features of climate models that is subsequently embraced (perhaps implicitly) in most climate change winner arguments is a curiously isolationist approach to a truly global problem. The argument fails to consider, at least in any serious way, the possibility that many of the costs and burdens that other countries are likely to experience as a result of climate change will, to varying degrees, spill over to the United States.[29] We argue that this spillover is likely to occur in the form of national security threats, which climate change will exacerbate in various regions of the world;[30] economic spillovers, such as higher oil and other resource and commodity prices, along with supply shocks, demand shocks, and disruption to financial markets;[31] spillovers resulting in the spread of infectious disease;[32] significant human migration;[33] and the risk of food and water shortages, species extinction, and biodiversity loss.[34]

We do not claim that all of these things will happen at catastrophic levels, or that the United States will necessarily be dragged into every climate-related conflict around the world, but simply that the United States cannot sequester itself from all such spillovers. To assume otherwise seems unduly optimistic—perhaps even naïve—given the reality of global interdependence. Within the last decade, both the 9/11 attacks and the

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Talks, Seattle Times, May 26, 2009 ("[At the Major Economies Forum] France and Germany . . . said the United States wasn't going far enough in its emissions targets."); James Kanter, Europe to U.S.: You're a Big Polluter, N.Y. Times Green Inc. Blog, Jan. 27, 2009, at http://greeninc.blogs.nytimes.com/2009/01/27/europe-to-us-youre-a-big-polluter (on file with the *Columbia Law Review*) (noting Dimas "reinforc[ed] the idea that the United States bears a special responsibility to take swift action to lower emissions").

29. See generally infra Part III.
30. See infra Part III.B.
31. See infra Part III.A.
32. See infra Part III.D.
33. See infra Part III.C.
34. See infra Part II.B.4.

recent financial crisis have made clear that we live in a world in which events in one region of the globe can have seismic impacts in another.[35] Economic, political, military,[36] and public health developments[37] in other countries can and frequently do cross international borders, and would likely do so in response to climate change.[38]

Moreover, in our view, it is unlikely that the United States will react to conflicts, crises, and serious economic strife around the world by attempting to retreat into isolation. In any event, we doubt it would be in the national interest to do so. If the United States hopes to shape its strategic position in an increasingly interdependent world, we must expect to bear at least some costs associated with responding to crises that arise elsewhere. Some of these crises will arise because of climate change. Yet a policy of U.S. isolationism is what the climate change winner argument implicitly assumes.

Even if a strategy of going it alone were possible, it would be extraordinarily expensive to try to insulate ourselves from outside events. Yet no model we know of accounts for the costs of isolationism, or for spillovers from impacts in other countries, which stand to be substantial.[39] Although such costs are hard to quantify, the challenge of quantification is not a reason to count them as zero.

The fact that economic models fail to account for all relevant impacts is not news. The authors of these studies recognize their assumptions and typically make them clear.[40] The relevant studies are important inquiries by outstanding scholars and our understanding of climate

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35. See William Jefferson Clinton, Remarks as Delivered at Cornell University, 38 Cornell Int'l L.J. 1, 3 (2005) (pointing to 9/11 attacks as prime example of global interdependence); Steven L. Schwarcz, Systemic Risk, 97 Geo. L.J. 193, 249 (2008) ("[S]ystemic [financial] collapse in one country inevitably will affect markets and institutions in other countries.").

36. See, e.g., Ilan Alon & David L. McKee, Country Risk Spillovers in the Middle East: A Prelude to the Road Map for Peace and the War on Terror, *in* Corporate Strategies Under International Terrorism and Adversity 83, 83–94 (Gabriele G. Suder ed., 2006) (describing rapid spread of security risks across countries).

37. See Richard D. Smith, Responding to Global Infectious Disease Outbreaks: Lessons from SARS on the Role of Risk Perception, Communication and Management, 63 Soc. Sci. & Med. 3113, 3113 (2006) ("Globalisation increases the likelihood that an infectious disease appearing in one country will spread rapidly to another.").

38. C.B. Field et al., North America, *in* Intergovernmental Panel on Climate Change, Climate Change 2007: Impacts, Adaptation and Vulnerability 617, 640 (M.L. Parry et al. eds., 2007) [hereinafter IPCC, Impacts] ("In this interconnected world, it is possible that profoundly important impacts of climate change on North America will be indirect consequences of climate change impacts on other regions, especially where people, economies or ecosystems are unusually vulnerable.").

39. See, e.g., Dale W. Jorgenson et al., Pew Ctr. on Global Climate Change, U.S. Market Consequences of Global Climate Change, at iii-iv (2004), available at http://www.pewclimate.org/docUploads/Market_Consequences-report.pdf (on file with the *Columbia Law Review*).

40. To offer just one illustration, consider the explicit acknowledgement of excluded factors in one study:

change has been greatly enhanced by their efforts. No matter how capable the researchers, however, the problem forces climate scientists and economists to make simplifying assumptions in their models.[41]

Our concern is not with the assumptions or the models themselves, but rather with the way in which some commentators and policymakers may interpret the results of these models and overlook the limits that the assumptions impose. Climate change winner arguments tend to take the results of economic studies at face value, without serious consideration of their limits. To the extent such arguments acknowledge imperfections in the economic models at all, they do so only in footnotes and minor asides. Notice, for example, the following passing acknowledgement of the potential for spillovers from other parts of the world to affect the United States:

> To be sure, these rough estimates are at best only suggestive. . . . Because nations are economically interdependent, significant adverse effects on India, Africa, and Europe would probably have a major impact on the United States, China, and Russia. But on these estimates, or any reasonable variation, it is readily apparent that some nations are far more vulnerable than others. On some estimates, the United States, China, and Russia are expected to lose relatively little from 2.5°C warming . . . .[42]

Our point is simply that the spillovers mentioned in this excerpt, or the many other ways in which existing estimates understate impacts,[43]

> [T]here are important sectors and activities—such as tourism—that are omitted from this effort. Similarly, there is little information concerning possible interactions among the benefits and costs in different sectors. For example, the impacts on crop and livestock agriculture may have consequences for human health. Given the absence of reliable insights into such externalities or spillovers, these effects are also excluded from consideration. These limitations suggest that the results of this analysis are likely to understate the potential market impacts of climate change.
>
> More importantly, this analysis does not consider the non-market impacts of climate change such as changes in species distributions, reductions in biodiversity, or losses of ecosystem goods and services. These considerations are essential to a complete evaluation of the consequences of climate change but are very difficult to value in economic terms.

Id.

41. See supra note 15 and accompanying text.

42. Richard Posner & Cass Sunstein, Climate Change Justice, 96 Geo. L.J. 1565, 1581 (2008).

43. See O'Brien & Leichenko, supra note 13, at 97–99 (discussing ways in which existing estimates understate or obscure impacts of climate change); Easterbrook, supra note 6, at 56 (explaining potential for climate change to disrupt real estate markets); James Brosnan & Shan Carter, Winners and Losers in a Changing Climate, N.Y. Times, Apr. 2, 2007, available at http://nytimes.com/2007/04/02/us/20070402_CLIMATE_GRAPHIC.html (on file with the *Columbia Law Review*) (showing spillover costs on map); cf. Global Warming Could Boost Tourism, Farming, Augusta Chron. (Ga.), June 15, 2007, at A03 (citing Professor Robert Mendelsohn for proposition that many Northern Hemisphere countries will "'get such large gains [from climate change] . . . that they will be bigger than the losses'"). The climate change winner argument is not new. See, e.g., William K.

cannot be bracketed and ignored. They are critical to understanding the climate change problem and how the United States should respond to it.

D. *The Self-Interested Argument for Action*

A more realistic assessment of relevant costs and benefits ought to change the calculus of whether it makes sense for the United States to cut domestic emissions even in the absence of a multilateral agreement binding other high emitting countries to do so. Many prominent academics and policymakers subscribe to the view that unless major emitters in the developing world, such as China and India, join a multilateral agreement to cut global emissions, it is not in the U.S. interest—that is, it is not rational—to curb domestic emissions.[44] To the extent this argument turns on prevailing estimates of the relative costs and benefits to the United States of doing nothing, we think it is wrong.

While it is surely correct that climate change poses a collective action problem, it is also true that large players may internalize enough of the benefits from the production of collective goods (here, mitigated climate change) to make it worthwhile to invest in those goods. Every player, large or small, has an incentive to take action up to the point where the State's marginal cost of action exceeds the marginal benefit. This is why a more complete accounting of cost makes a difference. A large, hegemonic player like the United States internalizes a significant fraction of the global gains of climate change abatement, making it worthwhile to bear at least some costs. Although this might result in a less than optimal amount of mitigation, the reductions in emissions could still be significant and meaningful in terms of mitigating impacts.[45] Most importantly for this Essay, the reductions may require more action than is currently contemplated by U.S. policy.

Thus, without resorting to moral arguments, we claim that a more comprehensive assessment of what the United States has at stake suggests it *is* in the national interest to invest in mitigation. That is true even if the United States cannot fully internalize the benefits of mitigation, and even if some nations free ride on U.S. efforts. Given our assessment of what the United States stands to lose if climate change continues unabated, the more rational policy is to take action now, and look for strategies (other than a threat of inaction) to induce cooperation from the developing world.

It is important to separate the climate change winner argument we seek to debunk from other reasons why the United States might hesitate

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Stevens, In a Warming World, Who Comes Out Ahead?, N.Y. Times, Feb. 5, 1991, at C1 (explaining possibility some regions could benefit from climate change.).

44. See, e.g., Sunstein, Complex Incentives, supra note 5, at 1699 ("[M]any people appear not to appreciate the fact that significant steps, by states or even regions, will have no significant impact on climate change.").

45. See infra Part IV (discussing climate change as global problem requiring collective solution).

to act. For our purposes, these reasons can be summarized as follows: (1) the "futility thesis"—the belief that any effort at mitigation will be overwhelmed by the sheer volume of emissions generated elsewhere; this argument assumes we will hit "thresholds" or "tipping points" regardless of what the developed world does; (2) the "leakage thesis"—the concern that without the participation of the developing world, any effort at mitigation will be ineffective because emission-intensive industry simply will relocate to these unregulated jurisdictions; and (3) the "fairness thesis"—which says it is simply unfair to expect the developed world to bear all the cost of mitigation.

These three concerns are quite different from the climate change winner argument. First, although they may be used to argue against a particular course of action, they do not dispute the basic proposition that climate change is a threat to the United States and that some form of global action is needed. Second, while they might be persuasive either alone or in combination, each requires a separate defense. For example, it is debatable whether unilateral cuts by the United States would, in fact, be futile. Predictions of futility depend on a number of assumptions that remain controversial, including that U.S. leadership on emissions cuts will be met with international free riding, as if the United States has no instruments of persuasion at its disposal. Moreover, without a better understanding of thresholds and tipping points, it is difficult to say conclusively that marginal reductions in emissions will have no beneficial effects. Nor is it clear that leakage would be substantial enough to severely undermine mitigation efforts: Not every greenhouse gas (GHG) intensive industry can easily migrate overseas and, even if they do, there are policy instruments available that might minimize the impact.

In any event, such arguments, though important, are not our focus here. Instead, we seek only to disprove the climate change winner argument, which we think takes too much for granted. It assumes the accuracy of inherently constrained cost-benefit analyses, and then plays out the implications as if the underlying methodological limitations can be bracketed.[46] They cannot. In essence, we challenge the extent to which the United States ought to be viewed as a net "winner" from climate change by questioning what it means to be a "winner," especially in an interdependent world. How to count costs, what costs to include, and what to do when there is no established method for capturing costs are the most important questions in the debate over whether the United States should take action on climate change. As we show, the leading studies systematically skew toward undercounting costs. A more comprehensive accounting reveals that it is in the United States' interest to take unilateral action to mitigate climate change, even before other countries act. Indeed, our analysis suggests that the United States would be better

46. See, e.g., Sunstein, Complex Incentives, supra note 5, at 1693 (examining costs and benefits of climate change).

off paying the full cost of mitigating the impact of climate change by itself (if this were possible) rather than allowing the world to continue in a "business as usual" fashion. This result is even stronger if Europe and the rest of the OECD are assumed to shoulder some of the costs.

Our argument proceeds as follows: Part II explains why the methodologies of scientific and economic projections underlying the climate winner thesis are overly optimistic. Part III analyzes how spillover effects will have an impact on the United States and generate additional, as yet unconsidered, costs. Part IV explains why the more complete assessment of costs justifies aggressive action by the United States to address climate change, notwithstanding that some other countries have been reluctant to take meaningful steps in that direction. We conclude by arguing that the risks of these costs justify unilateral action. If we are right, the case for American action to reduce domestic GHG emissions and other mitigation strategies strengthens considerably.

II. THE LEADING SCIENTIFIC AND ECONOMIC PROJECTIONS

A. *Scientific Projections of Impact*

We take the predominant scientific consensus—that climate change is indeed occurring,[47] that its rapid acceleration in the last 150 years has been caused primarily by human behavior (notably the emissions of greenhouse gases as a byproduct of burning fossil fuels to produce energy),[48] and that it poses significant risks of substantial harm from a vari-

47. Before industrialization, the average concentration of greenhouse gases in the atmosphere was approximately 280 parts per million (ppm). Hervé Le Treut et al., Historical Overview of Climate Change Science, *in* Intergovernmental Panel on Climate Change, Climate Change 2007: The Physical Science Basis 93, 100 (Susan Solomon et al. eds., 2007) [hereinafter IPCC, Physical Science Basis]. As of August 2009 it was approximately 384 ppm. Earth Sys. Research Lab. Global Monitoring Div., Nat'l Oceanic & Atmospheric Admin., Trends in Atmospheric Carbon Dioxide, at http://www.esrl.noaa.gov/gmd/ccgg/trends (last visited Aug. 6, 2009) (on file with the *Columbia Law Review*). This change has caused the earth to warm by an average of 0.5°C, and will lead to at least an additional 0.5°C of warming in the coming decades. Stern Review, supra note 8, at 6, 15. Such increments of temperature rise may sound small, especially when we experience dramatic temperature swings between morning and evening as normal. However, the small changes in global average temperature have significant impacts. See Mark Lynas, Six Degrees 17 (2008) (describing such impacts). A relatively small amount of warming has already caused sea ice loss in the Arctic and Antarctic regions. Mountain glaciers and snow cover have declined on average around the world, contributing to sea level rise that has gone from an average of 1.8 millimeters per year from 1961 to 2003 to about 3 mm per year from 1993 to 2003. The Greenland ice sheet has been contracting about 7% per decade. Press Release, Nat'l Snow & Ice Data Ctr., Models Underestimate Loss of Arctic Sea Ice (Apr. 30, 2007), available at http://nsidc.org/news/press/20070430_StroeveGRL.html (on file with the *Columbia Law Review*) [hereinafter Nat'l Snow, Sea Ice]. And the incidence of flooding is up around the world, including in North America. Millennium Ecosystem Assessment, Current State & Trends Assessment 517 (2005).

48. The most recent Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC FAR), which represents the consensus of the international

ety of impacts—as a starting point.[49] Although the consensus is not universal, it does have considerable support across the political spectrum within the United States[50] and around the world.[51] Importantly, the climate change winner perspective we seek to rebut also assumes that man-made climate change is real.[52] Of greatest interest, of course, is what the future will bring. The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (FAR) provides "best estimates" and "likely" ranges for global average temperature under six different scenarios. Each scenario makes different assumptions about emission rates, technological development, and adaptation, among other things.[53] The IPCC's best estimate for the low emissions scenario is 1.8°C warming (with a "likely" range of 1.1°C to 2.9°C), and a best estimate for the high emissions scenario of 4.0°C warming (with a "likely" range of 2.4°C to 6.4°C).[54]

At current emission rates, GHGs are projected to reach an atmospheric concentration level of 550 ppm by 2050, which is expected to cause an increase in temperature of over 2°C.[55] The more likely scenario, however, is that emissions will not remain static but will increase as economies grow, especially those in the developing world.[56] Taking this

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scientific community, concludes that anthropogenic greenhouse gas emissions are "very likely" responsible for "most of the observed increase in global average temperatures since the mid-20th century." Richard B. Alley et al., Summary for Policymakers, *in* IPCC, Physical Science Basis, supra note 47, at 1, 10. Indeed, the data show a "spectacular record of human impact on the atmosphere." Daniel P. Schrag, Confronting the Climate-Energy Challenge, 3 Elements 171, 171 (2007). The geological record, from drilled ice cores and other geochemical measurement techniques, indicates that "we are perturbing the atmosphere beyond any state seen through the entire history of the human species" and that "the recent warming observed over the last 140 years of instrumental record is beyond the range of natural climate variability." Id. at 172.

49. See, e.g., Alley et al., supra note 48, at 2–3 (stating human activities since 1750 have resulted in unprecedented levels of greenhouse gases in atmosphere and claiming "with a very high level of confidence" that net effect of human activities over this time is responsible for radiative forcing).

50. See supra note 1 and accompanying text.

51. See United Nations Framework Convention on Climate Change, Kyoto Protocol Status of Ratification (2009), available at http://unfccc.int/files/kyoto_protocol/status_of_ratification/application/pdf/kp_ratification.pdf (on file with the *Columbia Law Review*) (listing 184 countries that have ratified Kyoto Protocol).

52. See, e.g., Sunstein, Complex Incentives, supra note 5, at 1676–77 (indicating United States and China have contributed to climate change).

53. Alley et al., supra note 48, at 18.

54. Id. at 11 tbl.SPM.3.

55. A recent analysis by James Hansen et al. projects a temperature rise of 2°C in the long term even if there is no growth in emissions due to warming already "in the pipeline." James Hansen et al., Target Atmospheric CO_2: Where Should Humanity Aim?, 2 Open Atmospheric Sci. J. 217, 225 (2008).

56. Alley et al., supra note 48, at 12 ("For the next two decades, a warming of about 0.2°C per decade is projected. . . . Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected."). Recent studies suggest that if CO_2 concentrations double by

into account makes it likely that GHG concentrations will reach 550 ppm by 2035. The IPCC FAR projects that a variety of impacts—including significant sea level rise due to melting sea ice, loss of coastal lands, flooding that could displace hundreds of millions of people, and inundation of freshwater systems with sea water—will occur under *all* the scenarios considered.[57] Warmer temperatures are also expected to contribute to more extreme weather events, including more severe storms and hurricanes, as well as droughts, heavy precipitation, and more intense heat waves.[58] Climate change will place stress on water supplies in many regions of the world, due in part to a reduction in the amount of water stored in glaciers and snow cover.[59] In addition, the IPCC FAR projects significant biodiversity loss. Twenty to thirty percent of plant and animal species assessed will be at increased risk of extinction if global temperature increases exceed 1.5–2.5°C.[60]

These global estimates of impact mask the fact that impacts will vary from one place to another.[61] There is little doubt that the United States is relatively well positioned to avoid the worst impacts, especially when compared with much of Asia and Africa, which are expected to be the most affected areas.[62] Not only is the United States geographically well situated to withstand the warming trend, it possesses both strong domes-

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2100 as expected, temperatures will correspondingly increase between 1.8 and 5.4°C. See, e.g., Richard A. Kerr, Latest Forecast: Stand by for a Warmer, but Not Scorching World, 312 Science 351, 351 (2006) (discussing how increased amounts of carbon dioxide could affect climate sensitivity).

57. Alley et al., supra note 48, at 12 ("Sea ice is projected to shrink in both the Arctic and Antarctic under all SRES [Special Report on Emissions Scenarios] scenarios. In some projections, Arctic late-summer sea ice disappears almost entirely by the latter part of the 21st century.").

58. Id.

59. For example, at higher latitudes and in some wet tropical areas, river runoff is expected to increase by 10–40%. In dry regions it is expected to fall by 10–30%. Neil Adger et al., Summary for Policymakers, *in* IPCC, Impacts, supra note 38, at 7, 11. Meltwater from glaciers and snow packs supply water to more than 15% of the world's population. Id.

60. Id. There are a host of other projected impacts as well, some of which are positive in the short term, at least under "moderate" warming scenarios. For example, global potential for food production is expected to increase unless average temperatures increase by more than 1–3°C. Id. If temperatures increase by *more* than this amount, however, food production potential is expected to decrease. At lower latitudes, crop productivity is expected to decrease in any event, increasing the risk of hunger and famine. Id. An increase in the frequency of droughts and floods will further harm food production efforts, particularly at lower latitudes. Id. at 12.

61. See Richard S.J. Tol et al., Distributional Aspects of Climate Change Impacts, 14 Global Envtl. Change 259, 261 tbl.1, 264 fig.1 (2004) (illustrating consistent regional variation in climate change impacts predicted by different economic models).

62. See Nordhaus & Boyer, supra note 8, at 96–98 (discussing countries' vulnerability to increases in temperature); Stern Review, supra note 8, at 179 ("In all scenarios, the highest impacts are in Africa and the Middle East, and India and South-East Asia."); see also Olivier Deschênes & Michael Greenstone, The Economic Impacts of Climate Change: Evidence from Agricultural Output and Random Fluctuations in Weather, 97 Am. Econ.

tic institutions and a relatively healthy, diversified economy, providing it with a comparatively robust adaptive capacity.[63]

This story of relative effects, however, is somewhat beside the point. For the purposes of making policy decisions it is the absolute impact on the United States that matters rather than the relative impact. For this reason, we focus on the absolute harms that are likely to have an impact on the United States. In the following section we discuss the economic consequences of climate change in absolute terms and explain why existing economic projections systematically underestimate their impact.

B. *Economic Projections of Cost to the United States*

To generate estimates of the economic impact of climate change, economists rely on integrated assessment models (IAMs). These models typically frame costs as changes in the level of gross domestic product (GDP) attributable to climate change.[64] Most of the economic models that focus specifically on the United States estimate that the long-term economic harm attributable to climate change will be between 0–3% of GDP.[65]

In this section we explain why the methodological limitations of these models almost certainly cause them to understate the impact and cost of climate change. We identify five problems that many of the studies share: optimism about projected temperature rise; failure to account for the possibility of catastrophic loss; omission of cross-sectoral impacts; exclusion of nonmarket costs; and optimism about projected economic growth (which assumes productivity will be unaffected by climate change). We explore each in turn below. In Part III we discuss an additional problem: the failure to account for international spillovers.

Rev. 354, 381 (2007) (finding net positive economic effects on U.S. agricultural sector from climate change).

63. The United States is not unique in this respect; other nations will also be less adversely affected. See Nordhaus & Boyer, supra note 8, at 96 (Japan, Russia, and China); Mendelsohn et al., Distributional Impact, supra note 9, at 170 (former Soviet Union and Eastern Europe); cf. Stern Review, supra note 8, at 110–13 (discussing weak adaptive capacities of many developing nations).

64. For examples of such models, see Nordhaus & Boyer, supra note 8, at 3–7 (Regional dynamic Integrated model of Climate and the Economy (RICE) and Dynamic Integrated model of Climate and the Economy (DICE)); Mendelsohn et al., Country-Specific, supra note 9, at 554 (Global Impacts Model); Tol, Dynamic Estimates, supra note 9, at 135–36 (unnamed dynamic IAM).

65. See William Nordhaus, A Question of Balance: Weighing the Options on Global Warming Policies 6 (2008) [hereinafter Nordhaus, Balance] ("[T]he best guess in this book is that the economic damages from climate change with no interventions will be on the order of 2.5 percent of world output per year by the end of the twenty-first century."); Joel B. Smith et al., Vulnerability to Climate Change and Reasons for Concern: A Synthesis, *in* Intergovernmental Panel on Climate Change, Climate Change 2001: Impacts, Adaptation and Vulnerability, at 913, 943 fig.19-4 (summarizing several prominent IAM studies).

1. *Optimism About Temperature Rise.* — Creating an estimate of the economic impact of climate change begins with assumptions about the extent of warming over time. If one assumes modest temperature changes the resulting economic impacts will obviously be smaller than if one assumes larger changes. The most important economic studies to date have generally chosen relatively optimistic estimates about temperature changes, with most assuming a warming of 2–3°C, which is in line with the IPCC FAR's low emissions scenario.[66] The resulting economic impact is in the range of 0–3% of global GDP lost.[67] If, however, one considers the possibility of warming in the 5–6°C range, the economic impact is 5–10% of global GDP.[68]

Though it is possible that the estimates used by most IAMs overstate future warming,[69] it is much more likely that they underestimate the dangers we face. First, measurement difficulties may cause some warming effects to be ignored. Water vapor, for example, may increase the effects of rising carbon dioxide (CO_2) concentrations, but we do not know with any confidence how large such an effect could be.[70]

Second, there is a possibility of "tipping points" or "threshold effects" which could dramatically increase the concentration of GHGs in the atmosphere, and result in "abrupt and irreversible change in the climate system."[71] These include, for example, the risk of a rapid collapse of ice sheets in Greenland or the Antarctic. Discrete events of this sort are not factored into the IPCC FAR conclusions.[72] Also excluded are a number of feedback mechanisms that could have dramatic effects on temperature rise, such as large releases of methane (CH_4) from frozen clathrates in the arctic polar region that will melt as temperatures warm.[73]

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66. See Alley et al., supra note 48, at 13 tbl.SPM.3.

67. Stern Review, supra note 8, at 166 fig.6.2 (surveying models of Nordhaus, Tol, and Mendelsohn).

68. Nordhaus & Boyer, supra note 8, at 95 fig.4.3.

69. See, e.g., David Henderson, Governments and Climate Change Issues, World Econ., Apr.–June 2007, at 183, 194–209 (arguing IPCC process is run by "true believers," has made numerous mistakes, especially in its treatment of economics, and is insufficiently transparent).

70. Schrag, supra note 48, at 173.

71. Id. at 174.

72. Alley et al., supra note 48, at 14 ("Models used to date do not include uncertainties in climate-carbon cycle feedback nor do they include the full effects of changes in ice sheet flow . . . .").

73. See Intergovernmental Panel on Climate Change, Special Report on Emissions Scenarios ch. 4.4.6 (Nebojsa Nakicenovic et al. eds., 2000), available at http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=104 (on file with the *Columbia Law Review*) (demonstrating IPCC assumption of continued existence of CH_4 gas in frozen clathrates); Intergovernmental Panel on Climate Change, Synthesis Report 67 (2007), available at www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf (on file with the *Columbia Law Review*) [hereinafter IPCC, Synthesis Report] ("Feedbacks between the carbon cycle and climate change affect the required mitigation and adaptation response to climate change. . . . [M]itigation studies have not yet incorporated the full range of these feedbacks."). The leading models also tend to ignore the effect of slow feedback processes

Third, almost every surprise about climate change thus far has underestimated both the rate of warming and its effects. For example, Arctic sea ice is retreating at a significantly faster rate than predicted by the best computer models, including all eighteen models used by the IPCC in preparing the FAR.[74] Indeed, it now appears that the Arctic will be seasonally free of sea ice thirty years ahead of expectations.[75]

Fourth, the process that generated the projections makes understatement more likely than overstatement. The IPCC consists of the IPCC Plenary and three Working Groups with clearly defined mandates.[76] One expert has described the Panel as a body dominated as much by politics as science because it is open to national delegations from all United Nations Environment Programme (UNEP) and World Meteorological Organization member states.[77]

There have been numerous allegations of political influence over the IPCC process, from charges that members have been voted out of the Panel for being overly aggressive in advocating policy responses,[78] to claims that the IPCC has softened or deleted parts of the Report offensive to some states that produce and consume large amounts of oil.[79] Al-

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on the climate. Recent work by James Hansen et al. suggests that even if GHG concentrations were stabilized at 550 ppm there could be a longer-term warming of 6°C because of slower feedback processes such as GHG releases from deep soils, ice sheet disintegration and slow vegetation migration that are not currently part of climate models. Hansen et al., supra note 55, at 219–20 (2008).

74. See Julienne Stroeve, Arctic Sea Ice Decline: Faster Than Forecast?, Geophysical Res. Letters, May, 2007 (arguing IPCC models underestimate real trends in ice melting).

75. Nat'l Snow, Sea Ice, supra note 47. Existing predictions estimate that the Arctic could be seasonably free of ice between 2050 and 2100. Id.

76. Intergovernmental Panel on Climate Change, About IPCC: How the IPCC Is Organized, at http://www.ipcc.ch/organization/organization_structure.htm (last visited Sept. 16, 2009) (on file with the *Columbia Law Review*).

77. See Bernd Siebenhüner, The Changing Role of Nation States in International Environmental Assessments—The Case of the IPCC, 13 Global Envtl. Change 113, 118 tbl.1 (2003) (characterizing Plenary in terms of "[p]olitical dominance" while describing IPCC's subject-specific Working Groups, which are open to government representatives but largely dominated by scientists, as "[b]alance between science and politics"). By comparison, the authors of the Working Group reports (which go into the IPCC Assessment Reports) are exclusively derived from the scientific community, and are characterized by "scientific [d]ominance." Id.

78. In 2002, IPCC Chairman Dr. Robert Watson was voted out of his position by the IPCC Plenary. Watson, an aggressive advocate for political responses to climate change, was replaced by Dr. Rajendra Pachaurii, who, at the time, was perceived to be more industry friendly. The United States initiated this change, which was followed by allegations that the United States acted in response to a memo from ExxonMobil to the White House seeking to blackball Watson. See Al Gore, Op-Ed., The Selling of an Energy Policy, N.Y. Times, Apr. 21, 2002, § 4, at 13.

79. Following the release of the Fourth Assessment Report in 2007, David Wasdell, who served as "an accredited reviewer of the report," viewed preliminary drafts of the report and asserted that "'reference to possible acceleration of climate change [was] consistently removed' from the final report. This happened both in its treatment of potential positive feedbacks from climate change in the future and in its discussion of recent observations of collapsing ice sheets and an accelerating rise in sea levels." Fred

though it is possible that scientists engaged in the process might collectively be biased in favor of overstating the results, it seems more plausible that the institutional forces of the IPCC process are tilted in the other direction. Governments with an interest in delaying progress on climate change have been known to challenge conclusions in assessment reports aggressively during the line-by-line approval process, leading to allegations that drafters ultimately weaken claims in order to garner consensus.[80] The process by which IPCC assessment reports are produced is highly constrained by the need for consensus on issues such as the nomination and selection of authors and reviewers, coordination of drafting by lead authors, and integration of comments by reviewers. Rather than extreme conclusions, it is more likely to produce cautious and centrist ones.[81] It is also fair to suggest that as a matter of disciplinary training and shared norms, scientists tend to err in the direction of conservative estimates that can be defended on the basis of existing data. For all of these reasons, it is appropriate to treat the IPCC projections as conservative, and to approach climate change policy with a measure of risk aversion.[82]

Pearce, Climate Report "Was Watered Down," New Scientist, Mar. 10, 2007, at 10. IPCC coordinating lead authors wrote a letter responding to Wasdell, arguing that "[a]ny draft versions of the Summary for Policymakers (SPM) or chapters were just that: documents in which inconsistencies needed rectifying, gaps needed closing, and complicated matters needed better and more accessible explanation." Piers Forster et al., Climate with Care, New Scientist, Mar. 23, 2007, at 24.

80. David Biello, Conservative Climate: Consensus Document May Underestimate the Climate Change Problem, Sci. Am., Apr. 2007, at 16, 16 ("For example, after objections by Saudi Arabia and China, the report dropped a sentence stating that the impact of human activity on earth's heat budget exceeds that of the sun by fivefold. 'The difference is really a factor of 10,' says lead author Piers Forster . . . .").

81. See Intergovernmental Panel on Climate Change, Principles Governing IPCC Work app. A (2003), available at http://www.ipcc.ch/pdf/ipcc-principles/ipcc-principles-appendix-a.pdf (on file with the *Columbia Law Review*) (detailing procedures for production of IPCC reports and other materials).

82. To us, it is entirely reasonable to support a policy of taking somewhat more action than the IPCC projections indicate is necessary, both to account for the possibility that existing estimates understate the actual impacts and, given the extent of the remaining uncertainties and the potential for catastrophic harm, to recognize that some risk aversion is appropriate in this context. To some commentators, climate change is a situation that calls for action as a kind of investment in insurance. See, e.g., Richard A. Posner, Catastrophe: Risk and Response 56 (2004) ("It would thus be a mistake to say that because some climatologists doubt there is a global warming problem we can ignore the problem until climatologists get their act together and forge a unanimous agreement on the problem and its solution."); Martin Weitzman, On Modeling and Interpreting the Economics of Catastrophic Climate Change, 91 Rev. Econ. & Stat. 1, 18 (2009) ("When analyzing the economics of climate change, perhaps it might be possible to make back-of-the-envelope comparisons with empirical probabilities and mitigation costs for extreme events in the insurance industry.").

The remaining uncertainties obviously create a challenge for both policymakers as well as scientists. Policymakers need a sense of how various choices will affect outcomes so they can engage in a sensible cost-benefit analysis of the available alternatives. Yet scientists are not able to predict the future impact of climate change with anything like certainty, let

Many models also implicitly assume that GHG emissions will level off or decline very soon. A recent study by Anderson and Bows shows that stabilizing CO_2-equivalent (CO_2-e) concentrations at 450 ppm (which yields a 46% chance of not exceeding 2°C warming) would require global emissions to peak in 2015, rapidly decline by 6–8% per year between 2020 and 2040, and eventually reduce to zero by 2050.[83] At present there is no reason to think that emissions will peak in 2015, let alone that they will then start to fall. In fact, present estimates suggest just the opposite.[84] Annual GHG emissions in the United States are projected to rise from 7.2 gigatons CO_2-e in 2005 to 9.7 gigatons in 2030,[85] and economic growth in the developing world is projected to dramatically increase emissions.[86] Adopting the 2–3°C change as an input into IAMs, then, implicitly assumes a level of cooperation and effort to reduce emissions that is belied by the current reality.

It follows that discussions should focus on a higher expected temperature change, along with associated changes in precipitation and other weather events. This focus would significantly affect the predicted eco-

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alone provide a menu of policy-outcome choices. So scientists are forced to offer their best projections, with careful qualification, and policymakers are forced to make decisions under conditions of highly imperfect information. Still, there is no logical basis on which uncertainty alone should be grounds for inaction. What is required instead is a balancing of the consequences of inaction against the consequences of action, under conditions in which policymakers cannot foresee all collateral effects. See Kenneth J. Arrow, Global Climate Change: A Challenge to Policy, Economists' Voice, July 2007, at 1, 3, available at http://www.bepress.com/ev/vol4/iss3/art2 (on file with the *Columbia Law Review*) ("Are the benefits from reducing climate change worth the costs?"); Thomas C. Shelling, Climate Change: The Uncertainties, the Certainties, and What They Imply About Action, Economists' Voice, July 2007, at 1, 4, available at http://www.bepress.com/ev/vol4/iss3/art3 (on file with the *Columbia Law Review*) ("[T]his idea that costly actions are unwarranted if the dangers are uncertain is almost unique to climate.").

Inaction (or, more accurately, delay) would only be justified if waiting a relatively short period of time would likely produce more information without significantly increasing the expected cost of acting. In the climate change context, however, the opposite is true. Waiting will, of course, yield some new information (it is impossible for it not to, since there will always be new data to collect on climatic conditions as time goes by), but it is *unlikely* to soon yield new information capable of resolving the important uncertainties that are relevant to policy choices. And delay will most certainly increase the cost of action by exacerbating the problem of GHG concentrations.

83. Kevin Anderson & Alice Bows, Reframing the Climate Change Challenge in Light of the Post-2000 Emission Trends, 366 Phil. Transactions of the Royal Soc'y A: Mathematical, Physical and Engineering Sci., 3863, 3877 (2008).

84. IPCC, Synthesis Report, supra note 73, at 58 fig.4.1 (2007) (indicating under IPCC's A2 "business as usual" scenario, GHG emissions are expected to increase by thirty gigatons CO_2-e between 2000 and 2030).

85. See McKinsey & Co., Reducing Greenhouse Gas Emissions: How Much and at What Cost? 6 (2007), available at http://www.mckinsey.com/clientservice/ccsi/pdf/US_ghg_final_report.pdf (on file with the *Columbia Law Review*) (citing data from U.S. Energy Information Administration, EPA and other government departments).

86. Jayant Sathaye et al., Sustainable Development and Mitigation, *in* Intergovernmental Panel on Climate Change, Climate Change 2007: Mitigation of Climate Change 691, 706–07 (Bert Metz et al. eds., 2007).

nomic analysis. For example, according to the Nordhaus and Boyer estimates, assuming a temperature rise of 3–4°C instead of 2–3°C causes an additional loss of approximately 1% of GDP.[87]

2. *Asymmetry Around Point Estimates.* — An additional problem arises because discussions about climate change often focus on a single point estimate, rather than a range of temperature changes, as an input. The point estimate, while intuitively satisfying, produces misleading results because economic harm increases at an accelerating rate as temperatures rise.[88]

Increases in temperature around a given average will generally have a larger impact on economic well-being than will reductions in temperature. For example, a 2–3°C rise in temperature is expected to cause a 0–3% loss of GDP while a 5–6°C rise would reduce GDP by 5–10%.[89] Notice that, using the upper end of the relevant ranges, doubling the assumed temperature increase from 3°C to 6°C more than triples the predicted economic impact, from 3% to 10%. An accurate estimate of economic impacts, then, requires that the full probability distribution of potential climatic changes be considered.[90]

As such, a better estimate would be to average the estimated economic impact over a range of possible climate outcomes. Figure 1 demonstrates this point, using data from Nordhaus and Boyer. They predict an impact on GDP of 0.5–4.5% where changes in global temperature range from 2.5–6°C.[91] The midpoint temperature increase would be 4.25°C, which Nordhaus and Boyer estimate would have an impact of 2%

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87. Nordhaus and Boyer predict a 0.0–0.75% loss for the United States if temperatures rise 2–3°C, but a loss of 0.75–1.75% for a 3–4°C change in temperature. Nordhaus & Boyer, supra note 8, at 96 fig.4.4. Note that this adjustment to conventional estimates seems small in isolation, but because similar adjustments are appropriate to account for weaknesses in existing models, the cumulative impact is substantially greater.

88. The "average projected change in temperature" is typically cited as the midpoint of the 5–95% confidence interval of projected temperature changes. This confidence interval is generated using probabilistic techniques that incorporate various kinds of uncertainties. See, e.g., Tom M.L. Wigley & Sarah C.B. Raper, Interpretation of High Projections for Global-Mean Warming, 293 Science 451, 451 (2001) (analyzing "limited subset" of probability density functions to predict climate change). In addition to asymmetry within the confidence interval, the exclusion of the most extreme 5% of temperature increases may lead to a downward bias in the point estimate.

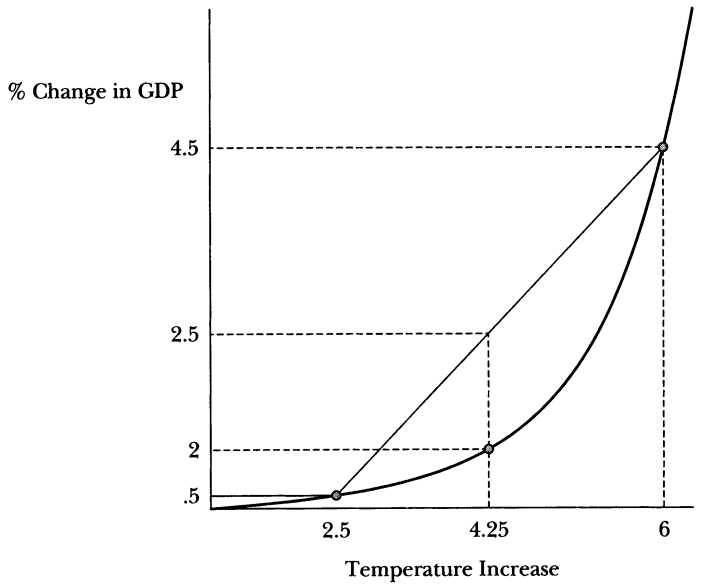
89. Stern Review, supra note 8, at 166 fig.6.2 (showing path of Nordhaus and Boyer estimates for global GDP loss with different changes in temperatures).

90. Using the average expected change in temperature also ignores the fact that the climate models do not account for the possibility of major shocks that might amplify the rise in temperature. These would include, for example, the unexpectedly rapid disintegration of major ice sheets or the release of greenhouse gases through slow feedback processes. This point is distinct from the one presented below (failure to account for catastrophic loss). Infra Part II.B.3. The former deals with the potential for a much larger than expected increase in temperature while the latter addresses the fact that increases in temperature make extreme weather events more likely to occur.

91. Nordhaus & Boyer, supra note 8, at 96 fig.4.4.

of GDP.[92] However, averaging the impact of a 2.5°C temperature increase (0.5% of GDP) and a 6°C increase (4.5% of GDP) yields an expected economic harm of 2.5% of GDP.[93] For these estimates, then, averaging over economic outcomes rather than climatic outcomes increases the expected harm by 0.5% of America's GDP.[94] For policy purposes, the higher estimates more accurately reflects expected economic impact.

FIGURE 1: TEMPERATURE INCREASE IMPACT ON GDP



Many (perhaps most) IAMs address this problem by estimating multiple scenarios, with alternative climatic assumptions.[95] When these results are deployed in policy discourse, however, the mid-range scenarios are frequently the ones cited.[96] The result is a tendency to understate the expected economic impact of climate change.

92. Id.

93. This simple averaging of the endpoints is fairly crude. Ideally one would want to calculate the expected change in GDP over the complete probability distribution function of potential temperature changes. This more thorough approach would yield similar results.

94. This figure is very sensitive to the specifics of a given study, but, as a rule, averaging over the economic outcomes always will yield a larger (and more appropriate) estimate of harm than averaging over temperature changes.

95. See, e.g., Nordhaus & Boyer, supra note 8, at 96 (presenting estimates of economic harm over range from 1–6°C temperature increase).

96. See, e.g., Bjørn Lomborg, Stern Review: The Dodgy Numbers Behind the Latest Warming Scare, Wall St. J., Nov. 2, 2006 (citing only one figure of 3% anticipated GDP loss for Nordhaus and Boyer model); Jerry Taylor & Peter Van Doren, What Will Climate Change Cost Us?, Cato.org, Dec. 18, 2008, at http://www.cato.org/pub_display.php?pub_id=9850 (on file with the *Columbia Law Review*) (highlighting only mean, median, and modal summary estimates from IAMs). It should be noted, though, that in some secondary

3. *Failure to Account for Catastrophic Events.* — Because IAM estimates are essentially extrapolations of existing experiences to expected climatic changes, they are unable to account for the risk of "catastrophic"[97] climate events.[98] This weakness, which Martin Weitzman calls the "fat tail" problem, has the potential to overwhelm all of the effects IAMs currently take into account.[99] There is no doubt, for example, that climate change will increase the incidence and the magnitude of floods, droughts, and storms,[100] with potentially serious consequences and high costs.[101] Yet these costs are not adequately considered in most IAMs.[102]

One exception is the study by Nordhaus and Boyer which attempts to account for such risks. Like other models, theirs examines impacts on a sector-by-sector basis and then tallies up the results to determine a regional impact.[103] In contrast to other studies, however, theirs pays close

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analyses, the use of point estimates is occasionally compelled by mathematical limitations. See, e.g., EPA, Analysis of the Lieberman-Warner Climate Security Act of 2008, at 108 (2008) (noting confidence intervals cannot be presented due to weaknesses in study's model).

97. We define catastrophic events as low probability but high magnitude occurrences.

98. See Stern Review, supra note 8, at 170–72 (noting many IAMs omit large-scale effects because including them would be cost-prohibitive).

99. Weitzman, supra note 82, at 1, 2. Weitzman argues that the low probability, highly uncertain scenarios of very large global average temperature increases (on the order of 10°C or more by 2200) merit further investigation, because the potential economic impact of these high risk scenarios could overwhelm the conventional cost-benefit analysis of current IAMs. Id. at 1–2. In other words, while the probability of these catastrophic scenarios is quite small, it nonetheless merits more thoughtful consideration in IAMs. Id. at 16.

100. See supra notes 57–59 and accompanying text.

101. The costs from natural disasters can be quite large. For example, the Congressional Budget Office estimates that the damages from Hurricanes Katrina and Rita are between $70 and $130 billion. Macroeconomic and Budgetary Effects of Hurricanes Katrina and Rita: Hearing Before the H. Comm. on the Budget, 109th Cong. 2 (2005) (statement of Douglas Holtz-Eakin, Director, Congressional Budget Office). More recent hurricanes have also left enormous damages. Press Release, Risk Mgmt. Solutions, Inc., Hurricane Ike Insured Losses Estimated at $7 Billion to $12 Billion (Sept. 17, 2008), available at http://www.rms.com/newspress/pr_091708_ike_industry_loss.asp (on file with the *Columbia Law Review*); Press Release, Risk Mgmt. Solutions, Inc., RMS Estimates Insured Losses of $4 Billion to $10 Billion for Hurricane Gustav (Sept. 1, 2008), available at http://www.rms.com/newspress/pr_090108_gustav_industry_loss.asp (on file with the *Columbia Law Review*). Therefore, climate changes that increase the frequency or severity of hurricanes could pose substantial costs to the United States.

102. See Megan Ceronsky et al., Checking the Price Tag on Catastrophe: The Social Cost of Carbon Under Non-Linear Climate Response 18–21 (Hamburg Univ. & Ctr. for Marine & Atmospheric Sci., Working Paper FNU-87, 2005), available at http://www.uni-hamburg.de/Wiss/FB/15/Sustainability/catastrophewp.pdf (on file with the *Columbia Law Review*) (noting previous literature did not account for nonlinear climate responses, including (1) change in thermohaline circulation, (2) release of CH_4 clathrates, and (3) climate sensitivities at high levels of temperature increases, and criticizing mainstream models for not doing same).

103. Nordhaus and Boyer employ the RICE model (Regional dynamic Integrated model of Climate and the Economy). For a more thorough discussion of the RICE model, see Nordhaus & Boyer, supra note 8, at 5–7.

attention to the increased potential for catastrophic risk.[104] By assuming a warming of 2.5°C they yield an estimated economic impact from catastrophic risk of slightly less than 0.5% of GDP for the United States, and about 1% globally. To this, one must add other impacts (agriculture, coastal resources, etc.), leading to a total estimate of harm of about 0.5% for the United States and 1.5% of GDP globally.[105]

These numbers are of modest magnitude, but like other results that rely on a 2.5°C warming, they likely understate the impact. Though Nordhaus and Boyer focus on the 2.5°C result, they report the impact of catastrophic harm under the less optimistic assumption of 6°C warming. This assumption yields a much larger (and much more alarming) cost of 7% of global GDP, and 3% of U.S. GDP due to catastrophic harm alone.[106] Including the other sectors considered by Nordhaus and Boyer (agriculture, sea level rise, other market sectors, health, nonmarket amenity impacts, and human settlements and ecosystems) yields an alarming forecast of a 10% loss of global GDP and a loss for the United States of 4.25%.[107]

For an increase in temperature between 2.5°C and 6°C, then, they estimate an economic harm of between 0.5% of GDP and 3% of GDP.[108] This estimate is only for the catastrophic loss and so must be added to whatever other harms are expected. If one assumes a temperature increase of 3–4°C, then the harm would be in the neighborhood of 1.5–2% of GDP.

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104. Nordhaus and Boyer's methodology illustrates the difficulty in arriving at a sophisticated estimate of harms that includes extreme weather events or, indeed, any one of several other factors. To calculate an estimate of the impact of catastrophic risk, they asked several experts to estimate the probability that a loss of 25% of global GDP will result from increases in temperatures of 3°C by 2090, 6°C by 2175, and 6°C by 2090. After a conservative doubling of experts' probabilities, the authors then used additional survey data to estimate people's willingness to pay to avoid the risk resulting from a 30% loss of global GDP. Id. at 87–90 & tbl.4.9.

Nordhaus and Boyer conclusively assume that "certain subregions . . . are relatively more vulnerable than other subregions." Id. at 88. However, it is not obvious that the same subregions which suffer increased vulnerability from moderate temperature increases will also suffer relatively more from higher temperature increases if climatic patterns are greatly disrupted. Also, the "catastrophic" losses discussed by Nordhaus and Boyer (i.e., a 30% GDP loss) may not represent anything near the true ceiling for climate change induced global catastrophe. See id. at 87–89 (discussing "catastrophic" losses).

105. Id. at 91 tbl.4.10. The impact on the United States is approximately 0.5% in both cases because the net impact in other sectors is roughly zero. The 1.5% global GDP loss is calculated by weighting countries by output level. Weighting countries by population yields a larger global GDP loss (about 1.9%). Id.

106. Id.

107. Id. at 95–96 figs.4.3 & 4.4. Global GDP loss is calculated by weighting countries by output level. Weighting countries by population yields a larger loss of 11% of global GDP. Id. at 96 fig.4.3. Intermediate temperature changes predictably yield intermediate results, with global GDP losses of about 5% for a 4°C warming and harm to the United States of slightly less than 2% of GDP for that same change in climate. Id. at 95–96 figs.4.3 & 4.4.

108. Id.

4. *Failure to Account for Nonmarket Costs.* — Our fourth concern about IAMs is that they tend to omit significant nonmarket costs, including those associated with the environment and human health.[109] These impacts are potentially enormous but the absence of reliable market prices makes them difficult to evaluate. For example, the polar bear and arctic seal may become extinct as warming oceans consume their sea ice habitat.[110] How should we value this loss? Or how should we account for the loss of many lower order marine species that will lose their coral reef habitat to bleaching, which may be ultimately more important to maintaining biodiversity than the charismatic megafauna on which so much attention has focused?

A significant loss of biodiversity as a consequence of climate change is very likely to occur yet is rarely included in estimates of economic harm.[111] The only leading study to make a serious attempt to quantify loss of biodiversity is the Stern Review.[112] Conventional models analyzing the economic impacts of climate change tend to disregard the costs associated with species extinctions as either too negligible or uncertain to quantify.[113] These costs are indeed difficult to quantify and hence uncertain. It is highly unlikely, however, that they will be negligible.

There are many reasons to be concerned about such significant biodiversity loss. Setting aside ethical or aesthetic arguments in favor of species protection, there remains a self-interested motive: the value of preserving biodiversity to support ecosystem services for human populations, such as pollination, soil fertilization, biological controls, nutrient cycling, and genetic resources used for medical research and the development of pharmaceuticals.[114] To illustrate, a 1997 study estimated the average value of ecosystem services to be $33 trillion.[115]

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109. See Richard S.J. Tol et al., How Much Damage Will Climate Change Do? Recent Estimates, World Econ., Oct.–Dec. 2000, at 179, 191 [hereinafter Tol et al., Damage] ("Non-market impacts will be more pronounced than early aggregate studies conveyed, as many (but not all) of the effects that have not yet been quantified could be negative. In particular, there is concern about the impact on human health and mortality.").

110. Juliet Eilperin, Study Says Polar Bears Could Face Extinction, Wash. Post, Nov. 9, 2004, at A13.

111. Although the impact on food production is often considered, the categories relating to natural biological processes have been ignored. Wayne Hsiung & Cass R. Sunstein, Climate Change and Animals, 155 U. Pa. L. Rev. 1695, 1716 (2007).

112. See Stern Review, supra note 8, at 93–95 (estimating extinction rates based on warming levels); cf. Tol, Climate Change Impact, supra note 18, at 15 (pointing out no major economic studies of climate change impacts adequately address biodiversity).

113. See, e.g., Nordhaus & Boyer, supra note 8, at 85–87 (noting "rather wild" economic valuations of species extinction and serious need for quantitative work in area).

114. As the supply of ecosystem services approaches zero, the demand and total economic value approach infinity, because ecosystem services are necessary to support human life. See Robert Costanza et al., The Value of the World's Ecosystem Services and Natural Capital, 387 Nature 253, 257 (1997) ("Many ecosystem services are only substitutable up to a point . . . .").

115. Id. at 259; cf. Gordon C. Rausser & Arthur A. Small, Valuing Research Leads: Bioprospecting and the Conservation of Genetic Resources, 108 J. Pol. Econ. 173, 191–95

Recent studies have produced information that reduces the uncertainty regarding the ecological effects of climate change. One such study found that as climate change causes species to move northward and upward in search of cooler climates, patterns of habitat loss emerge.[116] This study found that the range limits of species have shifted on average 6.1 kilometers toward the poles per decade.[117] Utilizing these numbers, another study estimated that 15–37% of all species will be extinct by 2050 due to habitat loss attributable to "climatic unsuitability."[118] This finding is consistent with the most recent IPCC report which states that "[a]pproximately 20 to 30% of plant and animal species assessed so far (in an unbiased sample) are likely to be at increasingly high risk of extinction as global mean temperatures exceed a warming of 2 to 3°C above pre-industrial levels."[119] The estimates become 40–70% if temperature increases exceed 3.5°C.[120]

Although it is difficult to estimate the economic costs associated with biodiversity loss, it is clear that ecosystems provide valuable services that would otherwise need to be replaced at considerable cost. As mentioned above, ecosystem services in the mid-1990s were estimated to have a value of $33 trillion, or about 1.8 times the value of global GNP at the time.[121] The portion of this value attributable solely to biodiversity is difficult to estimate as many ecosystem services are of mixed biological and nonbiological origin.[122] Authors of another 1997 study limited their valuation of ecosystem services to those in which biological sources contribute. It estimated the value of biodiversity to be $319 billion annually for the United States and $2.93 trillion annually for the world.[123]

(2000) (discussing one method of valuing biodiversity). The loss of 20%, or at worst 70%, of the species from which such discoveries could be made is a cognizable economic loss. The magnitude of possible species loss at issue here—possibly a quarter to half of species worldwide—overwhelms the argument that the value of any single species to new discoveries is negligible. See Amy B. Craft & R. David Simpson, The Value of Biodiversity in Pharmaceutical Research with Differentiated Products, 18 Envtl. & Res. Econ. 1, 2 (2001) (citing multiple studies disputing argument that loss of individual species results in negligible value lost).

116. Camille Parmesan & Gary Yohe, A Globally Coherent Fingerprint of Climate Change Impacts Across Natural Systems, 421 Nature 37, 40–41 (2003).

117. Id. at 38.

118. Chris D. Thomas et al., Extinction Risk from Climate Change, 427 Nature 145, 145 (2004).

119. Andrea Fischlin et al., Ecosystems, Their Properties, Goods, and Services, *in* IPCC, Impacts, supra note 38, at 211, 213.

120. Id. at 240 fig.4.4.

121. See Costanza et al., supra note 114, at 259 (calculating figures in 1994 U.S. dollars).

122. See Hsiung & Sunstein, supra note 111, at 1715–16 (noting significant portion of ecosystem value is generated by biological sources). Nonbiological services include, for example, ozone in the atmosphere for UVB protection and the weathering of rock in the soil formation process.

123. Daniel Pimentel et al., Economic and Environmental Benefits of Biodiversity, 47 BioScience 747, 748 tbl.2 (1997). Pimentel et al.'s numbers were calculated primarily from

Hsiung and Sunstein use this estimate of the value of biodiversity, combined with the 15–37% estimated extinction rate, to calculate the value of biodiversity loss due to climate change.[124] They multiply the extinction rate by the value of biological ecosystem services to the economy, generating an estimated cost of lost services due to climate-induced extinctions in 2050 of $539–1,322 billion for the world and $58–144 billion for the United States. For the United States, this represents an annual loss of 0.6–1.4% of GDP.[125]

As Hsiung and Sunstein note, these numbers are based on the value of natural systems for human use, and do not include non-use value.[126] Non-use value corresponds to the willingness of humans to spend money to protect a species from extinction, which will likely increase as more and more species are threatened.[127] The estimated annual cost to the United States of protecting species, based on current Endangered Species Act expenditures, is $104–255 billion, or 0.8–2.1% of GDP.[128] Combining the numbers for use and non-use values, Hsiung and Sunstein estimate the total annual cost of climate change to the United States in terms of biodiversity loss to be $162–399 billion, or 1.4–3.5% of GDP.[129]

These are dramatic estimates, but they should nevertheless be viewed as conservative. The authors used a low estimated temperature change range of 0.8–1.7°C and a high range of greater than 2°C.[130] If the actual temperature increase is much higher—say 5°C—then the impact on biodiversity could be far worse.[131] The likelihood that the study's results understate the actual costs is further increased by the fact that the models it relies on also produce conservative estimates. For example, the methods used to determine species extinction rates and the value of ecosystem services oversimplify the complex ecological interactions between species and ecosystems. Taking these interactions into account would probably make the numbers much larger.[132]

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the products of ecosystem services, or their human-generated substitutes, that pass through markets, such as waste disposal, soil, nitrogen fixation, pollination, biocontrol of pests, crop and livestock breeding, wild food production, biotechnology, and pharmaceuticals from plants. Id.

124. Hsiung & Sunstein, supra note 111, at 1715–18.

125. Id. at 1718–19. The low range in their estimates corresponds to a 0.8–1.7°C increase in global temperature, and the high range corresponds to an increase in global temperature that exceeds 2°C (same also holds true for infra notes 128–129). Id. at 1703 n.37.

126. Id. at 1715, 1722.

127. Id. at 1708, 1730.

128. Id. at 1734 (noting estimate excludes nonvertebrate life and fish).

129. Id.

130. Id. at 1703 n.37.

131. Id. at 1737.

132. See Costanza et al., supra note 114, at 253 (noting their estimate represents minimum value because of uncertainties, which would probably increase "with the incorporation of more realistic representations of ecosystem dynamics and interdependence"). But see Jason Scott Johnston, Desperately Seeking Numbers: Global

The impact of species extinctions on human health and the pharmaceutical industry in particular illustrates the magnitude of these costs. In terms of commercial potential, approximately 60% of anti-infective and anti-cancer drugs are either derived from or modeled after natural products.[133] To give just one example, coral reefs are especially vulnerable to changes in water temperature and have limited adaptive capacity,[134] and coral reefs likely are home to more species than have already been discovered in the rainforests.[135]

The loss of 20%, or at worst 70%, of the species from which such discoveries could be made is a cognizable economic loss. The magnitude of possible species losses at issue here—possibly one quarter to one half of species worldwide—overwhelms the argument that the value of any single species to new discoveries is negligible.[136]

In addition to unexplored potential, some species that currently provide important services to human populations may be threatened by climate change. Rosy periwinkle, the source of two anti-cancer drugs,[137] is native to Eastern Africa; the Himalayan yew tree is the source of a third anti-cancer drug.[138] Both species' native habitats are threatened by climate change.[139] Thus, as a result of climate change and related species extinctions, we could lose both known and unknown sources of drugs and other beneficial products.

Therefore, although it is difficult to estimate the precise cost or harm to the ecosystem, strong evidence suggests that it is greater than zero, and potentially much larger. Any credible analysis of the costs and benefits of climate change must include at least an effort to quantify bi-

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Warming, Species Loss, and the Use and Abuse of Quantification in Climate Change Policy Analysis, 155 U. Pa. L. Rev. 1901, 1907 (2007) (citing Gardner M. Brown, Jr. & Jason F. Shogren, Economics of the Endangered Species Act, 12. J. Econ. Persp. 3, 11 (1998)) (arguing these numbers overvalue species because of possibility that many substitute species could take place of extinct species and provide needed services). As an example of the complex interactions not accounted for by the above extinction rates, if a species near the base of the food chain, such as phytoplankton, goes extinct, many other species will be affected and could face extinction. These multiplier effects are not accounted for in the above models and could dramatically increase the numbers, especially if other effects of climate change, such as disease outbreaks, are factored in.

133. Walther H. Adey, Coral Reef Ecosystems and Human Health: Biodiversity Counts!, 6 Ecosystem Health 227, 232–33 (2000).

134. Cynthia Rosenzweig et al., Assessment of Observed Changes and Responses in Natural and Managed Systems, *in* IPCC, Impacts, supra note 38, at 80, 94.

135. Adey, supra note 133, at 233.

136. See Craft & Simpson, supra note 115, at 2 (detailing argument that "expected value of having an additional species may be negligible").

137. Rausser & Small, supra note 115, at 178 (noting rosy periwinkle's use for anti-cancer drugs vincristine and vinblastine).

138. Id. (noting yew tree's use for taxol).

139. See supra note 62 and accompanying text (noting Africa and Asia will be among hardest hit by climate change); see also infra notes 207–208 and accompanying text (discussing projected harm to Himalayan region).

odiversity impacts. At a minimum, uncertainty cannot justify ignoring these costs altogether.

5. *Failure to Account for Cross-Sectoral Impacts.* — Fifth on our list of concerns is that many studies calculate costs on a sector-by-sector basis, summing the impact on individual sectors to arrive at an overall estimated aggregate impact.[140] This approach, though understandable given the complexity of attempting to consider all sectors simultaneously, understates the impact of climate change because it does not capture how cumulative impacts might affect a particular sector—for example, how climate-induced negative impacts on both water resources and the energy sector might combine to reduce agricultural outputs.[141]

To illustrate, we draw on the leading work of Robert Mendelsohn, who, in several coauthored papers, calculates the cost of climate change to the U.S. economy based on an enumerative approach that cannot account for either cross-sectoral or international spillovers.[142]

Mendelsohn begins with an estimate of climate change taken from one or more General Circulation Models, which attempt to predict what will occur as a result of warming.[143] He identifies several sectors (agricul-

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140. See, e.g., Nordhaus & Boyer, supra note 8, at 10–12 ("The model contains both a traditional economic sector found in many economic models and a novel climate sector designed for climate-change modeling."); Robert Mendelsohn & Michael E. Schlesinger, Climate-Response Functions, 28 AMBIO 362, 363 (1999) ("A separate model was constructed for each sensitive sector of the economy: agriculture, forestry, coastal resource, energy, and water."); Robert Mendelsohn & Larry Williams, Comparing Forecasts of the Global Impacts of Climate Change, 9 Mitigation & Adaptation Strategies for Global Change 315, 323 (2004) ("The forecasts take the detailed climate predictions in each grid box, generate a country specific climate change and evaluate the impacts in each sector country by country."); Mendelsohn et al., Country-Specific, supra note 9, at 557 ("Separate response functions are estimated for agriculture, forestry, coastal resources, commercial and residential energy, and water."); Tol, Dynamic Estimates, supra note 9, at 137–45 (presenting separate cost data for agriculture, forestry, water, and energy sectors).

141. See Tol et al., Damage, supra note 109, at 192 (pointing out how current models may understate cross-sectoral, compounding spillovers). This weakness in existing models is familiar to those who work in the area, and has been discussed elsewhere.

> A[n] . . . omitted factor is possible interactions between impacts in one sector and impacts in another, which past IAMs have not generally taken into account. Climate damage in one sector could multiply damage in another—for example, if water-sector impacts amplify the impacts of climate change on agriculture. The reasons for excluding these effects have to do with the modelling approach: in the basic IAM method, impacts are characteristically enumerated on a sector-by-sector basis, and then added up to arrive at the overall economy-wide impact.

Stern Review, supra note 8, at 172–73.

142. See, e.g., Mendelsohn et al., Country-Specific, supra note 9, at 554–60.

143. For example, in his 2006 article Mendelsohn uses two different University of Illinois at Champaign-Urbana ("UIUC") models: the UIUC11 and UIUC2 models. Mendelsohn et al., Country-Specific, supra note 9, at 555; see also Michael E. Schlesinger et al., Modeling and Simulation of Climate and Climate Change, *in* Past and Present Variability of the Solar-Terrestrial System: Measurements, Data Analysis and Theoretical Models: Proceedings of the International School of Physics 'Enrico Fermi' 389–429 (G.C. Castagnoli & A. Provenzale eds., 1997) (using UIUC11 model); Michael E. Schlesinger &

ture, forestry, coastal resources, energy, and water) likely to be sensitive to the estimated change in climate and projects a "climate-response function" to estimate the welfare impacts in each of these sectors.[144] The economic impact on a sector can then be estimated as a function of temperature, precipitation, sea level rise (in the case of coastal resources), CO_2 concentration, and a set of additional parameters (e.g., land area, economic growth, length of coastline).[145] Mendelsohn then sums the sectoral impacts to produce an aggregate impact for a country. To produce a multicountry aggregate outcome, he sums the country-level market impacts.[146]

These models omit economic effects that implicate multiple sectors.[147] The impact of climate change on agriculture, for example, is modeled as a function of agricultural land area, growth in agricultural GDP, temperature, precipitation, and CO_2 levels.[148] The impact of climate change on energy prices, however, will not be reflected in these agricultural estimates; neither will the impact on water resources.[149] What Mendelsohn attempts to measure, then, is the economic impact of climate change on agriculture, forestry, coastal resources, energy, and water, with each treated as independent of the others, and assuming all other economic forces are unaffected by that same climate change.

Mikhail Verbitsky, Simulation of Glacial Onset with a Coupled Atmospheric General Circulation/Mixed-Layer Ocean-Ice-Sheet/Asthenosphere Model, 2 Paleoclimates, Data & Modelling 179 (1996) (using UIUC2 model).

Mendelsohn and Williams, in a 2004 article, supra note 140, at 316, use five models: CGCM1, from George Boer et al., A Transient Climate Change Simulation with Greenhouse Gas and Aerosol Forcing: Projected Climate to the Twenty-First Century, 16 Climate Dynamics 427 (2000); CSIRO, from Hal B. Gordon & Siobhan P. O'Farrell, Transient Climate Change in the CSIRO Coupled Model with Dynamic Sea Ice, 125 Monthly Weather Res. 875 (1997); CCSR, from Seita Emori et al., Coupled Ocean-Atmosphere Model Experiments of Future Climate Change with An Explicit Representation of Sulfate Aerosol Scattering, 77 J. Meteorological Soc'y Japan 1299 (1999); HAD2, from Timothy C. Johns, A Description of the Second Hadley Centre Coupled Model (HADCM2) (U.K. Meteorological Office, Climate Research Technical Note 71, 1996); and HAD3, from C. Gordon et al., The Simulation of SST, Sea Ice Extents, and Ocean Heat Transports in a Version of the Hadley Centre Coupled Model Without Flux Adjustments, 16 Climate Dynamics 147 (2000).

General Circulation Models represent "physical processes in the atmosphere, ocean, cryosphere and land surface" in order to "simulate[ ] the response of the global climate system to increasing greenhouse gas concentrations." Intergovernmental Panel on Climate Change, What is a GCM?, at http://www.ipcc-data.org/ddc_gcm_guide.html (last updated Apr. 3, 2009) (on file with the *Columbia Law Review*).

144. Mendelsohn et al., Distributional Impact, supra note 9, at 161.

145. Id. at 161, 163.

146. Id. at 161.

147. The climate-response functions do take into account that the economy will grow over time, but they ignore the possibility that harm in one sector may have an impact on other sectors or that harm abroad could affect the United States.

148. Mendelsohn et al., Country-Specific, supra note 9, at 558 tbl.1.

149. See id.

Cross-sectoral spillover effects might indeed be insignificant, and the associated welfare effects negligible, if Mendelsohn's assumption of 2°C warming proves accurate, and if the impact of climate change in each sector turns out to be both positive and very small, as he has found.[150] If, however, warming turns out to be greater than 2°C, some of the impacts in the United States become more worrisome, and there is a greater risk of costly interaction among the sectors. Moreover, as we noted above, it is quite likely that the assumption of a 2°C warming is overly optimistic.[151]

The potential for cross-sectoral interactions is important. If there are significant impacts on agriculture, forestry, coastal resources, energy, and water, it strains the imagination to think that these impacts will not affect each other. It is hard to believe, for example, that higher energy prices or water shortages will not affect agriculture costs.

6. *Growth, Productivity, and Long-Term Projections.* — Finally, existing IAMs tend to be static models, meaning they represent a snapshot of the economic situation. They generate predictions about what might happen by varying one variable at a time while holding all others constant. This approach greatly simplifies the task, but fails to capture other changes in the system. That failure is particularly problematic when the analysis requires considering very long time periods, as is the case with projecting climate change impacts.

When one considers periods of, say, 100 years or more, the rate of economic growth will have a critical influence on economic welfare. A small change in growth rates leads to enormous changes in economic outcomes over this time period. For example, a 2% growth rate over 100 years implies a more than seven-fold increase in the size of the economy. If, instead, that growth rate is 1%, after 100 years the economy will be less than three times as large as it was at the start of the period. It follows that when estimating the value of mitigation, it would be helpful to understand how climate change will affect growth rates. Investments today to prevent even a small reduction in growth rates can yield enormous future benefits.

Productivity is a critical determinant of growth rates, and greater capital accumulation leads to a higher rate of productivity. With respect to climate change, the problem is that a reduction in GDP is likely to cause a drop in investment. Lower investment will, over the long term, cause a reduction in the capital stock and, therefore, a drop in productivity.

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150. Id. at 558. Even this assumption could be challenged, however. As temperatures rise, some activities, such as agriculture, will have to be carried out in new locations. Mendelsohn's models simply assume that water, energy, and other resources will be as accessible in these new locations as they are in the places where agriculture currently takes place.

151. See supra Part II.B.1 (discussing why climate change-caused temperature increases are frequently underestimated).

Fankhauser and Tol estimate the impact of such a reduction in saving and investment[152] and find that the capital accumulation effects are more important, relative to the direct effect of climate change on GDP (i.e., the effect if one ignores the impact on growth, as almost all IAMs do) in places where climate change impacts are modest overall.[153] Indeed, under certain conditions they find that the capital accumulation effect may be larger than the "direct impact" measured by existing models. In other words, accounting for the capital accumulation effect may cause estimates of harm to be doubled. This result—that existing studies may understate impacts by 50%—is worrisome on its own, but becomes even more so when one considers that Fankhauser and Tol's study is subject to several of the same biases that have been discussed above.

III. SPILLOVERS

Overlooking international spillovers also leads existing models to understate the likely costs of climate change. Virtually all models generated to date have focused on how climate change will affect a given part of the world. Although one can find estimates of how projected rates of climate change might have an impact on the United States or Europe, there is almost no discussion of how impacts in different countries, and across regions, might interact with or affect other parts of the world. This section attempts to identify some of the ways in which impacts on one part of the world are likely to have spillover effects relevant to the United States.

Observers calculating climate change costs generally examine only the direct costs of a change in the environment, which they understand to be geographically local.[154] That is, they consider the impact of an increase in temperature on agriculture or flooding in the United States or some other country or region. This approach ignores the interdependence of the United States with the rest of the world.[155] It hardly needs emphasizing that in this era of globalization the economic well-being and security of the United States relies heavily on political and economic sta-

152. Samuel Fankhauser & Richard S.J. Tol, On Climate Change and Economic Growth, 27 Resource & Energy Econ. 1, 3–6 (2005).

153. Id. at 13.

154. Although we are concerned in this Essay with U.S. policy, it bears noting that many of the indirect effects we describe, including political instability in volatile regions of the world, large-scale migration, and the spread of disease, will affect other countries as well. That includes some countries that are crucial to solving the climate change problem, such as India and China. Furthermore, these indirect costs can have a multiplier effect. For example, if the cost of oil increases dramatically in part because of climate change's impact on the stability of supplier states, this could have a significant (indirect) effect on China's growth.

155. Cass Sunstein, for example, recites the likely harms to the United States from climate change and then simply notes, without further elaboration, that "this conclusion does not come to terms with the economic effects on the United States that would come from the very fact of serious economic harms in other nations." Cass R. Sunstein, On the Divergent American Reactions to Terrorism and Climate Change, 107 Colum. L. Rev. 503, 525 n.113 (2007).

bility in other parts of the world. It follows that we can only understand the impact of climate change on the United States if we understand how its impact elsewhere affects us.

To illustrate, the Nordhaus and Boyer model predicts that a 6°C warming would reduce European GDP by about 17%.[156] Implicit in every IAM is an assumption that such losses will not affect the United States. Were Europe to face harms of this magnitude, however, there is little doubt that there would be large and negative consequences for the United States.[157]

Economic models of climate change do not take such spillovers into account for good reason: It is difficult enough to estimate the impacts within a single economy, and even those single-economy models are subject to a variety of critiques, several of which were presented in Part II. Integrating multiple country models into a larger international model would be technically demanding and require additional strong assumptions. This difficulty reflects the enormous challenge inherent in estimating the impacts of climate change: The methodological limitations in even our most advanced models leave us with only a partial picture of the likely impacts and costs of climate change. For these reasons it would be unfair to criticize IAMs as being poorly or irresponsibly done. The problem is so complex that simplification is necessary. That said, when policymakers use these models, it is critical to keep the models' limitations in mind. This means recognizing that existing models systematically understate the impact of climate change on the United States because they fail to account for cross-border spillovers.

Consider, for example, some obvious ways in which American interests are negatively affected by climate change abroad. Imagine major economic downturns in the most important trading partners of the United States, including Europe and China. Now imagine that these downturns last decades. What would be the effect on the United States? How would the United States be affected by violent conflict in the Middle East prompted by disputes over water resources? What if drought and disease, exacerbated by climate change, topple already unstable governments in Africa, creating safe havens for terrorist groups? What happens if migration pressures from Latin America increase dramatically as living conditions there deteriorate? Or if the emergence of contagious disease in Asia (recall the SARS scare in 2003) threatens to or actually comes to the

156. Nordhaus & Boyer, supra note 8, at 96 fig.4.4.

157. There are other synergistic and multiplier effects that might arise if one considers the possibility of both cross-sectoral *and* international spillovers. See supra Part II.B.5. The 2°C warming assumed in Mendelsohn's model would produce negative impacts in several regions of the world. If the negative impacts turned out to be relatively small, they might not impose significant costs on the United States. Yet if the 2°C warming estimate turns out to be low, it stands to reason that those effects will be larger, and more negative. Under these new assumptions, there is a risk that losses in different sectors, and in different countries, will reinforce one another, creating a costly multiplier effect.

United States? None of these scenarios is particularly farfetched. Indeed, each of them is reasonably likely. Each of them would also have a significant economic and/or political impact on the United States. Yet the possibility of such events is not taken into account by existing IAMs. As we show below, once one takes into account the likely spillovers from climate change, the costs to the United States are clearly much larger than typically portrayed.

The analysis below focuses on a number of areas in which the United States is likely to suffer negative consequences from the impacts of climate change. These include a host of potential economic spillovers, as well as burdens that may arise due to national security threats, the risk of pandemics, and mass migration, among other things. The magnitude of these spillovers will obviously depend on the impact of climate change on other countries. To give some perspective, recall that the Stern Review estimates that a "business as usual" approach would lead to a global reduction of 20% in consumption per capita.[158] Even if this estimate overstates the actual impact, many parts of the world stand to be badly affected, creating competition for resources, demands for political change, increased migration, more disease, and other harms. These problems, even when they arise outside the United States, would be consequential for the United States because they affect American interests and require U.S. investment of resources.

A. *Economic Spillovers*

Although the costs of reducing GHGs will be significant,[159] the cost of not reducing them may well be even greater. There is widespread, if not universal, agreement that climate change will have a large impact on many parts of the world, including relatively wealthy Europe, where rising seas are projected to bring severe flooding, land loss, salinization of groundwater, and the destruction of physical infrastructure.[160] It is possible that up to 20% of existing coastal wetlands in Europe may disappear by 2080.[161] In portions of the Alps, retreating glaciers will initially increase summer flows, but as the glaciers melt those summer flows are projected to decrease substantially by up to 50%, and up to 80% in some parts of Southern Europe.[162] Also projected is an increase in extreme weather events, which will induce more frequent flooding.[163] The result of these events will be to dramatically increase the number of people living in water-stressed areas. For example, it is estimated that the percent-

158. Stern Review, supra note 8, at 186–87.

159. See infra Part IV.

160. Joseph Alcamo et al., Europe, *in* IPCC, Impacts, supra note 38, at 541, 551; see generally Robert J.N. Devoy, Coastal Vulnerability and the Implications of Sea-Level Rise for Ireland, 24 J. Coastal Res. 325 (2007) (discussing impacts for Ireland).

161. Alcamo et al., supra note 160, at 551.

162. Id. at 549–50.

163. Id. at 556.

age of river basin areas in the "severe stress" category will increase from 19% today to approximately 35% by the 2070s.[164] The number of people living in water-stressed areas in the EU15[165] and Switzerland and Norway is projected to increase significantly.[166] Europe will also be struggling with its own indirect effects. For example, significant migrations from Africa are possible, and because governments and institutions in Eastern Europe are less robust than those in Western Europe, stress there could certainly spread.

Other parts of the world stand to suffer even more. In Asia, decreases in crop yields are expected to place hundreds of millions of people at risk of hunger, while large-scale hydrologic changes will expose millions more to epidemics.[167] In Africa, the food and water security consequences of climate change are projected to be particularly grave, especially given the continent's already limited capacity to adapt.[168] In Latin America, water stress and extreme loss of biodiversity are expected in fragile ecosystems.[169]

Existing discussions of climate change tend to assume that the United States will be unaffected by hardships suffered in the rest of the world. However, the United States is integrated into the world economy. American exports in 2006 were $1.5 trillion, or 11% of GDP.[170] Imports into the United States were valued at $2.2 trillion, or 17% of GDP.[171] Beyond these trade statistics, the United States and private parties based in the United States are integrated into the global financial community—

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164. Thomas Henrichs & Joseph Alcamo, Europe's Water Stress Today and in the Future, *in* B.T. Lehner et al., EuroWasser—Model-Based Assessment of European Water Resources and Hydrology in the Face of Global Change 5–1, 5–7 (Kassel World Water Series Report No.5, 2001), available at http://www.usf.uni-kassel.de/cesr/index.php?option=com_content&task=view&id=134&Itemid=72 (on file with the *Columbia Law Review*).

165. The EU15 are the fifteen countries that comprised the EU before 2004. They are: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom. Org. for Co-Operation & Dev., Glossary of Statistical Terms: EU15, at http://stats.oecd.org/glossary/detail.asp?ID=6805 (last updated July 24, 2007) (on file with the *Columbia Law Review*).

166. Dagmar Schröter et al., Ecosystem Service Supply and Vulnerability to Global Change in Europe, 310 Science 1333, 1334–35 & tbl.2 (2005).

167. See Rex Victor Cruz et al., Asia, *in* IPCC, Impacts, supra note 38, at 469, 471 (summarizing effects of climate change on Asia).

168. Michel Boko et al., Africa, *in* IPCC, Impacts, supra note 38, at 433, 435.

169. Graciela Magrin et al., Latin America, *in* IPCC, Impacts, supra note 38, at 581, 583.

170. Foreign Trade Div., U.S. Census Bureau, U.S. Trade in Goods and Services—Balance of Payments Basis (2009), at http://www.census.gov/foreign-trade/statistics/historical/gands.txt (on file with the *Columbia Law Review*) [hereinafter Census—U.S. Trade (BOP Basis)]; World Bank, World Development Indicators, at http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20398986~menuPK:64133163~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html (last visited Aug. 7, 2009) (on file with the *Columbia Law Review*) [hereinafter World Bank Indicators].

171. See sources cited supra note 170.

they invest in opportunities and projects abroad, benefit from the arrival of skilled immigrants, and in countless other ways are better off because of their interactions with the rest of the world. Therefore, impacts elsewhere can have a substantial effect on the United States.

It is admittedly impossible to assign dollar amounts to American losses resulting from climate change in other parts of the world. First, the precise amount of warming experienced by foreign countries as well as the impact on precipitation, sea levels, catastrophic weather events, and the like are all uncertain. Second, the effect of these changes on the economies, governance, and behavior of foreign countries is difficult to predict. How much stress on the availability of freshwater in the Persian Gulf region will it take to cause a major disruption in the oil supply? The price and availability of oil is critical to the U.S. economy, but it is difficult to predict how supply will be affected by climate change.[172] Will Europe adopt protectionist strategies in reaction to the pressures generated by climate change? Again, the answer has profound implications for the United States, but is impossible to predict. Third, it is difficult to anticipate how the supply and demand of many American imports will be affected. For example, will the impact on China affect its productivity and, therefore, the supply of consumer goods that Americans have grown used to purchasing at low prices? If so, will other countries step into this market and provide those same goods at similarly low prices, or will the prices rise? Fourth, even if all of the relevant impacts were known, the predictions of the appropriate economic models come with large variances, further increasing uncertainty.

The inability to generate precise numerical estimates of the economic impact of climate change spillovers from other states does not mean, however, that they are unlikely to occur. Indeed, we can readily imagine a number of channels through which events elsewhere might have an impact on the American economic system. The discussion that follows confirms the intuition that American integration into the international economic system virtually guarantees that broad-based and substantial hardship abroad will lead to welfare losses in the United States. Any sensible policy consideration of the costs of climate change on the United States must take the prospect of such impacts into account.

1. *Shocks to International Trade.* — As already mentioned, the United States is part of the world economy, and as such undertakes a substantial amount of international trade. As climate change affects foreign states, American trading interests are also likely to be affected. First, and most obviously, trade flows will diminish. To the extent the foreign markets for American products contract, American exporters will suffer. Climate change may also have a negative effect on American imports by making them more expensive or of lower quality as foreign sources of production

172. See infra Part III.B (discussing enhanced security risks caused by climate change and associated with American demand for oil).

are affected. If states (including the United States) engage in protectionism as a response to climate change, that will likely aggravate the effects on both imports and exports.

Imagine, for example, how supply might be affected by severe economic and social dislocation in South and Southeast Asia caused by flooding, drought, and extreme weather events.[173] Affected countries, including China and India, may be unable to maintain production levels in the face of these impacts. This sort of disruption in supply would lead to a rise in prices, which would be harmful to American economic welfare.

A conventional approach to short-run supply shocks assumes that their impact fades over the long term. In the absence of a severe and long-term reduction in supply or a decline in productivity, a continuing demand for products will provide an incentive to overcome these supply shocks and rebuild capacity. If this is not done (or not done quickly enough) in one country, others will attempt to take advantage of the market opportunity.

In the context of climate change, however, there are good reasons to think these shocks may last beyond the short term. First, because climate change is not a one-time event but rather a process playing out over many years, and because the change may be profound, it is at least plausible that the world will face a series of severe supply shocks stretching over an extended period of time. Imagine, for example, that Asia is hit by a combination of severe weather events, major flooding, large-scale refugee crises, and water shortages; and imagine that these events do not happen all at once, but accumulate over twenty, thirty, or fifty years. These climatic events could severely hamper Asian economies for decades, creating a lasting economic (not to mention political and social) crisis. If the impact lasts for a long period of time it may not be possible to rebuild the productive capacity of the continent, in which case the above supply shocks would have significant long-term consequences for the United States.

One might ask whether, even in this example, the productive capacity could be built up elsewhere in the world to substitute for what is lost in Asia. Perhaps, but it is difficult to imagine where that would happen. Europe is unable to produce low-cost products in a way comparable to Asia. Africa lacks the financial markets, governmental structures, and human capital to successfully carry out economic activity of that type and at that scale, and is likely to suffer even greater devastation as a result of climate change. Latin America is a possibility, but it too will be affected by climate change[174] and so may be unable to build up entirely new industries. Moreover, given the vast differences in population, even if the

173. See infra notes 206–210 and accompanying text (discussing potential effects of climate change on Asia).

174. See supra note 169 and accompanying text (discussing potential effects of climate change on Latin America).

environmental conditions in Latin America were perfect, it would have difficulty replacing the volume of production that takes place in Asia.

A second way in which supply shocks could have long-term effects is through a loss of raw materials. If, for any number of reasons, there is a long-term reduction in the supply of the raw materials used in production, costs will increase on a long-term basis. The most likely candidates for such a shock are water and energy. Climate change poses a serious threat to the supply of each of these critical resources, and severe shortages of either could wreak havoc on production worldwide for decades.

A disruption of water or energy supplies is one example of how climate change could permanently reduce productivity levels. Productivity is the key ingredient in models of economic growth. In standard economic models the long-run rate of growth is ultimately determined by productivity, which is taken to be exogenous. If growth is to be affected in the long run, then it must be through productivity.[175] Unfortunately, there are no good models of factors that influence productivity. As a result, it is difficult to assess the impact of a hypothetical shock on long-term growth rates.

Consider, however, the possibility that highly populated parts of Asia might be unable to secure water in the quantities and at the times they are accustomed to, and that as a result economic activity becomes much more difficult and costly.[176] Should the glaciers on which these populations depend melt, there is every reason to expect a dramatic fall in productivity (not to mention enormous human suffering) in much of Asia. This fall in productivity may not be a short-term issue, but rather a permanent or nearly permanent change. Any adaptation—which could require massive population movements and new infrastructure, not to mention conflict over resources—to this change could be extraordinarily costly and take decades to achieve. These effects could, in turn, have a significant negative impact on the United States.

With respect to energy, it is difficult to imagine a scenario under which climate change fails to cause major disruptions in supply. Imagine a highly plausible scenario in which conflicts might arise over water resources in the Middle East or Nigeria, which affects the supply of oil to

175. The previous two examples of how climate change might have a long-run impact are consistent with this statement. The first, that the shocks may themselves persist over decades, is really a claim that the "long term" is sufficiently far off that we should be concerned with short-term shocks. The period over which the shocks continue is most accurately called the short term, but when this period extends to fifty years or more, the importance of worrying about the short term is clear. The second example is a special case of a shock affecting productivity. If natural resources (or any other essential inputs) are scarce, the productivity of labor is reduced and prices (though not wages) rise.

176. See infra notes 206–210 and accompanying text (discussing potential effects of climate change on Asia).

the rest of the world, including the United States.[177] The result would be a long-term increase in the cost of energy, which can certainly be expected to harm the U.S. economy.

A similar dynamic could occur if global food production is badly affected by climate change. Climate change is quite likely to negatively affect food production, at least for a period of decades.[178] Under even the most optimistic scenario, food production will fall in some regions and increase in others. These projections, taken from IAMs, likely overstate future agricultural production for two reasons. First, they are static estimates, meaning they ignore the costs and time required for adjustment from the status quo to a new equilibrium in a warmer world. Like any complex system, agricultural production relies on an established infrastructure, including farms, workers, suppliers, purchasers, distribution networks, and so on. Areas that currently enjoy a large amount of agricultural production, but that see that production decline, will have to adapt and find other things to do. Meanwhile, some regions will find themselves with increased agricultural potential due to climate change. Even if one accepts the assumption contained in most IAMs that these regions will increase their agricultural production, there is no reason to think that it will happen quickly or easily. A new infrastructure will have to be built to make agriculture work efficiently, and building it will require both time and money.

The second reason to believe that IAMs underestimate the agricultural impact of climate change relates to water supplies. IAMs focus on precipitation as the key source of water. This is accurate, up to a point. It is true that precipitation determines the amount of water available annually to a region, and water availability is critical for agriculture. Precipitation does not, however, account for *when* the water is available. Many existing agricultural regions do not rely exclusively on rainfall for their crops. They also rely on runoff from glaciers or snow pack to provide water during drier seasons. As climate changes there is no reason to expect that areas acquiring temperature and precipitation patterns that suit agriculture will also happen to have conveniently placed glaciers to store the water until the dry season.

Each of the supply shocks discussed above illustrates a more general reality. For many goods and services we live in a global market in which there is a global price. If climate change has the effect of driving up that price (in these examples due to a supply shock), the United States will suffer along with everyone else.

In addition to the above supply shocks, economic difficulties abroad are likely to be accompanied by demand shocks. Specifically, demand for American exports may be reduced by the economic harm imposed by

177. See infra notes 223–226 and accompanying text (describing destabilizing effects of climate change on Nigeria).

178. See, e.g., supra note 168 and accompanying text (discussing food shortages in Africa).

climate change on foreign states. This reduction, in turn, will harm the U.S. economy. As discussed in the context of supply shocks, these demand shocks would normally be considered short-term rather than long-term problems. To the extent climate change creates a series of negative demand shocks spread over many years, however, the impact on the United States could be felt for generations.

A substantial and ongoing shock to exports would represent a serious economic blow to the United States. Table 1 shows the contribution of exports to the U.S. economy in recent years.

TABLE 1: U.S. EXPORTS AS PERCENTAGE OF GDP[179]

Year	Exports (% of GDP)	Exports (Billions of $)
1993	9.9	654
1994	10.3	723
1995	11.1	812
1996	11.2	869
1997	11.6	934
1998	11.0	933
1999	10.8	966
2000	11.2	1071
2001	10.3	1005
2002	9.7	975
2003	9.5	1018
2004	10.1	1161
2005	10.5	1284
2006	11.1[180]	1457
2007	11.6[181]	1646
2008	12.9[182]	1843

179. World Bank Indicators, supra note 170. The query was limited to Country: United States, Series: Exports of goods and services (% of GDP), and Time: 1993 through 2008.

180. Census—U.S. Trade (BOP Basis), supra note 170.

181. Id.

182. Id.

To get some sense of the impact that a reduction in trade might have, we turn to the economic literature on the gains from international trade.[183] The first point to note is that the total estimated gains to the United States from trade are enormous. Since the Second World War, it is estimated that the annual gains realized through trade and investment are on the order of $1 trillion.[184] Because this represents a permanent increase in national income, the gain is enjoyed every year.[185] How much of that value is at risk from climate change depends on how much trade is disrupted. One way to get a sense of the potential magnitudes is to examine recent events and consider their impact. A useful point of comparison is the economic impact to the United States of the trade liberalization associated with the WTO's Uruguay Round, which took effect in 1995. Brown, Deardorff, and Stern estimate that the total impact of the agreement that emerged from this round of trade talks was $19.8 billion,[186] which represents slightly more than one quarter of 1% of U.S. GDP in 1995.[187]

The trade flows that generated this modest increase in GDP were an increase in imports of about $19 billion and an increase in exports of about $18 billion.[188] These are quite modest changes to the value of trade. Assuming that climate change causes a significant contraction of foreign demand for U.S. goods, for example, one would expect much larger effects. To illustrate, see Table 2 for how exports have been affected by the recession of 2009–2010.

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183. See generally Scott C. Bradford et al., The Payoff to America from Global Integration, *in* The United States and the World Economy: Foreign Economic Policy for the Next Decade 65—66 (C. Fred Bergsten ed., 2005) (summarizing gains in post-World War II trade and gains to come); Drusilla K. Brown et al., Computational Analysis of Multilateral Trade Liberalization in the Uruguay Round, *in* The World Trade Organization: Legal, Economic and Political Analysis, Part III: Economic, Political and Regional Issues 23 (Patrick F.J. Macrory et al. eds., 2005) [hereinafter Brown et al., Computational Analysis] (describing international trade as driving increased national income); Gary C. Hufbauer, Answering the Critics: Why Large American Gains from Globalization are Plausible (Peterson Instit. for Int'l Econ., Working Paper, 2008), available at http://www.petersoninstitute.org/publications/papers/paper.cfm (on file with the *Columbia Law Review*) (same). But see Josh Bivens, The Gains from Trade: How Big and Who Gets Them? (Econ. Policy Inst., Working Paper, 2007), available at http://epi.3cdn.net/f7ee27ab119cf817e9_ham6b9n89.pdf (on file with the *Columbia Law Review*) (questioning benefits of trade liberalization).

184. Bradford et al., supra note 183, at 68.

185. Id.

186. Brown et al., Computational Analysis, supra note 183, at 31.

187. World Bank Indicators, supra note 170 (citing for GDP amount).

188. Brown et al., Computational Analysis, supra note 183, at 28 tbl.1.

TABLE 2: U.S. MONTHLY EXPORTS[189]

Period	Exports (Billions of $)
January 2008	149
February 2008	153
March 2008	150
April 2008	155
May 2008	157
June 2008	163
July 2008	167
August 2008	165
September 2008	154
October 2008	150
November 2008	141
December 2008	133
January 2009	125
February 2009	127
March 2009	124

As the above chart indicates, U.S. exports fell dramatically: 25% from their peak, with perhaps more to come. This trade shock is much larger than that considered by Brown, Deardorff, and Stern.

If one assumes that climate change will cause a disruption in trade flows that is half as large as what was experienced from July 2008 to March 2009, the result is a reduction in exports of about $20 billion per month, or $240 billion per year. As Table 1 shows, this would not be out of line with fluctuations in exports that we have seen over the last fifteen years. Because climate change is a global phenomenon, it is reasonable to expect a similar impact on imports.

What would be the impact of this reduction in trade flows on welfare? As already mentioned, Brown, Deardorff, and Stern estimated that the Uruguay Round had a welfare impact of $19.8 billion and an increase in exports of $18 billion (and increase in imports of $19 billion).[190] This suggests a rough 1:1 ratio between exports and GDP impact, at least over this relatively modest increase in exports. Bradford, Grieco, and Hufbauer estimate the total impact of trade and investment to be approximately $1 trillion in 2003.[191] In 2003 the United States had just over $1

189. Press Release, Foreign Trade Div., U.S. Census Bureau, U.S. International Trade in Goods and Services, available at http://www.census.gov/foreign-trade/Press-Release/current_press_release/exh1.pdf (last visited Aug. 22, 2009) (on file with the *Columbia Law Review*).

190. See supra notes 187–188 and accompanying text.

191. See Bradford et al., supra note 183, at 69.

trillion in exports.[192] Again, we see a 1:1 ratio between exports and welfare impacts. Assuming that this ratio is accurate, the above-mentioned $240 billion reduction in exports can be expected to correspond to a $240 billion reduction in welfare—more than 1.5% of 2008 GDP.

2. *Financial Markets.* — Climate change's impact on financial markets may be even more important than its trade effects. The United States has run a current account deficit for many years, implying that its imports exceed its exports in value, with the difference being made up through borrowing from abroad.[193] Continuing to run this deficit may be impossible even without climate change, but global economic struggles will certainly not help. As countries suffer through climate-induced economic contraction, perhaps for long periods of time, their enthusiasm for continuing to lend to Americans is likely to wane more quickly than it otherwise would. This reluctance to lend would increase the interest rate at which American borrowing takes place and reduce the United States' ability to consume more than it produces. In practical terms this would mean higher interest rates in the United States, a contraction of investment, and a reduction in consumption.

The problem is further complicated by the fact that paying existing U.S. foreign obligations requires either that the United States run a trade surplus (in effect generating net revenue from trade that allows it to pay off its debts) or that there be a depreciation in the United States dollar relative to foreign currencies (making it less expensive to repay debts denominated in dollars). A trade surplus requires that American exports exceed imports, which of course requires that there be a market for exports. If key countries around the world were suffering economic hardship as a result of climate change, the market for U.S. exports likely would shrink.

Of course financial markets matter for more than simply bringing the current account into balance. Private parties in the United States invest abroad and could face losses if foreign economies suffer. For example, American firms operate abroad and shareholders in the United States would see the value of their investments reduced if foreign markets ceased to generate profits for those firms. Virtually all of the largest and best known American firms rely, to some extent, on foreign markets. These include Wal-Mart, Coca-Cola, Xerox, Microsoft, Nike, General Motors, ExxonMobil, Citigroup, and so on. Above, we discussed the fact that export markets for these companies are likely to contract and cause losses in the United States in the event of lower demand for American

192. See Census—U.S. Trade (BOP Basis), supra note 170.

193. See Press Release, Bureau of Econ. Analysis, U.S. Dep't of Commerce, U.S. International Transactions: First Quarter 2009 (June 17, 2009), available at http://www.bea.gov/newsreleases/international/transactions/2009/pdf/trans109.pdf (on file with the *Columbia Law Review*) (describing U.S. current account balance and its components).

products.[194] In addition, the market value of these (and many other) firms would fall as foreign markets shrank. This translates to lower returns on investment in these firms for everyone, including individual shareholders. To illustrate, about 20% of the corporate profits of American firms in 2007 were earned outside the country.[195] Losing a significant share of those profits due to economic weakness abroad clearly would affect the well-being of U.S. firms, their shareholders, and their employees.

More systemically, there is a risk that a global economic downturn would lead to a drying up of capital markets, an increase in the cost of credit, and a resulting reduction in investment. We are currently in the midst of a global credit crunch and recession. Climate change could trigger similar global slowdowns in the future, and it is clear that the United States would be unable to isolate itself from that sort of world downturn.

B. *National Security*

Until recently, climate change received virtually no sustained analysis in either academic or policy circles as a potential threat to national security.[196] In the last few years, however, a number of important studies of the connection between climate and security have emerged from academic, government, and nongovernment sources. These include well-respected organizations such as the Center for Strategic and International Studies, the Center for New American Security, the Center for Naval Analysis, the National Intelligence Council, and the Council on Foreign Relations. In 2008, the National Intelligence Council produced the most comprehensive analysis to date of the implications of climate change for U.S. national security over the next twenty years.[197] The study included input from all eighteen U.S. intelligence agencies. According to news reports, the classified assessment—unavailable to the public but on which Congress was briefed—concluded that climate change could destabilize fragile political regimes, exacerbate conflicts over scarce re-

194. See supra Part III.A.1.

195. Bureau of Econ. Analysis, U.S. Dep't of Commerce, National Income and Product Accounts Table, tbl.6.16D (Aug. 17, 2009), available at http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=239&Freq=Qtr&FirstYear=2007&LastYear=2009 (on file with the *Columbia Law Review*).

196. Jon Barnett, Security and Climate Change 2 (Tyndall Ctr. for Climate Change Research, Working Paper No. 7, 2001) (on file with the *Columbia Law Review*) (citing small number of studies making some connection between climate change and national security).

197. See Tom Gjelten, Intel Report Eyes Climate Change-Security Link, NPR, June 23, 2008, at http://www.npr.org/templates/story/story.php?storyId=91819098 (on file with the *Columbia Law Review*) (describing classified report).

Moreover, the Department of Defense will include climate change in the 2010 Quadrennial Defense Review, which "assesses threats and challenges the nation faces." U.S. Dep't of Def., 2010 QDR Terms of Reference Fact Sheet (2009), available at http://www.defenselink.mil/news/d20090429qdr.pdf (on file with the *Columbia Law Review*).

sources, increase the threat of terrorism, disrupt trade, and produce millions of refugees—all of which would seriously affect U.S. national security interests.[198]

The consistent message of these studies is that while climate change may not provoke national security threats by itself, it is certain to be a "threat multiplier"[199] because it will have serious impacts on many parts of the world with strategic importance to the United States.[200] The consistent message is that climate change is likely to exacerbate political instability around the world as weak or poor governments struggle to cope

198. Gjelten, supra note 197. Additionally, the effects of climate change can exacerbate tensions in already unstable regions. We are already witnessing how resource shortages can contribute to conflict and instability—even genocide—in weak states, as has happened in Darfur. Did Global Warming Cause a Resource War in Darfur?, Seed Magazine, Aug. 2, 2006.

199. See National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030: Joint Hearing Before the H. Select Comm. on Energy Independence and Global Warming and the H. Permanent Select Comm. on Intelligence, 110th Cong. 4–5 (2008) (statement of Thomas Fingar, NIC Chair) [hereinafter Fingar Statement], available at http://globalwarming.house.gov/tools/2q08materials/files/0069.pdf (on file with the *Columbia Law Review*) ("[T]he most significant impact for the United States will be indirect and result from climate-driven effects on many other countries and their potential to seriously affect US national security interests."); Ctr. for Strategic & Int'l Studies & Ctr. for a New Am. Security, The Age of Consequences: The Foreign Policy and National Security Implications of Global Climate Change 103, 105 (Kurt M. Campbell et al. eds., 2007), available at http://www.cnas.org/files/documents/publications/CSIS-CNAS_AgeofConsequences_November07.pdf (on file with the *Columbia Law Review*) [hereinafter Age of Consequences] (describing different impacts of climate change on world and arguing it "has the potential to be one of the greatest national security challenges that this or any other generation of policymakers is likely to confront"); CNA Corp., National Security and the Threat of Climate Change 6–7, 44–45 (2007), available at http://www.securityandclimate.cna.org (on file with the *Columbia Law Review*) ("Climate change acts as a threat multiplier for instability in some of the most volatile regions of the world" and "U.S. may be drawn more frequently into these situations"); John Podesta & Peter Ogden, The Security Implications of Climate Change, Wash. Q., Winter 2008, at 115, 116, 121, 123 (identifying effects of climate change across world and potential for international instability); Barnett, supra note 196, at 7–9 (arguing climate change may be factor in exacerbating international conflict resulting from migration); see generally Marc A. Levy et al., Assessment of Select Climate Change Impacts on U.S. National Security (Ctr. for Int'l Earth Sci. Info. Network, Working Paper, 2008), available at http://www.ciesin.columbia.edu/documents/Climate_Security_CIESIN_July_2008_v1_0.ed070208.pdf (on file with the *Columbia Law Review*) (identifying worsening areas of instability as result of sea level rise, temperature change, and water scarcity).

200. Fingar Statement, supra note 199, at 4; see also Joshua W. Busby, Council on Foreign Relations, Council Special Report No. 32, Climate Change and National Security: An Agenda for Action 5–10 (2007) (describing resulting "spillover security effects on the United States" of climate change on vulnerable locations). The cost of addressing such problems will only rise over time as they become more acute. Podesta & Ogden, supra note 199, at 116 ("It is therefore critical that policymakers do all they can to prevent the domino of the first major climate change consequence, whether it be food scarcity or the outbreak of disease, from toppling.").

with its impacts.[201] In especially hard hit nations, deteriorating economic conditions could lead to the fall of governments, creating, at worst, safe havens and, at best, fertile recruiting grounds for terrorist groups. Floods, droughts, and conflicts over scarce resources are projected to create refugees—"climate migrants"—who will spill into neighboring countries, potentially inflaming political tensions and burdening the already-stressed economies in these host nations.[202] Climate change also threatens to interrupt the free flow of trade in critical resources such as oil, gas, and other essential commodities on which the United States depends. Such threats will require the United States to take costly action to protect itself. However, even with such action, the United States almost certainly cannot avoid all of the significant negative effects.

Though the message from the national security studies is unambiguous, none of the leading studies of economic impacts have tried to quantify these effects. It is, of course, no simple task to quantify the economic impact of a threat multiplier. It is impossible to predict with any confidence what crises will arise in the future or how states will react to them. It does not follow, however, that we can safely assume that the economic cost of threat multipliers is zero. The best one can do at present, then, is provide a qualitative sense of plausible potential threats that ought to be considered when weighing options for climate policy.[203] We offer some examples below.[204]

In Asia, rising global temperatures are projected to result in reduced agricultural productivity, shrinking supplies of drinkable water, and increased risk of flood, drought, and extreme weather events.[205] Heavily populated areas in South Asia are expected to be hard hit by climate

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201. See John M. Broder, Climate Change Seen as Threat to U.S. Security, N.Y. Times, Aug. 9, 2009, at A1 ("[C]limate-induced crises could topple governments, feed terrorist movements or destabilize entire regions, say . . . experts at the Pentagon and intelligence agencies who for the first time are taking a serious look at the national security implications of climate change.").

202. See infra Part III.C.

203. Consistent with the leading assessments, we adopt a broad definition of "national security." See Fingar Statement, supra note 199, at 3 (describing NIA definition: "We first considered if the effects would directly impact the US homeland, a US economic partner, or a US ally. We also focused on the potential for humanitarian disaster [and] . . . if the result would degrade or enhance . . . Geopolitical, Military, Economic, or Social Cohesion . . . .").

204. Among those countries at highest risk of significant sea level rise and with high risk factors for political instability are China, India, and Indonesia. Among the most vulnerable countries in the aggregate (i.e., considering aggregate climate change vulnerability and risk of political instability) are South Africa, Bangladesh, Yemen, and Sudan. And among the countries most vulnerable to water scarcity and at high risk of political instability are Nigeria, Iraq, China, and Syria. See Levy et al., supra note 199, at 12, 14, 15, 43, 51.

205. Victor Cruz et al., supra note 167, at 471.

change.[206] Water shortages, for example, could be severe. Glacial retreat is already occurring in the Himalayas, causing increased flooding and long-term loss of natural water storage of freshwater in parts of Asia and South Asia.[207] Many glaciers in these areas could, at current rates of climate change, disappear within the coming decades. Such a disappearance would have serious long-term consequences for the half billion people in the Himalaya-Hindu-Kush region, and for an additional quarter billion people downstream, in countries like Pakistan, who rely on glacial melt waters for their water supply.[208] In the shorter term, increased glacial melt might temporarily increase water supply in some regions of Asia (assuming infrastructure proves capable of capturing it), but this increase is likely to be offset by growing populations and consumption in the region, leading ultimately to considerable stress on water supplies.[209] In addition, cereal crop yields are expected to drop between 2.5 and 10% in South, Southeast, and East Asia, contributing to a risk of hunger for as many as fifty million people as soon as 2020.[210]

These impacts will have spillover effects on the United States. For example, Bangladesh, with a current population of 142 million people, and a projected increase in population of 100 million in the next few decades, could find the fifth of its country comprised of low-lying regions uninhabitable by the end of the century.[211] Bangladesh has already become a security concern for the United States as the impact of Islamic extremism has grown. To illustrate, as of July 2005, the number of terrorist attacks in Bangladesh "exceed[ed] the total number of incidents in the preceding five years."[212] The effects of population displacement from flooding,[213] along with additional economic stress in an already

206. As the IPCC states, "[c]oastal areas, especially heavily populated megadelta regions in South, East, and South-East Asia, will be at greatest risk due to increased flooding." Adger et al., supra note 59, at 13.

207. Id. Nearly 70% of the world's freshwater is locked in glaciers and icebergs, which are already melting because of climate change.

208. Current trends in glacial melt suggest that the Ganga, Indus, Brahmaputra, and other rivers in India may become seasonal rivers as a consequence of climate change, which could significantly and adversely affect the economies in the region. Victor Cruz et al., supra note 167, at 493.

209. See Fingar Statement, supra note 199, at 9 (projecting between 120 million and 1.2 billion people will experience water stress).

210. Id. at 8–9.

211. Stern Review, supra note 8, at 104, 129.

212. Sudha Ramachandran, The Threat of Islamic Extremism to Bangladesh, The Mail Archive, July 27, 2005, at http://www.mail-archive.com/cia-drugs@yahoogroups.com/msg00909.html (on file with the *Columbia Law Review*).

213. See Lisa Friedman, Bangladesh endures ugly experiments in 'nature's laboratory,' N.Y. Times ClimateWire, Mar. 9, 2009, at http://www.nytimes.com/cwire/2009/03/09/09climatewire-ugly-experiments-in-natures-laboratory-10035.html (on file with the *Columbia Law Review*) (describing Bangladesh's increased risk of flooding from climate change).

unstable region, are likely to create fertile grounds for terrorist groups.[214]

China, a rising international power of tremendous strategic importance to the United States, is also vulnerable to disasters precipitated by climate change.[215] Climate change likely will affect China by reducing water supplies in the North, causing extreme weather in the South, and raising the sea level, threatening hundreds of millions of people in densely populated coastal regions.[216] China faces serious indirect costs, as well. China increasingly depends heavily on imports from East Africa and South Asia to fuel economic growth. As a result it is especially vulnerable to unstable energy supplies in these regions, which themselves will be among the hardest hit by climate change.[217] A serious interruption of supply could considerably slow China's growth, which could in turn undermine the legitimacy of the ruling Communist Party, leading to political instability. Of course this series of events is speculative, but it is certainly plausible. And although it is hard to predict how China's instability would affect the United States, China's military and economic might, combined with its ability to make trouble in a volatile region, make considerable and costly effects probable.

India is also vulnerable to climate change-related disasters. Any adverse effects to India could potentially spill over into the United States. Coastal populations in India are, like vulnerable populations elsewhere in South Asia, at high risk of inundation from rising sea levels and storms.[218] Like China, India is an important trading partner for the United States. India plays a crucial strategic role in the region as well, as a stable democracy and counterweight to a nuclear Pakistan.[219]

The impact of climate change on many nations in Africa is projected to be especially severe. With high risk of impact and low adaptive capacity, Africa stands to fare badly as global temperatures increase.[220] One might take the view that much of the suffering in Africa will not affect the

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214. See Podesta & Ogden, supra note 199, at 118 ("The combination of deteriorating socioeconomic conditions, radical Islamic political groups, and dire environmental insecurity brought on by climate change could prove a volatile mix with severe regional and potentially global consequences.").

215. See China Sees Climate Impacts Ahead, BBC News, Apr. 23, 2007, at http://news.bbc.co.uk/2/hi/science/nature/6585775.stm (on file with the *Columbia Law Review*).

216. Id.

217. Podesta & Ogden, supra note 199, at 117–20.

218. For example, the small islands in the Bay of Bengal alone are home to millions of people, many of whom will have no choice but to move to the mainland should sea levels rise. Id. at 117.

219. Any number of contemporary news stories illustrates the fragility of Pakistan. See, e.g., Jane Perlez & Pir Zubair Shah, Truce in Pakistan May Not Mean Peace, Just Leeway for Taliban, N.Y. Times, Mar. 6, 2009, at A6 (discussing influence of Taliban in Pakistan and government efforts to appease that group).

220. See Boko et al., supra note 168, at 435.

United States unless we are inclined to support humanitarian relief,[221] yet this overlooks the increasing strategic importance of the continent. Africa possesses critical natural resources over which there is increasingly intense competition,[222] and various countries in Africa pose a risk to the United States as potential bases for terrorist groups.

To put this in perspective, consider the impact of climate change on Nigeria, on which the United States increasingly depends for oil.[223] Disruptions in supply would have a significant impact on the world's oil market.[224] Nigeria already faces severe challenges as rebel groups undertake attacks in an effort to disrupt oil production.[225] In addition to being an oil producing nation, however, Nigeria is also the most populous nation in Africa, with more than 140 million people, a large number of whom are under the age of fifteen.[226]

In sum, Nigeria is an important oil producing country that is already engaged in a violent struggle with insurgents and that faces the risk of major domestic turmoil as a result of climate change. It is easy to imagine a collapse in oil exports due to a combination of increased rebel activity (fueled in part by more acute struggles for food and water throughout Nigeria and the continent) and a central government weakened by reduced agricultural production, flooding in Lagos, and already weak institutions. There is, of course, no way to predict exactly how these events might play out, let alone to quantify them. Nonetheless, it strains credulity to think that if oil production were to drop precipitously, the United States could remain entirely unaffected. As is familiar from American history in the Middle East, the United States considers threats to its oil supply to be threats to its national security.

On the other side of the continent, in East Africa, American security concerns present themselves differently. Most African states already suffer from fragile economies and weak governments. Many also have deep political and ethnic tensions within their borders that occasionally erupt,

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221. In the face of large-scale human suffering and deprivation, the United States may have moral reasons to help Africans cope with climate change. The United States will likely have difficulty defending its refusal to help a people in dire need. Nevertheless, because this Essay addresses only the narrow self-interest of the United States, it does not dwell on the potential climate change related catastrophe in Africa except inasmuch as it affects the United States.

222. The United States imports several thousand barrels of oil a day from Nigeria, making Nigeria the fifth largest oil exporter to the United States. Energy Info. Admin., U.S. Dep't of Energy, Crude Oil and Total Petroleum Imports Top 15 Countries (2009), at http://www.eia.doe.gov/pub/oil_gas/petroleum/data_publications/company_level_imports/current/import.html (on file with the *Columbia Law Review*).

223. Id.

224. Nigeria is the eighth largest oil exporter in the world. Jad Mouawad, Growing Unrest Posing a Threat to Nigerian Oil, N.Y. Times, Apr. 21, 2007, at A1.

225. Id.

226. CIA, The World Factbook: Nigeria (2009), available at https://www.cia.gov/library/publications/the-world-factbook/geos/ni.html (on file with the *Columbia Law Review*).

sometimes with catastrophic results. We have recently seen Kenya, once an example of African stability, descend into chaos.[227] Even countries that have enjoyed relative economic success remain vulnerable to backsliding as a result of corruption and violence. Against this backdrop, climate change is expected to dramatically reduce supplies of water and food in Africa,[228] exacerbating existing tensions.

New pandemics due to climate change may also create instability in Africa. Infectious diseases on the African continent may implicate U.S. national security to the extent that they contribute to economic hardship. Significant population loss due to epidemic disease can contribute to high unemployment, lower growth, and weak institutions—conditions terrorist groups might exploit.[229] The impact of AIDS in Africa is instructive: The disease has created a dangerous "youth bulge" with annual costs in foregone growth estimated at 1–2% of GDP. Losses among key professional groups are extremely high,[230] and there is a generation of AIDS orphans that might be vulnerable to radicalization.[231] Climate change would not only exacerbate the impact of AIDS to the extent it further incapacitates weak governments, but is also projected to produce new diseases that might create further pandemics. The resulting mixture of youth, economic strife, and disease would be, to say the least, highly combustible.

The United States has significant security interests in the Middle East as well. Among the threats to stability in this historically volatile region is the possibility of severe water shortages combined with rapidly growing populations. The region's population more than doubled between 1970 and 2001, and is expected to double again by 2050.[232] The Middle East

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227. See, e.g., Abraham Odeke, Kenya Chaos Hits Uganda Economy, BBC News, Jan. 4, 2008, at http://news.bbc.co.uk/2/hi/africa/7172008.stm (on file with the *Columbia Law Review*) (describing "political violence" in Kenya). Kenya was once among Africa's most "influential and capable countries" along with South Africa, Nigeria, Ghana, and Senegal. Council on Foreign Relations, More than Humanitarianism: A Strategic Approach Toward Africa 11 (2006), available at http://www.cfr.org/content/publications/attachments/Africa_Task_Force_Web.pdf (on file with the *Columbia Law Review*) [hereinafter CFR Africa Report].

228. Adger et al., supra note 59, at 13 ("In some countries, yields from rain-fed agriculture could be reduced by up to 50% by 2020.").

229. It is interesting to note that perhaps the greatest risk to the United States posed by AIDS is not likely to be from Africa (although the disease is devastating many African populations) but from Russia, where by 2050 population loss from AIDS is predicted to be as much as one-third. AIDS has the potential to cause severe economic problems in Russia, which may undermine the government's ability to staff a conventional army, and in turn might lead Moscow to rely more on nuclear force to maintain great power status. Susan Peterson, Epidemic Disease and National Security, Security Stud., Winter 2002–2003, at 43, 66.

230. CFR Africa Report, supra note 227, at 62–63.

231. Id. at 60, 120 (discussing danger of children being recruited as child soldiers or by terrorists).

232. Farzaneh Roudi-Fahimi et al., Population Reference Bureau, Finding the Balance: Population and Water Scarcity in the Middle East and North Africa 2 (2002),

and adjacent North Africa have 6.3% of the world's population, but only 1.4% of its renewable freshwater.[233] The large majority (about 75%) of the water in the region is in Iran, Iraq, Syria, and Turkey.[234] Other states in the region, including Kuwait, Libya, and Saudi Arabia, have very little freshwater within their borders.[235] With the exception of Turkey, every country in the region depends on water that originates outside its borders.[236] Climate change will likely adversely affect surface availability of major rivers in the region, like the Euphrates and the Tigris, which will increase in the winter and decrease in the spring.[237] The danger here is that competition for freshwater will exacerbate existing regional tensions and perhaps lead to violent conflicts.[238] This is entirely plausible given the history of serious conflicts over precious water resources in the region.[239]

There is no satisfactory way to estimate the costs of these security concerns. Much depends on exactly which security issues arise and how the United States and others respond. It is also difficult to put a dollar value on the sense of safety and security individuals lose when serious national security crises are at the forefront of international events. We can, however, fairly conclude that climate change raises the stakes for the United States with respect to global security issues, and that this threat is likely to translate into economic costs as well. As of the spring of 2009, for example, the Congressional Research Service estimated that the Iraq War has accounted for approximately $642 billion in congressionally approved spending.[240] This expense amounts to an annual cost over the five and a half years of conflict of close to 1% of U.S. GDP per year. The estimate, however, includes only the direct costs of the war. It excludes, for example, the cost of caring for injured veterans and the opportunity

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available at http://www.prb.org/pdf/FindingTheBalance_Eng.pdf (on file with the *Columbia Law Review*).

233. Id. at 1.

234. Id. at 2.

235. Id.

236. Podesta & Ogden, supra note 199, at 122.

237. See Victor Cruz et al., supra note 167, at 483.

238. See Press Release, United Nations Env't Programme, Fast Melting Glaciers from Rising Temperatures Expose Millions in Himalaya to Devastating Floods and Water Shortages (June 5, 2007), available at http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=512&ArticleID=5600&l=en (on file with the *Columbia Law Review*) (describing report documenting Himalayan glacial retreat).

239. In 1990, Turkey disrupted the water supply from the Euphrates River into Syria to fill a Turkish reservoir. Turkey threatened to cut off the water supply when Syria supported the Kurdish Workers Party. Turkey also possesses the ability to cut off the water supply to northern Iraq. Podesta & Ogden, supra note 199, at 122.

Water allocation also remains a contentious issue in Israeli-Palestinian negotiations and in Israeli-Syrian negotiations over the Golan Heights. Israel remains highly dependent on water from outside its borders. Id.

240. Amy Belasco, Cong. Research Serv., The Cost of Iraq, Afghanistan, and Other Global War on Terror Operations Since 9/11, at 1 (2009), available at http://www.fas.org/sgp/crs/natsec/RL33110.pdf (on file with the *Columbia Law Review*).

cost of having so many people away from their normal lives.[241] One estimate of all the relevant costs concludes that the war will ultimately cost $3 trillion: an amount equal to about 20–25% of U.S. annual GDP.[242] In other words, if climate change can be expected to cause one additional conflict like the Iraq War every twenty-five years, putting aside all other costs related to security threats, then the expected cost of climate change is at least 1% of annual GDP.

The ultimate impact of climate change on national security costs is unknowable at the moment, of course. One could fairly respond to the scenarios described above by saying that they are highly speculative, virtually impossible to model, and extraordinarily challenging to quantify. Nevertheless, sensible policy cannot simply ignore the potential for climate change to trigger events that would be costly for the United States. To be sure, any projected costs must be discounted to reflect the uncertainties involved, but to simply ignore these risks is intellectually indefensible.

C. *Migration*

In many parts of the world, climate change will present challenges that make life not simply difficult, but impossible. If the IPCC projections are accurate, millions of homes will be underwater, and a combination of droughts, flooding, and severe weather will ruin crops and destroy the livelihoods of perhaps hundreds of millions.[243] When populations are unable to survive where they are, they will do what people have done in similar situations throughout human history: They will move.[244]

When migration occurs on a small scale, it can help to reduce the stress in some regions while bringing a needed increase in population to another. This was, for example, the story of migration from East to West within the United States.

When migration happens on a massive scale, however, the results are often much less benign. Refugees have difficulty finding new places to settle, and occupants of countries or regions that refugees seek to move into become defensive and intolerant. It is a short step from this form of stress to violent struggle. For example, in the 1970s and 1980s hundreds of thousands of Bangladeshis fled land erosion, floods, and poverty, and

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241. Id. at 5–6.

242. Joseph E. Stiglitz & Linda J. Bilmes, The Three Trillion Dollar War: The True Cost of the Iraq Conflict, at x (2008).

243. See supra Part II.A.

244. Michael McCarthy, Climate Change 'Will Cause Refugee Crisis,' CommonDreams.org, Oct. 20, 2006, at http://www.commondreams.org/headlines06/1020-05.htm (on file with the *Columbia Law Review*) ("Mass movements of people across the world are likely to be one of the most dramatic effects of climate change in the coming century.").

settled in Indian territory.[245] Native residents in Assam, where Bangladeshi migrants settled, grew agitated; migrant Bangladeshis organized against the threat; and in the wake of political elections, violence ensued.[246] One five-hour massacre left more than 1,700 dead.[247]

Migration induced by changing environmental conditions is common. Historically, people have sought more favorable conditions in response to environmental stresses.[248] During the 1930s, large numbers of Americans left their homes in response to the prolonged drought and severe dust storms that plagued the Great Plains.[249] For a more recent example, consider the plight of New Orleans residents in the wake of Hurricane Katrina. Typically, environmentally induced migrants tend to relocate within their own countries or to neighboring countries if possible, but in dramatic instances, people will travel long distances in search of a safer place.[250] Given that climate change is expected to affect developing countries much more dramatically than developed countries,[251] and that developing countries are less capable of handling the stresses of climate change,[252] mass migrations are certainly plausible.[253] Some climatic refugees will likely seek asylum in the United States. Even if the United States refuses to admit these refugees many will enter without authorization.

Approximately one billion people worldwide live within a few meters of sea level,[254] and the most common estimate of total climate change migrants is 200 million people by the year 2050.[255] Like other estimates of climate change effects, this number is probably a low estimate because it does not consider the economic refugees that will be created by the economic effects of climate change, or the refugees fleeing human conflict triggered or exacerbated by warming. Although most of these refugees will not seek entry into the United States, both common sense and

245. Ashok Swain, Displacing the Conflict: Environmental Destruction in Bangladesh and Ethnic Conflict in India, 33 J. Peace Res. 189, 195–97 (1996).

246. Id. at 198.

247. Id.

248. Oli Brown, Migration and Climate Change 21 (Int'l Org. for Migration, Research Series Paper No. 31, 2008), available at http://www.iisd.org/pdf/2008/migration_climate.pdf (on file with the *Columbia Law Review*) [hereinafter Brown, Migration].

249. Id. at 23.

250. Id. at 23–24 (finding such intercontinental migrations tend to follow preexisting pathways); see also Rafael Reuveny, Environmental Change, Migration and Conflict: Theoretical Analysis and Empirical Explorations 18 (Human Sec. & Climate Change, Workshop Paper, 2005), available at www.gechs.org/downloads/holmen/Reuveny.pdf (on file with the *Columbia Law Review*) [hereinafter Reuveny, Environmental Change] (noting migration can be intrastate or interstate).

251. See supra notes 9–12 and accompanying text.

252. See supra notes 9–12 and accompanying text.

253. Reuveny, Environmental Change, supra note 250, at 20–21.

254. Id. at 20.

255. Brown, Migration, supra note 248, at 11–12 (citing Norman Myers, but not endorsing Myers' estimate).

experience suggest that at least some migrants will reach U.S. borders, thereby representing a spillover cost of climate change.

To illustrate, consider the most likely source of spillover into the United States: migration from Latin America. Even now, the impact of unauthorized immigration on the United States is significant. Official estimates project that nearly seven million, or close to 60%, of all unauthorized immigrants residing in the United States in 2007 were originally from Mexico.[256] Between 2000 and 2007, an average of 470,000 people entered the United States without authorization each year.[257] Of those, about 330,000 came from Mexico.[258] This is in addition to more than one million people granted legal permanent resident status each year, of which 148,000 to 170,000 came from Mexico.[259]

Northern Mexico is expected to suffer severe water shortages as the earth warms, creating a large increase in immigration to the United States.[260] If the United States is unwilling to admit larger numbers of Mexican immigrants legally, we can expect them to cross the border without authorization. Thus all of the pressures and challenges of unautho-

256. Michael Hoefer et al., U.S. Dep't of Homeland Sec., Estimates of the Unauthorized Immigrant Population Residing in the United States: January 2007, at 4 tbl.3 (2008), available at http://www.dhs.gov/xlibrary/assets/statistics/publications/ois_ill_pe_2007.pdf (on file with the *Columbia Law Review*) [hereinafter DHS, 2007 Unauthorized Estimates]. In the past, official projections have underestimated the population of undocumented immigrants. See Michael Hoefer et al., U.S. Dep't of Homeland Sec., Estimates of the Unauthorized Immigrant Population Residing in the United States: January 2005, at 1 (2006), available at http://www.dhs.gov/xlibrary/assets/statistics/publications/ILL_PE_2005.pdf (on file with the *Columbia Law Review*) (estimating, based on 2005 data, total of 10.5 million undocumented immigrants, including 6 million from Mexico); Jeffrey Passel, Pew Hispanic Ctr., The Size and Characteristics of the Unauthorized Migrant Population in the U.S.: Estimates Based on the March 2005 Current Population Survey, at i (2006), available at http://pewhispanic.org/files/reports/61.pdf (on file with the *Columbia Law Review*) (estimating, based on 2005 data, total of 11.1 million undocumented immigrants, including 6.2 million from Mexico).

257. DHS, 2007 Unauthorized Estimates, supra note 256, at 2.

258. Id. at 4.

259. Kelly Jefferys & Randall Monger, U.S. Dep't of Homeland Sec., U.S. Legal Permanent Residents: 2007, at 4 tbl.3 (2008), available at http://www.dhs.gov/xlibrary/assets/statistics/publications/LPR_FR_2007.pdf (on file with the *Columbia Law Review*) (providing data for years 2005–2007).

260. See Age of Consequences, supra note 199, at 56 ("Northern Mexico will be subject to severe water shortages, which will drive immigration into the United States in spite of the increasingly treacherous border terrain."); see also Cal. Dep't of Water Res., Water & Border Area Climate Change: An Introduction 35 (Special Report for the XXVI Border Governors Conference, 2008), available at http://www.water.ca.gov/news/newsreleases/2008/081508bgcreport.pdf (on file with the *Columbia Law Review*) (noting expected exacerbation of hot, dry conditions along border). Some of this migration has already begun to occur. Andrew Simms & Hannah Reid, Working Group on Climate Change and Dev., Up in Smoke? Latin America and the Caribbean: The Threat from Climate Change to the Environment and Human Development 40 (2006), available at http://assets.panda.org/downloads/upinsmoke_lac.pdf (on file with the *Columbia Law Review*) (discussing role of climate change in Mexican migration).

rized immigration will be amplified. There will be more undocumented immigrants in need of health care and education for their children, as well as work and housing.

Increases in both authorized and unauthorized immigration can be expected to result in political and economic consequences within the United States.[261] If history is any guide, racial animosities may be exacerbated as locals resist the arrival of new populations and the (real or perceived) impact on employment, political influence, social services, and the like. Competition for resources and ethnic tension may be particularly likely to foster conflict between U.S. citizens and climate-induced migrants.[262] Historically, environmentally induced migrations have resulted in violent conflict between existing and new populations.[263] During the 1930s Dust Bowl migration, for example, newcomers to California suffered beatings and lost their houses to arson.[264]

Already, tensions at the U.S.-Mexico border are high. In the last several years, the United States has sought to reinforce the border to deter unauthorized immigration, as well as to control the flow of drugs and reduce the threat of terrorist attacks.[265] In addition to government efforts, private vigilante border patrol groups have emerged to police the border. It is easy to image that a dramatic increase in migration (both authorized and unauthorized) might prompt a more aggressive response from both the government and private groups, potentially leading to significant political and social conflict.

Even an expensive wall along the U.S.-Mexico border—which some people support—likely would prove insufficient to stop the flow of undocumented immigrants to the United States, some of whom can be expected to arrive by sea. For example, climate change is projected to intensify hurricane activity in the Caribbean basin,[266] causing rising sea levels that will flood coastal areas of the Caribbean islands, where most of the Caribbean population lives.[267] We can expect significant numbers of Caribbean citizens to migrate to the United States. Already about twenty million Latin American and Caribbean nationals reside outside of their

261. See generally Peter Brimelow, Alien Nation (1995).

262. See Rafael Reuveny, Climate Change-Induced Migration and Violent Conflict, 26 Pol. Geography 656, 659 (2007) (discussing possibility of conflict resulting from competition for resources, ethnic tension, racial or political distrust, socioeconomic fault lines, and auxiliary conditions).

263. Id. at 662–68.

264. Id. at 660.

265. For instance, the United States has discussed keeping undocumented immigrants out by constructing an impenetrable border fence. See, e.g., Secure Fence Act of 2006, Pub. L. No. 109-367, 120 Stat. 2638 (codified as amended at 8 U.S.C. §§ 1101, 1103, 1701 (2006)).

266. Magrin et al., supra note 169, at 581, 583.

267. Céline Charvériat, Natural Disasters in Latin America and the Caribbean: An Overview of Risk 58–59 (Inter-American Dev. Bank, Working Paper No. 434, 2000), available at http://www.iadb.org/sds/doc/ENVNatDisastLACeline.pdf (on file with the *Columbia Law Review*).

home countries, mostly in the United States.[268] Quite apart from one's views on unauthorized immigration, substantial additional migration caused by climate change would have economic implications in North America.

While it is impossible to quantify the costs associated with climate-induced migration, it is clearly wrong to treat those costs as zero. Even if the most obvious impacts of unauthorized migration are moral (as with human trafficking), or social (as with the divisiveness that can arise when newcomers arrive), the impacts will be real, and the appropriate political response will require U.S. resources. The fact that the leading economic models overlook such costs leads to an incomplete picture of what the United States stands to lose from climate change impacts that occur elsewhere.

D. *Disease*

Climate change is likely to contribute to transmission of disease into the United States in two ways: (1) there will be more disease in the world, increasing the probability that a pathogen will travel down an established transmission path; and (2) the resources necessary to contain disease are likely to be less available, making the spread of contagious disease more probable. These threats, like those posed by national security concerns, are difficult to quantify but are nonetheless real; like national security impacts of climate change, estimates of economic costs to date have excluded the cost of disease.

The global disease burden will likely increase as a result of climate change.[269] Although scholars have anticipated some of the adverse health impacts of climate change, current predictions are almost certainly low and incomplete because of the inherent limitations of the models. Simply put, global models have not yet addressed all of the likely effects of climate change on health.[270]

The volume of migration and population displacement discussed above likely will augment the extent of these health impacts.[271] Although some countries are anticipating environmental refugees and presumably preparing in some ways for the influx,[272] it is unlikely that the ultimate

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268. Magrin et al., supra note 169, at 595.

269. Anthony J. McMichael et al., Global Climate Change *in* Comparative Quantification of Health Risks 1543, 1609 (Majid Ezzati et al., World Health Org. eds., 2004), available at http://www.who.int/publications/cra/chapters/volume2/1543-1650.pdf (on file with the *Columbia Law Review*).

270. Id. (noting potential omissions include "many infectious diseases, the health consequences of drought and famine[,] . . . population displacement, destruction of health infrastructure in natural disasters, increased pollution and aeroallergen levels, effects of plant pests and diseases on agriculture, and risk of conflict over declining natural resources").

271. See supra Part III.C.

272. See Anthony McMichael et al., Human Health and Climate Change in Oceania: A Risk Assessment 105–06 (2002), available at http://nceph.anu.edu.au/Staff_Students/

destinations of most refugees will be adequately prepared.[273] Thus, public health infrastructures could be strained, likely in places where they are already quite fragile and where they are most needed. For all of these reasons, it is clear that, even balanced with some positive health implications (such as decreased mortality from cold), the impacts of climate change on global health "will be overwhelmingly negative."[274]

In addition to the impact on existing diseases, there is good reason to be concerned about the implications of climate change for the emergence of new diseases. Ecological changes, including climate change, are factors in the emergence of new diseases.[275] Furthermore, several of the other factors that increase the risk of new diseases are likely to be exacerbated by climate change, including migration (as noted above) and breakdowns in public health infrastructures.[276] It is impossible to say with certainty that climate change will result in new diseases—such emergences are highly complex, multifactored developments—but it is very clear that climate change will substantially increase this risk.

As with many of the effects of climate change, though the direct health impacts are expected to be worse elsewhere in the world, climatic conditions in the United States are expected to become more hospitable to the root causes of some pathogens, including Lyme disease, fungus-derived Valley Fever, and West Nile virus.[277] These direct effects on the United States are significant, but the indirect effects are much greater.[278]

Staff_pdf_papers/Rosalie_Woodruff/Health_Climate_Change_Impact_Assessment_2002.pdf (on file with the *Columbia Law Review*) (discussing possibility "Australia would play a role in providing for environmental refugees from Pacific Island countries" in event of dramatic climate change).

273. The increased health risks of mass displacements are already apparent from the incidence of disease and other health problems in existing refugee settlements. See, e.g., Joseph Fair et al., Lassa Virus-Infected Rodents in Refugee Camps in Guinea: A Looming Threat to Public Health in a Politically Unstable Region, 7 Vector-Borne & Zoonotic Diseases 167 (2007); Rima R. Habib, et al., Harboring Illnesses: On the Association Between Disease and Living Conditions in a Palestinian Refugee Camp in Lebanon, 16 Int'l J. Envtl. Health Res. 99 (2006); C. Kamugisha et al., An Outbreak of Measles in Tanzanian Refugee Camps, 187 J. Infectious Diseases S58 (2003). And those settlements mostly do not reach the scale anticipated as a result of climate change.

274. Ulissess Confalonieri et al., Human Health, *in* IPCC, Impacts, supra note 38, at 391, 407.

275. S.S. Morse, Factors and Determinants of Disease Emergence, 23 Sci. & Technical Rev. 443, 445 (2004). This fact is not a surprise; we have seen this effect already. For example, the emergence of the Nipah virus in Malaysia was related to deforestation, drought, and increased pig farming, which facilitated the transmission from wild bats to pigs. The virus caused encephalitis in humans with a 38% mortality rate and devastated the Malaysian pig industry, resulting in the destruction of 45% of the pig population. R.C. Bengis et al., The Role of Wildlife in Emerging and Re-Emerging Zoonoses, 23 Sci. & Technical Rev. 497, 499–500 (2004).

276. Morse, supra note 275, at 445 tbl.1.

277. See Field et al., supra note 38, at 625 (discussing relationships between climate change, West Nile virus, and Lyme disease).

278. See, e.g., Jonathan A. Patz et al., The Potential Health Impacts of Climate Variability and Change for the United States: Executive Summary of the Report of the

As recent outbreaks of disease have demonstrated, no country is an island when it comes to infectious diseases. The SARS outbreak in 2003 illustrated the possibility of a global outbreak as a result of travel, and the world is now more interconnected rather than less. Concerns about a global flu pandemic such as avian flu or, more recently, the swine flu, also reflect the potentially global nature of infectious diseases.[279]

The economic costs associated with an outbreak are not simply the obvious ones of public health measures, treatment, loss of life, and reduced productivity for those infected. Outbreaks of disease also have economic ripple effects,[280] as people stay home and avoid contact with others,[281] resulting in employee absenteeism and substantially reduced demand on the services sector.[282] In addition, infectious diseases can and do affect animals, including valuable livestock.[283] Taking these diverse costs into account, the total immediate economic effect of SARS in East Asia, including the indirect effects of behavioral changes in response to the outbreak, is estimated at 2% of the East Asian regional GDP at the time, although the number of deaths was limited to 800.[284] Projections for an influenza pandemic are much higher.[285]

Preventing the introduction and spread of infectious diseases is extraordinarily difficult and, depending on the nature of the disease, could prove impossible. Diseases arrive through a variety of pathways, including

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Health Sector of the U.S. National Assessment, 108 Envtl. Health Persp. 367, 373 (2000) (suggesting past weather shifts may have caused worldwide epidemics, such as lepitosis in Nicaragua and Brazil, Lyme disease in United States and Europe, and dengue fever in Mexico).

279. In fact, one expert has even characterized avian flu "as a disease driven by . . . the international circulation of tourists, labor, food products, livestock, and capital." Stefan Elbe, Our Epidemiological Footprint: The Circulation of Avian Flu, SARS, and HIV/AIDS in the World Economy, 15 Rev. Int'l Pol. Econ. 116, 119 (2008).

280. Id. The hotline at the Centers for Disease Control and Prevention received over 1,000 calls a day during the peak of the SARS panic, the U.S. Secretary for Health and Human Services spent as much as 15% of his time on SARS, and manufacturers of face masks saw sales increase significantly. Sheryl Gay Stolberg, Lessons of Anthrax Attacks Help U.S. Respond to SARS, N.Y. Times, May 2, 2003, at A14.

281. See Dean E. Murphy, In U.S., Fear Is Spreading Faster Than SARS, N.Y. Times, Apr. 17, 2003, at A1 (describing how SARS scare caused rumors to fly, people to stay home or away from certain restaurants, stores, or communities, and businesses to suffer).

282. See World Bank, East Asia Update November 2005: Countering Global Shocks 13 (2005), available at http://siteresources.worldbank.org/INTEAPHALFYEARLYUPDATE/Resources/EAP-Brief-final-full2.pdf (on file with the *Columbia Law Review*) [hereinafter World Bank, Avian Flu] ("[D]uring SARS . . . people tried to avoid infection by minimizing face-to-face interactions, resulting in a severe demand shock for services sector . . . .").

283. See id. at 12 (describing how avian flu—both disease itself and control measures to prevent its spread—has reduced poultry stock in some countries by 15–20%).

284. Id. at 13.

285. See id. at 14 ("[A] new flu pandemic could lead to between 100000 and 200000 deaths in the US, together with 700000 or more hospitalizations, up to 40 million outpatient visits and 50 million additional illnesses.").

migration of people or animals,[286] travel,[287] and transportation of goods.[288] West Nile virus, malaria, avian flu, monkeypox, SARS, and Rift Valley fever, among others, have all traveled across national borders through one or more of these means. The H1N1 virus and SARS have demonstrated the difficulty of containment, of course, but the 1999 out-

286. The degree of the health impact related to migration is largely determined by two factors: (1) the degree of difference between health in the migrants' countries of origin and the United States; and (2) the size of the migratory population entering the United States. Brian D. Gushulak & Douglas W. MacPherson, Globalization of Infectious Diseases: The Impact of Migration, 38 Clinical Infectious Diseases 1742, 1742–43 (2004). Both of these factors will increase as a result of climate change. Much of the developing world countries will be severely affected by climate change, see, e.g., supra notes 167–169 and accompanying text, thereby widening the health gap with the United States. And, as conditions worsen elsewhere, more and more desperate attempts to migrate to the United States are predictable. Supra Part III.C. In addition, warmer temperatures in the United States will create conditions more favorable to mosquito hosts and to the incubation of disease within the host, further enhancing the risk of local transmission. This outcome is even more likely when the infected population lacks adequate healthcare due to poverty or immigration status, as delays in treatment increase the window during which a mosquito can acquire and pass on the infection. See John R. MacArthur et al., Probable Locally Acquired Mosquito-Transmitted Malaria in Georgia, 1999, 32 Clinical Infectious Diseases e124, e127 (2001) ("[A] symptomatic migrant worker [typically] faces difficulties in obtaining health care. Financial, linguistic, cultural, and legal barriers can all impede access to health care in this population. Delays in treatment allow for the development of gametocytes and increase the time during which a person is infective."). Such populations also tend to underreport infectious diseases within the United States itself, as evident in multiple studies of dengue fever in Florida. See, e.g., Gill et al., Imported Dengue—Florida 1997–1998, 48 Morbidity & Mortality Wkly. Rep. 1150, 1152 (1999) ("In this and previous investigations, dengue has been underreported."). Furthermore, underreporting undermines an adequate and effective response to any emerging threats to public health. Patz et al., supra note 278, at 373.

287. Disease can be spread through human travel or accidental simultaneous transport of carriers like mosquitoes. We also see the implications of travel for the spread of disease with "airport malaria," locally acquired malaria clustered near international airports. Andrew J. Tatem et al., Estimating the Malaria Risk of African Mosquito Movement by Air Travel, Malaria J., July 2006, at 1, 3.

288. Most often disease from trade in goods involves trade in animals, though there are other means. Trade in exotic pets, for example, introduced monkeypox to the United States from imported African rodents. Bengis et al., supra note 275, at 501. People in six states contracted the disease. Id. Livestock trade has also led to the spread of disease to new territories. Rift Valley Fever was transmitted from Africa to the Arabian Peninsula through livestock trade and ultimately infected 1,700 people (mostly in Saudia Arabia and Yemen). C. Brown, Emerging Zoonoses and Pathogens of Public Health Significance—An Overview, 23 Sci. & Technical Rev. 435, 437 (2004). Mad cow disease is also transmitted through trade, and fears of its spread have led to bans on imports and destruction of animals. See Thomas E. Walton, The Impact of Diseases on the Importation of Animals and Animal Products, 916 Annals of the N.Y. Acad. Science 36, 40 (2000) (describing U.S. ban on imported beef and ruminant products from Europe and estimated cost of $3 billion to U.K. as result of outbreaks). Finally, another established mode of transmission is through migratory animals, especially wild birds. Migratory birds have played a significant role in the transmission of avian flu. See Bjorn Olsen et al., Global Patterns of Influenza A Virus in Wild Birds, 312 Science 384, 384 (2006) (reviewing "current knowledge on global patterns of influenza virus infections in wild birds").

break of West Nile encephalitis in New York also demonstrates that difficulty.[289] Thus, in the United States, we must be concerned about transmission of disease along numerous pathways.[290] As the global disease burden grows, the incidence of such transmissions (including to the United States) can be expected to grow as well.[291] Given all of the possible pathways for disease transmission, no country can prevent the introduction of infectious agents without changes that seem politically and economically infeasible, such as substantial prohibitions on travel and radically reduced trade.[292]

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289. The specific strain of virus was genetically linked to a strain found in a wild goose in Israel in 1998. The exact path of transmission from the Mediterranean to New York is unclear, but possibilities include human travel, importation of illegal birds or other pets, and the unintentional introduction of infected ticks or mosquitoes. R. S. Lanciotti et al., Origin of the West Nile Virus Responsible for an Outbreak of Encephalitis in the Northeastern United States, 286 Sci. 2333, 2336 (1999). Mosquitoes and other carriers travel internationally by the same means as people and goods. See Elbe, supra note 279, at 121.

290. In fact, local mosquito-borne transmission of malaria within the United States, to choose one disease, is already increasing, perhaps due to globalization. MacArthur et al., supra note 286, at e124 (noting 77% of locally acquired malaria cases in United States were "within the past 15 years").

291. Because the incidence of such diseases will rise, supra notes 269–274 and accompanying text, the likelihood that refugees and immigrants will arrive carrying an infectious disease also will increase in the future. Obviously, migrants harboring an infectious disease could infect local populations within the United States. MacArthur et al., supra note 286, at e127 ("As more travelers and immigrants enter the United States from areas of endemicity, the number of imported cases of malaria is increasing."). Certainly, communities can and do put measures in place to reduce such transmissions (for example, spraying to reduce mosquito population). But those measures have costs, which will be discussed infra notes 292, 295 and accompanying text. And we should not assume that control measures are 100% effective. Despite them, in fact, the incidence of local malaria transmission has been rising. Id. at e124. As the incidence of disease increases, the spread of infectious disease most likely will continue and sharpen despite the implementation of control measures. This prospect raises the difficult question of how much the spread of disease will increase.

292. The United States already recognizes the importance of other countries' preparedness, surveillance and detection, and containment to reduce or prevent the spread of disease. President Bush and Congress authorized $434 million in expenditures to facilitate these activities in other nations and reduce the risk of a pandemic flu outbreak. U.S. Dep't of State, United States International Engagement on Avian and Pandemic Influenza 2 (2007), available at http://www.state.gov/documents/organization/95933.pdf (on file with the *Columbia Law Review*). The control measures used to prevent or reduce transmission of disease vary by pathogen. For example, SARS was brought under control through airport screenings (for body temperature and other indicia of infection) and quarantines, as well as through improved protective measures by and for healthcare workers. Spraying to eliminate and reduce mosquito populations helps limit the incidence of West Nile virus in the United States. And removing insects on airplanes after flights from malarial regions helps reduce the number of cases of "airport malaria." Tatem et al., supra note 287, at 62. The United States can independently accomplish some of these measures, such as insect control, though they are neither costless nor uncontroversial. The State of Louisiana has spent over $8 million on mosquito abatement as a result of a West Nile outbreak in 2002. Armineh Zohrabian et al., West Nile Virus Economic Impact, Louisiana, 2002, 10 Emerging Infectious Diseases 1736, 1740 tbl.3 (2004). While that

Stymieing an outbreak of disease often requires substantial international cooperation. This was apparent with SARS, which was successfully contained only because of unprecedented international cooperation among scientists and public health experts, cooperation that received strong governmental support.[293]

The dependence on other nations for reporting, research, and control measures (including identification and destruction of infected livestock, quarantines, etc.) suggests that the direct effects of climate change in other countries will hamper U.S. efforts to limit or prevent infiltration by infectious elements.[294] Even in developed countries, where limited resources and political instability are lesser concerns, compliance with control measures may not be complete.[295]

In other words, social, economic, and political factors can and already do inhibit acknowledgement of the emergence of a virus, even if the public health infrastructure is sufficient to detect that the outbreak exists in the country.[296] Now, consider that all of the relevant resources, including the detection infrastructure, will be severely stretched by the other effects of climate change (lack of food and water, flooding, severe weather events, heat waves, etc.).[297]

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number might seem small in the context of the federal budget or the costs of climate change generally, it represents expenditures for only a small fraction of the nation's cases. There were 329 cases of West Nile in Louisiana in 2002, and 4,129 cases total in the United States that year. If the U.S. government's per person abatement costs equaled Louisiana's, then the national figure would be something like $100 million. Presumably the government would undertake such measures on an ongoing basis.

293. Hitoshi Oshitani, Lessons Learned from International Responses to Severe Acute Respiratory Syndrome (SARS), 10 Envtl. Health & Preventive Med. 251, 253 (2005). SARS was contained through coordinated reporting, collaborative research into transmission, quarantines, and efforts to educate healthcare workers and the public. The initial isolation of the virus alone involved work in eleven laboratories in nine countries. Id.

294. We have seen this obstruction on a smaller scale in the case of SARS. Id. at 252–53 (noting delay of over month between arrival of WHO team in China and government approval for on-site investigation in Guandong, which "hindered work to understand the nature of the disease and its causative agent and to formulate the best strategy for containment").

295. For instance, the World Bank has noted governments' difficulty (especially in developing countries) in finding funds to compensate poultry owners for birds culled to prevent the spread of avian flu. This commitment is necessary to encourage poultry raisers to report, rather than hide, outbreaks. World Bank, Avian Flu, supra note 282, at 2.

296. Elbe, supra note 279, at 121–22 (noting large agricultural firms in Asia paid local farmers to remain quiet about infected poultry and "the history of international public health is littered with examples of states trying to deny, hide and postpone the detection of new viruses").

297. Current underreporting occurs because individuals, as well as regional and national governments, fear the consequences of reporting. Businesses fear a loss of livelihood; this fear led large agricultural companies in Asia to pay poultry owners to remain silent about infected animals. Mike Davis, The Monster at Our Door: The Global Threat of Avian Flu 105 (2005). Governments, too, fear loss of revenues from trade, tourism and other sources. Thomas Abraham, Twenty-First Century Plague: The Story of SARS 24 (2005) ("No country wants to bear the stigma or the economic costs associated

Again, SARS illustrates the difficulty and expense of controlling the spread of disease. On the basis of internationally collaborative research and information dissemination, some highly affected regions implemented airport screenings based on body temperature. In Taiwan, 151,270 people were quarantined and over 2.7 million passengers had their temperatures taken.[298] Moreover, Taiwan is a country with eighteen airports, only two of which are international, and a population of approximately twenty-three million people. Imagine trying to replicate that response for a country the size of the United States. The costs, both economic and social, would be astronomical.

Imagine further what would be required to address the outbreak of infectious disease in Indonesia, a country of 222 million people and seventy-one airports (seventeen of which are international). There, or in the many other places where the impact is expected to be far worse than in the United States, it is reasonable to assume that public health infrastructure will be more strapped, not less; that public officials will be more overwhelmed, not less; and that governments and firms will be more concerned, not less, about the economic consequences of reporting outbreaks, if their economies are already fragile as a result of climate change. Thus, the United States can expect more delays and less openness from affected nations when it comes to reporting potential infections. This is in direct opposition to the integrated and coordinated global alert and response system that the World Health Organization (WHO) says is necessary to prevent widespread outbreaks.[299]

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with disease. In a world where international trade and investment are the main engines of prosperity, a disease . . . is a kiss of death.").

298. Kow-Tong Chen et al., SARS in Taiwan: An Overview and Lessons Learned, 9 Int'l J. of Infectious Diseases 77, 82 (2005). It is also important to consider that the control measures for SARS (temperature screenings, quarantine, masks, etc.) were possible and effective because of the nature of the ailment and the speed with which we were able to understand it. Even in a world of perfect information sharing (which climate change will undoubtedly hamper), it would be unwise to assume all diseases can be so simply detected or even that entry will occur through human travel.

299. World Health Org., Global Outbreak and Response Network—GOARN, available at http://www.who.int/csr/outbreaknetwork/goarnenglish.pdf (last visited Sept. 11, 2009) (on file with the *Columbia Law Review*). The fact that the United States has, to date, avoided major outbreaks should not be taken as a sign of invulnerability. The effect of a given disease or pathogen in a specific environment is extraordinarily difficult to predict. That Canada was harder hit by SARS than the United States, for example, may be because the strain which arrived in Canada was simply, by chance, more virulent. Lawrence K. Altman, Canadian Strain of Virus Appears to Be Stronger Than the U.S. Variety, N.Y. Times, Apr. 25, 2003, at A21; see also Ctrs. for Disease Control & Prevention, In the Absence of SARS-CoV Transmission Worldwide: Guidance for Surveillance, Clinical and Laboratory Evaluation, and Reporting Version 2, at 1 (2004), available at http://www.nyc.gov/html/doh/downloads/pdf/cd/sars-cdc-absence.pdf (on file with the *Columbia Law Review*) ("Although the United States had only a limited SARS-CoV outbreak during the 2003 epidemic . . . the U.S. population is clearly vulnerable to the more widespread, disruptive outbreaks experienced in other countries."). Similarly unpredictable, West Nile virus has not spread nearly as widely or as rapidly in Europe as it

With respect to disease, in the interconnected modern world, the United States is not an island. It is not only susceptible to imported diseases, but also heavily dependent on information from and cooperation with other nations to prevent and limit outbreaks.

IV. The Rational Case for Action

The dilemma of climate change is often described (accurately) as a collective action or public goods problem.[300] No single country has an incentive to control its emissions of GHGs optimally because the cost of those emissions in the form of climate change are borne by all countries, while the benefits in the form of lower economic costs are enjoyed entirely by the emitting state. Indeed, in some ways climate change may be an especially difficult kind of collective action problem because the harmful consequences are not spread evenly among states. The standard prediction of such problems in models is that each player, if behaving rationally, should "free ride" on the efforts of the others.

One might think, therefore, that it is in the self-interest of the United States to do nothing (or very little) and free ride. A slight variation on this perspective is that the United States should not act unless all other major contributors to climate change also take action. One form of this latter argument suggests that if the United States stands to lose from the globally optimal agreement, then "the United States should be given side payments in return for its participation."[301] A more common argument in contemporary political discourse is that American business, especially energy-intensive trade-exposed manufacturers, will be put at a competitive disadvantage if countries like China do not adopt comparable mitigation measures that would raise the price of their goods.[302] Of course, thus far, high emitting developing countries—notably India and China—have signaled their reluctance to make binding commitments before the developed world commits to doing much more.[303] The result is a dangerous stalemate.

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has in the United States. The reasons for the difference are still not entirely clear to scientists. V. Chevalier, Epidemiological Processes Involved in the Emergence of Vector-borne Diseases: West Nile Fever, Rift Valley Fever, Japanese Encephalitis and Crimean-Congo Haemorrhagic Fever, 23 Sci. & Technical Rev. 535, 544 (2004). Early detection of disease, plus swift and decisive implementation of containment measures, is therefore essential to prevent transmission.

300. See, e.g., Arrow, supra note 82, at 3 ("[G]lobal climate is a public good (bad) *par excellence*."); Cole, supra note 23, at 4 ("[C]limate change presents a sizeable 'collective action' problem.").

301. Posner & Sunstein, supra note 42, at 1569.

302. See, e.g, Sen. Pete V. Domenici & Sen. Jeff Bingaman, U.S. Senate Comm. on Energy and Natural Res., Design Elements of a Mandatory Market-Based Greenhouse Gas Regulatory System 14 (2006) ("[W]ithout greenhouse gas mitigation efforts by all major emitters, including our largest trading partners, the U.S. economy could be placed at a competitive disadvantage.").

303. Jonathan Weisman, G-8 Climate-Change Agreement Falls Short, Wall St. J., July 9, 2009, at A8 (describing how at G-8 conference "[d]eveloping countries have responded

The problem of climate change is global, and addressing it effectively will require a collective solution. As a practical matter, even aggressive domestic mitigation efforts by the United States could not, without more, reverse climate change. Yet that reality does not answer the question: Is it in the interest of the United States to take action to address climate change—to cut emissions at home and subsidize reductions elsewhere—even in the face of reluctance by some other major emitters to act?

While it is surely correct that climate change poses a collective action problem, it is also true that large players may internalize enough benefits from the production of collective goods to make it worthwhile to invest in those goods. Every player, large or small, has an incentive to take action up to the point where the marginal cost of further action by the State equals the marginal benefit. A large hegemonic player like the United States internalizes a significant fraction of the global gains, making it worthwhile to bear at least some costs.

To illustrate this point, consider the (admittedly controversial) estimates provided by the Stern Review. According to the Review, the annual cost of stabilizing GHGs in the range of 500–550ppm CO_2 is approximately 1% of global GDP by 2050.[304] World GDP in 2007 was approximately $54 trillion, $13.8 trillion of which was accounted for by the United States.[305] The above estimated cost of a global stabilization of GHGs, then, would represent less than 4% of American GDP. Even if the Stern Report understates the cost of stabilizing GHGs dramatically, the costs to the United States of failing to act are likely to remain larger than the total global costs of acting. If, for example, one doubles the Stern estimate, the total global cost of stabilizing GHGs is 8% of U.S. GDP. As shown in Table 3 below, the cost of climate change to the United States is likely to exceed 10% of GDP.

Consider now that the European Union had a GDP of approximately $13.6 trillion in 2008.[306] Taken together, then, the United States and the EU account for 58% of global GDP. If they were to bear jointly the global cost of stabilization the impact would be less than 2% of their combined GDP. Broadening the pool of countries further, the GDP of the OECD was $35 trillion,[307] meaning that the cost of stabilization would be approximately 1.3% of the GDP for OECD countries.

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that they shouldn't have to slow or sacrifice their fossil-fuel-based economic growth to help the West atone for its historical consumption patterns").

304. There is a range of +/- 3% around this estimate, meaning that the costs are likely to fall somewhere between 4% and -2% of GDP. Stern Review, supra note 8, at 279.

305. World Bank Indicators, supra note 170.

306. Id.

307. World Bank, Key Development Data & Statistics, at http://web.worldbank.org/WBSITE/EXTERNAL/DATASTATISTICS/0,,contentMDK:20535285~menuPK:1192694~pagePK:64133150~piPK:64133175~theSitePK:239419,00.html (last visited Sept. 18, 2009) (on file with the *Columbia Law Review*).

We can expect the American and European share of global GDP to shrink because the economies of other states, China and India in particular, have been growing rapidly and may continue to do so for years to come. That said, with the United States accounting for about 25% of global GDP, and the OECD accounting for 65%, the United States and the OECD represent a substantial share of global GDP for the next hundred years under any plausible assumptions about growth rates. As such, the United States will have an interest in bearing a large share of the global costs of reductions in emissions.

Assuming GHGs could be stabilized at 500–550ppm by 2050, and the total global cost of doing so would be approximately 4% of U.S. GDP, we have figures against which to compare the costs of climate change. The following table provides a partial summary of how the conventional assessment of economic harm to the United States might be adjusted if we take into account the various factors that cause that conventional estimate to understate harms.

TABLE 3: QUANTITATIVE ADJUSTMENTS TO CONVENTIONAL ESTIMATES OF CLIMATE CHANGE IMPACTS

Factors Considered	Conventional Estimates of Reduction in U.S. GDP (%)	Marginal Impact on Annual GDP (%)
Conventional IAM Estimate	0.5	0.5
Optimism About Temperature Rise[308]	0	1
Asymmetry Around Point Estimates[309]	0	0.5
Catastrophic Events[310]	0	0.5–3
Nonmarket Costs[311]	0	1.4–3.5[312]
Export Losses[313]	0	1.5
SUBTOTAL	0.5	5.4–10
Growth and Productivity[314]	0	Double Above Impacts
TOTAL	0.5	10.8–20

Several factors discussed in this Essay are omitted from the above table because we are unable to estimate their impact in quantitative terms. It is important not to lose sight of these potential harms, which are presented in Table 4.

308. See supra Part II.B.1.
309. See supra Part II.B.2.
310. See supra Part II.B.3.
311. See supra Part II.B.4.
312. This includes only biological costs.
313. See supra Part III.A.1.
314. See supra Part II.B.6.

TABLE 4: QUALITATIVE ADJUSTMENTS TO CONVENTIONAL ESTIMATES OF CLIMATE CHANGE IMPACTS

Factors Considered	Impacts and Examples
Cross-Sectoral Effects	If climate change affects energy prices, agriculture will be affected
Supply Shocks from Abroad	Energy prices
Global Financial Markets	Impact on American investments abroad; lending to fund current account deficit
National Security	Total cost of Iraq War = $3 trillion[315]
Migration	Racial and ethnic tensions, undocumented immigration, human trafficking
Disease	Swine Flu, SARS, Avian Flu; U.S. cannot insulate itself from increases in incidence of disease

The impacts presented in Table 4 are not minor issues. National security, for example, could easily generate costs that exceed any of those listed supra in Table 3.[316] The estimate produced supra in Table 3, therefore, most likely understates the full impact of climate change.

To be sure, the figures presented above are also highly speculative. Some are taken from existing studies, but even those figures are crude estimates. Despite these qualifications, we think the impacts we have identified and sought to quantify represent a critical set of issues for policy debates about climate change. We are confident that estimating each of these effects to be zero (as is often done) is much less accurate than what we have provided.

With these two limitations (that our table leaves out a great deal, and that the numbers included are uncertain) in mind, what is the lesson for U.S. policy? The most obvious point is that if we simply tally the effects presented supra in Table 3, the resulting impact of climate change on GDP reaches 7.7%,[317] excluding the impact on growth and productivity. If we follow Fankhauser and Tol's results[318] and estimate that accounting for capital accumulation effects on productivity requires a doubling of this figure, we get a total decrease in GDP of 15.4% caused by climate change. To this one would have to add the factors that we have not quantified (cross-sectoral effects, supply shocks, financial market effects, national security issues, migration, and disease).

If one accepts the estimate of a 15.4% impact on the United States (or even if one were to cut that estimate in half), and if one accepts that the global cost of action would be about 4% of U.S. GDP, the obvious conclusion is that the United States would be better off paying the full

315. Stiglitz & Bilmes, supra note 242, at x.

316. See supra Part III.B.

317. Where there is a range of costs in Table 3, we have used the midpoint to calculate the total impact.

318. Fankhauser & Tol, supra note 152, at 12–14.

cost of mitigating the impact of climate change by itself (even if no other country cooperates) rather than allowing the world to continue in a "business as usual" fashion. This result is even stronger if Europe and perhaps the rest of the OECD are assumed to participate.

The point here is not that the United States or the OECD should actually bear these costs alone, or even that it would be possible to do so.[319] Rather, the point is that even if one assumes that international cooperation in general is difficult to achieve, and that binding commitments from India and China may be elusive given the political and economic constraints those countries face, it may still make sense for the United States to invest in mitigation without waiting for these other countries to act. While the problem is indeed a collective action problem, the United States is a large enough player, especially if it acts in conjunction with Europe and the OECD, that free riding is not a rational strategy.

At a minimum, all of this suggests that the United States should put considerable energy into the negotiation and entry into force of a substantive and effective international treaty to address climate change concerns. Beyond that, it suggests that if such a treaty is not possible in the near term, the United States may wish to enact significant domestic measures to reduce domestic emissions of GHGs.

One important caveat must be mentioned here, though a full discussion would take us too far afield. There is a dramatic difference between expenditures today (e.g., in pursuit of mitigation) and costs borne many years in the future (e.g., as a result of climate change). To evaluate costs and benefits across time it is necessary to specify some discount rate, and the choice of discount rate is the source of a great deal of debate within climate change discussions. Our own view is that a low discount rate is more appropriate, and our reasons reflect those that have already been discussed in the literature.[320] Because we do not have a great deal to add to the discount rate debate we refrain from marching through all the points made on both sides. Instead, we simply flag the issue here, noting that for a sufficiently large discount rate, even the costs and benefits men-

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319. Among the reasons the United States could not pay the full amount itself is that the cost of mitigation will be lower if all countries participate. Initial reductions in emissions will be achieved more cheaply than later ones. So if the United States truly were acting alone, the cost of stabilization would rise above the 4% mentioned supra notes 300–307 and accompanying text.

320. The most central reason for a low discount rate is more philosophical than economic. It relies on the notion that the welfare of future generations should be valued on par with our own. See Nordhaus, Balance, supra note 65, at 169–90; Stern Review, supra note 8, at 35; cf. Martin L. Weitzman, The Role of Uncertainty in the Economics of Catastrophic Climate Change 18–19 (AEI-Brookings Joint Ctr. for Regulatory Studies, Working Paper 07-11, 2007), available at http://ssrn.com/abstract=992873 (on file with the *Columbia Law Review*) (discussing disagreement over ethical discount rate). But see Robert O. Mendelsohn, A Critique of the Stern Report, Reg., Winter 2006–2007, at 42, 43 ("[U]sing low discount rates is unfair to every generation; the welfare of future generations will be reduced by low discount rates just as much as current ones.").

tioned above would not support an argument for substantial expenditures today.

There remain some potentially credible arguments against unilateral action by the United States. These include the futility, leakage, and fairness arguments we mentioned in the introduction. Although we do not tackle them in detail here, the persuasiveness of these arguments is not self-evident. The first two—futility and leakage—require an empirical defense. On futility, the question is how much mitigation is so little that it is not worth acting?[321] On leakage, the question is whether unilateral action will in fact lead to massive flight of energy intensive industry, and whether there are available measures to ameliorate its effects. The third argument, that it would be unfair to expect the United States to act without commitments from the developing world, requires a normative defense. We note only that there are certainly competing views on this question.

It is conceivable that a credible U.S. threat to do nothing until the major developing economies agree to share the burden of mitigation could increase the prospects of persuading other countries to participate in a new global climate change regime. Whether this is true or not, the climate change winner argument—that the United States will fare relatively better than other states and thus has no rational incentive to unilaterally mitigate climate change—is fatally flawed. This Essay will have succeeded if the strategic question of how best to induce cooperation becomes the focus of the climate change debate, and the climate change winner argument is abandoned.

V. CONCLUSION

Our goal in this Essay has been to debunk the climate change winner argument, which suggests that because the United States will fare better than many nations of the world as global temperature increases, it is not in the interest of the United States to take aggressive action to mitigate greenhouse gas emissions. To the extent any action is appropriate, the argument goes, the United States should focus on adaptation—a strategy under which the United States captures almost all the benefits from its

321. Given that we cannot project when important thresholds or "tipping points" might be crossed, the appropriate strategy is to assume that marginal increases in GHG emissions lead to marginal increases in climate change. Even if there is a tipping point, the above assumption makes sense. A reduction in emissions reduces the stock of CO_2 in the atmosphere and so reduces the probability that we will cross the tipping point. Thus, it also minimizes the expected harm from climate change. It is not, moreover, logical to assume that for every ton of emissions the United States reduces, such emissions are "replaced" by those of other emitters. There is no reason to believe other countries substitute their emissions for U.S. emissions. The question is whether the total volume of global emissions will exceed "safe" atmospheric concentrations or not. Even if this is not the case, the futility thesis can only prove true if American action were to wind up wholly failing to induce others to act.

actions. Figuratively, the idea is to wall off the country while the rest of the world deals with its own climate change issues.

Our argument takes as a starting point prominent economic models that project the costs of climate change. As we have shown, the leading economic models are methodologically limited in a variety of ways that systematically skew toward an understatement of costs. The models understate some impacts because of their optimistic assumptions about the rate and magnitude of warming. The models also fail to account for certain other impacts that fall into categories—like loss of biodiversity—that are difficult to quantify. In addition, leading models tend to adopt a myopic single economy view that fails to account for international spillover effects, even though, by many credible accounts, climate change is likely to be a "threat multiplier" in areas of the world where the United States has important strategic interests. We think this kind of mistake is the linchpin of the climate change winner argument. The climate change winner argument only succeeds if we assume that climate change impacts in other parts of the world do not reverberate in the United States.

In addition to omitting spillover effects, the models have other serious problems, including the so-called "fat tail problem": the tendency to gravely underestimate the risk of low probability/high consequence events like rapid glacial melting.

Economists may well appreciate all of these shortcomings, but influential thinkers in other disciplines and policymakers may not. It is tempting to base policy recommendations on the "best models currently available," but it would be irresponsible to do so without acknowledging their significant limitations. A more developed accounting of the costs associated with climate change not only calls the climate change winner argument into question, but also shows that argument to be wrong.

Where does this leave us? One might say the argument is moot. There are strong signs that the United States will take at least some action to mitigate greenhouse gases, perhaps by establishing a domestic cap-and-trade regime, or by using the Clean Air Act to address climate change pollution from stationary and mobile sources. It also appears that the United States will soon re-engage with the international community in pursuit of a global climate change agreement. So even if the climate change winner argument is a provocative idea, it has lost to political will. We are not persuaded. The climate change winner argument is still heard in debates among both academics and policymakers, and even if the United States is preparing to act, no decision has been made about the scale of the American response to the problem or the costs the United States is willing to bear. We do not yet know how the United States will engage China and India on the issue, or whether its own actions will be linked to some agreement from those countries. There is as yet no sign that the United States is considering funding mitigation efforts abroad. In other words, American policy remains fluid and there is much left to be decided. We have no doubt that the climate change win-

ner argument will continue to be made by those who support weaker American policies. We hope that this Essay has debunked their argument.

Our most basic conclusion can be stated quite simply: Based on a fuller accounting of what the United States stands to lose in a warmer world, investing in mitigation, even at the risk of other nations' free riding, is the most rational course. Though international cooperation should be pursued, the reluctance of others to fully engage the problem is not a sound reason for inaction by the United States. Whatever others do, the United States should move aggressively to reduce global GHG emissions.